

# Elliott State Research Forest Forest Management Plan

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DECEMBER 2023



**Oregon State**  
University

COLLEGE OF FORESTRY





*The forested landscapes that now constitute the Elliott State Research Forest lie in the heart of the traditional lands of the hanis and quuiich (Lower Umpqua) peoples, descendants of whom today are enrolled in the Confederated Tribes of the Coos, Lower Umpqua, and Siuslaw Indians, Confederated Tribes of Siletz, and the Coquille (Ko'Kwel) Tribe. This nik'wiin“ (hanis word for forest) or huunkuus ( quuiich word for dark, shaded area) remains, as it has been since time immemorial, a place where our youth first learn to steward, hunt, and gather and it is here where our Elders go to rest. This place has shaped our languages, defined our culture, and nurtured our spirits, and in reciprocity, we have continued to look to our ancestors to honor our sacred obligation as stewards of this place and will do so for the next seven generations.*

- Ashley Russell, Confederated Tribes of the Coos, Lower Umpqua and Siuslaw Indians



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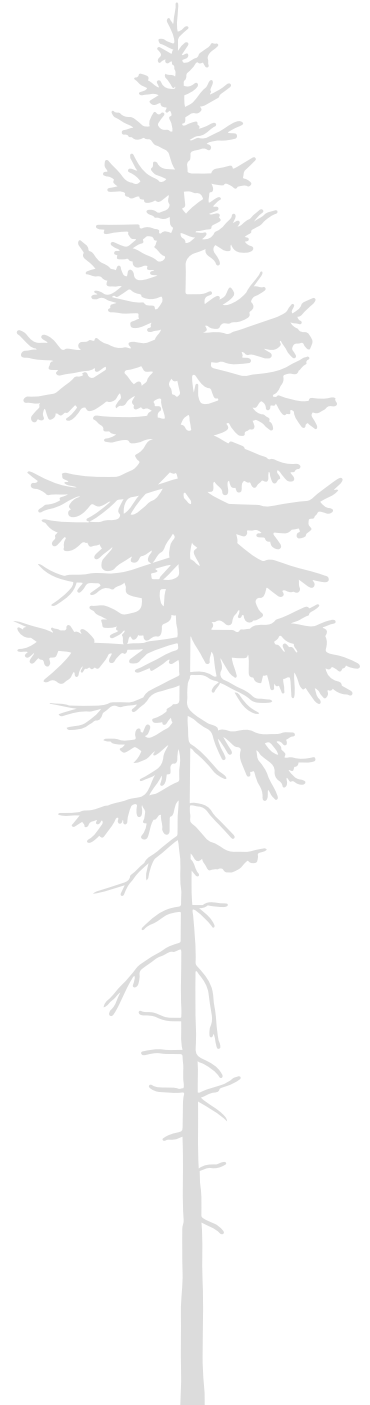
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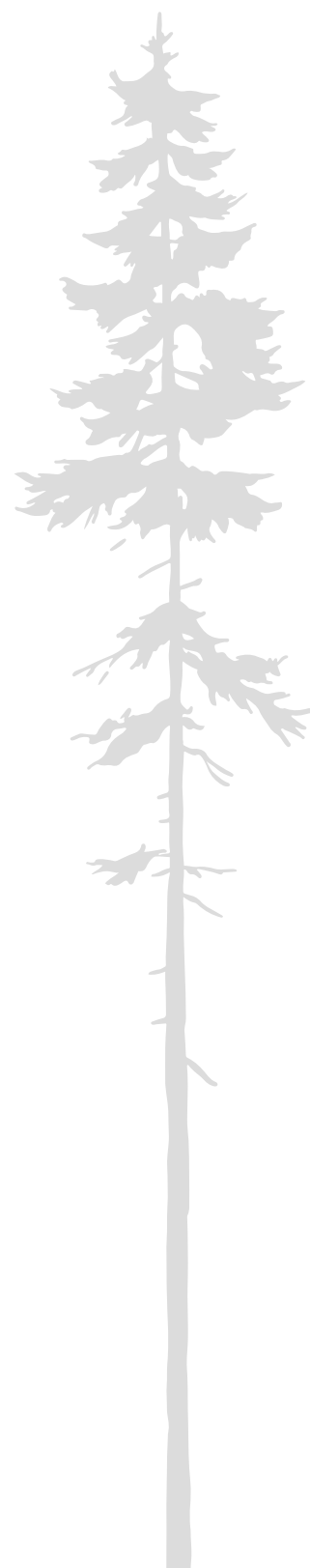
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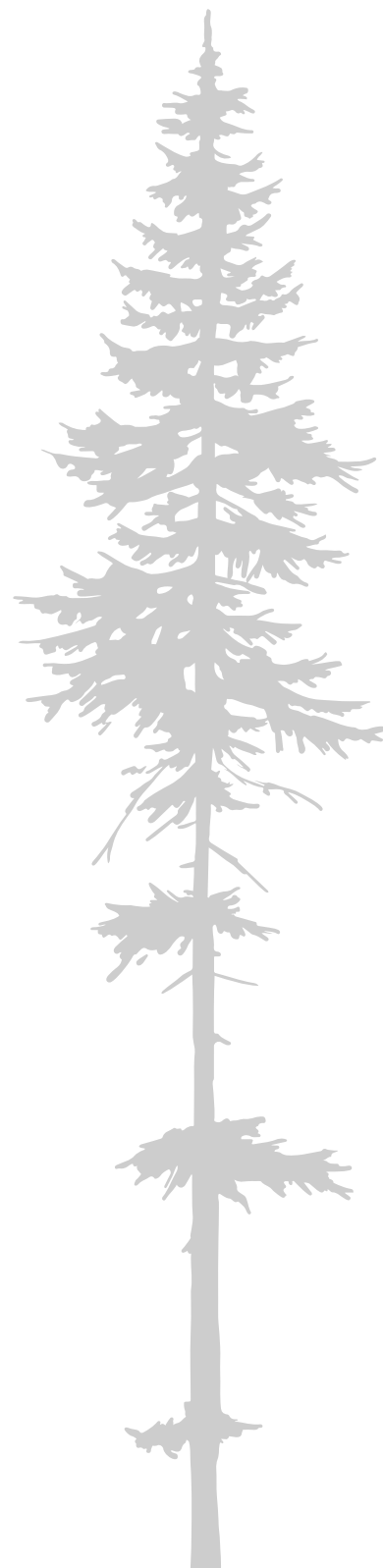
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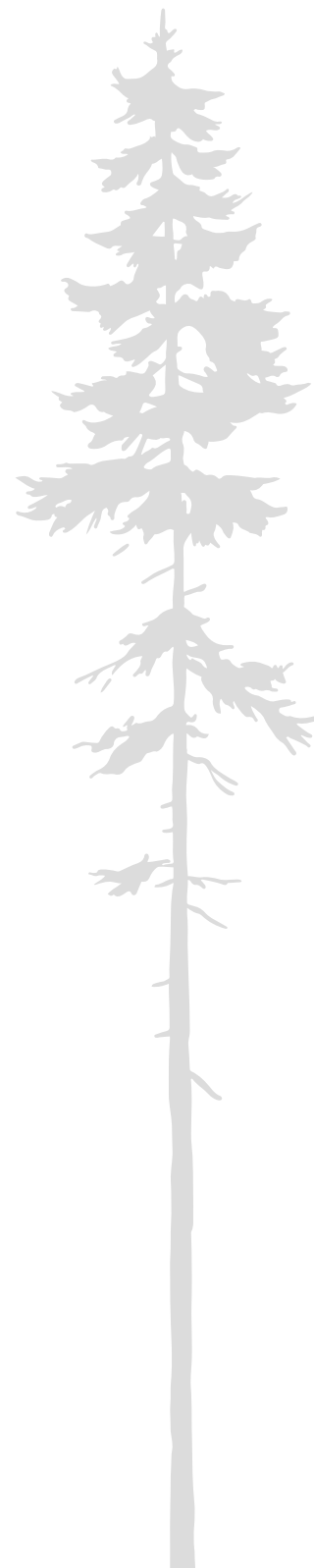




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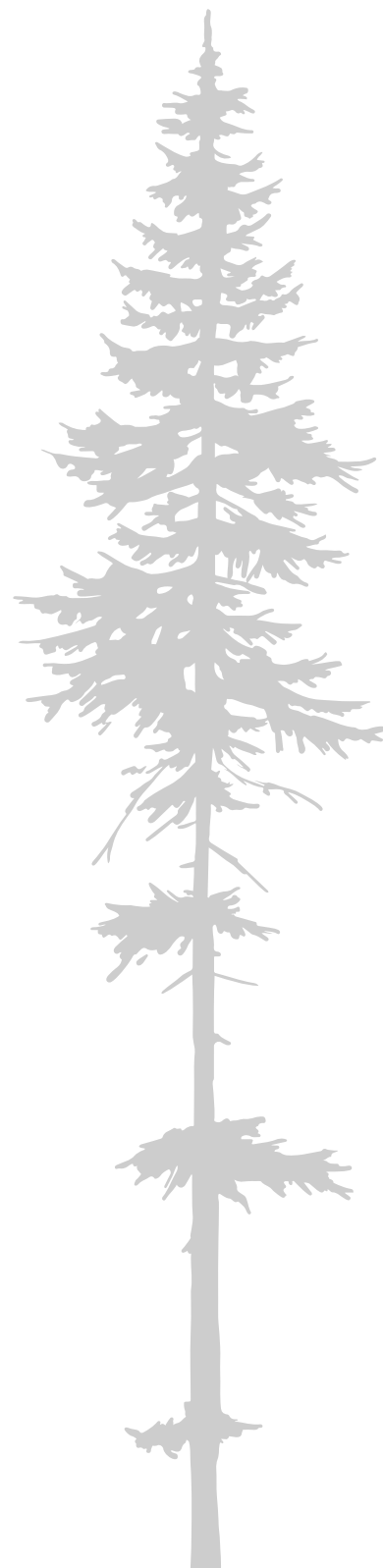
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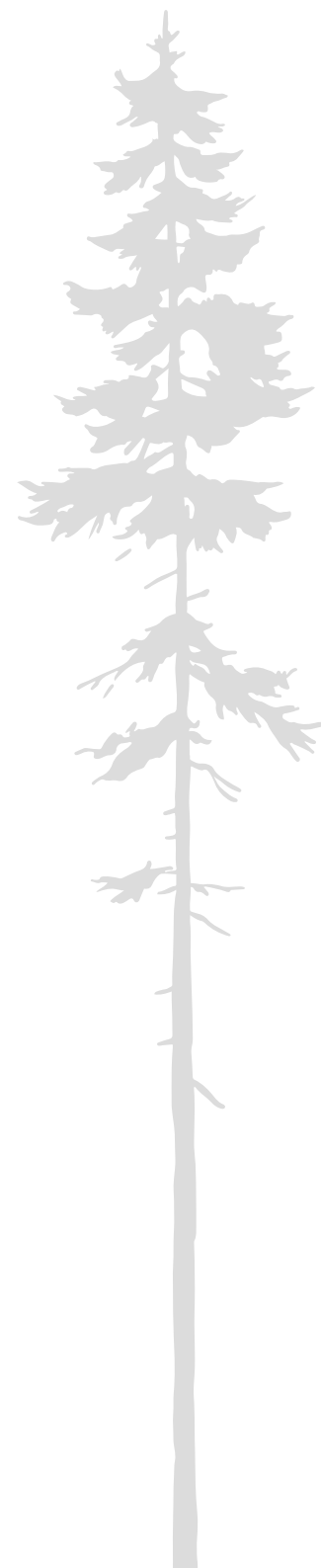
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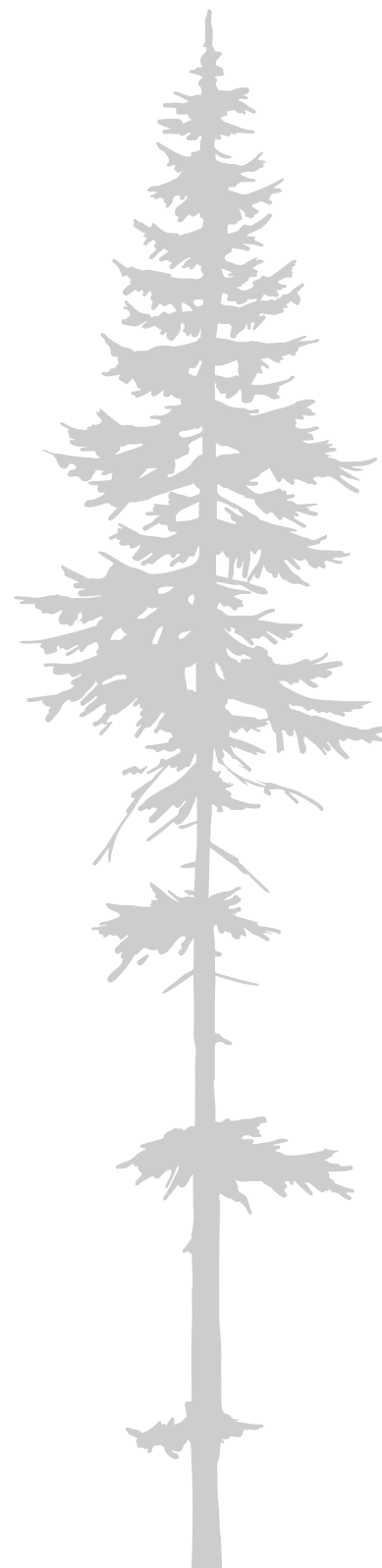
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## Summary and Perspective

### A Message from Thomas H. DeLuca, Dean of the Oregon State University College of Forestry

Is it possible for the Earth to support its rapidly expanding human population without further eroding the planet's biodiversity? What questions should we be addressing now to identify the best path to a truly sustainable future?

As our global population surpasses eight billion people, the world is experiencing growing climate and sustainability crises, as well as the devaluation of facts and knowledge and how they are derived. Forestry has a responsibility to meet human resource needs while minimizing the impact on our living world and contributing to a more sustainable future. The Elliott State Research Forest (ESRF) presents a rare opportunity to establish a long-term research forest that will provide knowledge to support conservation, education, Tribal cultural values, recreation, local economies, and more.

In December 2018, the State Land Board requested that Oregon State University explore with the Oregon Department of State Lands the potential transformation of the Elliott State Forest into a public research forest managed by OSU and its College of Forestry. This exploratory work has been ongoing since early 2019 and has included the engagement of advisory committees at the state and college level, preliminary Government-to-Government engagement with Tribes, coordination with agencies and partners, and the solicitation of input from a range of diverse stakeholders.

By creating a Research Proposal (accepted in April 2021) and now a Forest Management Plan (FMP), Oregon State University College of Forestry and collaborators are working toward a shared vision for the ESRF that respectfully incorporates multiple perspectives and ways of knowing. Jointly, these documents and the ESRF Habitat Conservation Plan (ESRF HCP), led by the Department of State Lands, provide a strong foundation for the forest, a vision for the future, and waypoints to guide implementation of the strategic plan. Yet, given how rapidly our world is changing, these documents are also just a starting point in exploring innovative sustainability solutions.

### Forest Management for a Changing World

We collectively took on the challenge of creating the ESRF, because we truly believe that a world-class research forest in the coastal range of Oregon can make a difference

to society here and around the world. We embarked on this effort as Earth is facing unprecedented threats. Our generation is being defined by changes in global climate, increasing resource demands from a growing population, unprecedented losses in biodiversity through extinctions, extractive management and exploitation that have threatened traditional cultural foods and medicine, as well as declining livelihoods for our most vulnerable communities.

The ESRF will serve as a living laboratory, allowing for transformative, relevant, and collaborative scientific research that yields critical insights into landscape-scale approaches to sustainable forest management, climate resilience, ecosystem functions, and ecocultural social benefits over the long-term. The research forest will also help build capacity for Tribal Nations, on whose ancestral lands the forest is situated, while providing all Oregonians with access to forest education and recreation, as well as jobs in forest products, forestry, and forest research.

Designed to integrate myriad measurements, assessments, and opportunities for adaptation, this plan aspires to develop the ESRF as a global model for forest management and best practices in environmental and natural resource policy. It also aims to not only meet the State Land Board's vision for a forest that shares Oregonians' values, but provide research and knowledge aimed at addressing policy and information needs of crucial importance.

### Adaptive Research that Weaves Together Multiple Ways of Knowing

Bringing this vision to life will take multiple perspectives and an understanding that research is not just about data and measurements, but also relationships—with one another and nature. Building these relationships takes time, and they will grow and evolve, just as the forest does. This constant state of change requires an adaptive plan for the forest. This plan is the first step, or the foundation from which we build relationships, with key benchmarks incorporated that will allow for flexibility in research-based decisions and adjustments in research implementation.

The College of Forestry strategic plan is rooted in values of trust, reciprocity, cultural humility, and inclusivity. Oregon State University believes in the great potential of the ESRF and that forests should be managed to support human needs, foster economic opportunity, and not only sustain but advance forest resiliency and conservation. To accomplish this, it is necessary that sustainable forestry practices be



developed by braiding together different ways of knowing including Indigenous Knowledge and careful scientific inquiry.

This Forest Management Plan outlines an approach that is inclusive, adaptive, dynamic, sustainable, and flexible. We have arrived here despite what at times may have seemed insurmountable differences across cultures and disciplines. OSU and its collaborators have navigated and overcome many complex challenges since the State Land Board provided the initial charge for exploring the ESRF in winter 2018.

## An Imperfect Process

Working within a settler-colonial system and in an effort to meet rigid and legislatively mandated deadlines, Oregon State University also initially failed to properly engage the public at key times and fell short of its responsibility to respectfully work with Tribes to develop co-stewardship plans for the forest. We are working to rectify this.

Through multiple legislative amendments that have shifted timelines and deliverables, Oregon State University has continued to seek the input of stakeholders and the public on this plan. The university continues to establish and formalize Government-to-Government relationships with Tribes – engaging them as Sovereign Nations, not stakeholders – with Memoranda of Understanding and Data Sharing Agreements. And, importantly, the Elliott State Research Forest Authority Board and OSU must build trust and meaningful partnerships with the Tribes whose appropriated land now makes up the inclusive acreage of the ESRF.

We are grateful to the Tribes, including the Confederated Tribes of Coos, Lower Umpqua and Siuslaw Indians, the Cow Creek Band of Umpqua Tribe of Indians, the Confederated Tribes of Grand Ronde, and the Confederated Tribes of Siletz Indians, who have helped us better understand other ways of approaching land stewardship as it was practiced for millennia before Europeans arrived. We are committed to continuing to develop equitable and respectful Tribal relationships based on best practices for partnering with

Tribal Nations. Once these partnerships are formalized, researchers and program staff will look to Tribal partners to take a leading role in developing sustainable co-stewardship plans for the forest that honor and respect traditional Tribal cultural values and Sovereignty Rights.

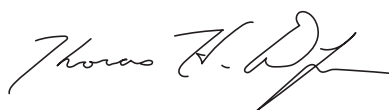
## Establishing the Path Forward

As a result of many collaborative compromises and restrictive deadlines, we know that the Research Proposal and this draft Forest Management Plan are not perfect. Even upon its approval by the State Land Board and the Oregon State University Board of Trustees later this year – a timeline mandated by Senate Bills 1546 and 161 – this plan is just a start. It will evolve over time, as will the research platform.

There is still much to consider, and we commit to continually seeking to do better as we move forward, working together across cultures to continue to listen, learn and adjust our processes. For example, while we have received conflicting input about the amount of space that is dedicated to reserves, we have also received requests to reconsider what we call these areas set aside for restoration and conservation, as the term “reserve” is tied to the settler-colonial act of forcible removal of Tribes to reservations.

To come to resolutions on these topics and more in a manner that builds community across cultures, Oregon State University will continue collaborating with the partners that have helped create the vision and strategies described in this draft Forest Management Plan, which include ancestors of the original inhabitants of these lands, researchers, forest managers, diverse stakeholders, students, local communities, institutions, and the forest itself. We will continue to build relationships with Tribes, offer opportunities for public input, and adapt the plan as we learn from the forest.

It is our shared desire that the ESRF will live well beyond these founding documents and continue to provide knowledge about forest ecosystems that will guide us in adapting to a rapidly changing world.



Thomas H. DeLuca  
*Cheryl Ramberg-Ford and Allyn C. Ford Dean*

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## Abbreviations and Acronyms

**AR** - Atmospheric river

**ARU** - Automated Recording Unit

**ASCC** - Adaptive Silviculture for Climate Change [project]

**BACI** - Before-After-Control-Intervention [research study design]

**BOD** - [Elliott State Research Forest Authority] Board of Directors

**cfs** - cubic feet per second

**COA** - [Oregon Conservation Strategy] Conservation Opportunity Area

**COMET** - CarbOn Management & Emissions Tool

**CoosWA** - Coos Watershed Association

**CRW** - Conservation Reserve Watershed

**CTCLUSI** - Confederated Tribes of Coos, Lower Umpqua and Siuslaw Indians

**CTSM** - Community Terrestrial Systems Model

**DEM** - Digital Elevation Model

**DSA** - Data Sharing Agreement

**eDNA** - Environmental DNA

**ELZ** - Equipment limitation zone

**ENAMES** - Experimental Network for Adaptive Migration and Establish Silviculture

**ESA** - Endangered Species Act

**ESRF** - Elliott State Research Forest

**ESRFA** - Elliott State Research Forest Authority

**ESU** - evolutionarily significant unit

**FEMA** - Federal Emergency Management Agency

**FISH** - Fish-bearing [stream]

**FMP** - Forest Management Plan

**FOP** - [Biennial] Forest Operations Plan

**FPA** - [Oregon] Forest Practices Act

**FRIA** - Forest Road Inventory and Assessment [Oregon FPA]

**GCM** - Global Climate Model

**GHG** - Greenhouse gas

**GIA** - [Sudden oak death] Generally Infested Area

**GRAIP** - Geomorphic Road Assessment and Inventory Package

**ESRF HCP** - Habitat Conservation Plan

**HSI** - Habitat Suitability Index

**IT** - Information Technology

**ITP** - Incidental Take Permit

**LiDAR** - Light detection and ranging

**MAMU** - marbled murrelet

**MRW** - Management Research Watersheds

**NEON** - National Ecological Observatory Network

**NEPA** - National Environmental Policy Act

**NGO** - Non-governmental organization

**NOAA Fisheries** - National Oceanic and Atmospheric Administration Fisheries (formerly National Marine Fisheries Service)

<b>NSO</b> - northern spotted owl	<b>SPTH</b> - site-potential-tree-height
<b>ODA</b> - Oregon Department of Agriculture	<b>SWOCC</b> - Southwestern Oregon Community College
<b>ODF</b> - Oregon Department of Forestry	<b>TLBP</b> - Tenmile Lakes Basin Partnership
<b>ODFW</b> - Oregon Department of Fish and Wildlife	<b>UAS</b> - Unmanned aerial system
<b>OFPR</b> - Oregon Forest Practice Rules	<b>USFS</b> - United States Forest Service
<b>OMMP</b> - Oregon marbled murrelet Project	<b>USFWS</b> - United States Fish and Wildlife Service
<b>OSU</b> - Oregon State University	<b>USGS</b> - United States Geological Survey
<b>OSWB</b> - Oregon State Weed Board	<b>VUMF</b> - Visitor Use Management Framework
<b>OWEB</b> - Oregon Watershed Enhancement Board	<b>WNFB</b> - Wood-delivery non-fish-bearing [stream]
<b>PFA</b> - (Oregon) Private Forest Accord	<b>WRD</b> - (Oregon) Water Resources Department
<b>PFC</b> - Proper functioning [stream/riparian] condition	<b>XNFB</b> - Other non-fish-bearing [stream]
<b>PNFB</b> - Perennial non-fish-bearing [stream]	
<b>PNW</b> - Pacific Northwest	
<b>PSG</b> - Pacific Seabird Group	
<b>PUR</b> - Partnership for Umpqua Rivers	
<b>RCA</b> - Riparian Conservation Area	
<b>ROS</b> - Recreation Opportunity Spectrum	
<b>SAC</b> - Scientific Advisory Committee	
<b>SAP</b> - Supplemental Action Plan [for the Millicoma Forks Coho Restoration Partnership]	
<b>SDM</b> - species distribution model	
<b>SNC</b> - Swiss needle cast	
<b>SOC</b> - Soil organic carbon	
<b>SOD</b> - Sudden oak death	





# Introduction

The Hanis (Coos) and Quuiich (Lower Umpqua) people are the original people and stewards of the lands that we now refer to as the Elliott. Today, many of the descendants of these original stewards of the Elliott are enrolled in the Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians. In 1930, the 83,000-acre Elliott State Forest was established as Oregon's first state forest on these ancestral lands. Starting in 1955 and for the next several decades, the Elliott helped fund Oregon public schools through the harvest and sale of sawtimber and replanting of clearcuts into single species, even-aged stands focused on continued timber production. By 2020, about 50% of the Elliott had been clear cut and replanted to stands from recently regenerated to 65 years old. In recent years the Elliott has been at the center of growing tension between the forest's historical role of helping fund public schools and the forest's potential to provide benefits beyond harvest revenue, including habitat for native species, carbon sequestration, clean water and recreation. In response, the Oregon State Land Board developed a modern vision for the Elliott as a public forest that has completed its obligation to funding Oregon schools, but will continue to contribute to conservation, recreation, education, local economies, and more as a research forest.



In December 2018, Oregon’s State Land Board requested that Oregon State University (OSU) and the Department of State Lands (DSL) explore the potential transformation of the Elliott into a state research forest managed by OSU and its College of Forestry. That work began in early 2019, involving Oregon’s state government and land agencies, OSU administrators and faculty, Tribal Nations and the people of Oregon. With input from advisory committees and a range of stakeholders, OSU developed a proposal and research platform for the forest that was accepted by the State Land Board in April 2021. In March 2022, then Oregon Governor Kate Brown signed Senate Bill (SB) 1546 enabling creation of the Elliott State Research Forest (ESRF). SB 1546 establishes an independent public agency – the Elliott State Research Forest Authority – to oversee the forest, sets expectations for public accountability and transparency, and locks in the ESRF’s ongoing contributions to conservation, economic growth, recreation, education, and forest research.

Management of the ESRF will advance long-term, operational-scale research on issues including forest management practices, ecosystem function, biodiversity, habitat conservation, water quality and quantity, carbon sequestration, rural livelihoods and the resilience of forests to the impacts of climate change. Bringing this vision to life will take multiple perspectives, and an adaptive approach to research and management of the ESRF. SB 1546 stipulates development of a plan that explains how ESRF forest land will be managed to sustain its diverse values, address fundamental research questions regarding working forests, and achieve the specific ecosystem good and service outcomes envisioned for it within the guidance provided by the ESRF Research Proposal and ESRF Habitat Conservation Plan (ESRF HCP). This Forest Management Plan (FMP) for the ESRF was developed in response to that direction. Much work remains to engage fully with Tribal Nations in a way that honors Sovereignty Rights, continue developing processes and plans for the research forest, engage partners and stakeholders, and build on the adaptive capacity of the ESRF research design to braid western science with Indigenous Knowledge. We will continue to build relationships with Tribes, offer opportunities for public input, and adapt the plan as we learn from the forest.

At the time of completion of this ESRF Forest Management Plan, the ESRF HCP had not been finalized. The ESRF HCP provides the regulatory sideboards for the FMP. Once completed, any adjustments in the HCP will need to be incorporated into this FMP document so that the text is aligned. Within this document, the ESRF HCP is referred to as the ESRF HCP, but it should be noted that it is referring to the draft form of the ESRF HCP.

Within this context, the ESRF Forest Management Plan is organized as follows:

**Chapter 1:** Background provides an overview of the ESRF, including its mission, vision and guiding principles, physical and ecological attributes, land use and disturbance history, and current socioeconomic context.

**Chapter 2:** Governance, Organization, and Financial Overview describes the Elliott State Research Forest Authority (ESRFA), initial organizational structure and staffing, and how research and management on the ESRF is to be financed.

**Chapter 3:** Managing a Research Forest for Multiple Values: Research, Conservation, Education, and Recreation sets expectations on developing collaborative partnerships from communicating with the general public to co-stewardship relationships with Tribal Nations, and outlines processes for developing education and recreation plans.

**Chapter 4:** Research Platform and Experimental Design describes the ESRF research platform, including types and scales of research and how these research initiatives will fit within the Triad experimental design on the forest.

**Chapter 5:** Research Planning and Implementation lays out structures and processes for proposing and integrating new research on the ESRF to complement, buttress and nest within the Triad research framework.

**Chapter 6:** Silviculture, Harvest Systems, and Operations Planning details specific goals, objectives, silvicultural treatments and harvest systems that will be used to implement the Triad research design outlined in Chapter 4 and in the ESRF Research Proposal.



**Chapter 7:** Aquatic and Riparian Systems provides details on how aquatic and riparian systems on the ESRF will be analyzed, protected and restored through adaptive research, including strategies for implementation.

**Chapter 8:** Climate Change, Adaptive Silviculture, and Forest Carbon reviews climate projections and vulnerabilities on the ESRF, frameworks for research and management for climate resiliency and adaptation, “climate smart” forestry, and a robust approach for carbon tracking on the forest.

**Chapter 9:** Species Conservation summarizes broad conservation approaches connected to the ESRF research design and goals, more targeted strategies for the three species covered under the ESRF Habitat Conservation Plan (ESRF HCP), and other species of interest or concern.

**Chapter 10:** Monitoring describes a framework to assess baseline conditions and change across different biological, physical and sociological parameters using monitoring protocols structured to meet diverse science and management information needs for the ESRF.

**Chapter 11:** Adaptive Research Strategy and Implementation details how adaptive approaches will be utilized on the ESRF to adjust, refine, optimize and improve research and management outcomes based on the incorporation of new science and monitoring information.

**Chapter 12:** Disturbance, Forest Health and Resilience summarizes abiotic and biotic disturbance agents that interact to affect the structure, diversity, resilience, sustainability and productivity of ESRF forest ecosystems and describes approaches to maintain these conditions across the different ESRF land classifications.







# Chapter 1

## Background

This chapter summarizes the mission and vision under which the ESRF will be managed, describes the planning area (including biophysical characteristics, cultural importance, and socioeconomic connections to surrounding communities), and provides a brief historical overview of the forest.



## 1.1 ESRF Mission, Vision, Guiding Principles

### 1.1.1 Mission

The mission of the Elliott State Research Forest (ESRF) is to become an enduring, publicly owned, world-class research forest that advances and supports all aspects of forestry, including forest health, climate resilience, carbon sequestration, biodiversity, recovery of imperiled species, water quality and quantity, recreational opportunities and local economies. Creation of the ESRF seeks to address essential questions about balancing ecosystem health, biodiversity, and social and cultural use of natural resources through a systems-based holistic approach that braids multiple ways of knowing that are grounded in long-term collaborative research. The ESRF will create a platform for this vital research while providing educational opportunities and access for recreation and traditional cultural uses of the forest for Indigenous Peoples. The ESRF lies within the ancestral lands of the Confederated Tribes of the Coos, Lower Umpqua, and Siuslaw Indians. The ESRF is committed to partnering with Tribal Nations to develop co-stewardship plans for the research forest that honor Sovereignty Rights and support Tribal cultural values. The forest will be managed to promote collaboration, partnerships, inclusive public processes and equity, and consistent with a Habitat Conservation Plan (ESRF HCP) approved pursuant to the Endangered Species Act of 1973.

### 1.1.2 Vision from the Oregon State Land Board

This forest management plan draws on the vision for the ESRF articulated by the Oregon State Land Board. This vision prioritizes providing for multiple forest benefits, including recreation, education, and working forest research, while keeping the forest publicly owned with public access. Accordingly, the ESRF Research Proposal, ESRF Forest Management Plan, and other foundational documents include specific commitments to support key public values. These include commitments to recreation and public access, a transparent governance structure, partnerships with Tribal Nations, adherence to strong and enduring conservation ethics, collaboration to promote education programs, and plans for a working research forest that will support local rural communities.

### 1.1.3 Guiding Principles

To articulate a vision for how the ESRF will be managed, the Department of States Lands (DSL) Advisory Committee approved a set of *guiding principles* for each of five categories that help form the foundation for research, management, education, and recreation on the ESRF. See ESRF Research Proposal (OSU College of Forestry 2021) Section 3 for complete descriptions of these guiding principles and accompanying commitments to achieve the Mission and Vision for the ESRF and facilitate transparency in the management of this public forest.

#### Forest Governance

Transparency and accountability in management of the ESRF is grounded in meaningful engagement with public interest groups, local communities, the private sector, Tribal Nations, and others. The ESRFA will be overseen by a Board of Directors that represents a full complement of experience and expertise in subjects related to the mission, management, and operations of the forest. As described in SB 1546 and Chapter 2: *Governance, Organization, and Revenue to Support Research Management*, the Elliott State Research Forest Board of Directors provides governance and policy oversight to ensure that the ESRF mission and management policies are effectively implemented, operational and fiscal integrity of the ESRF is maintained, and that decision-making on the ESRF occurs with transparency and public participation. In addition, as described in Chapter 5: *Research Planning and Implementation*, an ESRF Scientific Advisory Committee will bring science expertise from a range of institutions and subject matter areas to advise on the research management program. An ESRF HCP Implementation and Adaptive Management Committee will participate in research and monitoring planning conversations as they pertain to covered species and their habitat. The ESRF will advance equity and inclusion in all aspects of forest management and operations.

#### Recreation

The ESRF will ensure public access that supports diverse recreational experiences that are compatible with research and ecological integrity considerations around public safety, ongoing research, harvest, and conservation of both at-risk species and historically present species. The forest will remain publicly accessible by both motorized and non-motorized transportation, but not all places at all times due to the considerations above. Under the guidance

of the ESRF Recreation Plan (to be developed according to the framework discussed in Chapter 3: *Managing a Research Forest for Multiple Values*), the ESRF will partner with local communities to provide a range of user experiences within the context of a working forest landscape while enhancing and protecting identified recreation values. Research and monitoring conducted on the forest will address sustainable recreation practices and track social values for the forest over time.

### **Tribal Nation Traditional Uses**

A Guiding Principle on Tribal Nations Traditional Uses was developed during the FMP process in addition to the ESRF Advisory Committee's original Guiding Principles. Prior to Euro-American settlement, traditional uses occurred in usual and accustomed places on the land for thousands of years, including hunting and gathering of culturally significant plants. The Hanis (Coos) and Quuiich (Lower Umpqua) people are the original people and stewards of the lands that are now referred to as the Elliott State Research Forest. They managed the forest to provide natural resources that supported their communities and their culture, including by gathering and cultivating culturally important plants such as hazel, huckleberries, blackberries and blackcaps, harvesting trees to provide logs for canoes and planks for houses, and hunting deer and elk for food and hides. Today, many of the descendants of these original stewards of the Elliott State Research Forest are enrolled in the Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians. As all lands that make up the Elliott State Research Forest lie within the ancestral land of the Coos, Lower Umpqua, and Siuslaw Indians (CTCLUSI), co-stewarding for traditional uses with Tribes is an important role for the ESRF. Through co-stewarding the lands with Tribes, the values of reciprocity and humility, and a seventh generation approach, can be embodied in the sustainable management of the ESRF.

### **Educational Partnerships**

The ESRF will integrate with existing local and state programs and seek opportunities to identify new educational partnerships that support forest and natural resource-based knowledge. Under the guidance of the ESRF Education Plan (to be developed according to the framework discussed in Chapter 3: *Managing a Research Forest for Multiple Values: Research, Conservation, Education, and Recreation*), ESRF research and educational programs will promote expanded accessibility to forestry and natural resources education through programmatic links with

K-12 schools, community colleges, informal collaborative initiatives, programs at other universities, and OSU Extension to serve all students, including Native American students, at all levels of education and foster public understanding of forest ecosystems, sustainable forest management, conservation, human and natural history, and the role of healthy working forests in local economies. Through active partnerships with local Tribal Governments, the Elliott State Research Forest will seek to partner on research, provide demonstration areas that use traditional forest management practices, and focus on Indigenous Knowledge outcomes for use in educational programs.

### **Local and Regional Economies**

The ESRF will operate as a working forest, supporting local economies through active forest management, timber harvest, recreation, education, and research. A sustainable supply of quality wood volume will be produced over time through the research program on the forest, contributing both to local economies and a financially self-sustaining forest. Management and operations of the ESRF will be based within the community surrounding the ESRF, and will promote partnerships that provide opportunities to local businesses and residents through research, management, and recreation on the forest. The ESRF will study and report on relationships between the research forest and local economies and advance financial partnerships tied to recreation, education, research, forest management, and habitat restoration that individually and collectively improve local economic and workforce benefits both on and off the forest.

### **Conservation**

The ESRF will use science-based conservation efforts to enhance the productivity and conservation values of the research forest. Under the mission of the ESRF and structure of the research management program, the forest will advance and support forest health, climate resilience, carbon sequestration, recovery of imperiled species, and water quality and quantity. The ESRF will preserve and proactively steward high quality habitat for threatened and endangered species (including through conservation measures outlined in the ESRF Habitat Conservation Plan) as well as other wildlife by fostering the growth of older forest stands, while also providing and enhancing other habitat such as complex early seral forest. The ESRF will conserve, enhance, and sustain essential ecosystem processes, including carbon storage, soil productivity, and vital ecological functions that influence aquatic systems.

Collaborative partnerships with institutions, Tribal Nations, and local organizations will support monitoring and habitat restoration efforts, while providing a unique opportunity to conduct innovative research on the intersection of forest ecosystems functions and climate change.

## 1.2 FMP Purpose, Scope, and Objectives

The purpose of this FMP is to provide ESRF staff, researchers, administrators, and partners with the practical guidance they need to implement the integrated research management approach in conjunction with relevant policies and plans, including the ESRF Habitat Conservation Plan. This FMP also provides interested stakeholders, additional partners and the public with details on the ESRF and how it is managed. In the initial stages of developing a vision for the creation of the ESRF, Tribal Nations and their people were directly engaged as stakeholders for the forest. This approach with Tribal Nations and their peoples did not respect Tribal Sovereignty and their long and deep relationships with these lands. As such, and as we continue to learn and grow, modifications to the purpose, scope, and objectives are anticipated.

The *OSU College of Forestry ESRF Research Proposal (RP)* approved by the Oregon State Land Board in 2021, describes guiding principles and commitments for the ESRF, establishes the ESRF research platform and describes the overarching Triad experimental design, outlines an adaptive strategy, describes integrated conservation strategies, and provides an overview of potential “nested” research projects. Under SB 1546 the ESRF is to be managed consistent with the applicable version of the research proposal. With State Land Board and ESRFA approval, OSU may further amend the research proposal.

In the overall planning process for ESRP, this FMP fits between the broader strategic planning embodied in the *Research Proposal* (OSU College of Forestry 2021), and the more detailed and focused *Biennial Operational Plans* where site-specific research and management and activities are described using the guidance and tools presented in this FMP. Development of the FMP involved input from the DSL Advisory Committee and members of the prospective ESRFA board working with OSU College of Forestry research committees and technical groups, along with regular public outreach, listening sessions and updates.

As a research forest, scientific knowledge and Indigenous Knowledge are complementary knowledge generation processes that are both fundamental to planning for management of the ESRF in the context of multiple ecological and social values and global change. For many decades the OSU College of Forestry has been a leader in developing the western science knowledge base, along with other universities in the PNW region, state and federal agency scientists, and forestry practitioners. Research findings from landscape, forest, fisheries and wildlife ecology, forest management and economics, human dimensions, recreation, hydrology, geomorphology, climatology, and ecological forestry and silviculture informed technical groups as they worked to develop the objectives, strategies and tactics described in this FMP. After the ESRF development was well-underway, OSU College of Forestry started emerging as a leader in embracing and promoting Indigenous Knowledge systems through leadership positions, creation of an Indigenous Natural Resources Office, and fostering sustainable relationships with Tribes. The plan is a first step in reflecting and promoting a synergistic multiple-systems view for adaptive implementation of research on the forest to make the ESRF a worldwide leader in advancing the braiding of multiple ways of knowing in an inclusive and respectful way. We recognize that we are at the beginning of this journey and it will take time.

This implementation plan for a research forest is characterized by several key differences when compared to typical plans for managed forests, which often start with a primary objective of sustained non-declining harvest yield based solely on western science knowledge systems. In contrast, with a “research first” mission the ESRF is focused on forest management activities (including timber harvest) primarily under the vision outlined in the research platform and supported by the ESRF HCP, rather than a specific timber yield target. On the ESRF researchers are addressing conservation objectives to protect forest species and processes while sustaining human presence and needs that will inform conservation actions beyond forest borders. Researchers working with the ESRF intentionally learn by collaborating and doing, experimenting with new silvicultural techniques and conducting research and monitoring in conjunction with ongoing restoration, habitat improvement, timber harvest and other management activities to understand critical links between those activities and ecological and social conditions. Course corrections are made along the way through adaptive research and a co-stewardship implementation process.

These differences and others make this implementation plan novel in several ways. The braiding of western science and Indigenous science embraces multiple ways of knowing that guide planning and practices on the forest. For example, large tracts of the ESRF will be managed using a range of thinning and variable retention harvesting treatments to increase forest complexity and diversity through ecocultural restoration that improves resilience under climate change. Designing and implementing such treatments is considerably more complicated than for even-aged plantation forestry. A well-designed and inclusive research platform is an essential component of the implementation stage for this research forest management plan. Compared to a traditional forest plan with one dominant objective and knowledge system, this plan for the ESRF reflects the additional complexity of planning for a landscape that truly integrates multiple objectives for the land and its people within a core research mission.

### 1.2.1 Regulatory Setting and Policy Mandates

State and federal regulations, as well as several key legal and policy mandates guided the development of strategies in this plan as well as future management of the ESRF. These include, but are not limited to, the regulations and policies described below.

#### Federal Endangered Species Act

The federal Endangered Species Act (ESA) of 1973 provides a regulatory framework to conserve, protect and recover endangered and threatened species and the ecosystems upon which they depend. National Marine Fisheries Service (NMFS) is responsible for enforcing the provisions of the ESA for most marine and anadromous species, while U.S. Fish and Wildlife Service (USFWS) is responsible for all other terrestrial and aquatic species. In accordance with Section 10 of the ESA, a Habitat Conservation Plan (HCP) and application for Incidental Take Permits (ITPs) were submitted to the NMFS and USFWS (the Services). The ESRF HCP currently covers the marbled murrelet, northern spotted owl, and Oregon Coast coho.

Under Section 10(a)(2)(A), a nonfederal party may apply to USFWS or NMFS for an Incidental Take Permit (ITP), and the application must include a Habitat Conservation Plan (ESRF HCP). That ESRF HCP must describe the impacts that are likely to result from the incidental take and the measures the applicant will carry out to minimize and mitigate such impacts. In addition, the ESRF HCP must

include a discussion of alternative actions that the applicant has considered that would reduce or avoid take of covered species, and the reasons these alternative actions are not being used. The ESRF Habitat Conservation Plan is described in further detail below and throughout this document. ESRF management will follow all requirements of the ESRF HCP, including regular reporting and continued coordination with the Services to minimize and mitigate the impacts of authorized incidental take. Each issuance of an ITP by the Services is subject to an intra-agency Section 7 consultation, because issuance of a federal permit is a federal action; thus, incidental take authorized pursuant to an HCP must be quantified, must not jeopardize the continued existence of the species, and must not destroy or adversely modify critical habitat.

#### Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) established a management system for national marine and estuarine fishery resources. Pursuant to Section 305(b)(2), all federal agencies are required to consult with NOAA Fisheries regarding any action permitted, funded, or undertaken that may adversely affect “essential fish habitat” (EFH), which includes migratory routes to and from anadromous fish spawning grounds.

#### Oregon Endangered Species Act

Under the Oregon Endangered Species Act (Oregon ESA), the ESRF must coordinate with Oregon Department of Fish & Wildlife (ODFW) and the Oregon Department of Agriculture in developing plans that comply with the state ESA. For threatened or endangered species listed after 1995, the Oregon Fish and Wildlife Commission must establish quantifiable and measurable guidelines considered necessary to ensure the survival of individual members of the species. ESRF management will meet the requirements of federal and state regulations under both the federal and Oregon ESA.

#### Oregon Forest Practices Act

The Oregon Forest Practices Act and its associated rules sets standards for all commercial activities involving the establishment, management, or harvesting of trees on non-federal forestland in Oregon. The Forest Practices Act (FPA) declares it public policy to encourage economically efficient forest practices that ensure the “continuous growing and



harvesting of forest tree species and the maintenance of forest land for such purposes as the leading use on privately owned land, consistent with sound management of soil, air, water, fish, and wildlife resources and scenic resources in visually sensitive corridors...” (Oregon Revised Statutes 527.630(1)).

ORS 629-605-0100 compliance requirements states that landowners, managers, and operators shall comply with FPA practices described in the forest practice statutes and rules unless approval has been obtained from the State Forester for a plan for alternate practice. Included in the situations when the State Forester may approve a plan for an alternate practice to waive or modify forest practice rules is when the State Forester determines that a federal or state agency, a college or university, or a private landowner has submitted an application to the State Forester for a bona fide research project involving activities not in accordance with the rules. Further details are provided in ORS 629-605-0100 and Section 6.1.2 of this FMP.

### **Oregon Plan for Salmon and Watersheds**

The Oregon Plan for Salmon and Watersheds, adopted by the Oregon State Legislature in 1997, is a cooperative effort of state, local, federal, tribal, and private organizations and individuals to support existing regulatory programs and encourage efforts to improve conditions for salmon through non regulatory approaches. The ESRF HCP (which guides the ESRF forest management plan) was prepared to be consistent with the Oregon Plan for Salmon and Watersheds.

### **Oregon Fish Passage**

Under Oregon Fish Passage Laws (Oregon Revised Statute [ORS] 509.580 to 509.910), ODFW requires the owner or operator of any artificial obstruction located in waters where native migratory fish currently or historically occur to address fish passage when certain activities are planned. If a proposed project is within current or historic native migratory fish habitat and if a fish passage trigger identified in the law (Oregon Administrative Rules 635 412-0005(9) (d)) will occur, then fish passage must be addressed. Common triggers for fish passage include culvert and bridge construction, removal, replacement or major repair, and in-channel work for scour protection or grade control.

### **Oregon Department of Fish and Wildlife Scientific Take Permit**

Additional ODFW Scientific Take Permits may be required to implement certain conservation measures, research, and

monitoring for the ESRF HCP and ESRF research program. Those permits are not part of the federal ITPs issued under the ESRF HCP. The ESRF will obtain these state Scientific Take Permits separately as needed to conduct research or monitoring activities.

### **Clean Water Act**

The objective of the Clean Water Act (CWA) is to restore and maintain the physical, chemical and biological integrity of U.S. waters, via national water quality criteria developed and administered by the Environmental Protection Agency (EPA) and mostly delegated to the States and Tribes for implementation. The CWA requires states to develop and adopt water quality standards to protect waters. These standards include beneficial uses (e.g., fish and aquatic life, domestic water supply), anti-degradation policies, and narrative and numeric definitions for how much of a pollutant can be in the water and still allow it to meet designated beneficial uses. Oregon’s water quality standards are adopted in Oregon Administrative Rules (OAR) Chapter 340 Division 413 and administered by the Department of Environmental Quality (DEQ).

### **Oregon Senate Bill 1546**

Oregon Senate Bill 1546 (SB 1546) establishes Elliott State Research Forest and prescribes an effective date of Jan. 1st, 2024, with a mission to create an enduring, publicly-owned research forest. The bill establishes a new public agency, the Elliott State Research Forest Authority (ESRFA) to administer and oversee governance of the research forest through a Board of Directors. The bill requires that the ESRF be managed to support the ESRF mission and promote collaboration, partnerships, transparent public processes and equity consistent with the ESRF Habitat Conservation Plan, ESRF Forest Management Plan (FMP), and ESRF Research Proposal. SB 1546 also describes the roles of the State Land Board, ESRFA Board of Directors, ESRFA Executive Director, and Oregon State University (or the entity contracted to implement forest management and operations. Further details on the governance structure outlined in SB 1546 and connections between administration and management are provided in Chapter 2: *Governance, Organization, and Revenue to Support Research Management*.

### **ESRF Habitat Conservation Plan**

The ESRF Habitat Conservation Plan (ESRF HCP) is a long-term regulatory plan authorized under the federal Endangered Species Act that describes, in a suite of habitat

conservation strategies, how management on the ESRF will restore and enhance habitat for the northern spotted owl, marbled murrelet and Oregon Coast coho salmon in conjunction with other forest management activities. The ESRF HCP and associated Incidental Take Permits (ITPs) have concurrent terms of 80 years in the permit area. The ESRF HCP and ITPs will cover and provide incidental take authorization for covered activities related to research management and the conservation strategy.

The ESRF HCP and associated ITPs cover and provide incidental take authorization for research activities on the forest, as well as activities needed to carry out the conservation strategy described in the ESRF HCP. General categories of covered activities are as follows:

- **Stand-Level Research Treatments.** Research actions, harvest activities (intensive, extensive, and reserve), and stand management activities that will be utilized to maintain the research platform.
- **Supporting Management Activities.** Activities used to facilitate stand management activities.
- **Supporting Infrastructure.** Infrastructure needed to facilitate implementation of the research platform and programs, including roads, landings, drainage structures, and quarries.
- **ESRF HCP Implementation Activities.** Activities identified in the conservation strategy and monitoring program that may result in short-term effects on covered species.

Some activities are not covered under the ESRF HCP because they do not meet the criteria described in ESRF HCP Section 3.1. See Appendix D: *Activities Not Covered Under the ESRF HCP* for further details.

## 1.3 Location and Planning Area

The main area of the ESRF is a contiguous 18-mile by 16-mile tract of forestland in the Oregon Coast Range, located between the towns of Coos Bay and North Bend to the southwest and Reedsport to the northwest. The ESRF also includes East Hakki Ridge, a 788-acre parcel on the northern side of the forest which is located in the Lower Umpqua Watershed. East Hakki Ridge is separated from the main ESRF forestland tract by Oregon Board of Forestry lands, and is not contiguous with the rest of the forest. The ESRF lies just south of the Umpqua River and extends to within 6 miles of the Pacific Ocean to the west. On the east the

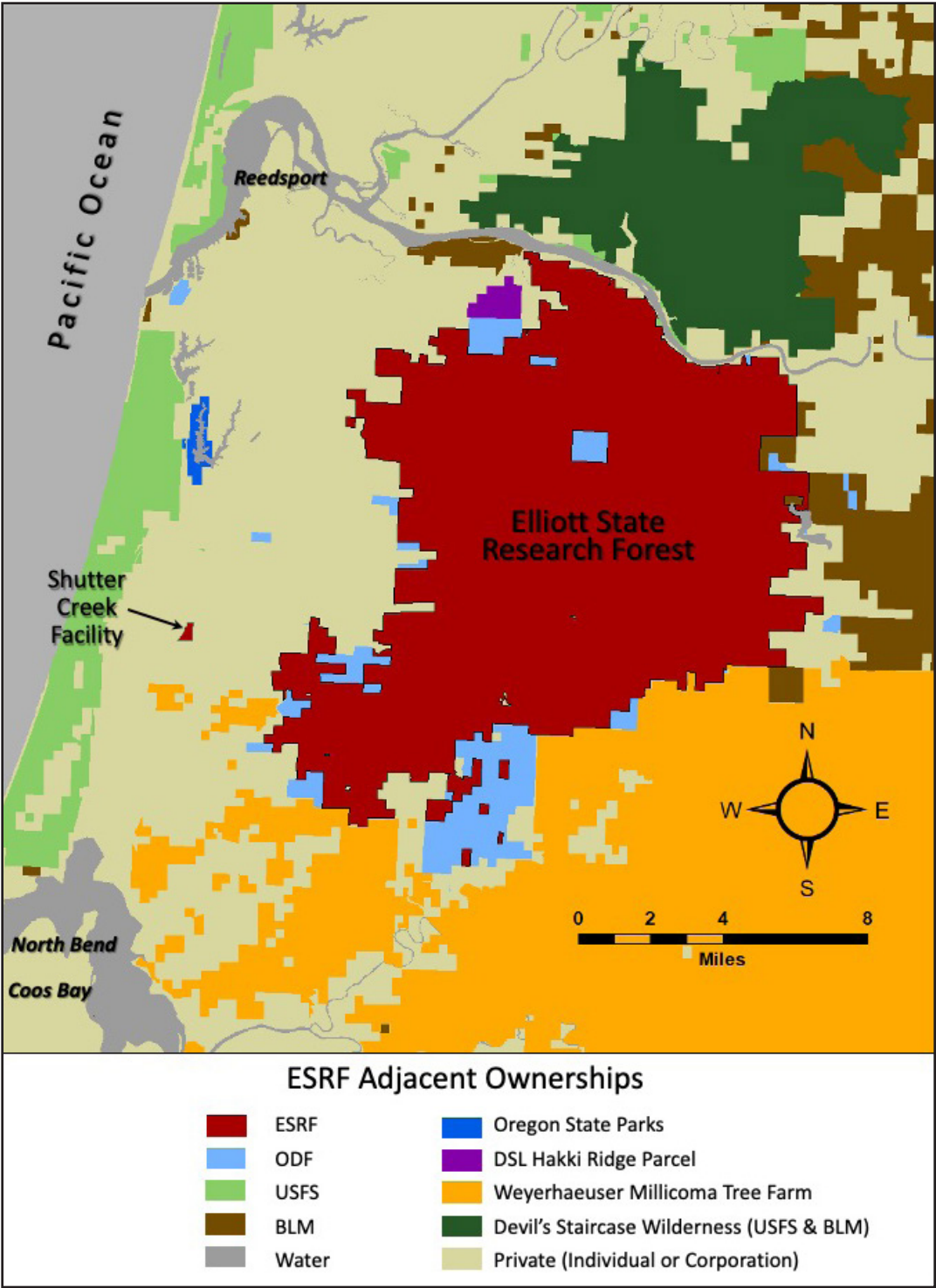
forest extends 21 miles inland to the Coast Range crest with a high point (Elk Peak) of 2,100'. The ESRF is located in Coos and Douglas Counties in the south Oregon Coast region, defined as the geographic area in the southern one-third of the Oregon Coast Range physiographic province (Franklin and Dyrness 1988).

Adjacent land ownership includes lands managed under private ownership, Oregon Board of Forestry, Oregon State Land Board, Bureau of Land Management (BLM), and the U.S. Forest Service (see Figure 1.1). Most private lands are managed as commercial timberlands dominated by even-age Douglas-fir (*Pseudotsuga menziesii*) plantations. The Weyerhaeuser Millicoma Tree Farm is adjacent to the ESRF, and the 1.5-mile radius home ranges of three northern spotted owl activity centers located in the southern portion of the ESRF overlap with the Millicoma Tree Farm. Federal land, including Bureau of Land Management “checkerboard” lands, and state lands contain both young and late-successional forest. The Devil’s Staircase Wilderness (established in 2019), is located directly north of the ESRF, separated by the Umpqua River, State Highway 38, and private lands.

### 1.3.1 Road Network and Access

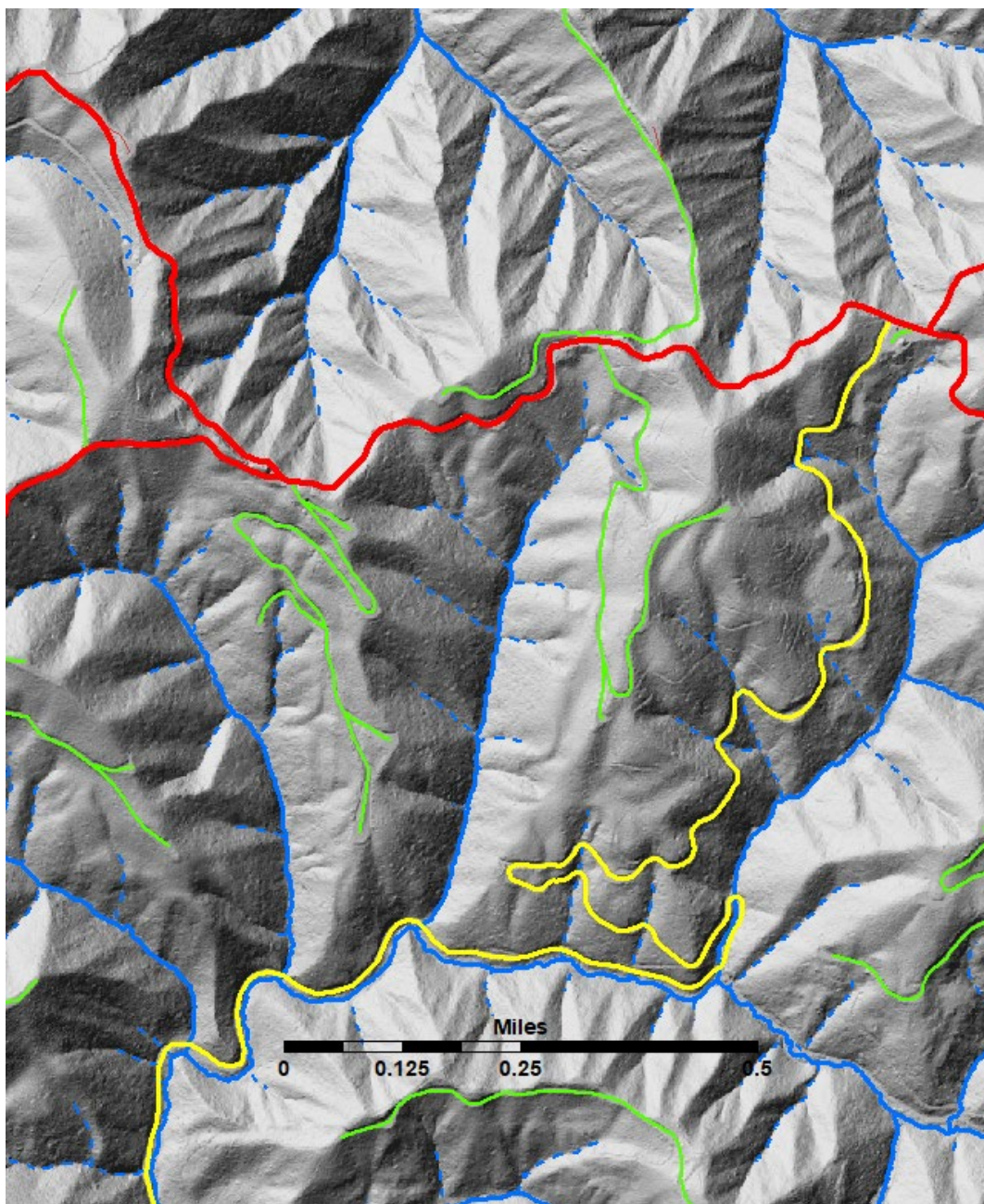
The initial road network on the Elliott was established by the Civilian Conservation Corp (CCC) in the 1930s, and the system was gradually extended after World War II. Road building increased at a faster rate after 1955 with the transfer of forest management from DSL to ODF and ramp-up of timber sales. At least 150 miles of road were rapidly constructed in the western part of the forest after the Columbus Day windstorm of 1962 to provide access for salvage harvest. By approximately 1968 the all-weather road system on the Elliott was essentially complete, although construction of spurs, and upgrades and maintenance of existing roads continued (Biosystems et al. 2003, Phillips 1997). See Section 1.9.2 below for further details on the history of Elliott State Forest road construction.

The current ESRF road network consists of approximately 550 miles of roads, over 300 miles of which are located along ridgetops. About 175 miles of road are on side slopes, with the remainder along valley bottoms and varying in proximity to streams. For purposes of the FMP and ESRF HCP, *primary roads* are mainline roads that receive high use by forest managers and researchers for forest operations, the public for recreation access, by fire safety personnel, and/or for hauling forest products. These roads are primary arterial connectors in and out of the forest and receive routine maintenance.



**Figure 1.1.** The Elliott State Research Forest and surrounding land ownership. The Shutter Creek Facility is currently being explored as a base of operations for the ESRF.





**Figure 1.2.** Approximately 1x2 mile area in the ESRF illustrating 3 types of forest road. The ESRF road network is constrained by the steep topography characteristic of the forest. *Primary roads*, or mainlines (red), typically follow prominent ridgelines, though they must drop to lower elevations for access to highways and major county roads, which usually follow the major rivers and streams of the region. *Secondary roads* (yellow) provide interconnection between mainlines and access to otherwise isolated parts of the forest. *Spur roads* (green) are short, dead-end roads that terminate at landings, which are typically located on major or minor ridgetops to facilitate cable yarding. Roads that follow streams or that cross side-slopes, such as the secondary road shown here (yellow), usually require many stream crossings and can be a major source of stream sedimentation.



*Secondary roads* are lightly trafficked roads that receive periodic use by researchers and forest managers, the public, and for hauling forest products. These are either dead-end roads or connectors between primary roads and receive periodic maintenance as needed (Figure 1.2).

Roads are also classified by geomorphic position on the landscape – *ridgetop, side slope, valley, streamside* – with roads near streams and on steep slopes of higher concern from a conservation perspective (Biosystems et al. 2003). Less than 30 miles of road are located within 100 feet of a fish-bearing stream, mainly in the Coos Region. Under ODF management, unsurfaced roads were closed to vehicles (except for all-terrain vehicles being used for reforestation work) after active forest operations were complete. Additional details regarding inventory and management of the ESRF road network can be found in Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*.

## 1.4 Elliott State Research Forest Biophysical Overview

### 1.4.1 Ecoregion

Nearly all of the ESRF is situated within the mountainous Level IV *Mid-Coastal Sedimentary Ecoregion*, typically underlain by massive beds of sandstone and siltstone, with dissected, steeply sloped and forested mountains that are prone to mass movement. Stream gradients and fluvial erosion rates can be high. A small area in the far northwest corner of the forest grades into the Level IV *Coastal Uplands Ecoregion* where the climate is moderated more strongly by marine influence and abundant fog during the summer dry season which reduces vegetation moisture stress. Forests inland from the coast were once a mosaic of western redcedar, western hemlock, and Douglas-fir. Today, much of this forested area has been converted to Douglas-fir timber plantations on an intensively logged and managed landscape (Thorsen et al. 2003).

#### 1.4.1.1 Pre-Settler Colonial Landscape

This Ecoregion also experienced and was influenced by people for thousands of years before their first interaction with settler colonials prior to the 1800s. The Hanis (Coos) and Quuiich (Lower Umpqua) people are the original people and stewards of the lands that we now refer to as the Elliott State Forest. They managed the forest to provide natural resources

that supported their communities and their culture, including the use of fire to provide for culturally important plants such as hazel, huckleberries, blackberries, blackcaps, and sweet grass, cultivation of trees to provide logs for canoes, planks for houses, and bark for basket weaving, and maintaining early seral conditions to provide for deer and elk abundance that they used for food and hides.

While the following descriptions are primarily guided by western science knowledge and definitions, it should be acknowledged that these landscapes included people who influenced their conditions.

### 1.4.2 Watersheds

Streams draining the ESRF flow into three hydrologic catchments that follow the boundaries of the three independent populations of Oregon coast coho found on the forest – the Coos, Lower Umpqua, and Tenmile populations. Approximately 44% of the forest's area drains southwest into the Coos (USGS HUC-8) watershed, about 32% drains north to the Umpqua (USGS HUC-8) watershed, and approximately 24% drains west to the North Tenmile Lake and Tenmile Lake-Tenmile Creek (USGS HUC-12) watersheds. Chapter 9: *Species Conservation*, Section 9.2.4 includes a map of the three independent populations of Oregon coast coho found on the forest that are contained within each of these three major basins.

In the Coos watershed, slopes are more moderate than elsewhere on the ESRF, and more timber harvesting occurred here in recent decades under ODF management compared to other regions of the forest. The West Fork (WF) Millicoma River runs through the Coos Region and the center of the ESRF, providing important habitat for coho salmon and steelhead.

In the Umpqua watershed, past timber harvest under ODF management was curtailed in areas directly upslope of Highway 38 (along the Umpqua River) and Loon Lake Road (along Mill Creek) owing to landslide safety concerns and to maintain visual quality along this corridor. By 2003, land directly upslope of Highway 38 was designated as a scenic conservancy. Landslide concerns extended the no harvest provision to Charlotte Ridge. Streams in the eastern portion tend to be steeper and shorter than in other areas of the forest.

In the Tenmile watersheds, timber harvest was limited by the early 2000s as the basins had been designated as 160-240 year-old rotation and past harvesting did not allow for

much additional near-term harvest. Fish-bearing streams in this region (under 2003 ODF classifications) do not have active roads adjacent to them and are important for coho salmon because of the high-quality rearing habitat found within them and downstream.

### 1.4.3 Geomorphology, Topography and Soils

#### Geomorphology and Topography

The Oregon Coast Range is in the forearc region of the Cascadia subduction zone where the North American tectonic plate overlies the subducting Juan de Fuca plate. The mountains consist of an accretionary wedge of marine sediments scraped off the subducting Juan de Fuca plate and additional sediments deposited on top of this wedge, all of which were then uplifted (Smith et al. 2012). The area remained unglaciated during the last glacial maximum, and studies in the vicinity of the ESRF suggest a landscape that is in approximate steady-state, with long-term rates of uplift and erosion in approximate balance (Heimsath et al. 2001). Erosion of the relatively weak sandstones and siltstones (middle Eocene Tyee Formation and Elkton Formation) that underlie the ESRF has resulted in a landscape of sharp ridges and steep slopes dissected by numerous streams and draws.

A major ridge running north-south separates the WF Millicoma River watershed to the east from streams flowing westward. Another primary ridge, oriented east-west, divides the upper WF Millicoma drainage from streams flowing north to the Umpqua River. The steepest terrain in the ESRF is adjacent to smaller ridges that branch west and north from these two main ridges, all situated in Tyee Formation. The southeast section of the ESRF has broader ridges and more moderate slopes and is collocated in Elkton Formation. Rock outcrops and cliffs are found mostly along steep draws.

Oregon Coast Range mountain basins have three distinct topographic features. *Nose slopes* (shared with adjacent basins) are generally convex both downslope and cross-slope, resulting in relatively thin soils and divergent runoff and subsurface flow. *Side slopes* are generally planar and oriented between convex nose slopes and convergent areas that transition downslope into headwater stream channels. These bowl-shaped transitional areas between adjacent hillslopes and stream channels below have been defined as *unchanneled headwater basins*, *zero-order basins*, *bedrock hollows* (Smith et al. 2012) or simply *hollows* (Reneau and Dietrich 1991). Since about 1990, the term *headwall* has

been used in Oregon forest practice guidance to describe “obviously concave-shaped slopes in headwater areas (as seen along the slope contour on the ground surface) that can concentrate water to increase landslide susceptibility” (e.g., ODF 2019). The term *colluvial hollow* is used in this FMP to refer to these convergent hillslope landforms.

Colluvial hollows are common features of soil mantled hillslopes, so-named because they accumulate *colluvium* – unconsolidated sediments infilled from nose slopes and side slopes (Yamada 1999) by rainwash, sheetwash, occasional small-scale slope failures, and slow continuous downslope creep, including biogenic processes. With small drainage areas and steep gradients, colluvial hollows are primary locations for sediment storage between disturbance events, serving as sediment reservoirs for periods spanning decades to centuries. Accumulated sediment and wood are then episodically mobilized by shallow landslides and debris flows, often following short duration events of heavy precipitation and saturation of stored sediment. These events are key geomorphic disturbance agents, delivering significant amounts of materials that shape riparian habitats lower in the watershed (Benda et al. 2005).

#### Forest Soils

Soil generally accumulates downhill via soil creep – the gradual plastic flow of the soil mass in response to gravity – but also as a result of deep-seated and shallow landsliding, ravel (surface movement of soil particles), and displacement by small burrowing mammals or windthrow. Streams often incise soil terraces that develop at the base of valleys. The ability of soil to resist detachment during intense rainfall and surface flow generally increases with increasing organic matter content, infiltration rate and the amount of vegetation present to attenuate raindrop kinetic energy. Soils on the ESRF are highly permeable, so overland flow rarely occurs and is limited to areas where soils are very shallow or anthropogenically altered (e.g., roads, skid trails).

Soils in the ESRF are generally shallow on the nose slopes, side slopes and ridgelines, but tend to be much deeper in colluvial hollows, terraces and valley bottoms. Most soils of the area are classified as Inceptisols, and exhibit only moderate degrees of weathering. However, local variation in soil age and biologically mediated geochemical processes cause wide variation in carbon and nutrient accumulation, and depletion of rock-derived weathering products, which shapes patterns of soil fertility (Lindeburg et al. 2013, Hynicka et al. 2013). Similar soils derived from Tyee sandstone in the middle Coast Range support some

of the highest accumulations of soil carbon and nitrogen ever reported worldwide, with locally deep accumulations (Perakis et al. 2011, Hunter et al. 2023). Moderately-deep to deep clay loams overlie three-quarters of the ESRF, and primarily support Douglas-fir site class II and III (Biosystems et al. 2003). Oregon Coast Range soils display a very wide range of soil carbon and nutrient accumulation, including some areas of deep soil with some of the highest C contents on Earth (Perakis et al. 2006, 2011).

Forest soils possess highly diverse microbial communities with functional representation from bacteria, archaea, fungi, and animals with all four possessing keystone organisms in a complex and dynamic food web. Microbial-mediated reactive interfaces in forests, such as interrelations and dynamics of fungi, bacteria and roots, affect ecosystem processes ranging from short-term seasonal changes to long-term stand development and responses to global climate change. Studying these dynamics in different forest habitats and stand ages will provide a more unified framework for understanding large-scale ecological-geographical patterns and drivers involved in microbial-mediated biogeochemistry and predicting forest responses to climate change (Li et al. 2023). The ESRF offers abundant opportunities for exploring the complex forest microbiome to advance in-depth knowledge of this vital aspect of forest ecology.

Soil health in forest systems is defined by the variety of relationships and interactions between soil physical parameters, chemical components, and biological communities. Soil organisms are, arguably, the most mutable and dynamic of these components and while they are organized by functional categories, it is important to consider these functions as spatially and temporally distinct and in no way static (DeLuca et al. 2019).

#### 1.4.4 Landslides and Mass Wasting

The ESRF encompasses steep, mountainous terrain with an abundance of landforms that reflect past slope instability. Situated in two geological units consisting of weak and weathered sedimentary rock – the Tyee and Elkton formations – deep-seated failures such as earthflows and bedrock landslides are prevalent throughout much of the ESRF, although the current activity of most of these features is largely unknown. Shallow-seated features prone to significant mobility, such as shallow landslides in soil or weathered rock, are also frequent in this terrain. However, the magnitude and distribution of these failures are largely event-driven and dependent on climatic drivers

like atmospheric rivers and/or rain-on-snow events, such as those in the winter of 1996-1997. The outflows of many channels exhibit fan-like topography, suggesting that debris flow events stemming from landslides or failed logjams are prevalent and likely source from smaller-order channels in the numerous tributaries upstream of major streams. Anthropogenic slope failures occur in the ESRF, primarily in the form of shallow-seated failures at roads, channel crossings, and fillslopes.

As defined in Oregon Forest Practice regulations, the ESRF lies within the *Tyee Core Area*, with geologic conditions including thick sandstone beds with few fractures. These sandstones weather rapidly into residual soils and concentrate water, creating potential for shallow, rapidly moving landslides. The Tyee Core Area is located within coastal watersheds from the Siuslaw watershed south to and including the Coquille watershed, and that portion of the Umpqua watershed north of Highway 42 and west of Interstate 5. Within these boundaries, locations where bedrock is highly fractured or not of sedimentary origin as determined in the field by a geotechnical specialist are not subject to the Tyee Core Area slope steepness thresholds.

High landslide hazard locations are defined by OAR 629-600-0100 (34) as specific sites that are subject to initiation of shallow, rapidly moving landslides. The specific criteria for determination of these sites is:

- a. The presence, as measured on-site, of any slope in western Oregon (excluding competent rock outcrops) steeper than 80 percent, except in the Tyee Core Area, where it is any slope steeper than 75 percent; or
- b. The presence, as measured on-site, of any headwall or draw in western Oregon steeper than 70 percent, except in the Tyee Core Area, where it is any headwall or draw steeper than 65 percent.

Continued observation and monitoring of all ESRF landslide features in context of management variables will provide scientific insight – both basic and applied – towards balancing healthy stream wood and sediment delivery and reducing hazard in context of landslide magnitudes, frequencies and mobilities. Landslide rates in the ESRF are largely unconstrained, but evaluation of these rates in both Conservation Research Watersheds and the spectrum of treatments in Management Research Watersheds (detailed in Chapter 4: *Research Platform and Experimental Design*) will enable exploration of these currently unknown thresholds as it relates to this balance. A landslide inventory was developed in 2022 to catalog the boundaries of past

landslide features through interpretation of bare earth LiDAR collected in 2021 and serves as a first step towards constraining baseline landslide activity, frequency and magnitude (Appendix O).

### 1.4.5 Climate Patterns

The ESRF has a generally moderate climate. Most precipitation falls from October to May; summers are dry. In winter temperatures are mild with few days below freezing. Summer temperatures can reach 90-100° F, but cool marine air usually keeps them more moderate. Summer fog, especially in mid-summer, often keeps the western edge of the ESRF cooler than inland portions. Snow is uncommon. Average annual precipitation is 70-90 inches, with the most rainfall along high ridges. A rain shadow on the inland side of interior high ridges occurs along the eastern boundary of the forest where annual precipitation drops to about 60 inches.

Despite the overall mild climate on the ESRF, storms (particularly spring storms) can result in major disturbances. Short-term, high intensity rainfall during atmospheric rivers controls the initiation of shallow landslides on steep slopes. Such rainfall events during the winters of 1981-1982 and

1996-1997 triggered numerous shallow landslides and debris flow events throughout the forest. The Columbus Day Storm in October 1962 with recorded coastal wind speeds of over 140 miles per hour resulted in 100 million board feet of blown down trees on the Elliott.

Fog is common in the Coast Range during the low-precipitation months of July through September and is an important yet seldom studied contributor to the hydrological budget in these forests (Harr 1982, Figure 1.3). Fog drip results from fog condensing on leaves and branches of trees overnight, then dripping to the ground. Many fog events do not result in enough condensing to produce drip but still result in wet needles and leaves for hours at a time, providing water that trees can access via foliar uptake, helping to alleviate drought stress. Orographic cooling can also result in fog and fog drip as clouds contact trees in higher elevations. Fog and drip also contribute to the low frequency of wildfire in coastal forests by providing water that trees can access so as not to become flammable (Hessburg et al. 2015).

A key question is how low clouds, fog events and fog drip in the Oregon Coast Range will be affected by climate change.



**Figure 1.3.** Fog and fog drip contribute substantially to the water available to trees in the western regions of the ESRF, reducing moisture stress and risk from wildfire during the summer dry season.



Fog has decreased in recent years in redwood forests to the south (Johnstone and Dawson 2010) and may be decreasing over terrestrial areas in the PNW (Dye et al. 2020). Warmer night-time temperatures under climate change may lead to a decrease in dew formation frequency in the future (Sibley et al. 2022). However, Snyder et al. (2003) provide some evidence that intensification of wind-driven upwelling in the California current as a result of increased CO<sub>2</sub> could lead to more fog and increased moisture flux along the PNW coast during the summer months. Overall, scientific information on this topic is limited making it an important area for potential future studies on the ESRF, which commonly experiences fog in its western regions.

### 1.4.6 Climate Change Vulnerability and Projections

Climate change is increasing temperatures, lengthening the summer dry season and changing precipitation patterns in the Pacific Northwest, trends that are expected to continue and intensify in coming decades (Mote et al. 2014). Climate change can cause multiple concurrent shifts in forest growing seasons, growing conditions (temperature and soil moisture), site conditions (wet, dry), winter minimum temperatures and frost-free days, phenology, biotic disturbance (insects and disease), abiotic disturbance (wildfire, extreme weather events, drought) and exotic species invasions (Halofsky et al. 2018). Warmer temperatures and increasing spring precipitation has contributed to greater severity and distribution of Swiss needle cast in the Oregon Coast Range (Littell et al. 2013). Future warming and changes in precipitation may considerably alter the spatial distribution of suitable climate for many important tree species and vegetation types in Oregon by the end of the 21st century (Dalton et al. 2017).

The planning area for the USFS-led Oregon Coast Adaptation Partnership (OCAP) encompasses the ESRF. Future climate and vegetation scenarios were developed for the OCAP planning area using the MC2 dynamic global vegetation model which simulates biogeographic patterns of vegetation, biogeochemistry, and fire (but not other disturbances) and is driven by long-term climate data from a suite of global climate models (GCMs). MC2 outputs include potential future vegetation distribution, fire effects, and ecosystem conditions, including various ecosystem carbon pools and water balance information. Model outputs project increases in productivity, likely driven by warmer temperatures and longer growing seasons. However, these patterns may be potentially offset by summer drought and climatic water deficits.

Douglas-fir is expected to remain dominant, but all scenarios projected major climate-driven changes in forest vegetation across the planning area by 2050-2100, such as loss of coniferous forests with gains in subtropical and temperate warm mixed forests. Wildfire return intervals were projected to decrease and wildfire severity to increase (Reilly et al. in press).

Over the planning horizon envisioned for the ESRF, climate change and its effects on the forest's ecosystems will become increasingly important and potentially central in forest planning. Topics including future climate projections and implications for species and ecosystems, carbon cycling and sequestration, and climate-related research initiatives are discussed in more detail in Chapter 8: *Climate Change, Adaptive Silviculture, and Forest Carbon*.

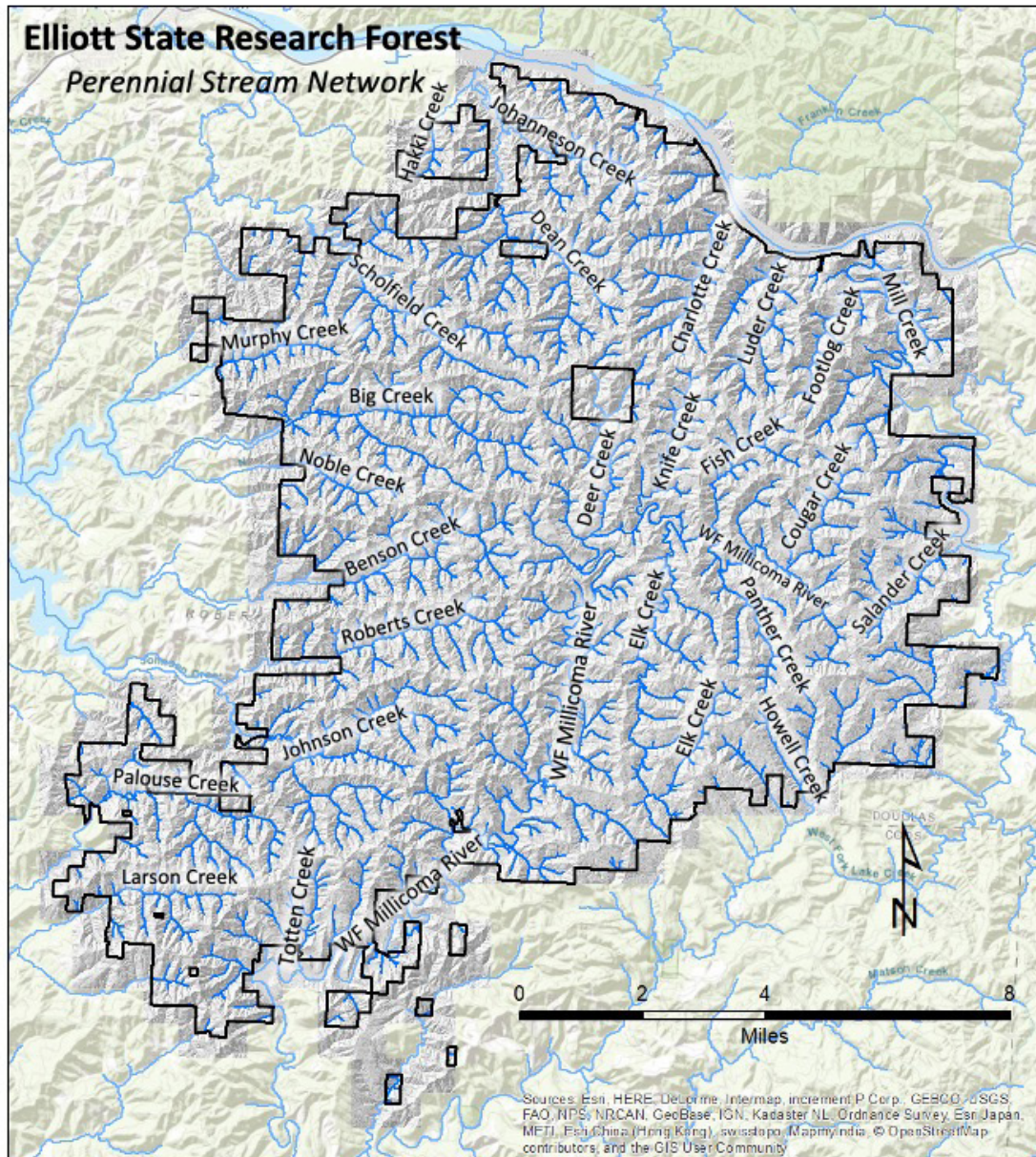
### 1.4.7 Aquatic and Riparian Systems

#### 1.4.7.1 Streams and Other Surface Waters

Water is critical to virtually every other resource on the ESRF. Instream flows provide substantial habitat and ecosystem service benefits, including support of fish and other aquatic life, recreational opportunities, and maintenance of water quality. The ESRF has a high density of streams (Figure 1.4) but few lakes, ponds, and wetlands. Where they are found, wetlands are a part of stream channels and often a result of beaver activity (Biosystems et al. 2003). These areas tend to be small and on aerial photographs often hidden by trees. Almost all ponds outside of streams have been mapped as water sources for fighting wildfire. The streams themselves are also occasionally used for water withdrawal for firefighting, pesticide application, road construction and dust abatement. Water removed from streams is generally taken from small pools behind culverts and artificial ponds (Oregon DSL and ODF 2011).

The West Fork (WF) Millicoma River drains much of the Coos Region and is a primary waterway on the ESRF, with most of the subwatershed lying within ESRF boundaries. The river provides important habitat for wild runs of winter steelhead, coho, and fall chinook. Starting from the headwaters, WF Millicoma tributary streams include Cougar, Panther and Fish Creeks, the major tributary of Elk Creek, then Knife, Deer and Otter Creeks. After the river turns south, Joes, Buck and Trout Creeks enter from the right then the river descends Stulls Falls and Henrys Falls. Further downstream are Schumacher Creek, Pidgeon Falls then Totten and Daggett Creeks.





**Figure 1.4.** The ESRF Perennial Stream Network

Past practices, including stream cleaning and splash damming, have likely caused substantial reductions in large wood and stored sediment in the WF Millicoma (Biosystems et al. 2003). Much of the WF Millicoma River channel within the ESRF is now bedrock substrate, which can result in higher daytime water temperatures and greater diurnal water temperature fluctuations, as compared to reaches with alluvial substrates that support hyporheic flow (Johnson 2004). Palouse and Larson Creeks drain southwest out of the Coos Region. Over the past 25 years, the Coos Watershed Association (CoosWA), in coordination with Oregon Watershed Enhancement Board (OWEB) Oregon Department of Forestry (ODF) and other partners, has completed numerous culvert replacement, large wood placement and other projects to improve aquatic and riparian habitat on the Coos Region.

In the Umpqua Region, primary streams draining into the Umpqua River include Dean, Hakki, Scholfield, Charlotte, Luder and Mill Creeks. As with the Coos Region, stream cleaning and historic logging practices have impacted stream function and habitat quality in Umpqua Region streams. The Partnership for Umpqua Rivers (PUR) along with OWEB, ODF and other partners, has coordinated substantial projects focused on improving salmon habitat by placing numerous pieces of large wood in Dean, Charlotte and Luder Creeks. (e.g., Winn 2009, Ruwaldt 2011a,b).

In the Tenmile Region, Murphy, Big/Noble, Benson, Johnson and Adams Creeks drain primarily from the ESRF (Biosystems et al. 2003). The lower reaches of Roberts Creek and Johnson Creek flowed through former ranches that were later incorporated into the forest. Several Tenmile Region streams transition west across ESRF boundaries and meander through wetland habitats important for salmon and other species before entering the Tenmile Lakes.

The 215-acre Loon Lake is a popular recreation site with approximately 1 mile of ESRF ownership along its northwestern shores. Mill Creek, which drains Loon Lake north to the Umpqua River, is bordered by the forest on its west side. Elk Lake, also known as Gould's Lake, is a small lake located within the forest on Elk Creek. Outside the ESRF, Tenmile Lake and the chain of lakes to which it belongs are influenced by waters draining from the forest. Several adjacent landowners draw surface water from sources on or close to the ESRF. No municipal water systems are located within the plan area. The Oregon Department of Fish and Wildlife (ODFW) operates the Millicoma Interpretive Center located on the WF Millicoma River on Board of Forestry (BOF) lands within the ESRF boundary.

This educational facility produces coho, chinook, and steelhead with the assistance of students and volunteers. Its water source is a nearby spring. Coordinating with ODFW at the Millicoma Interpretive Center on educational programming related to aquatic and restoration ecology on the forest would be consistent with the education component of the ESRF mission, and should be explored as a partnership opportunity during development of the ESRF Education Plan (see Chapter 3: *Managing a Research Forest for Multiple Values*, Section 3.2).

#### 1.4.7.2 Annual Flows, Peak Flows, and Low Flows

Factors related to the quantity and timing of water produced by forested watersheds have been studied for many decades, including: (1) *annual yield of water*, (2) *peak flows* and flooding, (3) *low flows*, and (4) the *timing* of water runoff from forested watersheds. On the ESRF and elsewhere in the Oregon Coast Range, stream flows are highest during the winter rainy season, with peak flows and sporadic flooding associated with storm events. Approximately 90-95% of total annual flow occurs from October-May. Flows in southern Coast Range streams are lowest toward the end of summer.

The WF Millicoma River gaging station is located near the southwestern boundary of the ESRF. The gage was operated by the USGS from 1955-1981 and reactivated by the Coos Watershed Association (CoosWA) in 2002. The CoosWA makes daily average stream flows available for each water year (Oct 1-Sept 30) from 2003 to 2021, as well as real time data updated every 15 minutes (CoosWA 2022).

Nearly all the WF Millicoma watershed upstream of the gage is within the ESRF (46.9 mi.<sup>2</sup>). Precipitation in this basin is typical of the ESRF, although late summer flows in streams in the western part of the forest may not be quite as low due to their proximity to moist, marine air and diminished solar radiation resulting from frequent coastal fog. Thus, general trends summarized for the WF Millicoma can be reasonably extrapolated to most other ESRF streams. Based on data from 1955-1981, Biosystems et al. (2003) found that the average WF Millicoma flow in December, when runoff was highest, was 65 times greater (650 cubic feet per second; cfs) than the average flow in August (10 cfs), the month with the lowest runoff.

Winter average daily flows are generally at least 100-200 cfs and often higher, with at least one or two peaks of 1000-2000 cfs or more during rainstorms in most years and considerably higher peak flows every few years. During such storms, flows usually rise, peak and then fall quickly



as the storm passes. For example, on Dec. 2015, the mean daily flow on the WF Millicoma was 6800 cfs, with flows being just half that amount on the preceding and following days. Biosystems et al. (2003) list 9800 cfs as the peak flow associated with the 50-year recurrence interval. The WF Millicoma also experiences an extended period of very low flows from mid-July through mid-September when flows of 10 cfs or less are common.

Table 1.1 shows highest and lowest mean monthly flow volumes and months when they occurred on the WF Millicoma River for the 2011-2021 water years (Oct. 1-Sept. 30). For these 10 years of data, mean monthly flows (~850 cfs) for the highest flow month were 170 times greater than mean monthly flows (5 cfs) for the lowest flow month.

This stark contrast between summer and winter flows is projected to become even more pronounced as a result of human-induced climate changes. Summer low flows are of increasing concern in the PNW due to more frequent dry years (Mantua et al. 2010; Arismendi et al. 2013; Luce et al. 2014) and evidence that suggests declining low flows and longer annual low-flow periods (Luce and Holden 2009; Leppi et al. 2012). Decreasing summer low flows may be driven by higher temperatures over longer periods and increased evapotranspiration (Tohver et al. 2014). Winter flooding may increase as a result of earlier and more intense winter storms (Salathe et al. 2014).

#### 1.4.7.3 Stream Classification

There are numerous stream classification systems that might be used to characterize a watershed or stream network. Two classification systems of relevance to planning and management of the ESRF are the stream network and associated stream classifications developed by OSU during the development of the ESRF research proposal (Table 7.1), and the stream network and associated classifications used in the implementation of Oregon's forest practices regulations (Table 1.2). At the time of this writing the regulatory stream layer is in transition from a system developed and administered by the Oregon Department of Forestry (ODF) to a system mandated by the Private Forest Accord and administered by the Oregon Department of Fish and Wildlife (ODFW).

Both the revised ODF regulatory stream layer and the ESRF stream layer are based on LiDAR-derived digital elevation models (DEMs), which provide far greater accuracy than older, pre-LiDAR stream delineations based on low-resolution topographic maps. Although there is a difference

in stream miles between the two stream layers this does not mean that one is correct and one is incorrect, as the respective stream layers are intended to serve different purposes. The Oregon regulatory stream layer is used by ODF for administration of Oregon's forest practices rules, and this stream layer represents stream characteristics relevant to the administration of these rules. The ESRF stream layer was used in the development of the ESRF Research Proposal for the ESRF and subsequent planning efforts, and will continue to be used in operations planning and research. It provides a more expansive definition of fish presence than the regulatory stream layer. Similarly, the ESRF stream layer delineates almost twice the total number of stream miles than the regulatory network, and more than twice the number of miles of perennial stream. This more finely delineated stream layer represents the emphasis of the ESRF stream layer on stream processes and interactions, compared to the administrative and regulatory function of the regulatory stream layer.

The ESRF stream layer places greater emphasis on non-fish bearing (NFB) streams than does the regulatory stream layer, with NFB streams comprising 89% of stream miles in the ESRF stream layer. Almost all of these NFB streams are headwater streams in the upper reaches of drainages. These small, NFB streams cumulatively contribute to and can profoundly affect water quality and riparian habitat downstream (Nadeau and Rains 2007). *Intermittent* and *ephemeral* streams dominate the upper portions of ESRF stream networks. Because they do not directly provide habitat for salmonids such streams are often underappreciated as aquatic and riparian resources; however, the significance of NFB intermittent and ephemeral streams is increasingly being recognized for their role in supporting diverse communities of riparian and aquatic species, as-well-as supporting downstream salmonid populations.

#### 1.4.7.4 Riparian Habitat

While relatively limited in areal extent compared to forest uplands, riparian areas are extraordinarily important because of their vital roles in maintaining aquatic and terrestrial habitats, biodiversity, and water quality. The ecological and physical conditions of a stream are strongly influenced by the adjacent terrestrial environment. This streamside riparian area is broadly defined as the zone of influence between streams and upland landscapes. The influence of riparian areas can be particularly notable in forested systems such as the Elliott (Naiman et al. 2005). Streams and their adjacent riparian areas are closely linked and influence each other in

**Table 1.1:** West Fork Millicoma River highest and lowest mean daily flow volumes and months, water years 2011-2021.

Water Year*	Highest Mean Daily Flow (cfs) and Month	Lowest Mean Daily Flow (cfs) and Month
2021	562.11 (February)	2.43 (August)
2020	806.00 (January)	8.63 (August)
2019	713.39 (February)	6.04 (August)
2017	894.38 (January)	4.98 (July)
2016	1238.22 (December)	3.57 (August)
2015	877.09 (December)	2.82 (August)
2014	795.75 (February)	5.56 (August)
2013	774.59 (December)	6.39 (August)
2012	1088.60 (March)	2.85 (September)
2011	777.13 (January)	6.72 (August)
10-year mean	852.73	5

\*Water years run from Oct. 1-Sept. 30. Water year 2018 excluded due to incomplete data. (Coos Watershed Association 2022.)

**Table 1.2.** Miles of stream on the ESRF based on revisions made to Oregon’s regulatory stream layer mandated by Oregon’s Private Forest Accord, and the ESRF stream layer developed by OSU. Oregon regulatory layer data displayed below are from June 30, 2023 revisions to the regulatory stream layer. Units are in acres.

ESRF Stream Layer (miles)					ESRF Stream Layer (miles)
Stream Class	OFPA Stream Size (miles)			Total (miles)	
	Large	Medium	Small		
Fish Streams, Total	60.5	61.6	59.3	181.4	237.5
Fish Streams, Perennial	58.9	52.3	35.4	146.5	237.5
Fish Streams, Seasonal	1.6	9.3	23.9	34.9	0.0
Non-Fish Streams, Total	0.0	7.3	1003.0	1010.3	1870.1
Non-Fish Streams, Perennial	0.0	4.0	58.4	62.4	246.1
Non-Fish Streams, Seasonal	0.0	3.3	944.6	947.9	1624.0
Grand Total	60.5	68.9	1062.3	1191.7	2107.6

many important ways. In particular, riparian forests supply large logs to the stream channel, where they are important structural components of streams. Large, fallen trees in streams create pools, modify the stream gradient, and retain organic material and sediments.

Streams are naturally dynamic ecosystems. Periodic major disturbances (such as fires, wind, floods, and landslides) add logs, boulders, and gravel, which are important building blocks of stream structure and aquatic habitats. In streams, floodplains, wetlands, off-channel habitats, complex stream structures, beaver dams, and deep pools provide the resilience that enable streams to benefit from these disturbances in the long-term.

Riparian forests can affect the types of disturbance characteristic of stream channels, filter sediment from uplands, provide root reinforcement that affects the geometry of the stream channel, affect stream exposure to sunlight and wind, and deliver terrestrial insects and plant material into the stream (Everest and Reeves 2007). Ecological functions of riparian areas include shade, bank stability, food subsidies at the base of the food web (as leaves and wood drop into the water), large wood, and complex margins to the stream (Naiman et al. 2005). These functions are important for healthy fish habitat, and also for the many wildlife species that rely partially or completely on riparian habitats. Extreme floods may occur rarely, but a healthy riparian area is especially important at these times and may influence whether the flood renews or degrades conditions within the stream.

Since the early 1990s, stream ecologists have increasingly recognized the importance of considering the entirety of the stream network. This has led to extending our concept of riparian corridors to encompass smaller systems including non-fish bearing streams in headwater areas. This broad network perspective on streams and their associated riparian areas is particularly important in the ESRF where non-fish bearing streams comprise 89% of stream miles based on the OSU stream data layer for the ESRF. Almost all of these streams are smaller headwaters in the upper reaches of drainages. Hillslopes, headwaters and larger downstream waterways are all elements of fundamentally connected and integrated hydrological systems (Bracken and Croke 2007). In steep landscapes such as the ESRF, headwaters are particularly important sources of sediment and wood for fish-bearing streams, and provide habitat and movement corridors for native amphibians and macroinvertebrates.

Riparian forests in coastal Oregon have been substantially altered by historic land use. Until at least the 1970s, timber was often clear cut up to the stream margins which were then typically planted with commercial conifers, usually Douglas-fir, resulting in dense, even-aged conifer stands and a decrease in riparian hardwoods. By the 1980s and especially the 1990s, riparian buffers were phased in on many fish-bearing streams but non-fish-bearing streams, mostly in headwater areas, rarely had such protections. Overall, the distribution of conditions in riparian forests has changed dramatically compared to natural disturbance regimes.

In recent decades, to limit potential cumulative effects from multiple actions (none of which individually might be sufficient to impair water quality) vegetation management in riparian areas has generally been limited to the zone beyond 120-150 ft up to one site-potential tree-height (240' on the ESRF) from fish-bearing streams.

#### 1.4.7.5 Channel Habitat Types

Biosystems et al. (2003) used a system described in the Oregon Watershed Assessment Manual (OWEB 1999) to delineate stream segments with similar channel gradient and geometry to evaluate fish habitat and sediment transfer characteristics for the forest. Combinations of channel gradient classes (<1%, <2%, 2%-4%, 3%-10%) and channel confinement classes were determined for each fish-bearing stream segment. Confinement classes were:

- Large flood plain; broad valley flood plain not confined by hillslopes
- Moderately confined; floodplain width greater than 2X but less than 4X bank full width
- Confined; flood plain width less than 2X the bank full width

This resulted in six distinct channel habitat types for fish-bearing streams on the forest:

- FP = low gradient (<1%), large flood plain
  - FP1 = large streams
  - FP2 = medium streams
  - FP3 = small streams
- LM = low gradient (<2%), moderately confined
- LC = low gradient (<2%), confined
- MM = moderate gradient (2%-4%), moderately confined
- MC = moderate gradient (2%-4%), confined
- MV = moderately steep (3%-10%), narrow valley



Over 50% of fish-bearing stream miles were moderate gradient, confined channel (MC). Moderately steep, narrow valley channels (MV) make up 19% of the overall stream mileage. Confined channels, regardless of gradient, make up nearly 75% of fish-bearing stream miles. The moderate gradient, moderately confined stream type (MM) is found mostly in the Marlow Creek basin and lower WF Millicoma River drainage in the Coos Region. The low gradient, moderately confined stream type (LM) is relatively rare and occurs mostly in Palouse and Larson Creeks.

Low-gradient channels with a large flood plain occur only in Scholfield Creek and in lower reaches of larger streams in the Tenmile Region. Fish-bearing streams on most of the forest have favorable gradients for salmonids (less than 4%) but are tightly confined by adjacent hillslopes. Some streamside roads have further confined the stream channels. At high flows, considerable energy is conveyed by water flowing through narrow and non-meandering channels. Thus, slower water where fish can rest during high flows is limited mostly to that provided by large wood in the channel. Unconfined streams common to the Tenmile Region provide unique, high-quality habitat for fish not found elsewhere on the forest. These low-gradient streams are more likely to provide high-quality refuge habitat during high water since the channel can meander freely and create backwater areas.

#### 1.4.7.6 Wetlands

As defined in Oregon FPA rules, “wetland” means those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands include marshes, swamps, bogs, and similar areas. Owing to the generally steep terrain, there are no significant wetlands on the ESRF aside from scattered, mostly-beaver created small ponds and adjacent boggy areas. The National Wetlands Inventory shows some limited, patchy areas of *freshwater emergent wetland* and *freshwater forested/shrub wetland* along Mill Creek near Loon Lake Road on the east side of the forest, and along Palouse Creek and Larson Creek on the west side. Just outside the forest borders there are wetlands along lower reaches of Benson Creek, Dean Creek, Johnson Creek and Hakki Creek. Under the Oregon Conservation Strategy, both the Elliott and the Tenmile Lakes region just to the west of the ESRF boundary are listed as *Conservation Opportunity Areas*. The Tenmile Lakes area is influenced

by ESRF hydrology where streams coming off the forest transition into wetlands. Most larger Tenmile Lakes wetlands were converted to pasture decades ago, but some are recovering after being fallow for 30 or more years and others have been identified as possibilities for restoration. Several smaller drainage basins in the Tenmile Lakes region have mostly intact wetlands (TLBP 2002).

#### 1.4.7.7 Groundwater and Hyporheic Flow

Groundwater is subsurface water that percolates down and accumulates in spaces in soil or loose rock, or crevices in rock formations. Groundwater moves from higher to lower pressure zones and discharges into springs and streams. Streams often exchange water with groundwater repeatedly along their course, with groundwater discharging into the stream at various points, and stream water downwelling into the groundwater zone in other places. Uplands are part of the hydrologic cycle. Precipitation can evaporate, infiltrate into the soil, or flow overland to a stream or area where it can soak into the ground.

*Hyporheic flow* is the movement of surface water through gravels adjacent to and below the channel and then back to the stream. The hyporheic zone, where surface water and groundwater mix, is critically important in moderating stream temperatures, nutrient cycling, and providing unique habitats. Some ESRF streams – notably the WF Millicoma – are believed to have significantly reduced hyporheic flow and associated cooling as a result of past stream cleaning to purposely remove large wood from the channel, and also splash damming which has similar effects. Removal of large wood leads to rapid erosion of the sediment that logs in the channel retain. Lacking sediment, a stream loses its hyporheic flow. Replacing large wood components, in part to retain sediment that supports hyporheic flow, has been a key focus of stream restoration on the forest. (Figure 1.5.)

Nearly all annual flow on the ESRF occurs between October and June. Streams on the forest experience a period of extended very low flow from July through September. Daily average flows on the WF Millicoma River are regularly 5 cfs or less from late July through late August. *Base flow* is the component of streamflow that can be attributed to ground-water discharge into streams. Base Flow Index (BFI) is the ratio of base flow to total flow volume for a given year (Wolock 2003). Just to the south of the ESRF, Mayer (2012) found that BFI values for the main three tributaries of the Coquille River were within the lowest 10th percentile for all rivers in Oregon. Mayer (2012) attributed this to the basin's Tyee Formation geology, which also underlies most



**Figure 1.5.** Bedrock substrate in WF Millicoma River. Past practices of stream cleaning and splash damming removed large wood, causing erosion and loss of stream gravels that facilitate hyporheic flow. Restoring large wood and processes that supply it to streams can improve conditions for salmonids and other aquatic and riparian species by increasing sediment retention and hyporheic flow, attenuating water temperatures and flow velocities, and reconnecting off-channel habitats.

of the ESRF. These marine sedimentary rocks are not very permeable, which limits groundwater accumulation and contribution to streams in this type of geology.

In 1999-2000, ODF staff researched whether perennial streams in upper watersheds on the Elliott could be identified via measures such as drainage area, aspect, and distance from the drainage divide. Perennial flow was noted in some tributaries that drained only a few acres, suggesting that groundwater movement in this geology was not necessarily associated with surface topography. Field observers noted that water often surfaces at boundaries between sandstone beds and relatively porous siltstone. If

summer groundwater is carried along these weak layers, even a slight dipping in the strata may transfer flow from one topographic basin to the next. The study concluded that thick blocks of non-porous sandstone separated by thin layers of porous siltstone result in groundwater movement on the ESRF that does not necessarily correspond to topographic features (Biosystems et al. 2003).

#### **1.4.7.8 Water Supply**

Water that flows through ESRF lands sustains ecosystems and also provides for out-of-stream uses such as irrigation, domestic use, and municipal use. Several adjacent landowners



draw surface water from sources that are on or close to the ESRF. No municipal water systems are located within the ESRF.

Consumptive water uses: Adjacent landowners regularly use water from streams flowing off the ESRF for irrigation, domestic use, and pond filling and thus could conceivably be affected by changes in water quantity or quality associated with ESRF management. The Oregon Water Resources Department (WRD) issues permits for water withdrawals from streams and regulates water rights. Holders of water right certificates are authorized to withdraw a specific volume of water from Oregon waterways. The point of diversion, amount of water allotted, place of use, and purpose of water diverted are indicated on each water right.

Biosystems et al. (2003) analyzed spatial patterns of adjacent water rights and uses and identified 141 dwellings within ½-mile of the forest boundary that could potentially obtain surface water from streams exiting the Elliott. At that time, 167 surface water rights existed within this zone for domestic use, irrigation, and pond filling. Most water diversion points are outside of the Elliott, although locations of many rights could not be precisely determined. Houses within ½-mile of the forest are often grouped along terraces in valley bottoms. Locations of water permits for domestic use and irrigation generally correspond with houses, but some individual houses or groups of houses are far from a surface water right extraction point and some may have an alternative water source. Houses along the broad terraces of the WF Millicoma River and Mill Creek may obtain water from wells, and many houses along the Umpqua River are probably served by a community water system.

Biosystems et al. (2003) were unable to make a full accounting due to incomplete information but in general, individual water rights were small (usually 0.01 cfs or less), with only a handful of larger water rights issued for irrigation purposes. Biosystems et al. (2003) noted a considerable number of houses along the western and eastern edges of the forest with no nearby surface water permit and no obvious alternative sources of domestic water. Stands inside the western boundary (CRW) have been in long rotations and will be managed for conservation purposes in the ESRF with potential restoration treatments followed by no further harvest. Along the eastern boundary within Management Research Watersheds, there may be somewhat more potential for management activities to affect downstream uses of water for domestic purposes. The ESRF is legally allowed to deny use of water from a stream or spring by an adjacent landowner if the diversion point is on ESRF property and that landowner has no deed of conveyance or water right.

However, the long-term custom of Coast Range forest landowners is to avoid unnecessary conflict over water uses. Short of a detailed and comprehensive field study on neighboring residents and their source of domestic water, ESRF managers may need to address any potential water use problems on a case-by-case basis.

Instream flows and water rights: Instream flows provide substantial public benefits and ecosystem services, including support of fish and other aquatic life, recreational opportunities, and maintenance of water quality. In recognition of these benefits, the WRD works to restore and enhance stream flows by establishing instream water rights through new allocations and transfer of existing out-of-stream rights to instream uses. There are instream water rights on 23 streams that flow partially or wholly across the ESRF (Table 1.3). These instream flows can be critical for aquatic species during late summer and early fall when flows are lowest.

Most larger fish-bearing streams on the ESRF have instream water rights granted by WRD to the Oregon Department of Fish and Wildlife (ODFW) from 1974-1992. Instream water rights have priority dates and are superseded by more senior water rights established earlier. Since most of these instream water rights were granted in 1990 and 1992, older consumptive water rights usually control the amount of water in ESRF streams during the summer. Nevertheless, the existence of instream water rights on these streams has largely prevented further allocation of water, especially during the summer. However, the WRD can continue to grant domestic water rights (usually less than 0.01 cfs) for streams that are otherwise closed to further allocation (Biosystems et al. 2003).

#### 1.4.7.8 Water Quality

As required by the federal Clean Water Act (CWA) the Oregon Department of Environmental Quality (DEQ) has designated *beneficial uses* (e.g., fish and aquatic life, recreation, water supply) for Oregon waters and establishes water quality standards (benchmarks) to maintain these uses. The DEQ has established standards for criteria including sedimentation, biocriteria (e.g., fecal coliform), dissolved oxygen, and water temperature. In the case of temperature, the most sensitive beneficial use is Oregon's native cold-water aquatic communities, indicated by the presence of fish such as salmon and trout. Several temperature standards have been established to protect various life stages and fish species, depending on their thermal requirements (Oregon DEQ 2008).

**Table 1.3.** Instream water rights for streams partially or completely within the ESRF (Biosystems et al. 2003.)

ESRF Region	Stream	Priority Date	Minimum cfs in Fall	Minimum cfs in Winter	Location of Instream Right
Tenmile	Wilkins	1992	0.2	13.9	from headwaters (NWSW sec 25, T.22S, R.12W) to mouth
Tenmile	Murphy	1992	0.5	17.0	from headwaters (SWSW sec 29, T.22S, R.11W) to mouth
Tenmile	Big	1992	2.1	26.0	from tributary (NWNW sec 4, T.23S, R.11W) to mouth
Tenmile	Noble	1992	0.5	12.0	from headwaters (SWNE sec 8, T.23S, R.11W) to mouth
Tenmile	Benson	1992	1.3	60.4	from tributary (NE1/4 sec 16, T.23S, R.11W) to mouth
Tenmile	Roberts*	1992	1.1	17.0	from tributary (NWSW sec 21, T.23S, R.11W) to mouth
Tenmile	Johnson	1992	2.8	17.0	from tributary (SESW sec 31, T.23S, R.11W) to mouth
Tenmile	Robertson	1992	0.1	3.8	from headwaters (NE1/4 sec 35, T.23S, R.12W) to mouth
Tenmile	Adams	1992	0.5	9.0	from tributary (SESE sec 28, T.23S, R.12W) to mouth
Coos	Palouse**	1990	1.5	26.0	from tributary (SWNW sec 10, T.24S, R.12W) to mouth
Coos	Larson	1990	1.5	26.0	from Sullivan Creek to mouth
Coos	Sullivan	1992	0.3	14.0	from headwaters (SE1/4 sec 23, T.24S, R.12W) to mouth
Coos	Upper W.F. Millicoma	1990	3.1	100	from headwaters (sec 16, T.23S, R.10W) to Deer Creek
Coos	Lower W.F. Millicoma	1990	7.1	155.0	from Deer Creek to mouth
Coos	Deer	1992	0.5	26.0	from tributary (SE1/4 sec 2, T.23S, R.11W) to mouth
Coos	Knife	1992	0.4	17.0	from tributary (SE1/4 sec 31, T.22S, R.10W) to mouth
Coos	Fish	1992	0.3	17.0	from tributary (NE1/4 sec 5, T.23S, R.10W) to mouth
Coos	Elk	1992	1.0	43.0	from tributary (SE1/4 sec 24, T.23S, R.11W) to mouth
Coos	Marlow	1992	0.7	31.7	from tributary (NW1/4 sec 23, T.24S, R.11W) to mouth
Coos	Glenn	1992	2.1	85.0	from Silver Creek to mouth
Umpqua	Mill	1974	20.0	130.0	from Camp Creek to mouth
Umpqua	Dean	1974	2.0	20.0	from Hakki Creek to mouth
Umpqua	Scholfeld	1974	2.0	20.0	from Oar Creek to mouth

\*Roberts Creek also has an instream water right with a priority date of 1980; it applies throughout its main channel and tributaries. The amounts are 1 cfs in the fall to 10 cfs in the winter.

\*\*Palouse Creek also has an instream water right with a priority date of 1980; it applies to a point near the mouth at tide-water (sec 25, T.24S, R.13W). The amounts are 2 cfs in the fall to 15 cfs in the winter.



To assess whether standards are being met, the DEQ acquires water quality data from its monitoring program, other state and federal agencies, and individuals. If the data suggest that a water body does not meet a standard, the water body is then added to what is known as the “303(d) list”. No segments of stream on the Elliott were included on the 303(d) list as of 2003, although several water bodies west of the forest boundary were listed (Biosystems et al 2003). As of 2022, four streams on the ESRF of stream order 5 or above are 303(d) listed as having an impairment: segments of Dean, Johnson and Big Creeks along the western border of the forest (dissolved oxygen) where past land use has included agriculture, and the WF Millicoma River below its confluence with Panther Creek (temperature). Several other stream segments, smaller than stream order 5 and aggregated at the watershed level for EPA reporting, are listed as having an impairment (mostly for temperature). See Figure 1.6 (Oregon DEQ 2022). The impairments identified since the 2003 analysis do not necessarily reflect declining trends in water quality, but may be due to new data collection efforts informing the DEQ integrated report.

A stream on the 303(d) list has not necessarily been impaired by human activity. Listing simply means that a numeric or qualitative water quality standard established by DEQ has been exceeded at a point in time based on available data. The question of whether human activities caused the standard to be exceeded is addressed through a *Total Daily Maximum Load* (TMDL) process, a science-based approach to mitigate impairments and meet state water quality standards. A TMDL for sedimentation is in place for the Elliott, including segments of Johnson, Benson and Big Creeks near the ESRF western border (Oregon DEQ 2022).

Oregon’s TMDL priorities are reviewed every two years when the state submits its biennial 303(d) integrated report to the EPA. TMDLs are prioritized (high, medium) based on factors that include listing parameter, severity of impairment, water uses, availability of resources to develop TMDLs, judicial requirements, number of listed waters in a watershed, and public input. The 2022 integrated report lists no water quality limited stream segments on the ESRF as being a high or medium priority for a TMDL (Oregon DEQ 2022). The temperature TMDL for the Umpqua Basin Program is currently being revised, with anticipated completion in February 2025.

One factor that is not typically considered in a temperature TMDL and which may contribute to warmer temperatures

in some ESRF streams, is the role of streambed gravel and hyporheic flow in keeping water cool. Large wood plays an important role in trapping gravel in ESRF streams and a number of projects in forest streams have focused on replacing large wood removed by past land use practices. As large wood recovery continues in the future – both from additional active placements and proposed riparian restoration to increase large wood supplies and delivery – declines in water temperature may occur. In-stream and riparian restoration research planned for the ESRF has the potential to help address relevant questions through experimental projects and long-term monitoring (see Chapter 7: *Aquatic and Riparian Systems*).

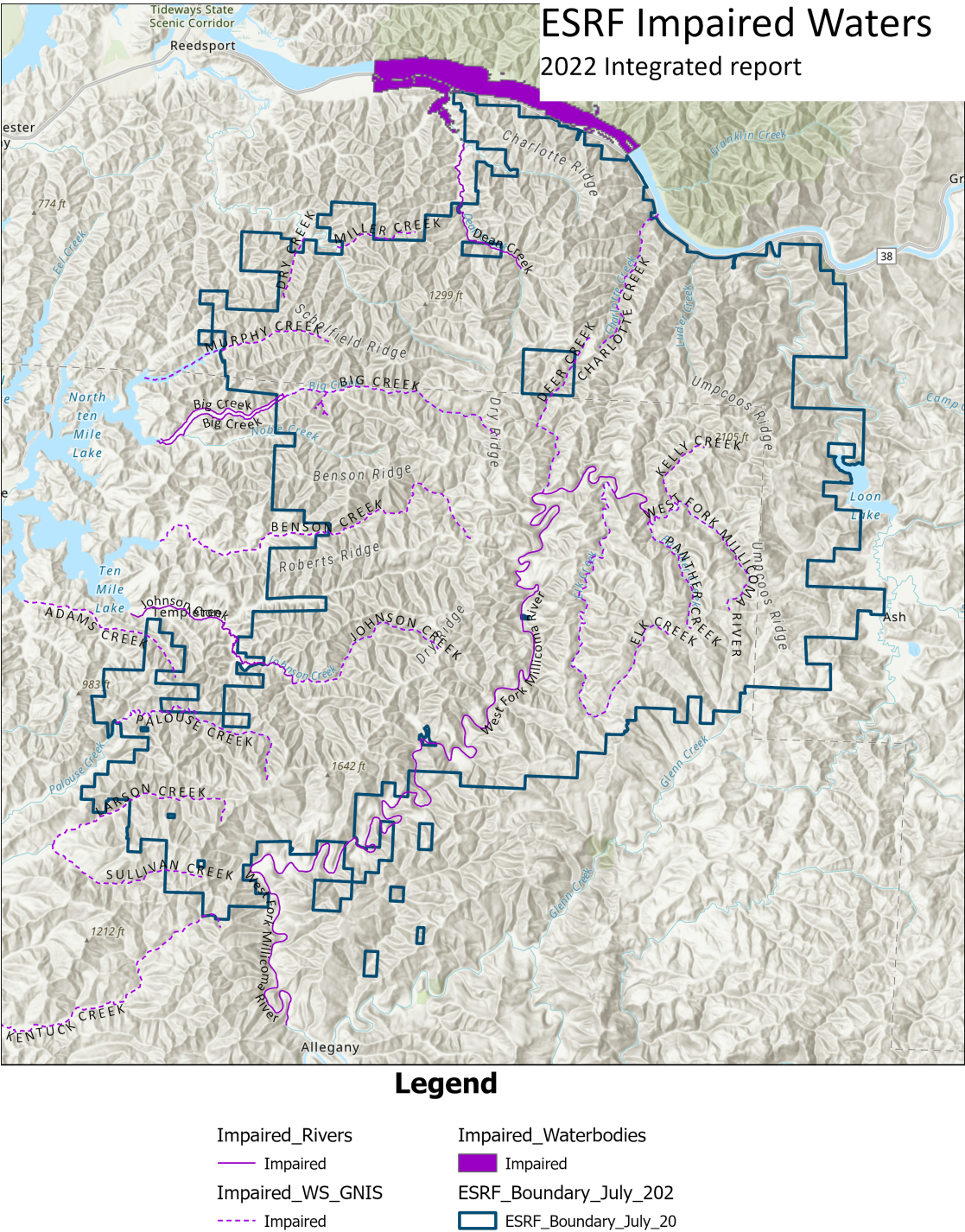
### 1.4.8 Vegetation

Different combinations of geology, geomorphology, climate, soils, past disturbance and land use result in complex vegetation patterns across the ESRF. Most of the forest lies within the *western hemlock* vegetation zone, with a small area along the northwestern edge in the *Sitka spruce* vegetation zone (Franklin and Dyrness 1988).

#### 1.4.8.1 Overstory

Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), and western redcedar (*Thuja plicata*) are prevalent conifers in the western hemlock association. The forest is currently dominated by Douglas-fir, an early successional species which establishes after wildfire and is also the preferred commercial timber species in the PNW for replanting after harvesting. Sitka spruce (*Picea sitchensis*) and grand fir (*Abies grandis*) are also present but in lower abundance. The ESRF’s natural and planted stands of Douglas-fir include a range of age classes, stand densities, and species composition. Western hemlock is the second most common conifer in the forest, followed by Western redcedar. Pacific yew (*Taxus brevifolia*) is rare but does occur. There are two small (~3-5 acre) plantations of approximately 20-year-old Port-Orford-cedar (*Chamaecyparis lawsoniana*) on the forest.

There is also a significant hardwood component on the ESRF. Red alder is most abundant, and quickly inhabits any site with exposed soil. Bigleaf maple (*Acer macrophyllum*) is common, and Oregon myrtle (*Umbellularia californica*) is found in the western portion of the forest. Other tree species include willow, golden chinquapin (*Chrysolepis chrysophylla*), Pacific madrone (*Arbutus menziesii*), cascara (*Rhamnus purshiana*), and Pacific dogwood (*Cornus nuttallii*) (Oregon DSL and ODF 2011).



**Figure 1.6.** Stream segments within ESRF listed as having an impairment under Clean Water Act section 303(d). Most impairments are for water temperature or for diminished levels of dissolved oxygen (DO). (Oregon DEQ 2022.)



Streamside forest stands on the ESRF regenerate and grow differently than upslope stands. Under natural conditions, conifer regeneration along streams tends to be sparser, probably owing to competition from riparian hardwoods and the presence of streamside terraces, which can be too moist for conifers. Those conifers that establish and survive along streams tend to grow very quickly as a result of an ample year-round supply of water. Timber management also can influence riparian vegetation competition. Biosystems et al. (2003) noted that the intensity of effort to establish conifers in clearcut areas next to streams on the Elliott has varied since harvesting ramped up in the 1950s, resulting in variable plantation success in these areas. Their analysis showed that among managed stands, hardwood domination of streamside stands appeared greatest where a road paralleled the stream, where buffers were retained 25-30 years ago, or where harvest occurred 55-80 years ago, when efforts to regenerate conifers near streams were weak. Conifers next to streams in managed stands were most abundant next to the most recently clearcut harvest units (up to 26 years ago) and harvest units with trees in the 35- to 55-year age class. Trees within units from this latter age class were typically harvested to the edge of streams followed by aggressive site preparation and conifer planting (Biosystems et al. 2003).

#### 1.4.8.2 Understory

Comprehensive surveys of understory plants on the ESRF are lacking. However, native Oregon Coast Range forests contain many dozens and perhaps hundreds of understory plant species that fill a range of important ecological roles, including provision of organic matter to forest soils, modification of micro-climates, and cover and forage for many animal species. Common Coast Range forest understory species known or likely to occur on the ESRF include rhododendron (*Rhododendron macrophyllum*), salmonberry (*Rubus spectabilis*), Oregon grape (*Mahonia aquifolium*), western swordfern (*Polystichum munitum*), common ladyfern (*Athyrium filix-femina*), oxalis (*Oxalis oregana*), black twinberry (*Lonicera involucrate*), wax myrtle (*Myrica californica*), red huckleberry (*Vaccinium parvifolium*), evergreen huckleberry (*Vaccinium ovatum*), salal (*Gaultheria shallon*), thimbleberry (*Rubus parviflorus*), stink currant (*Ribes bracteosum*), hazel (*Corylus cornuta*), and elderberry (*Sambucus racemosa*). Understory plant diversity is often greatly reduced in dense, even-aged, planted forests.

### 1.4.9 Fish and Wildlife

A list of species observed or thought to occur on the ESRF, along with information regarding their listing statuses, is provided in Appendix T.

#### 1.4.9.1 Terrestrial Species

A substantial amount of wildlife surveying and monitoring has occurred in the past by ODF, ODFW, watershed councils, and others, including for the three species covered under the ESRF HCP. Recent biodiversity surveys in 2022 and 2023 by Oregon State University researchers are adding to current knowledge about species presence and distribution across the forest using audio recording, camera traps, sample collection, and eDNA. A description of preliminary results from the 2022 biodiversity pilot study can be found in Appendix V.

Mammals that are known or likely to occur on the ESRF include deer, elk, bear, cougar, bobcat, most native weasel species, mountain beaver, skunks, squirrels, voles, mice, and other forest floor small mammals. There are extensive assemblages of native forest resident and migratory songbirds and raptors. Upland game birds such as grouse, quail, and turkey are known or likely to be present, as are resident and migratory waterfowl and other aquatic birds that are dependent on riparian, aquatic, and wetland habitats.

Beavers are known to be present in the forest and of particular interest because of their outsized role as ecosystem engineers and effects on habitat for other animals and plants, especially those associated with riparian areas. Bats forage over aquatic habitats and use forests for roosting.

#### 1.4.9.2 Fish and Other Aquatic Biota

Four salmonid species are found on the ESRF, the coho salmon (*Oncorhynchus kisutch*), fall chinook salmon (*Oncorhynchus tshawytscha*), winter steelhead trout (*Oncorhynchus mykiss*), and both sea-run and resident cutthroat trout (*Oncorhynchus clarki clarki*). Other native fish species present on the ESRF are Millicoma dace (*Rinichthys cataractae*), speckled dace (*Rinichthys osculus*), reddsideshiner (*Richardsonius balteatus*), Pacific lamprey (*Lampetra tridentata*), western brook lamprey (*Lampetra richardsoni*), largescale sucker (*Catostomus macrocheilus*), threespine stickleback (*Gasterosteus aculeatus*), Coast Range sculpin (*Cottus aleuticus*), and prickly sculpin (*Cottus asper*) (Biosystems et al. 2003).



**Figure 1.7.** The different ages and compositions of forest stands currently present across the ESRF represent a complex history of human and non-human disturbances.



The moist and mild climate of the ESRF also provides habitat for a range of aquatic and riparian dependent salamanders and frogs, which are listed and discussed in greater detail in Chapter 9: *Species Conservation*.

#### 1.4.10 Threatened and Endangered Species

The federal Endangered Species Act (ESA) of 1973 provides a regulatory framework to conserve, protect and recover endangered and threatened species and the ecosystems upon which they depend. When a species is listed as *endangered* under the ESA, it means that species is in danger of extinction throughout all or a significant portion of its range. Being listed as *threatened* means the species is likely to become endangered within the foreseeable future. *Candidate* species have been studied and warrant being proposed for listing as threatened or endangered.

Three species listed as threatened or endangered under the federal ESA, the northern spotted owl, marbled murrelet and Oregon Coast Evolutionarily Significant Unit (ESU) coho salmon are covered under the Habitat Conservation Plan (HCP) for the ESRF and discussed in detail in that document. See ESRF HCP Appendix B of for the full list of species that was considered for proposed coverage using the selection criteria. Other species that are listed or candidates for listing under the federal ESA and that occur or potentially occur on the ESRF include the coastal marten (*Martes caurina humboldtensis*) and red tree vole (*Arborimus longicaudus*). These and other sensitive species or species of special management concern are discussed in greater detail in Chapter 9: *Species Conservation*. ESRF managers will coordinate with appropriate agencies to track the status of species that are under review for potential listing under the Oregon state or federal ESAs.

#### 1.4.11 Ecology and Disturbance History

This section summarizes the primary natural disturbance processes that interact to shape and alter forest habitat and stand conditions on the ESRF. Each of these topics is covered in greater detail in Chapter 12: *Disturbance, Forest Health and Resilience*.

##### 1.4.11.1 Wildfire

Wildfire is an essential disturbance process in the Oregon Coast Range and has likely been dominant over large spatial and temporal scales. Disturbance regimes in Douglas-fir/ western hemlock forests within these “moist” forests have often been characterized as driven by predominately

infrequent, high-severity fires, with intermittent gap-scale disturbances generated by wind and biotic disturbance agents (Agee 1993; Franklin and Johnson 2012). These infrequent, severe fires are usually associated with large-scale east wind events that occur sporadically during the dry season from late August until early October. Much of the ESRF experienced a stand-replacing fire in 1868 and the conventional wisdom has been that most mature forests on the forest originated at that time. However, a growing body of evidence suggests considerably more variation in historical fire regimes across these moist, westside forest ecoregions with significant areas characterized by mixed-severity fire regimes and highly varied return intervals, including in the southern Oregon Coast Range.

To better understand these dynamics on the ESRF, the OSU College of Forestry (COF) coordinated with the USFS PNW Research Station Westside Fire Initiative to develop a robust dendrochronological reconstruction of historical fires on the ESRF. Results document several fires on the ESRF in the 19th century. The well-known 1868 fire and previously undocumented fires in 1849 and 1883 and 1894 were all likely influential to the development of mature stands that are common across the ESRF today. Results also suggest that temporal variation in fire frequency and severity facilitated multiple successional pathways and increased forest structural and compositional diversity across the ESRF prior to fire suppression. Findings, conclusions and management implications from this study on the disturbance history of the ESRF are presented in more detail in Chapter 12: *Disturbance, Forest Health and Resilience* and in Appendix J.

##### 1.4.11.2 Wind Storms

The Oregon Coast Range, including the ESRF, is directly in the path of large winter storms from the Pacific Ocean. These storms are accompanied by high winds, which alter forest structure by toppling trees and changing vegetative succession in the gaps created. Extreme windstorms blew down 3.7 billion board feet in the Coast Range in 1951 and approximately 3 billion board in 1962. Less severe windstorms can also blow down trees along the edges of clearcuts, including riparian buffer zones, increasing the amount of large, downed wood on hillslopes and in stream channels. For the Coast Range, windstorms severe enough to cause substantial tree uprooting have occurred in 1971, 1973, 1981, 1983, and 2002.

The Columbus Day storm of 1962 was a signature event in the history of the ESRF. The storm’s high winds blew down an estimated 100 million board feet of timber within the

forest boundary. Most of the downed trees were on the western half of the forest where few roads were in place. Nearly one-third of the 550 miles of roads on the ESRF were quickly built after the 1962 storm to access and salvage the downed timber before it rotted (Phillips 1997). An additional 200 MMBF were cut to access the blowdown, resulting in a total of 300 MMBF harvested in a relatively short period of time (Biosystems et al. 2003; Oregon DSL and ODF 2011).

#### 1.4.11.3 Drought and Heat Waves

Drought and heat waves are normal components of climate cycles, but their occurrence and severity have increased with climate warming. Longer-term drought interacting with generally higher temperatures and heat waves (“hotter drought”) is a potent threat to forest health (Millar and Stephenson 2015) and may be increasingly likely to affect the ESRF in coming decades by causing serious moisture stress in trees, abnormally dry forest fuels and associated increases in wildfire risk, and abnormally low stream water levels that impact fish and other aquatic life. Extended drought can make trees more vulnerable to insect infestations, compounding stresses and eventually leading to forest die-offs.

Summer dry seasons are becoming warmer and longer in the Oregon Coast Range. Since early 2020, much of the Douglas and Coos County area has been in some stage of drought and in severe or extreme drought for extended periods (U.S. Drought Monitor 2023). Compared to drier inland forests in Oregon, some of which are already experiencing extensive drought stress and tree mortality, wetter coastal forests may be somewhat more resilient under climate change. But as temperatures continue to rise, temperate coastal forests such as the ESRF are likely to be increasingly vulnerable during hotter droughts.

#### 1.4.11.4 Atmospheric Rivers, Extreme Precipitation and Flooding

*Atmospheric rivers* (ARs) are the cause of many of the most extreme precipitation and storm events along the U.S. west coast and a large majority of floods in the region. ARs are naturally occurring, transitory, long, narrow pathways of water vapor transport that contain massive amounts of warm, moist air and strong winds that often connect tropical storm moisture to the western U.S. When an AR reaches Oregon, the fast moving, moisture-laden air usually flows up and over the Coast Range, producing intense and sustained orographic rain. Both winter average precipitation

and extreme precipitation events associated with ARs are expected to significantly increase along the west coast in coming decades under the warming 21st century climate (Warner et al. 2015).

Flooding occurs regularly during winter storms in the Pacific Northwest. The WF Millicoma River gauging station recorded peaks of 5,560 cubic feet/second (cfs) in December 1964, a flood return period of 2 years, and 8,100 cfs in November 1960, a return period of about 8 years (FEMA 2018). The gauging station was inactive from 1982 until 2002, when Coos Watershed Association reactivated it. Since then, annual peak discharge on the WF Millicoma ranged from a low of 1380 cfs in 2020 to a high of 6870 cfs in 2015. The Cornell Place, located on Palouse Creek, was purchased and added to the Forest after the 1982 flood deposited large amounts of debris onto its fields from upland lands in state ownership. Some other properties on Palouse Creek were purchased in 1983 for the same reason. (Biosystems et al. 2003.) However, extensive flooding currently appears to be relatively uncommon on the ESRF owing to its steep terrain and minimal floodplain area, with winter high flows mainly confined to existing channels. Instead, the most influential effect of extreme precipitation on the forest may be to saturate soils on steep slopes, which tends to increase the probability and frequency of landsliding.

#### 1.4.11.5 Ice and Snow Events

Ice storms are infrequent in the PNW but can cause significant, widespread tree damage with long-term impacts. Phillips (1997) reports that the Elliott experienced a severe ice storm during the winter of 1929-30, signs of which were still apparent during timber cruises in the 1960s. In the Oregon Coast Range wet snow is somewhat more frequent than ice. Severity of tree damage appears to be closely related to the intensity of winds following snow or ice accumulations (Irland 2000). In general, small trees appear to receive the least severe damage, intermediate-sized trees receive the most, and large trees an intermediate amount.

On the ESRF, risk of tree damage from wet snow or glaze events may be greatest in established, younger stands with intermediate-sized trees (Priebe et al. 2018). With its generally mild winter climate, the risk of snow or ice events would also likely be greater at higher elevations on the forest. Most climate models predict warmer and wetter winters for the region (May et al. 2018) but conditions are also expected to become more variable, with increases in extreme weather events, including the potential for ice and snow.

#### 1.4.11.6 Insects and Disease

Forest insects, pathogens, and parasitic plants affect tree vigor and mortality at a range of scales, from chronic localized occurrences of root diseases and dwarf mistletoes to landscape-scale outbreaks of bark beetles or defoliating insects. These biotic disturbance agents are key drivers of structural and species diversity in forests. Most often, infestation does not kill the host tree rapidly but rather initiates a lengthy period of decline in growth and vigor that eventually results in mortality. The resulting snags and downed logs provide habitat for numerous wildlife species. Gaps and openings of various sizes created when individuals or groups of infested trees die also contribute to floral and faunal diversity. When operating within a historic range of variability (Keane et al. 2009) or in a manner characteristic of the ecosystem, native biotic disturbance agents often provide biodiversity benefits. However, uncharacteristic, larger-scale biotic disturbances, including exotic invasive insects and pathogens, can seriously impact forest ecosystem resilience and services.

Effects of biotic disturbance agents are currently not thought to be widespread or pervasive on the ESRF. However, Swiss needle cast is present and may be increasing, there are occasional outbreaks of Douglas-fir bark beetles, and pathogens such as laminated root rot and black stain root disease can cause problems in managed stands. There is also growing concern and supporting science that the frequency and intensity of interactions among biotic agents (e.g., bark beetles) and abiotic disturbances (e.g., drought stress and wildfire) are increasing as climate warming progresses, resulting in large-scale declines and dieoffs in western forests. (Agne et al. 2018.) Wet, coastal forests may be at lower risk for these effects, although the southern Oregon Coast Range has experienced serious drought in recent years (U.S. Drought Monitor 2023). Up-to-date information on biotic disturbance agents on the ESRF is limited but should increase as baseline monitoring ramps up. More details regarding biotic and abiotic disturbances and climate can be found in Chapter 12: *Disturbance, Forest Health and Resilience*.

## 1.5 Social and Economic Conditions

### 1.5.1 The ESRF and Local Economies

The economy of the Coos and Douglas County region has long been fueled by its rich and beautiful natural resources. While historically forest-products dominated, employment in the industry declined starting in the early 1980s as a result of multiple factors including the export of raw logs overseas, shifting industry investments, global competition, and uncertainty over federal timber harvests (Robbins 2006). However, the county maintains reduced but active forest and fishing industries (including significant export activity from its deep-water port), and the coast remains a significant tourist draw. Local tourism infrastructure includes casinos owned by Tribal Nations, the Oregon Dunes National Recreation Area land, a major golf resort, several coastal state, county, and private parks, and camping, hiking, angling, and hunting opportunities in the uplands portion of the county.

There are seven incorporated cities in Coos County (Bandon, Coos Bay, Coquille, Lakeside, Myrtle Point, North Bend, and Powers) along with unincorporated centers and dispersed populations. The Coos Bay (15,921) and North Bend (10,224) area is the most populous; Powers is the smallest city, with a population of 922. Just over 40% of the population of Coos County lives outside of the seven incorporated cities.

Since the 1960s, both the amount of timber harvest and the role of public lands in timber supply have fallen in Coos County. During the 1960s and 1970s, average annual harvest was more than 550,000 thousand board feet (MBF), with 40-45% of that volume coming from public lands (Figure 1.8).

In the 1990s, average annual harvest was just over 323,000 MBF, 80% of which came from private lands; by the 2000s, average annual harvest hovered just over 309,000 MBF, with private timber supply comprising 86% of the total (Oregon Department of Forestry, Oregon Timber Harvest Data Set). The role of natural resources in the economy has also consolidated in recent years (Figure 1.9); between 2001 and 2021, the number of people employed in the industry has declined from almost 1,846 to 1,432 (U.S. Bureau of Labor Statistics). As described by the U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages, “natural resources” industries include Wood Products Manufacturing, Forestry and Logging, Fishing, Hunting, and Trapping, and Support Activities for Agriculture and

Forestry. The BLS defines an establishment as a single physical location where one predominant activity occurs.

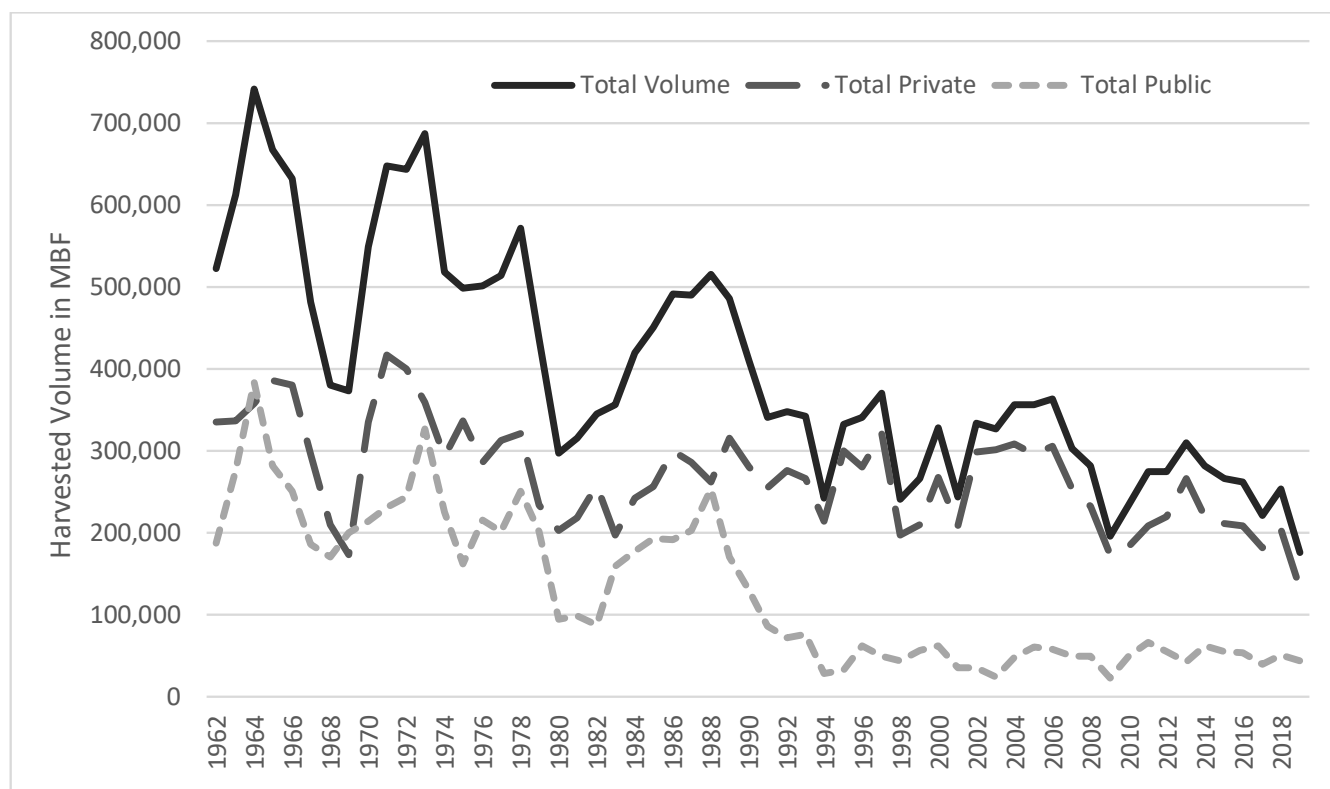
Today, the structure of the economy closely resembles that of Oregon (Table 1.4). While employment in natural resources is larger in proportion in Coos County (6% compared to 3% for the state), the largest industries by employment are educational, health care, and social assistance services (25%); arts, entertainment, recreation, and accommodation and food services (12%), and retail trade (11%); in proportions similar to Oregon (22%, 6%, and 11%, respectively) (U.S. Census Bureau).

Coos County had just under 65,000 estimated residents in 2021 (Table 1.5). The population is slightly older than the state as a whole, with 25.9% of the population 65 years or older and a county-level median age of 48.4 years (17.7% and 39.6 years and for Oregon). Although growing, Coos

County is growing at a slower rate than the state; between 2011 and 2021, Coos County grew by 2.4% while Oregon grew by 10.7%. Coos County had a median household income of \$52,548, and a poverty rate of 16.3% in 2021; for comparison, Oregon's poverty rate was 12.1% and median household income was \$70,084. The poverty rate in 2021 varied by town, from an estimated low of 14.8% in Lakeside to a high of 20.8% in Powers (U.S. Bureau of Labor Statistics).

### 1.5.2 Timber

Timber markets in southwest Oregon have been historically, and continue to be, strong due to the diversity of products that are produced across the region. Every size of log and nearly every timber species is desirable to at least two mills within economical haul distance, which ensures timber owners can receive competitive prices for their logs at the time of harvest.



**Figure 1.8.** Timber harvest in Coos County by landowner, 1962-2019. Data from Oregon Department of Forestry.



### 1.5.2.1 Markets

Southwest Oregon’s timber markets are consistently strong due to the diversity of finished products that are produced and access to log export buyers at the deep-water port in Coos Bay. Softwood lumber, plywood, engineered products, structural beams, mass timber products and wood chips are all manufactured within the Coos, Curry, Lane, Douglas county area. The export log market provides both a relief valve to handle surplus volume generated during good domestic markets, as well as an outlet for timber owners when domestic demand wanes. The regional domestic market is able to handle both small and large diameter logs. Plywood mills are capable of peeling logs up to 50 inches on the large end, and specialty mills that cut high value, tight grain logs have no maximum size. These mills will quarter logs until they are small enough to fit in the mill.

Log and lumber markets are constantly changing. Lumber prices are changing on a daily basis, while purchase orders

for logs are usually set a month at a time. The majority of logs are sold on a “delivered basis”, which means the timber owner is responsible for delivering the log to the mill location. Timber sales are also common, especially on government lands. Historically these timber sales have a two- or three-year term and the timber sale purchaser will be responsible for hiring a logger and delivering the logs.

### 1.5.2.2 Mill Infrastructure

Mill owners continue to invest in state of the art technology that helps them remain efficient and competitive in the global forest products market. This automation reduces their human resources need, while allowing them to continue to produce high quality, high value products that consumers across the country want and need. Multiple mills are in competition for each log at any given time. Finished product pricing and haul distance/cost will determine what is the most advantageous mill to send logs to. A sample of mills by county and type of finished product is shown in



**Figure 1.9.** Number employed and number of establishments in natural resources in Coos County, 2001-2022. Data from the U.S. Bureau of Labor Statistics. 2022 data are preliminary.

**Table 1.4.** Percent employment by industry for 2021, Oregon and Coos County. Data from the U.S. Census Bureau, 2017-2021 American Community Survey 5-Year Estimates.

Industry	Coos County	Oregon
Agriculture, forestry, fishing and hunting, and mining	6%	3%
Construction	6%	7%
Manufacturing	8%	14%
Wholesale trade	2%	3%
Retail trade	11%	11%
Transportation and warehousing, and utilities	6%	5%
Information	2%	2%
Finance and insurance, and real estate and rental and leasing	4%	6%
Professional, scientific, and management, and administrative and waste management services	9%	12%
Educational services, and health care and social assistance	25%	22%
Arts, entertainment, and recreation, and accommodation and food services	12%	6%
Other services, except public administration	3%	4%
Public administration	9%	6%

**Table 1.5.** Socio-economic characteristics, 2021, for Coos County and Oregon. Data from the U.S. Census Bureau, 2017-2021 American Community Survey 5-year Estimates.

Socio-economic Characteristic	Coos County	Oregon
Population, 2020	64,619	4,207,177
Population, 2010	63,108	3,801,991
Percent population change, 2010-2020	2.4%	10.7%
Median age, years	48.4	39.6
Percent of population, 65 or older	25.9%	17.7%
Median household income	\$52,548	\$70,084
Percent of population in poverty	16.3%	12.1%
Labor force participation rate	51.6%	62.6%
Unemployment, percent	6.1%	5.6%
Percent of adults with bachelor's degree or higher	20.0%	35.0%
Percent that moved from a different state in the last year	4.4%	3.3%

Table 1.6 below, with a corresponding map of regional mill infrastructure (as of 2022) in Figure 1.10.

### 1.5.3 Recreation

Current recreational use of the ESRF is largely determined by its location, topography, and accessibility. Most recreational visitors to the ESRF come from the surrounding communities given its distance from major metropolitan areas and general lack of awareness and accessibility for visitors to Oregon's coastal tourism resources. Highest visitation times occur in the summer months, especially over long holiday weekends, and in the fall for deer and elk hunting seasons, although overall recreation use remains low across most of the forest. The steep terrain concentrates recreational use to certain low-lying areas and access via the forest road network.

Current recreational uses and allowances on the ESRF include primitive camping, fishing, hunting, hiking, motorized and off-highway vehicles, firewood cutting, and non-commercial special forest products gathering (e.g., mushrooms, berries, boughs, etc.). Hunting, fishing and trapping are allowed as regulated by Oregon Department of Fish and Wildlife (ODFW). During extreme fire conditions, recreational and other public access to the forest may be limited or restricted.

## 1.6 Scenic Resources and Viewsheds

State Highway 38, adjacent to Elliott State Forest lands, is designated as scenic for the purpose of visual corridor management. The visually sensitive corridor is defined as the area within 150 feet of the outermost right-of-way boundary along both sides of the highway.

Two state forest land management classifications are used to designate areas for visual sensitivity. Where legal requirements or the management of visual resources dominate over the management of other resources, the lands are classified as *Special Stewardship–Visual*. Where management of visual resources allows for integrated management of other resources, but is subject to legal restrictions, supplemental planning, and/or modified management practices, the lands are classified as *Focused Stewardship–Visual*.

On private lands between the river and the ESRF, the lower Umpqua River along Highway 38 and its immediate visual foreground is protected either by Department of Transportation-owned scenic buffers or by scenic statutes and FPA rules. Some areas farther back from the highway, but still visible from the road, are considered mid-ground scenic areas and are designated as Special Stewardship–Visual. This means that harvesting is only allowed to enhance the visual characteristics of the forested landscape and/or viewshed. The background areas adjacent to these lands are classified as Focused Stewardship–Visual. Management activities for these areas have been adjusted for visual considerations during the FMP planning process, with the potential for further adjustments during operational planning.

## 1.7 Cultural Resources

Cultural resources include natural resources (such as plants, animals, and inanimate objects like water, minerals, and stones) and the ecological and social processes and systems (such as sun, wind, fire, and rain) that provide them, as well as physical sites or locations. The natural resources as cultural resources have been discussed previously. Here focus is on the physical sites or locations associated with human activities, including prehistoric and ethnohistoric Native American archaeological sites, historic archaeological sites, historic buildings, and elements or areas of the natural landscape which have traditional cultural significance. Prehistoric sites represent objects, structures, or material remains of Native American societies and their activities. Ethnohistoric sites are Native American settlements occupied after the arrival of European settlers in the area. Historic sites may also include buildings, old roads, bridges, and graves. Areas of traditional cultural significance are spaces that have been, and often continue to be, important to Indigenous Peoples today. This includes sacred areas for ceremony, as well as areas where Tribal Nations or Indigenous Peoples gather plants for food, medicine, or economic purposes (State of California Native American Heritage Commission 2023).

The Elliott has not been comprehensively surveyed for cultural resources. A cultural resource literature search for potential sites was completed in 1998 (Oregon DSL and ODF 2011). This report (Stepp Consulting 1998), identified four potential prehistoric sites and 50 historic site locations. Currently, only two of these sites have been field verified:



**Table 1.6.** Mill locations tributary to the ESRF by county and product

County	Mill	Product	City
Coos	East Fork Lumber	Sawmill	Norway
Coos	Oregon Overseas Timber	Sawmill	Bandon
Coos	Rose City	Sawmill	Broadbent
Coos	Roseburg Forest Products	Plywood	Coquille
Coos	Southport Lumber	Sawmill	North Bend
Curry	South Coast Lumber	Sawmill	Brookings
Curry	South Coast Lumber	Plywood	Brookings
Douglas	C&D Lumber	Sawmill	Riddle
Douglas	Douglas County Forest Products	Sawmill	Winchester
Douglas	DR Johnson Lumber	Sawmill	Riddle
Douglas	Herbert Lumber	Sawmill	Riddle
Douglas	Keller Lumber	Sawmill	Roseburg
Douglas	Murphy Plywood	Plywood	Sutherlin
Douglas	Nordic Veneer	Plywood	Roseburg
Douglas	Roseburg Forest Products	Sawmill	Dillard
Douglas	Roseburg Forest Products	Plywood	Dillard
Douglas	Roseburg Forest Products	Plywood	Riddle
Douglas	Swanson Group	Plywood	Glendale
Douglas	Umpqua Lumber	Sawmill	Round Prairie
Lane	Emerald Forest Products	Plywood	Eugene
Lane	Northwest Hardwoods	Sawmill	Eugene
Lane	Roseboro Lumber	Sawmill	Springfield
Lane	Roseboro Lumber	Plywood	Springfield
Lane	Sierra Pacific Industries	Sawmill	Eugene
Lane	Starfire Lumber	Sawmill	Cottage Grove
Lane	Stella Jones	Other	Eugene
Lane	Sundance Lumber	Sawmill	Springfield
Lane	Swanson Brothers Lumber	Sawmill	Noti
Lane	Swanson Group	Plywood	Springfield
Lane	Swanson Superior Forest Products	Sawmill	Noti
Lane	Weyerhaeuser	Sawmill	Cottage Grove
Lane	Weyerhaeuser	Other	Springfield
Lane	Zip-O Lumber	Sawmill	Eugene



**Figure 1.10.** Map of mill locations tributary to the ESRF by county and product.

two European settler cemeteries that are protected as heritage sites. Areas of traditional cultural significance are important resource considerations for management, as the Hanis (Coos) and Quuiich (Lower Umpqua) people are the original people and stewards of the land. Many of the descendants of these peoples today are enrolled in the Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians, and further consultation is needed.

There also are a few cultural resources associated with early Euro-American historic settlements that remain in the Elliott State Forest. The ESRF contains two homestead areas totaling 480 acres, two European settler cemeteries (protected as heritage sites), and four fire lookout towers. In addition, a foot trail may still exist by the former Trail Butte lookout. An historic wagon trail stretched from Allegany north along the East Fork Millicoma River, by Glenn Creek, east of Loon Lake, and continuing east to Scottsburg. Most of this old trail has been covered by current road systems, just as these systems likely covered Indigenous travel networks that pre-dated them.

## 1.8 Easements for Legal Access

Legal easements are often necessary to access state forestland through privately-owned forest, including for forest management activities. Depending on the needs of the landowners involved, easements can be temporary or permanent and allow either public use or use only staff and contractors. In managing the Elliott State Forest, ODF worked with landowners to create easements for roads and inholdings on the forest.

Forest roads on the ESRF will continue to be maintained, and in some cases developed, to provide access for the sale of timber and other forest products, timber management activities, and protection from fire. Forest roads will be designed, constructed, and maintained to meet or exceed rules of the FPA.

Elliott State Forest roads and private roads with easements will continue to be maintained under a road maintenance contract or by contractors as a requirement of a timber sale contract. ESRF staff will monitor road use, determine maintenance needs, and develop maintenance plans as part of the biennial planning process and continuous management planning efforts. These plans include road surface maintenance (grading and rock application); ditch,

waterbar, and culvert maintenance; roadside vegetation control; storm monitoring; and damage repair.

## 1.9 A Long-Term History of the ESRF

### 1.9.1. The Original Stewards of the ESRF

Indigenous People have lived along the southern Oregon Coast and Coast Range since time immemorial. Archaeological evidence shows that human occupation in Oregon began as long as 16,000 years ago, with physical evidence of occupation on the coast as early as 10,000 years ago. The variance in dates found archaeologically is likely due to the drastic changes to the coast line caused by periodic major earthquakes and changes in sea level, erasing miles of the coast line over thousands of years.

The Hanis (Coos) and Quuiich (Lower Umpqua) people are the original people and stewards of the lands that we now refer to as the Elliott. The Hanis people spoke hanis, a language closely related to miluk in the Coosan branch of the Coastal Oregon Penutian language family. The Quuiich people spoke another Coastal Oregon Penutian language, the quuiich dialect of sha'yuusht'a u4 quuiich which is also known as the Siuslaw language. Tenmile Creek was the general dividing line between the Hanis and Quuiich people. Large village sites were primarily located on solid ground above rivers and estuaries and some smaller villages were located along creeks and lakes. There were seasonal fish camps along many rivers and creeks, and seasonal hunting and plant gathering camps were numerous in the Coast Range.

The Hanis and Quuiich people managed and stewarded the Elliott to provide the natural resources that supported their communities and their culture. They gathered and cultivated culturally important plants such as hazel, huckleberries, blackberries and blackcaps. They managed and harvested trees to provide logs for canoes and planks for houses. They hunted deer and elk for food and hides, and the antlers and bones were used to make tools. To manage these resources and to create a resilient and diverse landscape with a full spectrum of habitat conditions, these people actively managed the Elliott. They routinely utilized trimming, harvesting, and fire to keep large portions of the Elliott clear of trees and brush. This use of fire maintained large



areas of early-seral conditions, which benefited deer and elk populations, benefited the soil, kept pathogens in check, and also promoted the light-loving plants that sustained their communities and their culture.

Today, many of the descendants of these original stewards of the Elliott are enrolled in the Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians (CTCLUSI). Despite its recent history of clearcutting and conversion to timber plantations, and related lower quality and lack of abundance across much of the forest, the present-day members of these tribes continue to rely on the Elliott as a source of traditional foods and medicines. They continue to practice their culture and lifeways on these lands as best they can. They continue to possess, and work to actively apply valuable Indigenous Knowledge related to the management of the Elliott that is built on millennia of experience practicing ecologically sustainable stewardship of these lands.

### 1.9.2. A History of the Elliott State Forest Since 1930

The Elliott State Forest was established on these lands as Oregon's first state forest in 1930, overseen by the State Land Board and managed by the Department of State Lands and Oregon Department of Forestry. Much of this section is drawn from the work of Biosystems et al. (2003) and Phillips' (1997) detailed history of the Elliott State Forest. Sources for more recent history include Oregon DSL and ODF (2011) and Oregon DSL (2022). Biosystems et al. (2003) characterized four phases of management on the Elliott. The following overview follows and builds on that model.

**Phase I: 1930-1945:** The origin of the Elliott State Forest dates to 1859, when Oregon achieved statehood and was granted sections 16 and 36 in every township (or similar lands) to be held as assets in the Oregon Common School Fund and used to finance public schools. Over time, most of this land passed into private ownership, but about 70,000 acres were scattered inside the newly established national forests in Oregon. To turn these isolated parcels into one manageable block of state-owned Common School Forest Land, State Forester Francis Elliott and Governor Oswald West arranged to trade the state parcels inside the national forests for one large block of the Siuslaw National Forest. This block of land became the Elliott State Forest, Oregon's first state forest, in 1930.

From the time of its establishment until the end of World War II, a system of roads was initiated on the Elliott,

but little timber harvesting occurred. After creation of the Civilian Conservation Corps (CCC) in 1933, camps were quickly established on the forest from which crews surveyed and marked forest boundaries, conducted timber inventories, constructed fire towers, and built roads. One of the main road routes constructed by CCC crews on the Elliott was the Scholfield Ridge (5000) and Umpcoos Road (7000) system, regarded as the toughest CCC project in Oregon. A key purpose of roads built during this period was to access fire towers at Dean Mountain, Cougar Pass, Elk Peak, and Trail Butte. The era of CCC camps and associated activity on the Elliott dwindled by 1941, and Phillips (1997) describes a period of relatively low activity on the forest during the war years. During the late 1930s and early 1940s, ODF awarded annual contracts to harvest cascara (*Frangula purshiana*) bark from the Elliott, which was used to formulate a natural laxative. Annual harvests reached 21 tons in 1943, then declined after the active ingredient was synthesized. Peeling the bark often killed cascara trees, which are not common in the forest today.

Fire protection for the Elliott was provided by the Coos County Fire Patrol Association from 1930-38. From 1938 into 1940, protection was provided by the State of Oregon. In 1940, fire protection reverted back to the Coos County Fire Patrol Association, which was renamed the Coos Fire Protective Association in 1948, and continues to provide fire protection for the forest to this day.

**Phase II: 1945-1962:** After World War II ended, active forest management and timber harvesting on the Elliott gradually increased. The timber sale program was initiated, accompanied by a rise in road construction. In 1945, the first timber was sold in the Ash Valley and Mill Creek areas to the E.K. Wood Lumber Company which had a mill in Reedsport and timberland holdings adjacent to the Elliott. Sales during the immediate post-war period were set up adjacent to existing roads and in proximity to lumber mills. After the sales were made, administration of them was often minimal, owing to travel distances from Salem and the lack of onsite staff.

In 1955, with the market for sawtimber gradually strengthening, and the need for a more active approach to timber sale administration becoming apparent, the Oregon Legislature directed the state to begin local oversight of forestry activities on the Elliott. Responsibility for on-the-ground management of the forest was transferred from the Department of State Lands (DSL) to the Oregon Department of Forestry (ODF). ODF then set up a local office in Coos Bay out of which they began to inventory timber resources

(which took three years) and directly oversee timber sales, harvesting and associated work on the forest. The Oregon Board of Forestry (BOF) prioritized timber sale and harvesting activities as follows:

1. salvage insect-killed, fire-killed, or blowdown timber;
2. sell “over-mature” timber generally more than 170 years of age;
3. sell mature stands of between 90-170 years old; and
4. conduct thinnings of immature stands.

(*Over-mature* timber refers to stands in which the trees have begun to decline in rate of growth and vigor and are increasingly prone to disease and insect infestation. It is now understood that these old-growth forest stands are important wildlife habitat, often high in biodiversity, and sequester immense amounts of carbon.)

The BOF also stipulated that any additional road construction beyond the existing road network on the Elliott would be built and paid for by timber sale purchasers directly related to the sale. These policies resulted in a gradual ramp-up in timber sales throughout the late 1950s until 1962, with initial efforts focused on accessing early post-war timber sales on the eastern edge of the forest in Ash Valley and along Mill Creek. During this period virtually no roads were constructed in the western half of the forest where stands averaged about 70 years old (in 1955) and were not a BOF priority for harvest. Instead, roads were generally extended from existing ones to access older stands. Over the 7-year period from 1955 until the Columbus Day windstorm in 1962, about 65 miles of standard (16-foot width) road and 78 miles of lower standard (14-foot width) road were built, with almost 104 miles built from 1960-1962. (Biosystems et al. 2003, Phillips 1997.)

Timber harvests (and the Allowable Annual Cut) during this period were initially 36 million board feet (MMBF) with 100-year rotation then raised to 44.6 MMBF with rotation reduced to 90 years in 1960. As Oregon’s population continued to grow, and consistent with the original land grants under the federal Oregon Admissions Act and the Oregon Constitution, the state’s public school system became increasingly reliant on timber harvest revenue. In 1958, ODF initiated its first “stand management” or thinning program of partial cuts instead of its usual clearcuts. In these harvests, objectives were to remove slower-growing conifer species, defective trees, and any alders in 75- to 125-year-old stands by “thinning from below,” and to leave the larger, residual trees for harvest at the end (rather than the beginning) of their

rotation age. This program lasted until 1978 and covered about 15,000 acres of the forest. (Biosystems et al. 2003, Phillips 1997.)

Phase III: 1962-1990: The Columbus Day windstorm of 1962 sparked a third phase of management on the Elliott. It was the most damaging storm to strike the PNW in 150 years (Mass and Dotson 2010), and on the ESRF, it blew down approximately 100 MMBF of timber. ODF responded with a program to access and salvage the blowdown before it lost commercial value and became a vector for bark beetles. At least 150 miles of new roads were needed to access the downed timber, which was scattered across some 250 different zones, mostly in the western part of the forest. These roads were generally constructed below prior standards, with little engineering, a lot of side-cast material, no surfacing or ditches, and a minimal 14-foot width. Each salvage unit involved a distinct set of decisions regarding practicality, economics, and long-term effects on management of adjacent stands. In all, about 200 MMBF of green trees mixed haphazardly among the blowdown were harvested to access the downed trees. From 1963-1965 about 100 MMBF of combined green and salvage timber was harvested annually (Phillips 1997).

In 1966, the BOF policy of only building roads into timber sales was relaxed. This allowed forest managers to begin upgrading roads built earlier, especially during the salvage program. Improvements included road surfacing, adding ditches, and upgrading bridges from log stringers to concrete. The first concrete bridge was built over the WF Millicoma River for the 2300 Road; after 1966 concrete bridges (or abutments) were used more often and included three on the 8000 Road from the mouth of Joe’s Creek to Elk Creek. By 1968, with the surfacing of the upper WF Millicoma Road (2000), the all-weather road system on the Elliott was essentially complete, although construction of spur roads and upgrades and maintenance of existing roads continued. In 1968 a single road maintenance contract replaced the system of having each timber purchaser perform maintenance on roads they used. (Biosystems et al. 2003.)

The ODF “stand management” (commercial thinning) program initiated in 1958 continued and peaked in the late 1960s, eventually encompassing 15,000 acres of the Elliott. The program was dramatically reduced in 1970 and eliminated by 1978 because costs (sale preparation and logging costs, some residual stand damage) were perceived to outweigh the benefits of increased growth and vigor of remaining trees. In 1968, the basis for the Annual Allowable

Cut was changed from “volume control with an acreage limit” to “acreage control with a volume limit,” with the initial annual target set at 1,300 acres per year.

Beginning in 1963, the first riparian buffer strips were left in the form of older stands of alder along the WF Millicoma River. At first, buffers were left on one side of the stream only. In 1968, the first sale with a 100-foot riparian buffers on each side of the stream occurred on the Alder Fork of Big Creek, a tributary to North Tenmile Lake, instituted at the request of ODFW to keep stream temperatures down (Biosystems et al. 2003, Phillips 1997).

The late 1960s and 1970s was a period of broad-scale societal shifts in awareness and concern about environmental issues and species conservation. The federal National Environmental Policy Act (NEPA) passed in 1970, the Clean Water Act in 1972, and the Endangered Species Act (ESA) in 1973. The Oregon Forest Practices Act (FPA) passed in 1971, the first state-level legislation of its kind in the nation. On the Elliott, the timber harvest program became more complex in the 1970s and early 1980s as additional scenic restrictions, high landslide risk assessments, and restrictions on harvesting to protect fish and wildlife were instituted in response to these changes.

Phase IV: 1990-2018: The listing of the northern spotted owl (in 1990) and marbled murrelet (in 1992) as threatened under the federal Endangered Species Act (ESA) signified the beginning of a fourth phase of management on the Elliott. The listing of these birds was emblematic of a regional shift in forest management that had been decades in the making. From about 1960-1990, timber harvests on federal forests in Oregon averaged roughly 4000 million board feet (MMBF) per year, private industrial forest harvests about 3000 MMBF, and state forests roughly another 200 MMBF annually (ODF 2005). Much of this harvesting was of trees that were hundreds of years old and occurred for many years with relatively weak environmental and water quality protections in place. Public concern over the rate of harvesting and loss of late successional and old-growth forests and associated impacts on wildlife and fish (especially salmonids), supported by increasingly reliable science, culminated in the early 1990s with ESA listings of the northern spotted owl and marbled murrelet, followed by widespread injunctions on logging based on these listings and passage of the Northwest Forest Plan in 1994. Relatively quickly, the focus on millions of acres of federal forests in the PNW shifted from timber production to ecosystem-based, landscape-level biodiversity and habitat conservation with an emphasis on endangered species (Thomas et al. 2006).

Timber sales on the Elliott dropped from their annual level of 40 to 50 MMBF in previous years to 19 MMBF in 1991. Up to that point, long-range plans for the forest were primarily timber management plans. In 1991, the State Land Board directed the ODF to work with the Oregon Department of Fish and Wildlife (ODFW), the Department of State Lands, and other state agencies to develop a new long-range forest management plan (FMP) to address the entire forest ecosystem, consistent with the timber management contract between the State Land Board and the ODF. Concurrently, ODF worked with the U.S. Fish and Wildlife Service (USFWS) for several years to develop a Habitat Conservation Plan (ESRF HCP) for spotted owls and marbled murrelets to allow for incidental take of these species to occur during forest management operations (Oregon DSL and ODF 2011). Timber sales were 22 MMBF in 1992, with no harvests in 1993, and sales capped at 18 MMBF for two years pending completion of the ESRF HCP (Phillips 1997).

A new FMP was approved for the Elliott State Forest in 1994. In 1995, the USFWS approved an ESRF HCP for the northern spotted owl and the marbled murrelet, accompanied by a 60-year Incidental Take Permit (ITP) for the owl, and a six-year ITP for the murrelet. As part of the 1995 ESRF HCP, the Elliott was zoned into long-rotation basins of 160 or more years and short-rotation basins of 80+ and 135+ years. In addition, Habitat Conservancy Areas (HCAs) and marbled murrelet Management Areas (MMMA) were established to protect habitat for these species. Under the terms of the 1995 ESRF HCP, the annual clearcut sales target was reduced to 460 acres with an expected volume of 22 to 25 MMBF. The thinning target was 500 acres per year with an expected volume of 3 MMBF.

The ITP for the marbled murrelet permit expired in 2001 and was the prime driver for revision of the Elliott State Forest FMP and ESRF HCP starting that year. The Oregon Coast coho salmon and its 18 independent populations had been listed as threatened under the federal ESA in 1998, and this species was included in ESRF HCP planning for the forest. After a ten-year planning process, ODF, DSL, USFWS and National Marine Fisheries Service (NMFS) were unable to agree to an ESRF HCP that would be consistent with the Common School Forest Land mandate and meet the issuance criteria for Incidental Take Permits. Instead, as directed by the State Land Board and Board of Forestry, ODF developed a “take-avoidance plan” by modifying the draft 2006 FMP to accommodate a take-avoidance approach for compliance with the federal ESA. The final revised FMP was published in 2011, without an ESRF HCP (Oregon DSL and ODF 2011).



Tension between the forest’s historical role of helping fund public schools and the potential to provide benefits beyond harvest revenue continued, despite the updated 2011 FMP. Timber harvesting was restricted in 2012 after a lawsuit over protections for ESA-listed species, and the forest began to require more funding to manage than timber sales were bringing in. Subsequent efforts by the state to generate revenue by selling parts or all of the Elliott into private ownership were met with public and legal resistance. In May 2017, the State Land Board voted to keep the Elliott State Forest in public ownership and directed DSL to move forward with a public ownership project for the forest.

Phase V: 2018-Present: In 2018, the DSL solicited a report on options for decoupling the Elliott from the Common School Fund (Harkema et al. 2019) and entered into multi-year agreements to work with the USFWS and NMFS on a new ESRF HCP for the forest. In December 2018, the State Land Board requested that Oregon State University, in collaboration with the Oregon Department of State Lands, explore the potential transformation of the Elliott into a publicly owned research forest managed by the OSU College of Forestry.

By early 2019, DSL and OSU began working together in response to the State Land Board’s request. The OSU project team initiated development of a proposal to balance species conservation with research on long-term, landscape-scale approaches to sustainable forest management, climate resilience, biodiversity and ecosystem functions, and social benefits on the Elliott’s Common School Fund lands. From 2019-2022, planning work for the Elliott was guided by the State Land Board and a 15-member Advisory Committee established by the state representing diverse perspectives including conservation, timber, schools, recreation, local governments, and Tribes. At this stage, Tribal Nations were included in the process as stakeholders through the state planning process. In December 2020, OSU submitted its proposal for an Elliott State Research Forest, which was refined in response to feedback and accepted by the State Land Board in April 2021. Input and insight from the ESRF Advisory Committee, along with extensive engagement of Tribes, community stakeholders and the public, contributed to development of the ESRF Research Proposal, and beginning in October 2021, the ESRF Forest Management Plan.

In April 2022, Oregon Senate Bill 1546 was signed into law, creating the Elliott State Research Forest and a new public agency, the Elliott State Research Forest Authority, to administer it. In December 2022, the Elliott State Research Forest Advisory Committee completed their service and the State Land Board appointed a prospective Elliott State Research Forest Authority Board of Directors. The Elliott State Research Forest was officially decoupled from the Common School Fund.

The transformation of the Elliott State Forest to the Elliott State Research Forest, including acceptance of the OSU College of Forestry Research Proposal, passage of Oregon Senate Bill 1546, decoupling of the forest from the Common School Fund and establishment of the Elliott State Research Forest Authority mark a “paradigm shift” in management of the forest. For the first time since its inception as a state forest, management of the Elliott will be guided by a new mission to become an enduring, publicly owned, world-class research forest that advances and supports all aspects of forestry while providing public access and educational opportunities to Oregonians and the world. Bringing this vision to life will take multiple perspectives and close collaboration as we continue to learn from each other and the forest, adapting together over time.



# Chapter 2

Decisions regarding the governance, organization, and financial overview of the ESRF remain undecided at this time. This chapter currently reflects recent discussions between DSL, OSU and the prospective ERFA Board of Directors.

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## Governance, Organization, and Revenue to Support Research Management

Effective governance and management of the Elliott State Research Forest will require ongoing collaboration and coordination among OSU, the ESRF Authority, Tribal partners, and stakeholders. This chapter summarizes roles and responsibilities of these entities as laid out in SB 1546, and provides a framework for implementing this statutory guidance for administering the ESRF to achieve its mission. Development of additional details, including regarding governance and public process, require continued work by the prospective ESRFA Board of Directors in coordination with partners.

## 2.1 ESRF Foundational Documents

As described in the enabling legislation for the Elliott State Research Forest and new Elliott State Research Forest Authority (ESRFA), there are three foundational documents that provide guidance for forest management, operations, and governance. These three documents are the Elliott State Research Forest Proposal, the ESRF Habitat Conservation Plan (ESRF HCP), and the ESRF Forest Management Plan (FMP). Research operations, management, and administration of the Elliott State Research Forest will be consistent with objectives, guidance, and requirements in the foundational documents and SB 1546.

### 2.1.1 Elliott State Research Forest Proposal

At the direction of the State Land Board, which includes Oregon's Governor, Secretary of State and State Treasurer, the Oregon Department of State Lands (DSL) and OSU began working together in early 2019 on a proposal to transform the Elliott State Forest into a world-class public research forest. From 2019-2022, planning work for the ESRF was guided by the State Land Board and a 15-member advisory committee convened by the Oregon Department of State Lands. The ESRF Advisory Committee included representatives from:

- The Oregon Outdoor Council
- Confederated Tribes of the Coos, Lower Umpqua and Siuslaw Indians
- Douglas Timber Operators
- Coos County
- Oregon State University
- Oregon Department of State Lands
- Confederated Tribes of Siletz Indians
- Confederated Tribes of Grand Ronde
- Oregon Hunter's Association
- Oregon School Boards Association
- The Audubon Society of Portland
- The Nature Conservancy
- Wild Salmon Center

The resulting ESRF Research Proposal was presented to the State Land Board in December 2020, and a revised version was accepted in April 2021.

A key function of the ESRF Research Proposal is to explain the research platform and Triad experimental design, which form the core of the ESRF research program as a landscape-scale investigation into forest management approaches that support multiple values, including forest ecosystem services, biodiversity, cultural resources, and wood products. The Research Proposal describes the three primary ESRF land management categories:

1. *Conservation Research Watersheds*, a contiguous area in the western portion of the forest where active timber harvest will be limited to restoration treatments in plantation stands less than 65 years old as of 2020.
2. *Management Research Watersheds*, where the Triad research platform will be implemented through a combination of Intensive, Extensive, and MRW Reserve treatments.
3. *Riparian Conservation Areas*, where management is focused on conservation and restoration of linked riparian and stream ecosystems.

Adjustments to the ESRF HCP in 2023 added several land management categories to the ESRF. See Chapter 4: *Research Platform and Experimental Design* for further detail. Nested research will occur across these areas as described in Chapter 5: *Research Planning and Implementation*.

The ESRF Research Proposal describes guiding principles developed by the ESRF Advisory Committee for Forest Governance, Recreation, Educational Partnerships, Local and Regional Economies, Conservation, and Tribal Engagement. The proposal provides an explanation of the Triad research platform, including the three types of forest management – *intensive*, *extensive* and *reserve* - that would be implemented in four different, replicated treatment combinations – *Extensive*, *Triad-Extensive* (Triad-E), *Triad-Intensive* (Triad-I), and *Reserve with Intensive*. A deliberative, adaptive process is outlined for acquiring baseline information about the ESRF through a landscape analysis, setting up a rigorous monitoring program, and phasing in the Triad research platform.

Senate Bill 1546 stipulates that the ESRF Research Proposal may be amended in the future by Oregon State University after receiving input and approval from the State Land Board and approval from the ESRFA Board of Directors. The ESRF is to be managed consistent with the most current version of the ESRF Research Proposal, available publicly on the ESRF website.



### 2.1.2 ESRF Habitat Conservation Plan

A Habitat Conservation Plan (HCP) is a long-term plan, prepared in agreement with federal agencies, to guide protection and enhancement of habitats for fish and wildlife species listed as threatened or endangered under the Endangered Species Act (ESA) in the context of natural resource management. An HCP addresses species protections, generates a long-term commitment to conserve the covered species, and delivers regulatory assurances to the landowner. The plan seeks to offset any harm that may occur to an individual of a listed species during active natural resource management, with protections that promote the long-term viability of the species as a whole through habitat conservation and restoration.

An HCP agreement includes an Incidental Take Permit (ITP) which allows that individuals of a listed species may be incidentally displaced or killed in the course of management activities in or near their habitats. This incidental “take” is allowed in view of broader support for the species as a whole through habitat conservation and improvement as well as mitigation measures in place to limit take. Conditions and conservation measures of an HCP are negotiated and reviewed with the U.S. Fish & Wildlife Service or National Marine Fisheries Service, referred to in the ESRF HCP document as the “Services”.

The ESRF HCP and associated ITPs cover three species, the northern spotted owl, marbled murrelet and Oregon Coast coho salmon over an 80-year permit term. The ESRF HCP differs from most forest land ESRF HCPs in that covered activities are focused primarily on research and restoration, rather than timber production as a separate goal. The ESRF HCP focuses on minimizing risks of take as research and restoration treatments are implemented. Over the ESRF HCP’s 80-year term, restoration actions within former timber plantations on the ESRF are expected to substantially improve not only the quality but also the extent of habitat for the covered species. Key chapters and sections of the ESRF HCP that assess the effects and prescribe the locations and types of allowable forest research, management and restoration activities on the ESRF include:

- Chapter 3: *Covered Activities* describes the activities for which the Permittee will receive “take” coverage for management of the ESRF as the Permittee. This includes management of different parts of the forest for specific research purposes, silvicultural activities that will be used to create the research platform, experiments conducted within that platform, and infrastructure needed to facilitate the research.

- Chapter 4: *Effects Analysis and Level of Take* presents the Services’ analysis of effects of covered activities on each covered species and their habitat on the ESRF including, for each species, an assessment of sources and types of take, amount of projected take, impacts of the taking of individuals on population levels, beneficial and net effects of the conservation strategy, and effects on designated critical habitat.
- Chapter 5: *Conservation Strategy* describes strategies and measures the ESRFA/DSL will use to minimize and mitigate impacts of take and forms the core of efforts to protect and restore habitat for the three listed species on the ESRF. The ESRF HCP conservation strategy is also discussed in Chapter 9: *Species Conservation* of this FMP.
- Chapter 6: *Monitoring and Adaptive Management* describes an integrated monitoring and adaptive management framework designed to ensure compliance with the ESRF HCP, to assess the status of covered species habitat, and to evaluate the effects of management actions such that the conservation strategy, including the biological goals and objectives, is achieved. Monitoring and adaptive management are also discussed in Chapter 10: *Monitoring*, and Chapter 11: *Adaptive Research Strategy and Implementation*.

At the time of completion of this ESRF Forest Management Plan, the ESRF HCP had not been finalized. The ESRF HCP provides the regulatory sideboards for the FMP. Once completed, any adjustments in the HCP will need to be incorporated into this FMP document so that the text is aligned. Within this document, the HCP for the Elliott State Research Forest is referred to as the ESRF HCP, but it should be noted that it is referring to the draft form of the ESRF HCP.

### 2.1.3 Senate Bill 1546

Senate Bill 1546 (SB 1546), codifies into law the establishment of the ESRF, specifies its mission and management policies, and outlines details of ESRF ownership, governance structure, management, and funding. SB 1546 establishes the Elliott State Research Forest Authority (ESRFA) as a new state agency to administer the forest. Establishment of the ESRFA has an effective date of January 1, 2024 pending completion of planning steps and approval of documents described in the legislation. In June 2023 a separate bill, Senate Bill 161, extended the deadline for completion of planning actions from July 1, 2023 (as described in SB 1546) to December 31, 2023.

SB 1546 includes direction for how the Elliott State Research Forest Authority (ESRFA) is to be administered, duties and authorities of the ESRFA Board of Directors, responsibilities of the ESRFA Executive Director, management policies for the forest, administration of funds, and policies regarding exchange of lands constituting the Elliott State Research Forest. The legislation also identifies the three foundational documents upon which management and administration of the research forest are based. Section 2.2 below references specifics of SB 1546 in describing governance and policy for the ESRF.

## 2.2 Governance and Policy

### 2.2.1 Role of the Elliott State Research Forest Authority

The Elliott State Research Forest Authority (ESRFA) is a new public agency established by the state to administer and provide oversight for the Elliott State Research Forest. The ESRFA is governed by a volunteer board of directors, consisting of seven or nine voting members appointed by the State Land Board for 4-year terms, and the Dean of the College of Forestry at OSU, who is a nonvoting member. As described in SB 1546, the State Land Board appoints members to the board of directors after consulting with and considering input from Oregon State University and existing members of the board. In making these decisions, the State Land Board will strive to appoint members who have a full complement of relevant experience or expertise in subjects related to the mission, management policies and operations of the ESRF and demonstrated interest in the success of the mission and management policies of the forest. Board members will serve staggered terms in order to support continuity of collective knowledge and operations.

The ESRFA Board of Directors provides governance and policy oversight to ensure that the ESRF mission and management policies are effectively implemented, operational and fiscal integrity of the ESRF is maintained, and that decision-making on the ESRF occurs with transparency and public participation. The Board of Directors approves annual budgets; biennial operating reports and plans; forest management, recreation, and education plans and any amendments to these plans; sale of carbon credits consistent with the management policies described in SB 1546 Section 2; entry into easements or encumbrances

of ESRF lands; expansion or exchange of ESRF lands; amendments to the ESRF HCP or Research Proposal; and any funding requests to federal or state agencies or the Legislative Assembly. The Board of Directors works to support the ESRF vision and foundational documents, including its research design, public commitments, and related foundational elements captured in the State Land Board decision or statutory framework establishing the ESRF. Bylaws will be developed and adopted by the ESRFA Board of Directors, which becomes operational as a governing body pending completion of the actions outlined in SB 1546.

The ESRFA Board of Directors oversees, delegates responsibilities to, and works closely with the ESRFA Executive Director, whose role is to lead the agency. The board delegates authority to the Executive Director, and provides guidance and direction to that individual on implementation of operations and research programs consistent with the ESRF mission, management policies, and approved biennial forest operations plans.

In addition, the ESRFA Board of Directors will provide the State Land Board with biennial programmatic reviews that address ESRFA functions including its fiscal integrity, the status of forest operations, research initiatives, Tribal partnerships, ties with local and regional economies, implementation of conservation, recreation and education programs, compliance with federal and state agency requirements and any policy directives from the executive branch.

### 2.2.2 Role of Oregon State University

ESRF research operations, management and scientific inquiry will be led by Oregon State University. The Board of Directors of the ESRFA will contract with OSU for implementation of forest management operations consistent with the mission and management policies described in SB 1546 (Section 2), the foundational documents, and a biennial operations plan, unless implementation of forest management operations is provided for as otherwise agreed to by the State Land Board, the Board of Directors, and the university. OSU will seek partnerships with Tribes as Sovereign Nations, not stakeholders, to advise on co-stewardship practices that honor Sovereignty Rights. Oregon State University's participation in management of the forest and research operations is dependent on approval by the Oregon State University Board of Trustees.

### 2.2.3 Role of the State Land Board

The State Land Board provides policy guidance to the ESRFA Board of Directors at the request of the board or OSU and as deemed necessary by the State Land Board as well as reviewing biennial programmatic reviews submitted by the board of directors. The State Land Board also approves the following:

- ESRF forest management plan and subsequent amendments
- Any amendments to the ESRF HCP proposed by the ESRFA Board of Directors prior to submittal to federal or state regulatory agencies
- Any proposed amendments to the ESRF Research Proposal
- Any expansion of ESRF lands, or exchange of lands in the forest or timber on those lands. Relevant conditions and actions related to expansion or exchange of lands are detailed in Section 14 of SB 1546.

The State Land Board will receive annual operations reports from the ESRFA Board of Directors for the first six years after the ESRF becomes operational.

### 2.2.4 ESRF Management Policies

In accordance with the ESRF mission, enabling legislation, and foundational documents, management policies for the research forest will advance long-term, operational-scale research that supports scientific inquiry, allows public access for recreation and education, supports local rural economies, promotes opportunities at all education levels, and seeks active partnerships with Tribal Nations and Indigenous Peoples. The ESRF will prioritize and build collaborative partnerships with organizations and seek opportunities that recognize local and statewide values for the forest alongside the ESRF research forest mission. The management goals, objectives, and strategies described in this FMP provide the guidance and direction for forest operations policies on the ESRF. Together with the ESRF Research Proposal, ESRF HCP, and forthcoming ESRF recreation and education plans, these documents guide management of the forest.

The forest will maintain a high level of public accountability and transparency in forest management decisions and operations, and advance equity and inclusion in all aspects of forest management and operations. The ESRFA Board of Directors will develop and implement bylaws, public process guidance, and mechanisms for transparency regarding the

agency's functions, public process for reviewing materials and decision-making. The ESRF will maintain a financially self-sufficient forest management entity capable of operating and overseeing the forest and necessary infrastructure.

Security issues on the research forest, including trespass, vandalism, theft, and dumping will be addressed by the ESRFA Board of Directors, Executive Director, and in coordination with the ESRF Research Director (PI) and the appropriate authorities. The Executive Director and ESRF operations staff will work with neighboring landowners to maintain easements for legal access and to communicate about road conditions, road maintenance, storm damage, access, and security issues and coordinate as appropriate.

## 2.3 Organizational Structure and Staffing

ESRF and ESRFA staff will be stationed at the Elliott State Research Forest and based in the local community. The Elliott State Research Forest Authority (ESRFA) is a public agency staffed by an Executive Director to lead the agency, an administrative assistant, and a 0.5 FTE policy analyst. The ESRFA is governed by a volunteer board of directors, consisting of 7 or 9 voting members plus the Dean of the OSU College of Forestry (ex officio), who oversee and administer the research forest. The ESRFA Board of Directors oversees, delegates responsibilities to, and works closely with the ESRFA Executive Director, providing guidance and direction to this position on implementation of operations and research programs consistent with the ESRF mission, management policies, foundational documents, public commitments, and approved biennial forest operations plans.

The following section provides descriptions of initial staffing structures for the ESRFA agency staff and ESRF research forest operations based on two funding levels, a *full capacity scenario* and a *reduced capacity scenario*. These initial organizational structures are consistent with current planning efforts, but are not intended to limit staffing structures or position descriptions if additional funding is available. As envisioned by the ESRF Research Proposal and in support of a full capacity Elliott State Research Forest, Figure 2.1 provides an organizational chart that describes a full staffing scenario of ESRF management and operations personnel. The ESRF research operations staffing structure under Oregon State University consists of a Research Director (Principal Investigator, PI) who reports to the

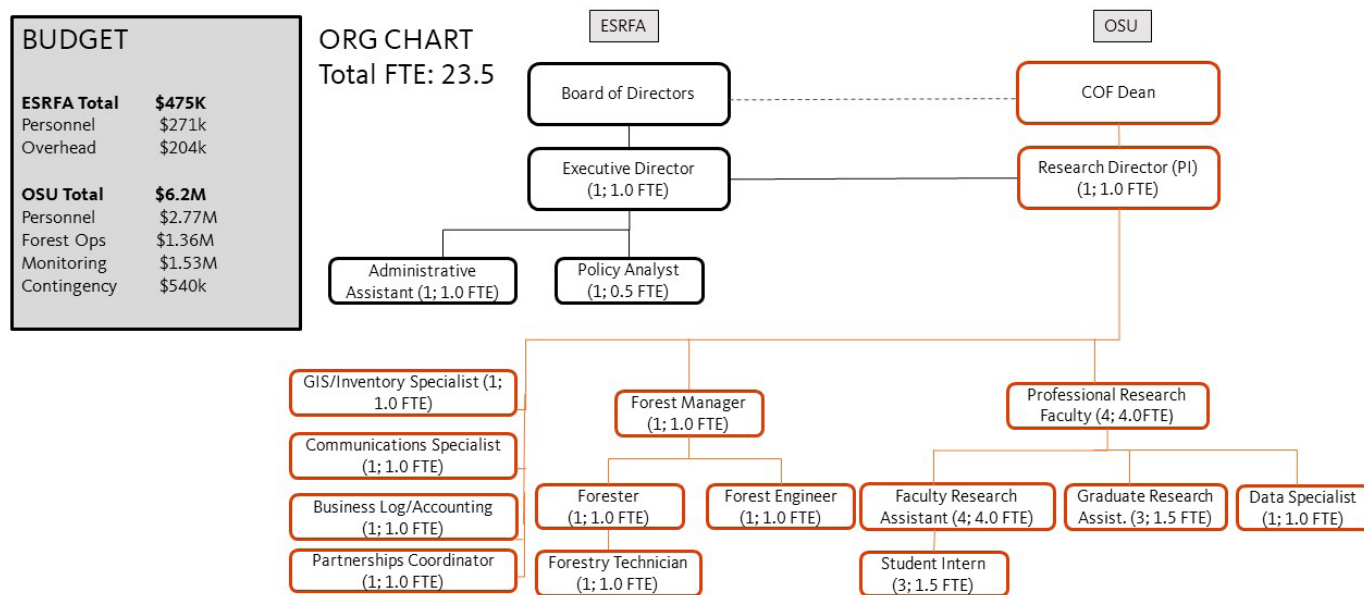


Dean of the College of Forestry and supervises research operations and forest management staff. The Research Director (PI) works closely with the ESRFA Executive Director to coordinate planning and operations of the research forest, and both regularly engage with the ESRFA Board of Directors, partners, Tribal Nations, and the public to communicate about proposed actions and intended outcomes on the ESRF.

Research forest operations staff initially include a lead forester (forest manager), forester, forest engineer, and forestry technician, communications specialist, and business accountant. A GIS/inventory specialist and data specialist provide important technical expertise to daily forest operations, long-term research, and data management. Four research faculty dedicated to the ESRF provide expertise in areas of importance to the research forest, including

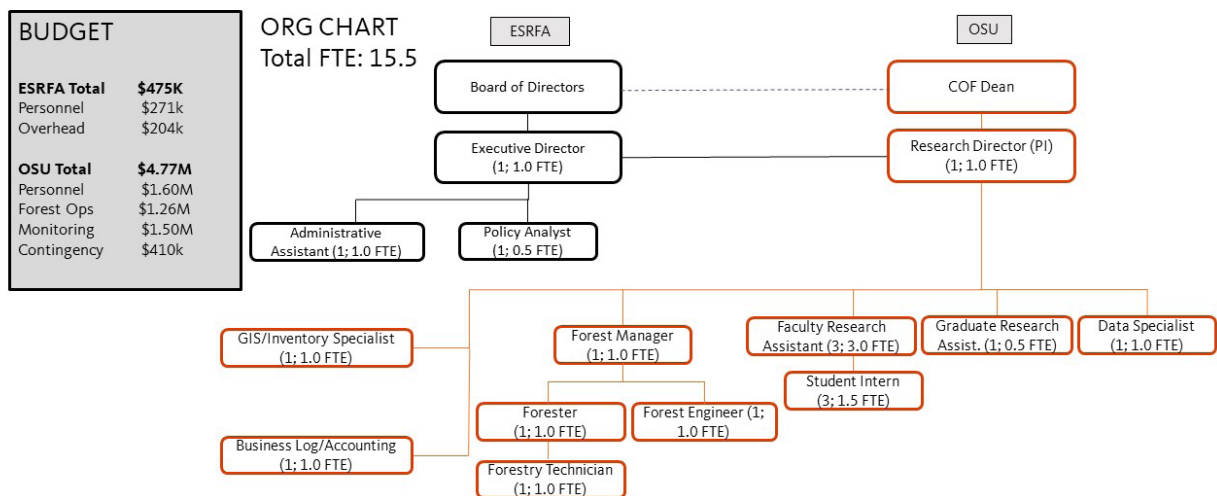
physical and biological sciences, human dimensions, and Indigenous Knowledge. It is anticipated that these faculty will bring focused capacity to research on the forest, support broader student involvement with research and learning opportunities, seek additional grant funding to support research projects, and help develop regional, national, and international partnerships relevant to the ESRF mission. Four faculty research assistants provide additional capacity and expertise for field work, data collection, equipment maintenance and calibration, analysis, and communication/publication. Dedicated student support for 3 graduate research assistants and 3 undergraduate student interns is provided in this staffing scenario, creating a strong platform for student engagement from OSU as well as other institutions and Tribal Nations. Total staffing in this scenario is 23.5 FTE, with details from the associated budget in Appendix E.

## OPERATING BUDGET SCENARIO (Full)



**Figure 2.1.** Organizational chart for a *full capacity* staffing scenario, ESRF forest operations personnel and ESRFA personnel (23.5 FTE).

## OPERATING BUDGET SCENARIO (Reduced)



**Figure 2.2.** Organizational chart for a *reduced capacity* staffing scenario, ESRF forest operations personnel and ESRFA personnel (15.5 FTE).

Figure 2.2 outlines a scaled, lower budget staffing scenario that maintains core functions of the research forest, monitoring, and ESRF HCP commitments while reducing overall capacity and annual estimated cost. ESRF positions removed in this lower staffing scenario are four research faculty, one faculty research assistant, the communications specialist, the partnerships coordinator, and two graduate research assistants. Total staffing in this scenario is 15.5 FTE, with details from the associated budget in Appendix E.

## 2.4 Revenue to Support Research and Operations on the ESRF

### 2.4.1 Sources of Revenue

The ESRF is expected to be financially self-supporting, with management and operations funded by forest activity revenue, including timber harvest and research grant revenue. The budget model is designed to fund the core or “backbone” research and associated long-term monitoring on the forest as described in the ESRF Research Proposal and Chapter 10: *Monitoring*. This core research includes

the Triad design in the MRW, CRW restoration and riparian restoration experiments in Douglas-fir plantations, and the Marbled Murrelet Research Experiment. Monitoring associated with this core research includes biodiversity, aquatic, landslides, forest carbon (vegetation and soil), forest yields and logging costs, and recreation/human dimensions and Tribal cultural values associated with the forest. Additional research proposed on the forest will go through an approval process as outlined in Chapter 5: *Research Planning and Implementation* to ensure it doesn’t conflict with the broader ESRF research goals or other existing studies on the forest. As part of the approval process, proposed studies will need to demonstrate that funding has been secured and appropriate capacity planned to complete the work.

#### 2.4.1.1 Timber Harvest

Timber harvests will occur as part of the research treatments on the ESRF, according to the ESRF Research Proposal and guidance in this FMP. This includes intensive allocations, extensive (ecological forestry) allocations, and restoration harvests in reserve plantations and RCAs as outlined in Chapter 6: *Silviculture, Harvest Systems, and Operational Planning*.

### 2.1.4.2 Research Grants

External and internal funding sources will provide funds for experiments proposed by collaborators, such as OSU and other universities, Tribes, agencies and other researchers from across Oregon and around the world. There are a multitude of research projects that fit under the umbrella of the ESRF research platform either nested within the Management Research Watersheds (MRW), the Conservation Research Watersheds (CRW) or the more than 10,000 acres in the “flexible” watersheds (known as “partial” watersheds in the ESRF Research Proposal. Successful research grant proposals have already begun funding some work on the ESRF with the anticipation that researchers will seek grant funds to support a range of short- and long-term research on the forest.

Data collected as part of the monitoring program (Chapter 10: *Monitoring*) and implementation of the research design will create an expansive, long-term data set that can support new research projects and both built upon by researchers designing nested studies and leveraged as a resource when seeking grant funds. Direct collaboration with agencies and organizations, including the U.S. Forest Service and USDI Bureau of Land Management, create opportunities for funding research. Other target opportunities include the National Oceanic and Atmospheric Administration (NOAA) Pacific Coastal Salmon Recovery Fund, a competitive grants program that provides funding to States and Tribes to protect, conserve, and restore populations of West Coast salmon that are in decline. Some grant funds may not be applicable to ESRF HCP commitments and monitoring requirements.

Federal agencies have regular calls for grant proposals, requiring 3-5 year budgets typically between \$500,000 - \$1M. These are highly competitive grants with funding success rates around ~5%. Examples of federal grant opportunities that may apply to the ESRF are:

- USDA National Institute of Food and Agriculture (NIFA) Agriculture and Food Research Initiative (AFRI) programs, including:
  - Plant Health and Production and Plant Products
  - Physiology of Agricultural Plants
  - Plant Breeding for Agricultural Production
  - Pollinator Health: Research and Application
- Bioenergy, Natural Resources, and Environment
  - Soil Health

- Water Quantity and Quality
- Sustainable Bioeconomy through Biobased Products
- Sustainable Agroecosystems
- Agriculture Economics and Rural Communities
  - Economics, Markets and Trade
  - Social Implications of Food and Agricultural Technologies
  - Rural Economic Development
  - Environmental and Natural Resource Economics
- National Science Foundation (NSF) programs, including:
  - Division of Integrative Organismal Systems Core Programs
  - Biology Integration Institutes (BII)
- Department of Energy
  - Biological and Environmental Research (BER) - Environmental System Science

### 2.4.1.3 Foundation Support

OSU, in collaboration with the ESRFA Board of Directors, will seek to secure external private funding support for the research and learning activities associated with the forest, including foundation support. Opportunities for foundation funding may grow over time as the ESRF research program is launched, innovative projects build on the wealth of knowledge being developed, collaboration grows the adaptive research strategy is applied.

### 2.4.1.4 Carbon Monetization

The legislation that enables the creation of the ESRFA requires that all carbon offset opportunities be reviewed and approved by the ESRFA Board of Directors prior to making any form of carbon offset sales or commitments. Consistent with SB 1546, the ESRFA may participate in available ecosystem services or forestry carbon programs and markets consistent with the management policies described in Section 2 of the legislation.

### 2.4.2 ESRF Budget Model

Two main budget scenarios have been developed for the ESRF – a full capacity staffing structure that meets the needs of the research forest as envisioned throughout the planning process, and a scaled staffing structure reflecting



a lower budget scenario focused on core research forest operations and ESRF HCP commitments (Appendix E). The budget scenarios each include different annual research operations budgets, ranging from \$6.16M (for a fully staffed research operations program) to \$4.77M (for a program that supports core research management, monitoring, and staffing costs but has limited research personnel). The scenarios include annual contributions to a contingency fund that is expected to build over time. In addition, an ESRFA budget of \$475,000 outlines costs for agency staff and supporting services for the ESRFA itself.

In the ESRF budget model, research and operations personnel will be full-time employees based in the community surrounding the research forest. The full capacity budget scenario includes full funding for research faculty dedicated to the forest, as well as a communications specialist, and greater capacity for field work provided by Research Assistants and students. The scaled, lower version of this budget eliminates direct faculty support, the communications specialist, one research technician, and some of the student support.

In the operating expenses portion of the ESRF budget model, core expenses for forest management and the foundational research monitoring program are outlined. Some of the line items are true fixed costs, while others are scaled to the FTE covered by each budget. The notes columns provide additional detail on how these estimates were made. The scenarios include annual contributions to a contingency fund that is expected to build over time. The line item for “Research Monitoring & Equipment Replacement” includes cost estimates for surveys/plots, field crews, technology (e.g., LiDAR), and equipment replacement. These costs are dependent on the availability of additional start-up funds to launch the research monitoring program, purchase equipment, and hire staff.

### 2.4.3 ESRF Startup Funds

As identified in the ESRF Research Proposal, startup funding from the state is necessary for financial viability of the forest. This funding includes support for necessary infrastructure and equipment as well as bridging for the annual costs until timber revenue begins in year four of operations. OSU and the Department of State Lands have both received federal funds to support some of the startup costs, with other funding requests pending. The state is pursuing additional funds along several avenues, which will be critical to successfully launching hiring and operations of the research forest.

### 2.4.4 Projected Annual Operations

Specifics of annual research forest operations will be determined through development of biennial operations plans in agreement with the guidance and conditions of the ESRF Research Proposal, ESRF Habitat Conservation Plan, and ESRF Forest Management Plan as foundational documents. Biennial operations plans will go through a public process and be subject to approval by the ESRFA Board of Directors.

As part of 2023 forest management plan development, two modeled harvest scenarios described were created project decadal timber harvest (in acres) for eligible stands by allocation category over the 80-year term of the ESRF HCP in order to facilitate the analysis of potential financial, operational, and environmental outcomes of implementation of the ESRF Research Proposal (Appendix H). These scenarios inform planning for the ESRF by identifying stands eligible for timber harvest by decade according to their treatment allocation, stand age, and assumptions in the model. The two harvest scenarios are not intended to serve as implementation blueprints, and actual operations will differ from the information presented in Appendix H. Plans for annual operations will be determined by coordination between the Research Director (PI), foresters, ESRFA Executive Director, and other relevant ESRF research operations staff based on details including (but not limited to) eligible stands, near and long-term objectives under the research design, more information including stand visits and further data analysis, and tracking the four-year rolling average harvest cap.

## 2.5 Public Engagement and the ESRF

Public engagement is an important part of the Elliott State Research Forest mission and management. The ESRF will maintain a robust online presence, including a data portal with real-time and archived data for use by researchers, managers, partners, and the public. Educational partnerships and plans will be developed to create opportunities for learners from K-12 programs, colleges and universities, Tribal Nations, informal education participants, and visitors to the research forest (see Chapter 3: *Managing a Research Forest for Multiple Values*).

As a public agency, the ESRFA follows all applicable public meetings and public records laws. Materials being considered by the ESRFA Board of Directors, including biennial operations plans, reports, annual budgets, and governance and policy will be made publicly available prior to board meetings and archived for future reference. The ESRFA Board of Directors will provide to the State Land Board and the public, 45 days for the Board of Directors approves or denies a biennial operation, written materials related to the biennial operations plan that contain operational details and guidance sufficient to ensure compliance with the relevant management plan direction described in the forest management plan and habitat conservation plan. As outlined in SB 1546, the ESRFA Board of Directors will consider public comment before making decisions to approve biennial operations plans, biennial operations reports, and annual budgets. Details of this public engagement process will be provided by the ESRFA Board of Directors.

## 2.6 Near-Term Process and Planning

Looking ahead to 2024, multiple near-term planning processes will continue to support the launch of the Elliott State Research Forest, the creation of a new public agency in the Elliott State Research Forest Authority, continued engagement with Tribal Nations as leaders in co-stewardship, early implementation planning, development of public processes specific to the ESRFA, and continued collaboration that have helped create the vision and strategies in this Forest Management Plan. Oregon State University and the ESRFA Board of Directors will work together in a collaborative and transparent manner on this next stage of planning.



## Chapter 3

### Managing a Research Forest for Multiple Values: Research, Conservation, Education, and Recreation

The ESRF offers an array of opportunities for engaging with people, Tribal Nations, organizations, and institutions. These opportunities may range from information sharing through networking and public outreach to formal collaborations and co-stewardship in meeting the ESRF's goals for integrating research, conservation, education, and recreation. It is expected that over time, as baseline monitoring programs are initiated, phased implementation of Triad and nested research proceeds, and adaptation occurs as part of the research program, these opportunities will be maintained and may diversify. Opportunities for outdoor and experiential learning about aquatic and restoration ecology, wildlife biology, ecological silviculture, active forest management, ecosystem services, natural resource economics and related topics can be expected to increase as baseline monitoring and research, and associated knowledge about the forest, ramp up. Expansion of monitoring and research activities on the ESRF will be accompanied by an increase in personnel available to interpret and



transfer knowledge, as well as more field sites, experiments, monitoring stations and management actions to teach “about”. Recreation opportunities such as hunting, birding, and camping will be maintained and may diversify as ESRF watersheds are treated for greater complexity and resilience.

While there are currently no outlined plans to modify existing opportunities on the ESRF within the next two years, modifications during this time may be considered on a case-by-case basis. The enabling legislation for the ESRF, SB 1546, does contain explicit language regarding public outreach and partnerships and there is significant potential for diversification and enhancement of these opportunities as the ESRF transitions to a research and conservation focus. For these reasons, future work will involve developing a collaborative framework that encompasses research, conservation, education, and recreation. The latter two opportunities will have plans developed for them, while the other opportunities (research and conservation) will emerge organically as existing and new partners join in the delivery of the ESRF’s potential as a research forest.

## 3.1 Partnerships for Research, Management, and Conservation

Partnerships are important to meet the research, conservation, education, and recreation goals of the ESRF. Defining a collaboration framework assists people, groups, organizations, and other entities to be effective, resilient, and sustainable (National Network for Collaboration 1995). This framework is feasible when based on a foundation of shared vision, mission, principles, and values as outlined in the ESRF Research Proposal (OSU College of Forestry 2021) and as adopted by the ESRF Authority Board of Directors. At the core of these partnerships are relationships where people, groups, and organizations work together to achieve desired results. The National Network for Collaboration (1995) outlines a collaboration framework that defines five levels of relationships:

- Networking – basic sharing of information through public outreach.
- Cooperation or Alliance – working in parallel toward similar goals or interests.
- Coordination or Partnership – sharing of resources to address common issues.

- Coalition – sharing of ideas and entering short-term commitments.
- Collaboration – working toward a shared vision with interdependent structures and systems, including the co-stewardship of the land.

The level of commitment within each of these relationships increases from networking relationships to collaboration relationships (Figure 3.1), which concurrently means that the level of focus on the purpose and goals of the forest increase similarly. These changes in the level of commitment will likely require different degrees of formality and reciprocity in defining these relationships, with collaboration requiring formal guidelines and expectations through memoranda of understanding (MOU), data sharing agreements (DSA), and other binding rules for engagement.

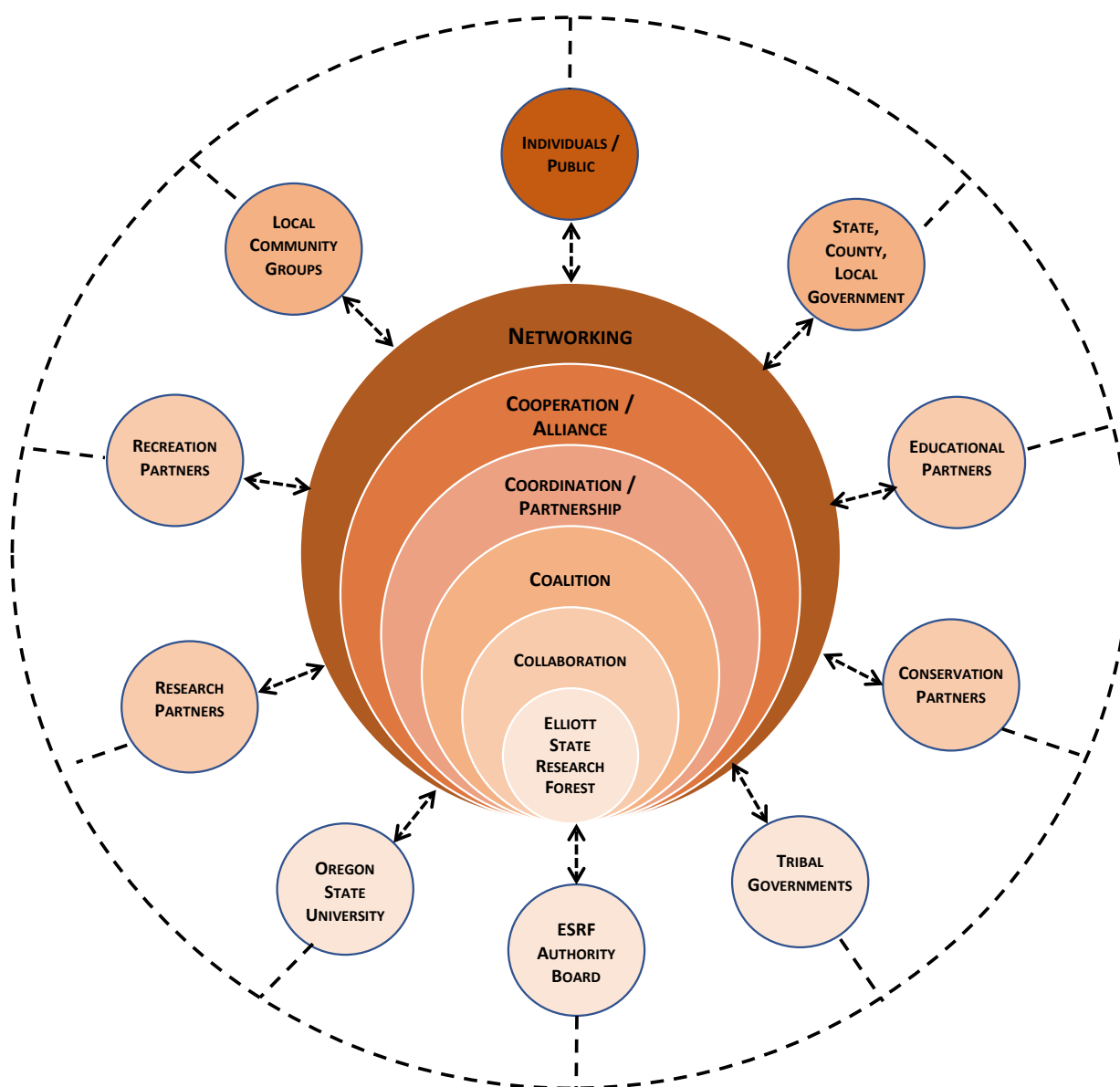
### 3.1.1 Tribal Partnerships

The College of Forestry is committed to going beyond the land acknowledgment and will work alongside Tribal partners to decolonize research methodologies (Smith 2012) and embrace multiple ways of knowing including Indigenous Knowledges. Partnering with Tribes and Indigenous Knowledge holders requires a high level of commitment from both parties. The College of Forestry has published its nine principles for working with Indigenous Knowledges and partnering with Tribal Nations and Indigenous Peoples (OSU College of Forestry 2023, Appendix C). The intent is to work closely with Tribal Nations, Indigenous Knowledge holders, and other sanctioned individuals to decolonize research practices, co-steward the forest resources, and co-generate applied research and educational opportunities on the Elliott State Research Forest.

The nine principles that will guide the College of Forestry’s work with Indigenous Knowledge and partnering with Tribal Nations and Indigenous Peoples are:

**Principle 1. Acknowledge the historical context of past injustice: genocide, ethnocide, and ecocide.** Indigenous people, our Nations, and the Lands continue to suffer trauma from the violent legacy of colonization – we need to acknowledge this as part of our history and collective stories.

**Principle 2. Practice early and sustained engagement with Tribal Nations and/or Tribal knowledge holders.** We acknowledge that the ESRF Research Proposal and this management plan, among other work regarding the future



**Figure 3.1.** Collaborative framework envisioned for ESRF. Note that the research forest is at the center as the shared vision, mission, and goals. Relationships that are closer to the research forest and a lighter shade of color have increasing degrees of reciprocity and commitment to the forest and between partners. Key entities are satellites around the research forest with direct connections through their defined relational types and indirectly with all other satellite entities.

of the Forest, did not fully engage Tribal Nations and Tribal knowledge holders. However, we commit to moving forward in a positive direction.

**Principle 3. Earn and maintain trusting relationships by being transparent, open about ideas and agendas, and honest at all times, in all forms of communication.** This trust must be built on decolonized foundations of respect, humility, and reciprocity.

**Principle 4. Respect different processes and worldviews.** While we have our standards of practice and engagement, we also must be adaptable to learning and working within differences of cultural expectations, timelines, and resources.

**Principle 5. Recognize, respond to, and adapt to challenges with cultural humility.** “Cultural humility is the ongoing process of self-exploration and self-critique and willingness to learn from others” by “honoring their values, beliefs, and customs, and accepting that person for who they are” (OSU College of Forestry 2023:6).

**Principle 6. Consider supporting co-management and co-stewardship structures.** This includes bringing Tribal Nations into decision-making in a meaningful way. To OSU, this means fostering a collaborative framework of co-stewardship. “Co-stewardship is broader [than co-management] and refers to a range of working relationships with Tribal Nations, as well as Tribal consortia and Tribal-led entities exercising the delegated authority of federally recognized Tribes. Tribal co-management and co-stewardship require a *Memorandum of Understanding* (MOU), defined as a Government-to-Government agreement that establishes standards of partnership; or a *Memorandum of Agreement* (MOA), defined as a document written between parties to cooperatively work on an agreed upon project that involves a transfer of funds” (OSU College of Forestry 2023:6).

**Principle 7. Pursue co-production of knowledge.** This means that we fully embrace multiple knowledge systems by practicing equitable and inclusionary principles in defining research questions and applications of knowledge acquired.

**Principle 8. Provide ample funding to Tribal Nations and Indigenous Peoples for involvement at each step of partnership and knowledge co-creation.** At a most basic level, inclusionary practices demand that all resources be shared when working together collaboratively. Decolonization of research practices is to provide equal standing to Tribes that also supports their social, economic, and cultural goals and priorities.

**Principle 9: Share power and decision-making authority with partnering Tribes and Indigenous Peoples.** This means that we may build trust by “creating supporting legal documents for work on Tribal lands, or that involves Indigenous Knowledge obtained from Tribal knowledge keepers on non-Tribal lands, such as an MOU and *Data Sharing Agreement* (DSA), defined as a formal contract that clearly documents the data being shared and the parameters under which those documents may be used, or a *Non-disclosure Agreement* (NDA), defined as a contract by which one or more parties agree not to disclose confidential information that they have shared with each other as a necessary part of working together” (OSU College of Forestry 2023:6). These protections are necessary given the sovereignty of Tribal Nations and their right to Indigenous Knowledges as intellectual property under U.S. law.

The College of Forestry believes that “clearly established policies...that acknowledge and respect Sovereignty Rights and enter into Government-to-Government relations with MOUs, MOAs, DSAs, and other types of formal legal agreements are essential to creating healthy intercultural relationships” (OSU College of Forestry 2023:7). The first few steps have been taken down the path of decolonizing cultural values and processes at OSU College of Forestry in collaboration with Tribal Nations and Indigenous partners in Oregon and beyond. Intentionally following the principles defined above and best practices (yet to be co-developed) in co-stewarding the ESRF will aim to foster trustful, reciprocal, and sustainable relationships. All entities engaged in the leadership and management of the ESRF, including the ESRF Authority Board, are strongly encouraged to follow similar protocol as described above.

### 3.1.2 State and Federal Agencies

The ESRF will build partnerships and identify collaboration opportunities to enhance restoration, research, and management through partnerships with state and federal agencies, including but not limited to, Oregon Department of Fish and Wildlife (ODFW), Bureau of Land Management (BLM), U.S. Forest Service (USFS), U.S. Fish and Wildlife Service (USFWS), Oregon Water Enhancement Board (OWEB), Oregon Department of Forestry (ODF), and the Oregon Department of Environmental Quality (DEQ). Many of these agencies have already played a crucial role in the development of this FMP and the monitoring strategies in both terrestrial and riparian systems.



Partnerships and collaborations with state and federal agencies will vary broadly in both scale and scope. For the USFS, BLM and ODF, which manage lands surrounding the ESRF, engagement is likely to be very frequent, as communication and coordination will be important in identifying mutual research interests, managing disturbance events/fire prevention, and coordinating monitoring efforts as well as removal strategies for species like the barred owl. At ODF, there is an incredible amount of institutional knowledge both about past management and monitoring on the Elliott that will be an essential component in planning the future of the ESRF. Consultation with ODFW and USFWS biologists in developing experiments and in planned monitoring efforts will be important to identify mutual needs, secure appropriate permitting, and draw on existing data and experience in these agencies. The ESRF may also partner with watershed associations to apply for OWEB grants and complete work associated with in-stream restoration efforts. Work on aquatic and riparian habitats may also include collaboration or consultation with DEQ on aquatic and riparian restoration and monitoring. In addition, the HCP Implementation and Adaptive Management Committee (see Chapter 5: *Research Planning and Implementation*) will include participants from USFWS, National Marine Fisheries Service (NMFS), ODFW, and other subject matter experts, to participate in research and monitoring planning conversations relevant to the HCP covered species. Acknowledging that this list represents a handful of the many ways that coordination and communication will be important between the research forest and state and federal agencies, the ESRF managers will work to set up regular meetings with agencies and additional partnerships to ensure clear communication and coordination.

### 3.1.3 Partnerships with Non-Local Institutions and Organizations

The ESRF has the potential to be a significant asset to the state of Oregon for delivering values and outcomes that benefit its citizens, as well as globally for the learning that occurs from research projects and other forms of scientific inquiry. There are numerous mechanisms for partnering with institutions and organizations, which may include sub-agreements, intergovernmental agreements, joint ventures, among others. In all cases, these partnerships will have defined goals and objectives, deliverables and expected outcomes associated with them. Reporting requirements can vary greatly depending on source of funding and the nature of the partnership.

Formal partnerships with other academic institutions will be necessary to meet the research goals of the forest. These partnerships will follow OSU and research funding institutions (such as the National Science Foundation) set guidelines and practices. At OSU, it is the general understanding that “the Lead Principal Investigator has overall responsibility for the technical aspects of a sponsored project, which includes serving as the primary point of contact with the sponsor’s programmatic representative. While there are some exceptions, the Office of Sponsored Research and Award Administration (OSRAA) has overall responsibility for the administrative aspects of a sponsored project, which includes serving as the primary point of contact with the sponsor’s grant/contract officer” (Oregon State University 2016:4).

### 3.1.4 Local Community Partnerships

Local partnerships are important as strong means to meet the local impact goals of the ESRF. Local community partnerships have the potential to ensure the overall success of the ESRF in meeting its goals and objectives as a public research forest. Enabling local groups to engage in the research and monitoring processes advances scientific understanding and leads to better informed decisions. Community science is the participation by the public (as individuals or members of community groups or organizations) in scientific research, including developing research questions, collecting and analyzing data, and interpreting results. The ESRF presents an opportunity to support community science and related educational programming. These partnerships have the potential to help increase shared capacity where objectives of the research forest and local organizations are in alignment. Coordination with local government and surrounding land ownerships, as well as partnerships with watershed councils and associations can help support shared goals for restoration, education, and landscape-scale management. However, in order for these community-based efforts to be effective and useful to the overall mission of the forest, a quality assurance project plan has been recommended to ensure a high level of quality of and integrity to their inputs (US Environmental Protection Agency 2019).

To the degree practicable, the ESRF will coordinate with these local organizations and coalitions to accomplish mutual goals related to local outreach and education, recreation access, as well as riparian protection, enhancement, and restoration.

### 3.1.4.1 Watershed Councils and Associations

Community-based natural resource management emerged in the 1990s and 2000s as a participatory approach to local, place-based projects and programs aimed at enhancing environmental and community health. Oregon has been a leader in this movement, primarily through locally organized, voluntary, non-regulatory *watershed councils* that conduct education, outreach, and watershed enhancement projects with support from the Oregon Watershed Enhancement Board (OWEB) and other funding entities. (Lurie and Hibbard 2008.) Watershed councils vary substantially in focus and capacity due to differences in local watershed size and characteristics, uses and issues, demographics and citizen perspectives, and other factors. The ESRF encompasses parts of three watersheds – the Coos, Tenmile and Umpqua – with a watershed association operating in each.

The *Coos Watershed Association* (CoosWA) has been leading innovative science, restoration, monitoring, and education programs with the Coos watershed community since 1994. Their mission is to support environmental integrity and economic stability by increasing community capacity to develop, test, promote and implement management practices in the interest of environmental health. To date, CoosWA has attracted and expended more than \$25,000,000 in the 610-square mile Coos watershed, with most of that money going to local contractors and suppliers. Much of the central ESRF lies within the Coos watershed, including the WF Millicoma River and its tributaries.

The *Tenmile Lakes Basin Partnership* (TLBP) is a community based cooperative endeavor involving industry, local citizens, natural resource agencies, Tribal Nations, and conservation groups to protect, encourage and enhance the use of natural resource principles that promote ecosystem health and diversity. The Tenmile Lakes basin encompasses about 98 square miles, the eastern 1/3 of which lies within the western portion of the ESRF.

*Partnership for the Umpqua Rivers* (PUR) is a 501(c)3 voluntary corporation that is charged with restoring and enhancing water quality and fish habitat within the Umpqua Basin. The PUR assists with development and completion of watershed improvement projects on a variety of landownerships through sourcing funding and technical assistance, as well as providing education opportunities. Lands in the northern and eastern portions of the ESRF lie within the Umpqua basin.

ESRF will seek opportunities to coordinate and collaborate with these and other conservation organizations focused on aquatic and riparian habitat and biota. This may include (1) supporting partner efforts to secure funds from OWEB and other sources, (2) collaboration in establishing restoration projects that align research with conservation and cultural resource priorities, and (3) data sharing and synergistic data collection efforts in monitoring systems before and after treatments in manipulate and reference sites (see specific example below in regard to in-stream wood additions and stream gaging).

## 3.2 Recreation Management and Education Management Planning Processes

This section of the ESRF FMP outlines a process for the future development of recreation and education plans for the forest. There are three primary reasons that recreation and education plans will be established in the future: (1) both will require active and inclusive public engagement and data collection (current use and desired potential future uses); (2) to facilitate implementation of the FMP to establish baseline public access zones; and (3) to support an active ESRF Authority Board of Directors to make decisions regarding acceptable recreation and education uses of the forest and any temporal or spatial restrictions to public access on the forest. The recreation and education plans are part of public access, with other types of public access to be established separately from these plans, such as local Tribes' access for cultural purposes (SB 1546, Section 2, Subsection 3.g.).

### 3.2.1 Recreation & Education Planning and Public Access

SB 1546 established the Elliott State Research Forest (ESRF) and ESRF Authority with a Board of Directors (BOD). The BOD will approve or deny (Section 7.1.i.) both recreation plans (7.1.i.D) and education plans (7.1.i.E) that are consistent with an applicable forest management plan and the mission and management policies described in Section 2 of SB 1546. In part, Section 2 Subsection 2 states that “The mission of establishing the Elliott State Research Forest is to create an enduring, publicly owned, world-class research forest that (a) Advances and supports forest health, climate resilience, carbon sequestration, biodiversity, recovery of imperiled species, water quality and quantity,

*recreational opportunities* and local economies” (2.2.a., emphasis added), as well as “(b) Is managed to promote collaboration, partnerships, inclusive public processes and equity” (2.2.b.). Section 2 subsection 3 further states that “The management policies for the forest are to: ... (c) Allow public access for recreational and educational purposes that is compatible with scientific and conservation purposes and the mission and management policies described in this section” (2.3.c.); ... “(e) Support rural economies through active forest management, timber harvest, recreation and research” (2.3.e.); and “(f) Promote opportunities at all education levels to interact with the forest and advance public understanding of the ecological, economic and social benefits of healthy forest ecosystems” (2.3.f.).

During the transition period in establishing the ESRF Authority and associated BOD and through the development of recreation and education management plans, it is anticipated that public access and use would remain based on historic use. Any changes in access and use would be approved through the remaining authority of DSL before transitioning to the ESRFA Board of Directors.

Public listening sessions and engagement with stakeholders during the ESRF Research Proposal and FMP planning processes indicate that there is strong interest locally and across the state for continued public access, educational programming, shared governance, and partnerships to capture and enhance opportunities for recreation and education associated with the ESRF. People strongly felt that the development of recreation and education management plans are necessary to help guide the appropriate use of the ESRF while balancing the needs of research, conservation, community, and economy. Separate ESRF recreation and education plans will be developed as outlined below.

### 3.2.2 Recreation and Education Guiding Principles

OSU’s ESRF Research Proposal provides the following guiding principles as developed by the DSL Advisory Committee after reviewing public input noted previously.

The recreation guiding principles are:

1. Ensure public access into the future
2. Promote recreational access and use that is compatible with research and ecological integrity
3. Support and promote diverse recreational experiences

4. Partner with stakeholders and manage locally
5. Conduct research on sustainable recreation practices
6. Cultivate multi-generational respect for the forest.

The educational partnership guiding principles are:

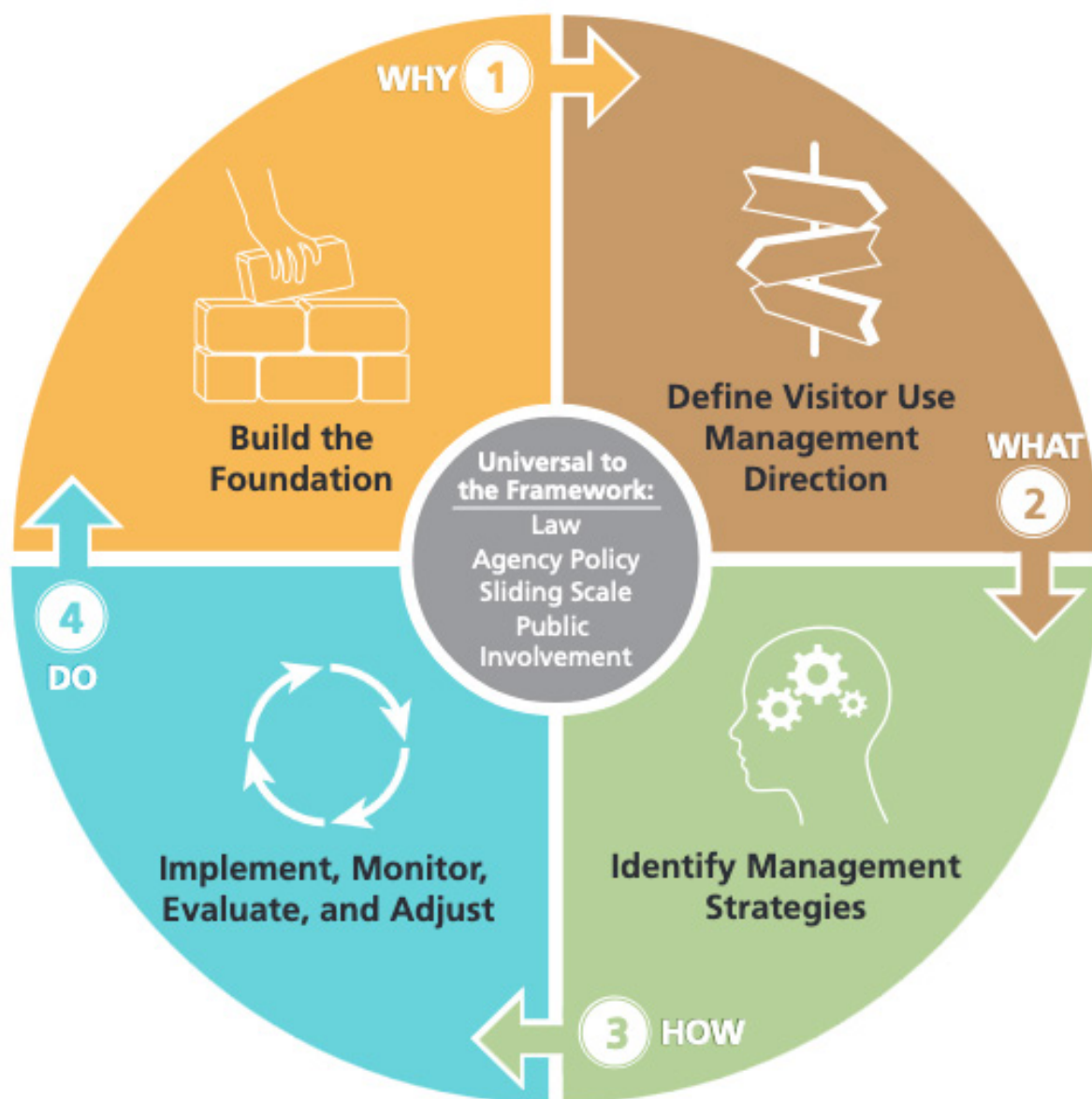
1. Seek and incorporate new educational partnerships
2. Expand accessibility to forestry education
3. Serve students at all levels of education through programs on the forest
4. Integrate and demonstrate elements of Indigenous Knowledge in educational programs on the forest
5. Foster public awareness and understanding of sustainable forest management
6. Develop educational partnerships plan.

### 3.2.3 Planning Process

As with the forest management planning process, recreation and education planning must be strategic in focus and dynamic in nature. They must account for the unique opportunities that the ESRF may provide at local and regional scales, as well as opportunities that leverage and/or complement existing resources, programs, and sites within the region, while promoting diversity, equity, and inclusion in experiences. The plans should be based on data, including compatibility with research designs, forest management plans and operations, community values and needs, and resource capacities. Use of the Visitor Use Management Framework (VUMF; Interagency Visitor Use Management Council 2016) is proposed to guide ESRF recreation and education planning. While the VUMF is focused on recreation planning, it may also be extended to education planning using the same strategic and dynamic processes.

The VUMF provides a series of four elements in the planning process: (1) building the foundation, (2) defining the direction, (3) identifying management strategies, and (4) adaptive management (implementing, monitoring, evaluating, and adjusting). Underlying and permeating all these elements are central factors, such as public involvement, use of new information, and relevant policies and laws (Figure 3.2). A description of the key components of each step of the VUMF is provided in Figure 3.3. Steps 1-3 (purpose and need; review policy and law context; assess current information and conditions) of element 1 (building the foundation) will be described in more detail below. All elements and steps will be revisited or completed in the





**Figure 3.2.** Steps in the Visitor Use Management Framework as outlined by the Interagency Visitor Use Management Council (IVUMC 2016).

future when an active planning process is undertaken for the recreation and education plans for the ESRF.

Another important component of the VUMF is the “sliding scale” element. This component provides guidelines to help managers decide the depth of analysis needed for each step of the planning process. This allows for flexibility in the amount of time and resources that are committed to the planning process based on specific evaluation criteria. The criteria in the sliding scale described in the VUMF include uncertainty, level of risk, level of public engagement, and potential for controversy (e.g., temporal or spatial closures of areas to public access).

### 3.2.4 Building the Foundation

Building the foundation is the first element of VUMF. This element includes clarifying the purpose and need for a plan, reviewing the policy and law contexts of the plan, assessing existing information and current and expected future conditions, and developing an action plan.

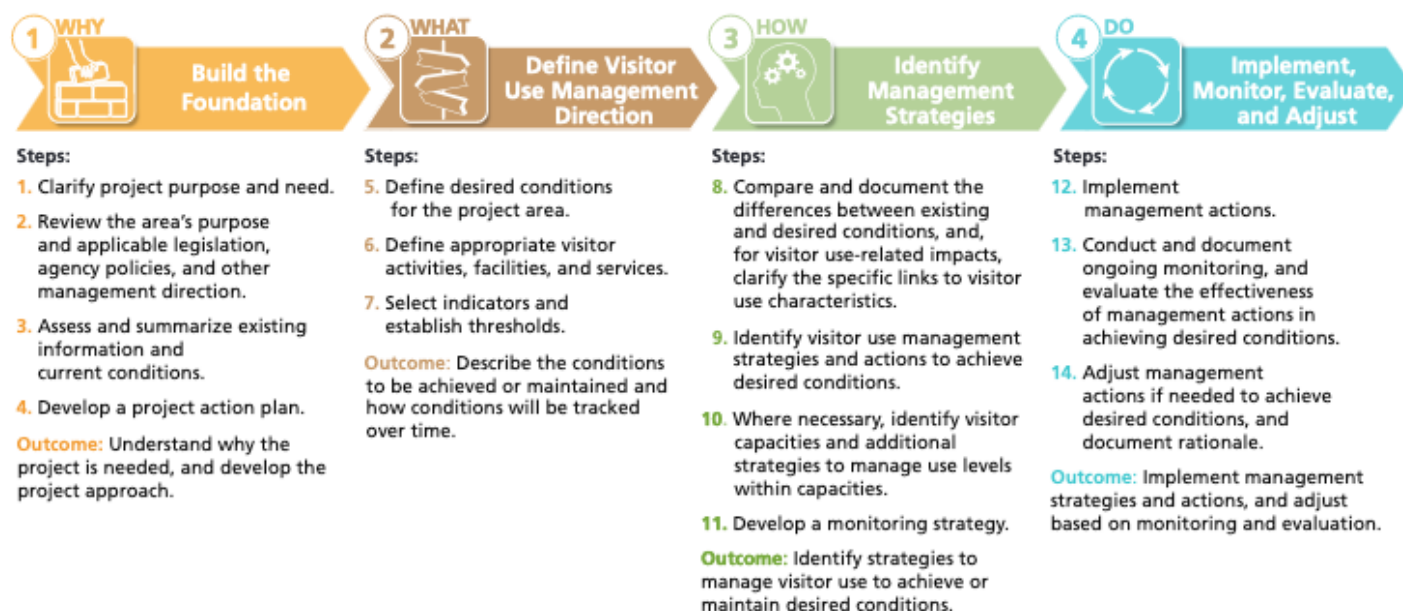
**Step One** is to define the vision, mission, and goals and objectives of recreation and education planning for the ESRF. Given public engagement underlies the entire process, the outcomes of this step should be co-generated with public input and done in an iterative process. For example, OSU Research Forests’ Recreation and Engagement Program mission is to “support and promote an integrated community made up of residents, schools, organizations, the College of Forestry and OSU by offering a high-quality local recreation destination and interactive opportunities to learn about forests.” The program’s vision statement is to “offer a variety of enjoyable opportunities for a diverse set of forest visitors to participate in close-to-home recreation and learning activities in a forested environment; a place where people feel comfortable engaging in outdoor activities as individuals or with their neighbors and friends, and come away learning something new about forests” (OSU College of Forestry 2022). Similar mission and vision statements regarding recreation and education planning should be developed for the ESRF.

Goals and objectives may be defined during this step, although a linear pathway should be avoided given the dynamic and iterative process of public involvement and incorporating new information. Goals and objectives for recreation and education in the 2011 Elliott State Forest Management Plan (Oregon DSL and ODF 2011) were:

1. Provide diverse recreational opportunities that supplement, rather than duplicate, opportunities available in southwest Oregon and that are consistent with the current activities on the forest.
  - a. Provide dispersed and undeveloped recreation opportunities such as hunting, trapping, fishing, camping, viewing, and other activities that are compatible with active forest management.
  - b. Minimize potential adverse recreational effects on other resources, such as water quality.
2. Provide opportunities for interpretation and outdoor education as staffing permits.
  - a. Assist schools and other organizations in providing resource management education for children using tours, field trips, and classroom discussions.
  - b. Provide tours for the public and other groups.
3. Manage recreational use of the forest to minimize adverse effects to other resources and adjacent ownerships.
4. Manage recreational use of the forest to accommodate a wide variety of existing uses while minimizing conflicts among user groups.
5. Maintain compatibility with Oregon’s Statewide Planning Goal 8 (Recreational Needs).
6. Maximize efficiency and diversify funding of recreational management through development of partnerships with user groups, neighboring landowners, and other agencies.
  - a. Consider proposals by user groups or other partnerships and participate as funding and workload allows to plan and develop trails in the Elliott State Forest.
  - b. Cooperate with the BLM in hiking trail construction on state land adjacent to the Loon Lake Recreation Area.
  - c. Supplement available recreation opportunities within the region, rather than duplicating existing services.

This foundation was developed specifically for the ESRF landscape, and its contemporary uses can serve as a practical baseline for future ESRF recreation and education planning.

**Step Two** is to define the ESRF’s purpose as it relates to public access for recreation and education, the authorities that established it, and legislation and regulations that apply to it. As noted earlier, the primary purpose of the ESRF is defined in SB 1546 as research, with secondary purposes associated with public access, conservation, and local economies. SB 1546 further establishes the forest and the



**Figure 3.3.** Brief description of each step of the Visitor Use Management Framework (VUMF). Details from each step can be found in the VUMF guide (IVUMC 2016).

ESRF Authority as a standalone, independent state agency that administers the mission and management policies of the forest through governance by a Board of Directors (Section 5, Subsections 1 and 2). Other foundational documents will need to be understood in the context of recreation and education uses of the forest, such as the Habitat Conservation Plan, the Forest Management Plan, the OSU Research Proposal, etc.

Scenic resources and their protection should also be identified and implemented as complementary to public access, values, and quality of experiences (see Chapter 1: *Background*). Scenic resources are not only visually important, but may be associated with significant natural, historical, cultural, and social values that support quality experiences and contribute to people's sense of place and connections to the forest. At a minimum, scenic resources management should maintain compatibility with Oregon's Statewide Planning Goal 5: *Natural Resources, Scenic and Historic Areas, and Open Spaces* (Oregon DLCD 2022).

Additional work in this step would gather information on other policies, laws, rules, and regulations that govern recreational and educational uses of public lands. With respect to the ESRF, the BOD will need to adopt or set other rules and regulations as determined as necessary and with public input. For example, existing rules and regulations

for hunting, trapping, and fishing, as well as forest products harvesting, will need to be gathered and understood in the context of the Elliott as a research forest. The BOD may consider adopting existing legislation such as Oregon Administrative Rule 629-025-0000, whose purpose is to "establish standards for recreational- and commercial-use of State Forest Lands"... in order to "protect the resources of State Forest Lands, to promote the safety of all users of those lands, and to minimize conflicts among the various uses of those lands." (OAR chapter 629, division 25.)

**Step Three** is an assessment and summarization of existing information and current conditions. The 2011 Elliott State Forest Management Plan (Oregon DSL and ODF 2011) summarized then current recreation use, which is still relevant today, as:

*"Recreation use within the Elliott State Forest is concentrated in several small areas of the forest. The remainder of the forest has little recreation use. The heaviest use occurs on long holiday weekends in the summer, and during deer and elk hunting seasons in the fall. Most forest visitors are residents who enjoy the state forest because it is undeveloped and relatively unregulated, with little competition for favorite sites." (p. 2-61)*



*“Hunting is the main recreation use on the Elliott State Forest. Activities such as hiking, nature viewing, sightseeing, trapping, and dispersed camping are expected to become more popular in the future. The Elliott State Forest has limited off-road driving opportunities, but those activities must be managed to avoid potential conflict with other forest uses. Even with continued growth of recreational activities on the forest, use is expected to be moderate because of the steep terrain, distance from major metropolitan areas, and relative lack of access.” (p. 6-7)*

Some additional background information on current and potential recreation and education uses of the ESRF have been defined in class projects for a course offered at Southwestern Oregon Community College (Kronsberg et al. 2018, Etzwiler et al. 2019, Allen et al. 2021). These student publications provide a window into local interest and engagement in recreation and education opportunities on the ESRF. However, there remains a general lack of data regarding current recreational uses and demands of the forest, including type, frequency, location, and quality of experiences sought. Beyond recreation and education uses, information on roles or contributions of the ESRF within the broader region, as well as regional information and trends on the supply and demand for recreation and education activities and programs, cultural and natural resources, and visitor experiences are needed. And some general understanding of existing administrative resources and operations (staffing, funding, facilities, and infrastructure) may constrain the types of goals and objectives or projects available for implementation on the ESRF.

A few areas of special interest for recreation, education, and scenic resources have been identified or suggested in prior documents and from public input sessions. These areas include the WF Millicoma River, the Elkhorn area, the Jerry Phillips Reserve, Cougar Pass Lookout Tower, Dean Mountain, the Gould Historic Trail, and the Hwy 38 visual corridor. Several trails and sites of historic and cultural significance were identified as well. These and other areas of special interest are attributes used when identifying appropriate forest management actions in early implementation watersheds of the Triad design.

Prioritizing data collection and assessment is needed that focuses efforts, especially if constrained by available resources, on those that are most helpful to the planning team, the public, and decisionmakers. The VUMF provides some guiding questions to help determine the type of data needed (VUMF: 26):

1. Which data sources are necessary to make defensible visitor use management decisions?
2. How will the identified data inform the project?
3. How much confidence is there in existing data?
4. Based on the previous questions, does new data need to be collected, or will existing data suffice?
5. If new data is needed, can it be collected with existing resources, or will outside or technical assistance be required?

While synthesizing the data, it should be provided in a useful framework. For example, the *Recreation Opportunity Spectrum* (ROS, USDA Forest Service 1990) is a well-established, structured way to catalog, organize, and think about spatial and temporal zoning of permissible activities that considers all the other goals and objectives of the ESRF at any point in time and place on the forest. Managers use the ROS to classify and inventory different types of recreation opportunities, typically via maps generated manually and through digitization by analysts with in-depth knowledge of the region of interest (USDA Forest Service 2019). The ROS allows accurate stratification of outdoor recreation environments by dividing a spectrum of recreation opportunities into broad classes. Opportunity classes initially identified as relevant on the ESRF are *rural natural*, *semi-primitive*, and *primitive*. Each mapped ROS class is defined by a particular package of setting attributes, activities, experiences, and benefits. Some managers use seasonal ROS maps where opportunities vary significantly by season.

With changes in technology—especially increased availability of remotely sensed data and greater use of GIS—recent efforts have focused on better utilization of spatial data to generate ROS maps. This is especially true for biophysical setting attributes, although progress has also been made in bringing social recreation data into GIS environments. Opportunities to apply and learn from these and other emerging methods for recreation management will be assessed in detail as part of the ESRF recreation and education planning processes.

### 3.2.5 Initiation of Education and Recreation Planning Processes

When the ESRF becomes operative on January 1, 2024 (according to SB 1546 Section 31, Subsection 1.a.), processes for completing the ESRF Education Plan and ESRF Recreation Plan will become fully active, beginning with the ESRFA BOD securing funding and contracting with an entity to develop the plans.

Once the contracts are in place, the next step is to establish recreation and education planning committee(s) with broad representation including Tribes, educational institutions and organizations, local knowledge experts, technical experts, and users. The structure could include one committee with two work groups, or two committees following parallel pathways. The committee(s) will establish a timeline that includes milestones and deliverables for the period March 2024 – March 2025. The education and recreation planning teams will then work through VUMF Element 1: *Building the Foundation*, Steps 1-3:

- **Step 1** is to define the vision, mission, and goals and objectives of recreation and education planning for the ESRF.
- **Step 2** is to define the ESRF's purpose as it relates to public access for recreation and education, the authorities that established it, and legislation and regulations that apply to it.
- **Step 3** is an assessment and summarization of existing information and current conditions regarding education and recreation use and opportunities on the ESRF.

Once these steps are completed, development of the plan documents will begin in earnest including, as appropriate, development of one or more alternative suites of actions for consideration by stakeholders. The goal would be to submit draft plans by January 15, 2025, and final plans by March 1, 2025. Pending ESRF Authority Board of Directors approval, implementation of recreation and education plans would start in spring of 2025.



# Chapter 4

## Research Platform and Experimental Design

The ESRF will be a center – both in Oregon and worldwide – for research on forest ecosystems and sustainable forest management using the scientific method. Transitioning the forest from prior timber management goals to focus primarily on research is a complex, multifaceted undertaking. This chapter describes the ESRF research platform, including types and scales of research and how these research initiatives will fit within the Triad experimental design on the forest. The ESRF Research Proposal (OSU College of Forestry 2021) provides more background on the research platform and how it was developed.



## 4.1 Research Principles

As approved in April 2021 by the State Land Board, the ESRF Research Proposal (OSU College of Forestry 2021) includes a *unifying research question* and complimentary *research theme* that articulate the rationale and focus for the Triad experimental design and related nested research. Recognizing the importance of humility in science and that research questions change over time, the framing of this unifying research question will change through the adaptive research strategy, while adhering to the mission and vision of the ESRF and the six guiding principles of the research platform outlined below.

**Unifying Research Question:** *Given the societal need for a determined volume of wood supply, what is the best combination, in amount and spatial arrangement, of reserves, intensive and extensive (complex) forestry (at the landscape-level) to supply wood while maintaining water quality, biodiversity, human needs and other forest ecosystem services?*

**Research Theme:** *Research synergies and tradeoffs for conservation, production, and livelihood objectives on a forested landscape within a changing world.*

Six principles guide the establishment and implementation of the research platform. The ESRF Research Proposal outlined five principles in 2021. As part of the planning process since the ESRF Research Proposal was submitted, a principle on co-stewardship has been incorporated into the research platform principles.

**Principle 1:** Research: The ESRF will be managed to advance and sustain science-based research that does not introduce statistical bias. All management objectives related to fulfilling other public values as well as revenue generation on the forest will be accomplished within a ‘research first’ context.

**Principle 2:** Enduring: Research on the ESRF should aim to remain relevant across many years, generations, and social, economic, and environmental contexts. This requires taking a long-term view on research design and management, with the ability to adjust based on an adaptive research strategy.

**Principle 3:** At Scale: The unifying research question, research design, and long-term monitoring on the ESRF should leverage the unique opportunity to quantify the synergies and tradeoffs associated with different amounts and arrangements of treatments at a landscape scale through time.

**Principle 4:** Tailored to the Landscape: The unifying research question will guide a research design that is tailored to existing and potential future biological, physical, social, and economic conditions on the ESRF.

**Principle 5:** Practical, Relevant, and Collaborative: The Land Grant mission of Oregon State University and the history of the ESRF as a public forest require that research on the forest be relevant to forest management issues and challenges facing Oregonians. The scope and relevance of the research program are intended to contribute to scientific knowledge about forest ecosystems and management at local, national, and global levels.

**Principle 6:** Supporting Co-stewardship: Tribal Nations need to be brought into decision-making in a meaningful way. Regarding Oregon State University’s role in management of the ESRF, this means fostering a collaborative framework of co-stewardship. “Co-stewardship” is broader [than co-management] and refers to a range of working relationships with Tribal Nations, as well as Tribal consortia and Tribal-led entities exercising the delegated authority of federally recognized Tribes (OSU College of Forestry 2023:6).

## 4.2 Types, Spatial and Temporal Scale of Research

At 83,300 acres, the ESRF’s size and complexity enables landscape scale research on synergies and tradeoffs associated with intensively managed forests, forest reserves, dynamically managed complex forests, and aquatic and riparian ecosystems. At the broadest scale, the ESRF is subdivided into (1) *Conservation Research Watersheds* (CRW) where the focus is on conservation of habitat and species with minimal active management, and (2) *Management Research Watersheds* (MRW) where the landscape-scale Triad experiment will be implemented. A Triad approach to research on sustainable forestry options – implemented in phases across forty subwatersheds in the MRW– forms the foundation of this effort. In *Riparian Conservation Areas* (RCA) across the forest, research and management will focus on restoration, experimentation, and conservation of aquatic and riparian systems, including integration with adjacent stands in the CRW and MRW.

Seven *thematic research areas* define boundaries that collectively describe how research on the ESRF will support the unifying research question. Thematic areas may evolve over time, and are intended to function as guideposts to



ensure focus and continuity of research programs toward the long-term goals of the forest. Thematic areas help frame opportunities for nested sets of research activities, including short-term studies of specific research questions that are compatible with the research design:

- **Biodiversity and at-risk species:** As the ESRF contains a number of potentially at-risk and sensitive species, research needs to address the most pressing of issues associated with sustaining and enhancing terrestrial and aquatic species in the context of managed forest landscapes.
- **Climate change adaptation and forest carbon:** Research on forest carbon dynamics, carbon sequestration, forest and ecosystem health related to climate change impacts, and exploration of the potential suite of management approaches to help mitigate impacts with a goal of forest resiliency and reduced vulnerability.
- **Natural and human-caused disturbance:** Disturbances such as landslides, debris flows, fires, different types of harvest regimes and recreation all play a crucial role in forested landscapes. The ESRF has and will continue to be the site of significant disturbances – whether natural or human-caused. Research conducted on the forest will be tailored to account for this important opportunity.
- **Stand structure:** The ESRF has demonstrated inherent potential for older, larger trees to dominate as well as complex early seral conditions that can potentially dominate the northwest forests associated with our region. Research will explore management options that provide for a variety of stand structures, including late-successional conditions, and associated range of biodiversity, wood products and ecosystem services.
- **Socio-cultural intersections:** The ESRF presents numerous opportunities to investigate the human dimensions of forests and their management, including but not limited to ecosystem services, market and non-market economic benefits, recreation uses and benefits, practices and traditional uses by Tribal Nations and Indigenous Peoples, community engagement and values, and collaborative governance.
- **Water in relation to forest management:** The ESRF provides excellent opportunities to develop better scientific understanding of the effects and biological responses of natural and human-caused disturbances in forest landscapes on water quality, quantity, watershed storage and the timing of water delivery from watersheds.

- **Landscape and scale issues:** Opportunities to investigate the role of adjacency, fragmentation (amount and shapes), and connectivity on forest ecosystem processes and characteristics (e.g., source-sink relationships, migration potential [rates and barriers] for plants and animals, habitat area-population size relationships, edge effects).

The experimental unit for implementation of the ESRF Triad research design is the subwatershed scale. Smaller-scale research and collaborations on a wide range of topics relevant to sustainable forest management and forest ecosystem dynamics will “nest” within this Triad framework in the MRW. The CRW also have abundant potential for nesting studies across different scales. See the ESRF Research Proposal (OSU College of Forestry 2021) Appendices 2 and 3 for longer lists and descriptions of potential research initiatives and topics. Studies at these finer spatial scales with random allocation of treatments across a gradient of conditions will enable inference to forests beyond the ESRF. For stand-scale studies and collaborations nested within the Triad framework, the temporal scale of research and monitoring on the ESRF may range from one season to many decades and even centuries. At all spatial and temporal scales, research executed on the forest must collectively support the unifying research question and themes. See Chapter 5: *Research Planning and Implementation* for information on the process for reviewing and integrating nested studies under the ESRF research platform.

#### 4.2.1 Watershed Designations and Treatment Allocations

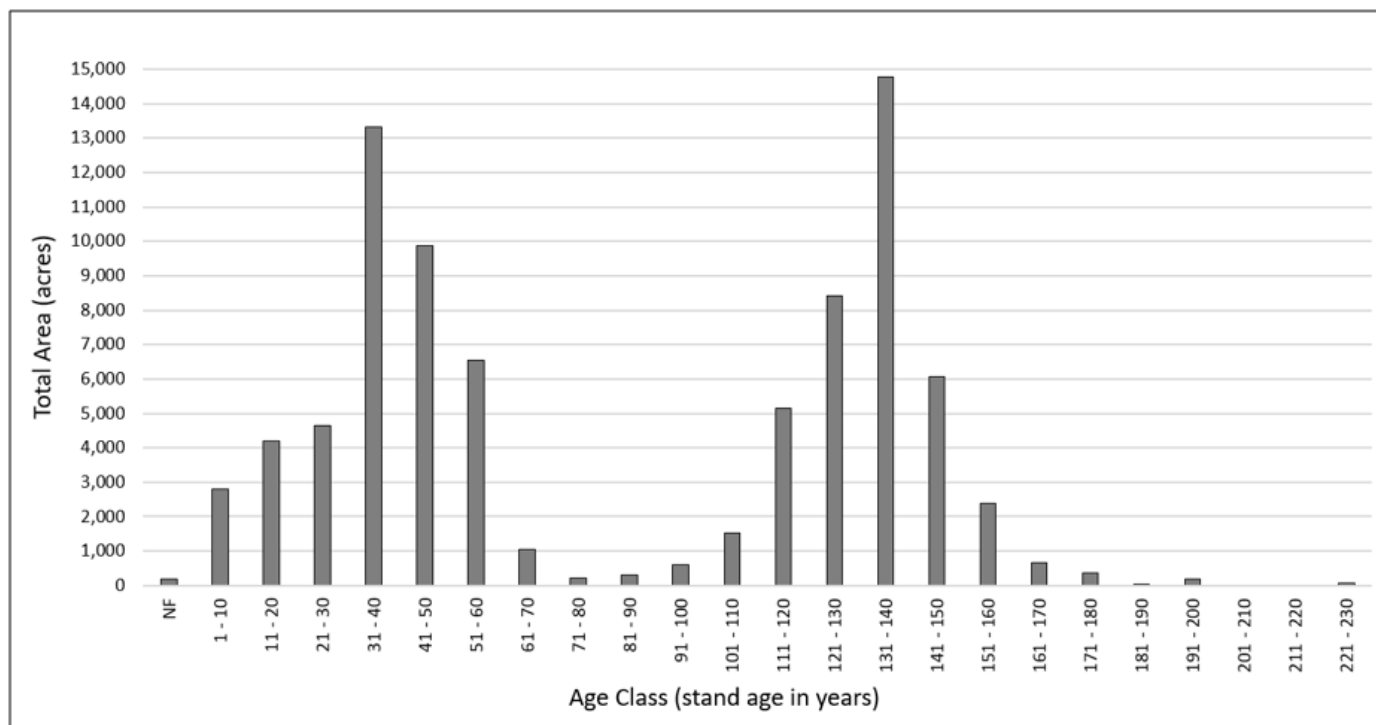
The ESRF has a bimodal age class distribution created by disturbance history and past management (Figure 4.1). Approximately 42,000 acres of the ESRF (roughly 51% of the forest) are even-aged plantations consisting primarily of Douglas-fir with some alder, western hemlock, and western redcedar that established primarily between 1955 and 2015 following clearcut harvests. These stands reflect conventional even-aged forestry practices over the past six decades, and as-of year 2020 are less than (or equal to) 65 years of age (described as LT65 in this document). Stands older than 65 years of age as-of year 2020 (described as GT65 in this document) comprise the balance of the forest (Figure 4.2).

Older forests on the Elliott primarily have one of three longer-term development and management histories:

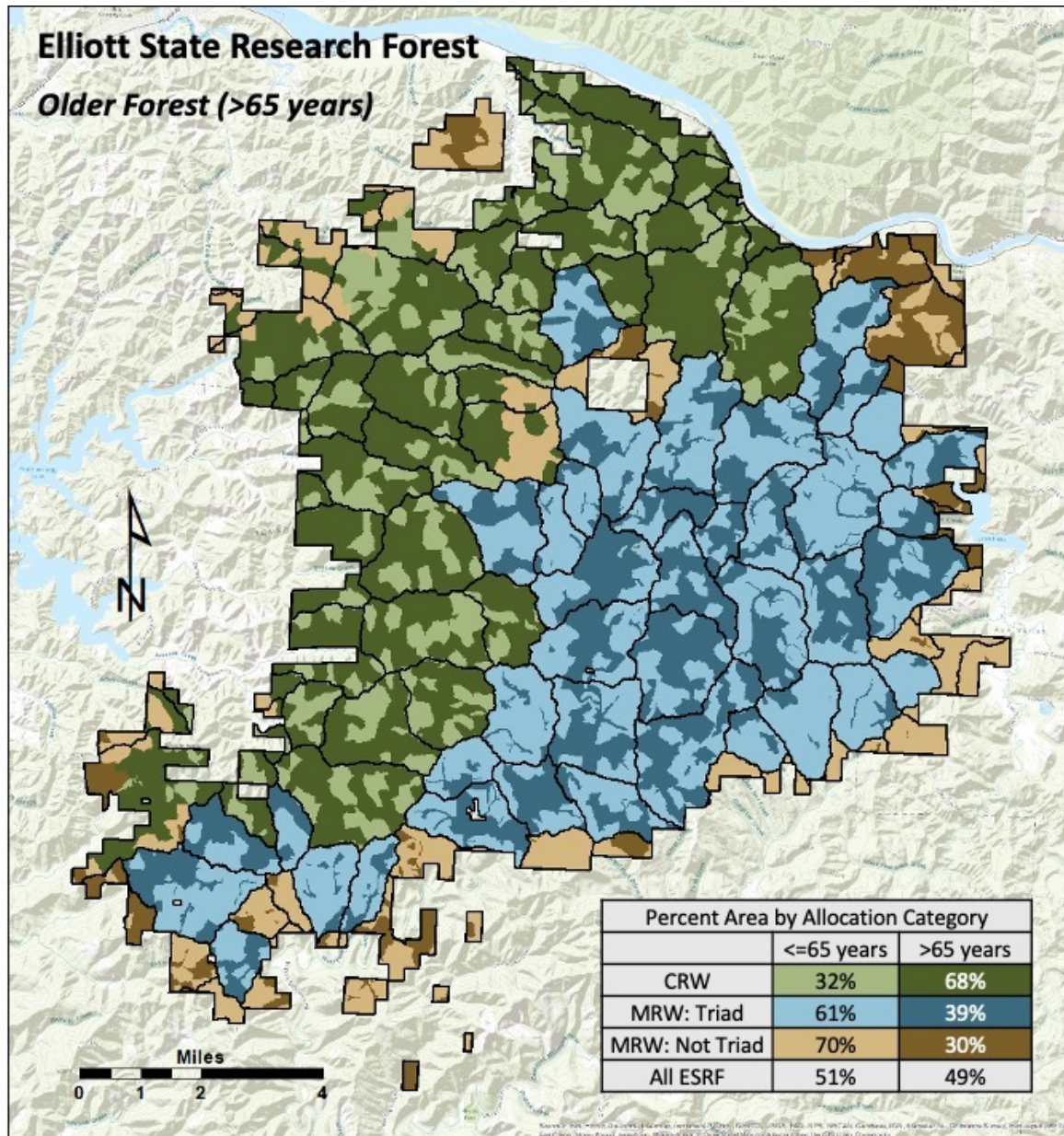
1. **Mature unmanaged** stands that naturally regenerated following extensive (cultural or wild) fires in 1849 and 1868 or smaller reburns of these fires in the late 19th century. Some stands may have regenerated after windstorms or landslides. The age range of these forests is approximately 80 to 170 years with most mature unmanaged stands aged between 120 to 150 years old as of 2020. Some of these stands were later clearcut and converted to Douglas-fir plantations.
2. **Mature managed** stands with the same establishment history as #1, but that had ~30% of the tree volume removed when they were approximately 75 to 125 years old to improve growth of remaining trees and to generate revenue. There were about 15,000 acres of mature managed stands on the Elliott, but some of these stands were later clearcut and converted to Douglas-fir plantations.
3. **Old-growth** stands established prior to and survived the extensive 1849 fire and later fires in the 19th century.

Old-growth stands have a broad range of Douglas-fir ages with trees aged 170 – 500 years in the same stand. In comparison to mature forests, old-growth forests have higher structural complexity, usually include mature hemlock and western redcedar and have a higher density of large snags and logs. Gray et al. (2009) provides criteria for tree structure, composition, and dead wood for old-growth stands in the Oregon Coast Range. Old-growth stands are rare on the Elliott due to high-severity fires in the 19th century and harvest of the relatively old stands in the 1950s and 1960s that survived these fires (Figure 4.3, see also Appendix J and Chapter 1: *Background*, Section 1.9.2).

During development of the ESRF Research Proposal (OSU College of Forestry 2021) the forest was delineated into separate subwatersheds that provide a spatial template for research (Figure 4.3). The 66 full-ownership subwatersheds in the ESRF are designated as *Management Research Watersheds* (MRW) or *Conservation Research Watersheds* (CRW). Subwatersheds are logical units for allocating the

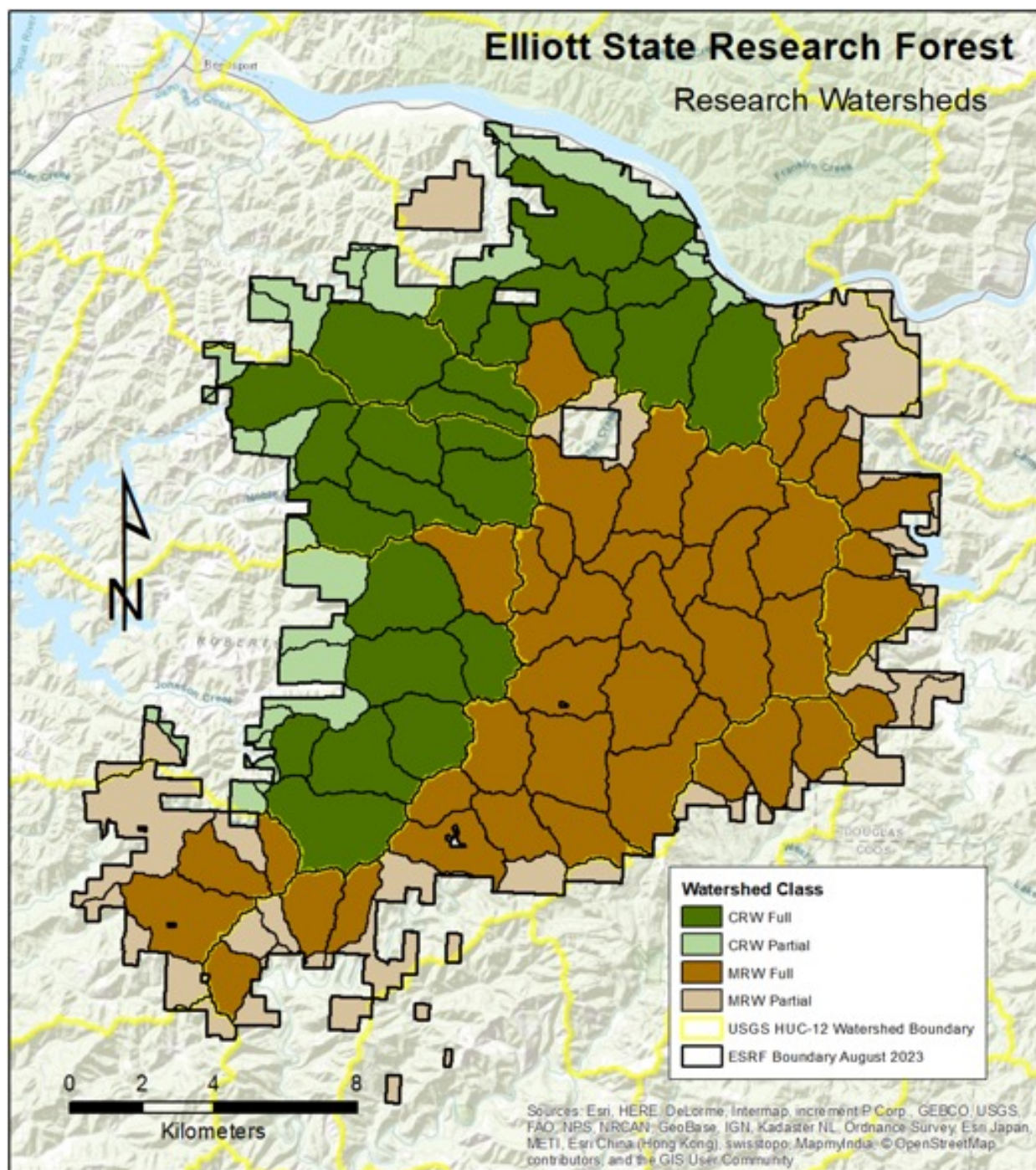


**Figure 4.1.** Age class distribution of the 83,300-acre ESRF, as-of year 2020. The bi-modal age-class distribution reflects stands older than 65 years (GT65) of age that originated following natural disturbance, and stands younger than 65 years of age (LT65) that originated following timber harvest.



**Figure 4.2.** Age class distributions across the CRW, MRW Triad watersheds, and MRW non-Triad watersheds based on (1) stands less than or equal to 65 years old as of 2020, and (2) stands greater than 65 years old as of 2020.





**Figure 4.3.** ESRF research watersheds are hydrologic subdivisions (subwatersheds) of USGS HUC-12 watersheds. *Full* subwatersheds are between 400 and 2,000 acres in size, and are substantially complete, with no appreciable part of the hydrologic subwatershed that is not within ESRF boundaries. There are 66 full subwatersheds on the ESRF totaling approximately 64,000 acres. *Partial* subwatersheds are smaller (<400 acres) watersheds within the boundary of the ESRF, or watersheds that lie mostly outside the ESRF boundary.

research treatments because they have readily definable boundaries (ridgelines) that allow the use of water as an integrator of treatment effects. In the MRW, management will focus on implementing the Triad research design, including various arrangements and intensities of active forest management such as timber harvests, stands in different stages of regeneration and stands in reserve status. The primary experimental units for the Triad research design comprise 40 full-ownership subwatersheds of between 400 to 2,000 acres in size, totaling 36,870 acres. There are 26 full-ownership subwatersheds in the CRW, totaling 27,100 acres.

Delineated subwatersheds less than approximately 400 acres, or that have greater than 5% of their catchment area outside of the ESRF boundary, are designated as *partial watersheds*. Approximately 19,350 acres of the ESRF are

classified as partial watersheds: 7,050 acres in the CRW, and 12,300 acres in the MRW (Figure 4.5).

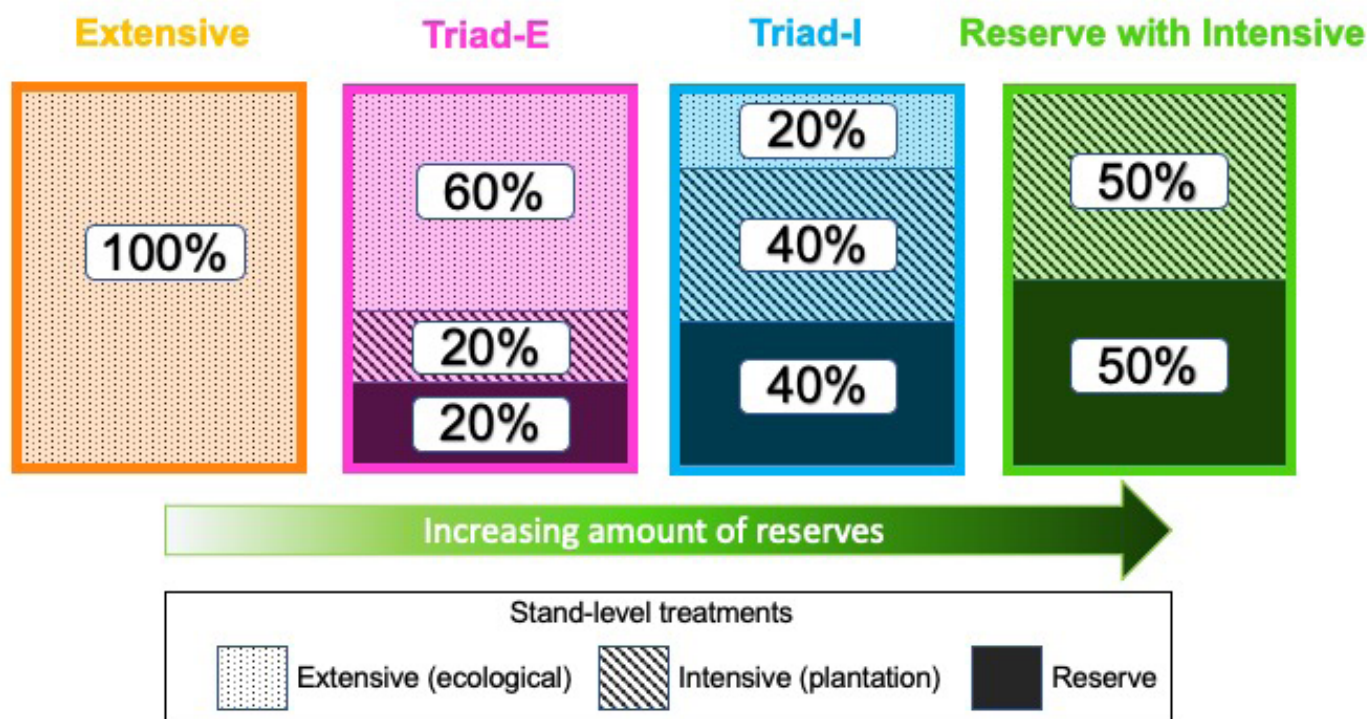
### Management Research Watersheds (MRW)

The MRW can be divided into those lands comprising the 40 Triad research subwatersheds (hence: *MRW Triad*), and lands comprising the balance of the MRW (hence: *MRW non-Triad*), which includes MRW partial watersheds, the East Hakki Ridge parcel, and the Upper Big Creek and Alder Creek allocations (Figure 4.2 and Figure 4.6).

### MRW Triad

In the MRW Triad the relative proportions of each Triad treatment type (*reserve*, *extensive*, *intensive*) are fixed according to the four Triad subwatershed designations

## Triad Landscape-level (Subwatershed) Treatments



**Figure 4.4.** Triad *landscape-level* (subwatershed) treatments. Treatments are designed to produce approximately equivalent wood yields using different combinations of stand-level treatments: reserves, extensive (ecological forestry), and intensive (even age) management. The *Extensive* Triad treatment (orange) is 100% ecological forestry, the *Reserve with Intensive* Triad treatment (light green) consists of 50% intensive forestry and 50% reserve. *Triad-E* and *Triad-I* contain differing proportions of reserve, ecological and intensive forestry.



(*Extensive, Triad-E, Triad-I, and Intensive with Reserves*; Figure 4.4). Although treatment acreages are fixed within each subwatershed, the spatial arrangements of these treatments are flexible within the bounds of other constraints, such as stand age. This flexibility in the spatial arrangement of retention areas facilitates the accommodation of non-timber values, such as habitat for old-growth dependent species, protections for areas prone to landslide and debris torrent not otherwise protected in RCAs, and refugia and migration corridors for amphibians. The 40 MRW Triad subwatersheds total 36,870 acres, with 9,860 acres allocated to intensive, 11,810 acres allocated to extensive, 10,060 allocated to reserve, and 5,140 acres allocated to Riparian Conservation Areas.

Research in the MRW will include implementation of strategies that apply different spatial arrangements and practices to these treatments in support of timber harvest, and the evaluation of corresponding ecological and economic outcomes. In MRW implementation of intensive and extensive prescriptions will include active vegetation management (e.g., pre-commercial and commercial thinning, selection harvests, clearcuts) with treatment frequency and intensity varying depending on prescriptions for particular stands. Only previously clearcut forests that were 65 years or younger as of 2020 will have intensive treatments (see Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*).

Integrated within the MRW is a network of *Riparian Conservation Areas* (RCA) with protective buffers along streams where management activities are focused on restoring and maintaining riparian processes and native biota. Buffers and other stream protections in the ESRF are evaluated using LiDAR-derived topographic data to properly account for the importance of headwater streams and areas of convergent topography susceptible to landslide initiation and debris torrent. Details on stream classifications and other aspects of RCAs are provided in Chapter 7: *Aquatic and Riparian Systems*.

### **MRW non-Triad**

MRW non-Triad comprises areas identified in the ESRF HCP as Flexible, Flexible-Extensive, and Volume Replacement allocations, and includes the Hakki Ridge parcel. MRW non-Triad allocations include 2,600 acres of reserve, primarily older stands identified as occupied MAMU habitat within the HCP Flexible allocation and on the Hakki Ridge parcel, and 1,560 acres of RCA. 1,010 acres of GT65 stands within the HCP Flexible allocation are conditionally allocated to extensive management, pending results of MAMU surveys. Following guidance for Flexible allocations from the HCP,

5,710 acres of LT65 are allocated to Flex50, which allows for either intensive or extensive management; an additional 50 acres of LT65 Flex50 is specified for extensive management. Approximately 970 acres of Hakki Ridge and Upper Big Creek are allocated to extensive management. MRW non-Triad also includes the 1,070 acres of the Alder Creek volume replacement allocation. Harvest allocations on Hakki Ridge, Upper Big Creek, and Alder Creek are restricted to LT65 stands.

### **Conservation Research Watersheds (CRW)**

Within the Conservation Research Watersheds (CRW), management will focus on testing a primarily hands-off approach to managing the forest ecosystem through minimizing human interventions, maintaining landscape-scale connectivity and processes, and conserving native biota. The CRW anchors the ESRF conservation strategy by establishing a contiguous 33,440-acre area managed for long-term ecological functions and supported by restored and undisturbed terrestrial, riparian, and aquatic ecosystems. Site-disturbing research and management activity in the CRW will be limited to projects likely to benefit the long-term conservation of native biota (e.g., stream restoration projects, road decommissioning). Established plantations in the CRW (stands less than 65 years old as of 2020) may be thinned as part of a restoration experiment in the first 20 years of the ESRF to diversify forest structure, shift their successional trajectory and optimize their conservation transition. Stands in the CRW that are greater than 65 years old will move through natural successional processes.

Stands totaling 12,350 acres in MRW subwatersheds will be designated as reserves as part of the Triad treatment design and managed similarly to the CRW. Inclusive of these MRW reserves, MRW RCAs, and the CRW, a total of 52,800 acres of the 83,300-acre ESRF (63% of total ESRF acres) will be in protected status. There will be no timber harvests in these reserve areas aside from (1) single-entry restoration treatments in existing plantations within the CRW during the first 20 years of the ESRF, and (2) riparian restoration treatments in plantations less than 65 years old (as of 2020) in the RCAs. (See Chapter 6: *Silviculture, Harvest Systems, and Operations Planning* for details on these treatments.) Though subject to natural biotic disturbance processes such as insect and tree decay pathogens and abiotic disturbances such as extreme weather events, these areas will follow successional pathways largely unaffected by human intervention (with the exception of fire suppression).



## Volume Replacement Allocations

Changes in the 2023 ESRF HCP have created a new category known as *volume replacement*, which encompasses Alder Creek in the northwest corner of the research forest. Acres identified as volume replacement in Alder Creek will remain in their designation within the CRW unless modeled potential marbled murrelet habitat within the MRW Extensive allocation is found to be ineligible for harvest due to occupancy by marbled murrelet as identified by surveys. In these cases, an equivalent amount of timber volume as the Extensive allocation acreage found to be ineligible would become available for extensive harvest in the Volume Replacement allocations.

## 4.3 Experimental Design

### 4.3.1 Overview of the Triad Experimental Design

The goal of the Triad research framework is to investigate promoting biodiversity, ecosystem processes, and ecosystem services while achieving a given fiber supply using existing and novel land management strategies. The Triad design that will be implemented within the MRW can be visualized as a triangle with endpoints being *reserve*, *intensive*, and *extensive* stand management practices applied in varying proportions (see ESRF Research Proposal [OSU College of Forestry 2021] Section 4, Fig. 3). The basic premise is that, for a given amount of land area, the amount of land in reserve can be increased as management is intensified elsewhere while maintaining a stable output of wood products. Extensive stand management, where multiple ecosystem service objectives are met, has no separate land set aside as reserves. Within the MRW, a set of Riparian Conservation Areas (RCA) will complement reserves to better integrate aquatic and terrestrial ecosystem management.

Requests have been received to reconsider what we call these areas set aside for restoration and conservation, as the term “reserve” is tied to the settler-colonial act of forcible removal of Tribes to reservations. In this FMP, the term “reserve” is still present as any potential change to this terminology would require further consultations with Tribes and the ESRFA Board of Directors, as well as revisions to the ESRF Research Proposal and ESRF HCP as coordinated foundational documents. This ability to adapt is an important part of the ESRF and the research design,

and such changes take time to implement effectively. For this current FMP, we recognize the settler-colonial system in which this document has been developed and the meaning of the term “reserve”. We are committed to continuing to develop equitable and respectful Tribal relationships based on best practices for partnering with Tribal Nations as we engage in these conversations.

Each of the forty subwatersheds that are wholly contained within the MRW (400 to 2,000 acres each) will receive one of these four treatments (ten replications per treatment), all of which are designed to produce approximately equivalent mean annual increment per-unit-area wood yields at the subwatershed level (Figure 4.4).

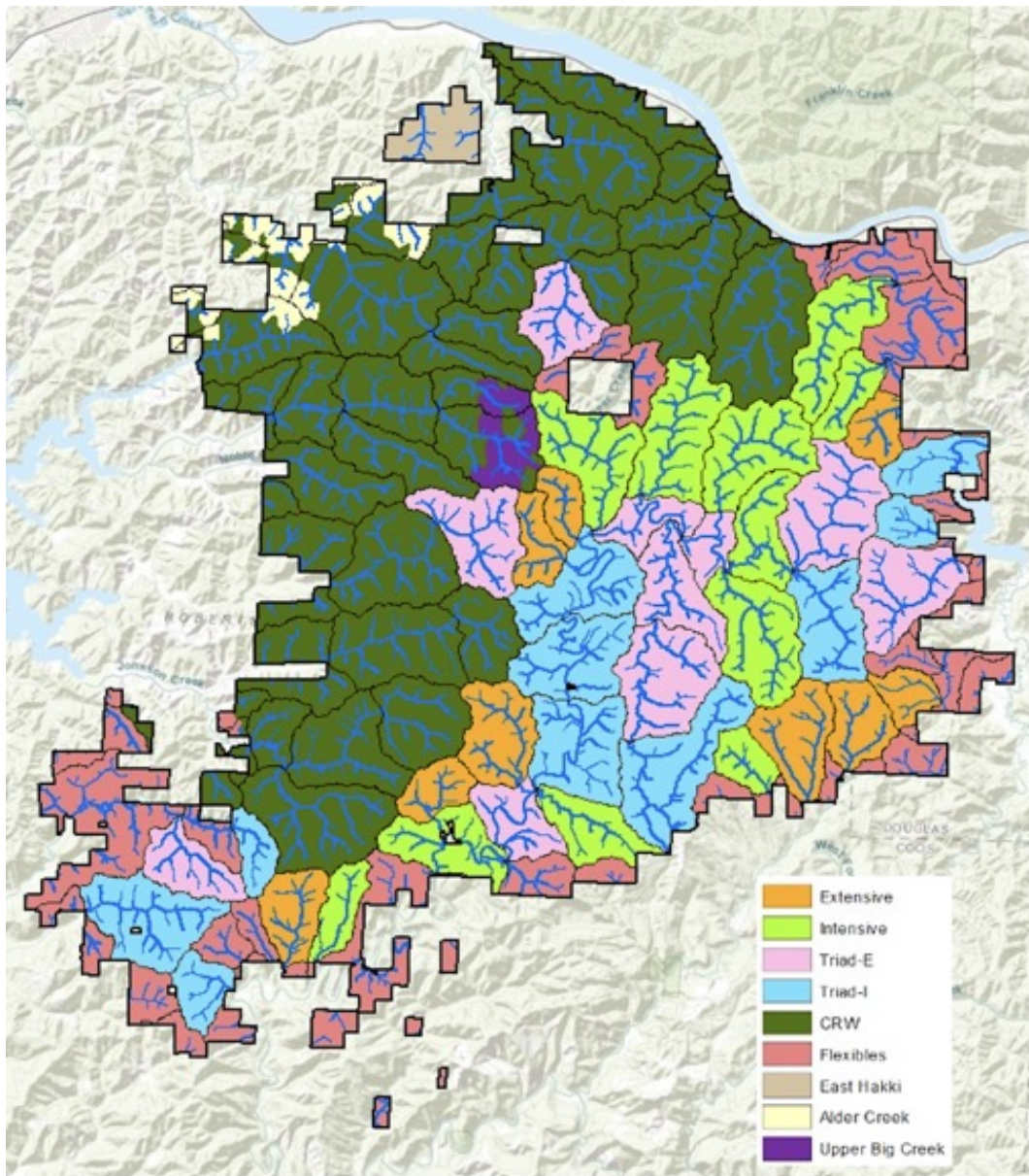
### Triad Landscape-Level (Subwatershed) Treatments

1. *Extensive* subwatersheds are 100% extensive stand management across the entire subwatershed, outside of the RCA.
2. *Triad-E* subwatersheds are 60% of the acreage in extensive, 20% intensive, and 20% reserve stand management, outside of the RCA.
3. *Triad-I* subwatersheds are 20% of the acreage in extensive, 40% intensive, and 40% reserve stand management, outside of the RCA.
4. *Reserves with Intensive* subwatersheds are 50% of the acreage in intensive and 50% reserve stand management, outside of the RCA.

### 4.3.2 Stand-Level Treatments: Intensive, Extensive and Reserve

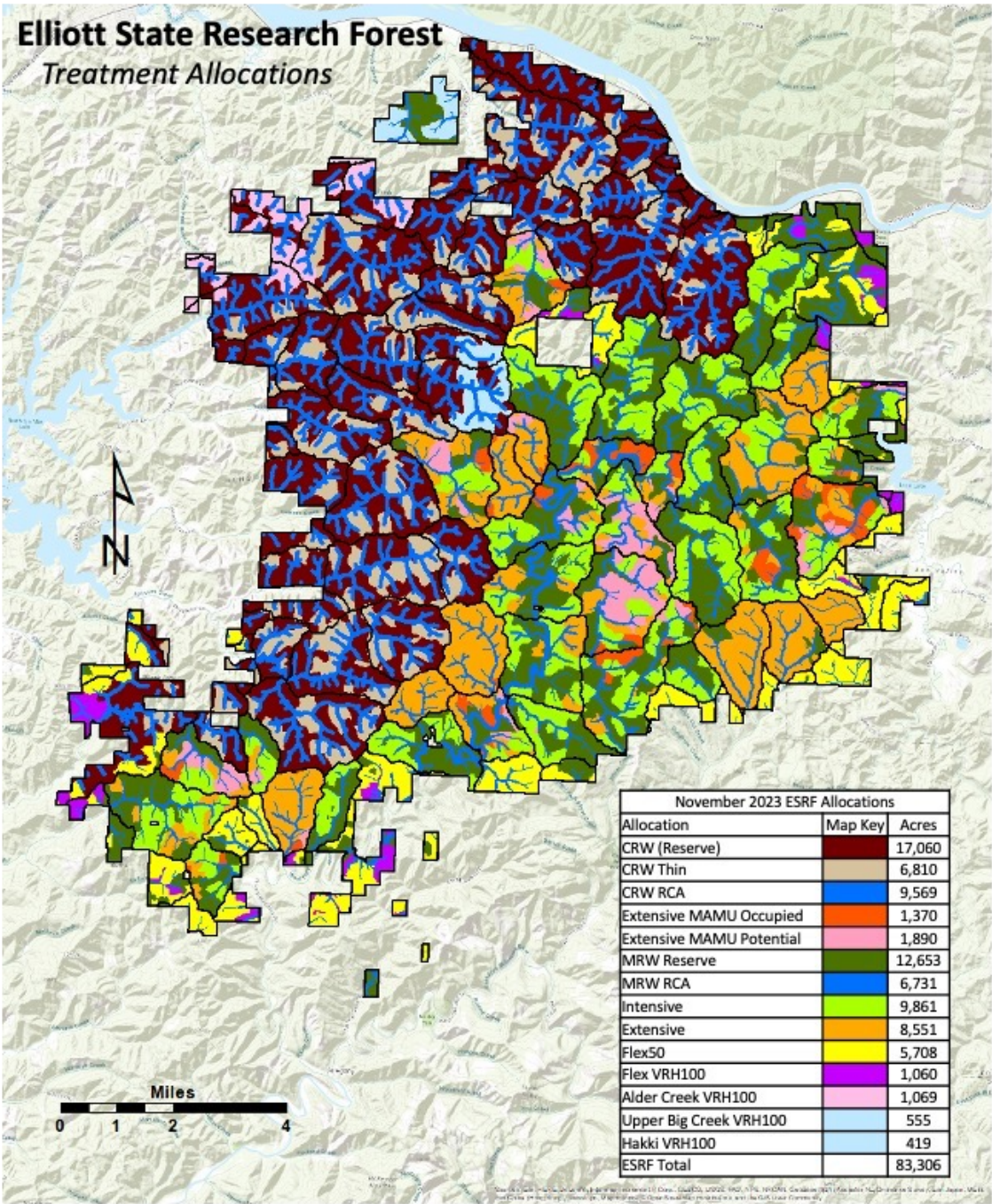
Within the Triad *landscape-level* subwatershed treatment allocations (i.e., Extensive, Triad-E, Triad-I, Reserve with Intensive), treatments are also allocated at the *stand-level* as either *intensive*, *extensive*, or *reserve* (Figure 4.6) using a set of criteria that includes:

- Stand age,
- Protections of colluvial hollows and steep slopes,
- Configurations to reduce fragmentation and promote connectivity (within and between subwatersheds),
- Protections for northern spotted owl and marbled murrelet habitat (aligned with the ESRF HCP),
- Stakeholder input,
- Silvicultural suitability, and
- Operational feasibility.



**Figure 4.5** ESRF subwatershed-level classifications. Revisions made during development of the ESRF HCP resulted in some changes to allocations compared to the 2021 ESRF Research Proposal. Allocations remain the same in the 40 Triad research sub-watersheds, but other changes are still being incorporated into the ESRF land allocation framework.





**Figure 4.6.** Stand-level treatment allocations on the ESRF, including partial subwatersheds.



See the ESRF Watershed Atlas Supplemental Document for a full description of the research treatment allocation process and stand-level allocations within each MRW subwatershed. Adjustments to these allocations may be made within the guidelines in this FMP and based on continued incorporation of decision-making criteria, including: (1) continuing to work with Indigenous communities to ensure that appropriate care is taken to avoid culturally significant areas and spiritual places, (2) updated inventory and landscape analysis (in progress under FMP development), and (3) fieldwork by the ESRF team to include more information on considerations such as operational capabilities and within-stand variation are taken into account.

**Intensive** (production-oriented) stand-level research treatments will allow investigation of management options that primarily emphasize wood fiber production at rotations of 60 years or longer. This minimum 60-year rotation applies in all intensive treatments, including in the Flex50 allocation, which may alternatively be managed using extensive silviculture. The aim is to compare various intensive management treatment options, including those that do not utilize herbicides, and assess methods to reduce the impacts of these treatments on attributes such as biodiversity, habitat, carbon cycling, recreation, and rural well-being. Intensive treatments are explicitly applied in areas with younger, previously managed forest stands. Intensive treatments will serve as a benchmark for wood production potential and trade-offs associated with wood production relative to extensive and reserve areas.

Examples of research concepts that may be associated with intensive treatments include:

- Resilience and resistance to minimizing tree loss to drought and diseases over decades
- Social values as represented by differences in perceptions and behaviors
- Economic and carbon analysis of increasing rotation length
- Market analysis and impacts of tree size
- Carbon fluxes and pools through time
- Logging technology and forest engineering
- Site preparation and seed sources
- Species and genotypes for climate resilience and resistance
- Clearcut harvest impacts on hydrological changes, erosion and mass wasting events
- Recreation use levels/patterns and perceptions over time
- Density management and wood yield over time

- Response of aquatic ecosystems
- Non-lethal strategies for animal control

**Extensive** stand-level research treatments will increase forest complexity to help achieve multiple values across the landscape. An experiment will be implemented and refined to explore methods for increasing the likelihood of achieving old forest structure, increasing species diversity and creating complex early seral forests from dense single-species plantations. On these widespread dynamically managed forests new alternatives will be researched along a continuum between intensive plantation management and unlogged reserves. Extensive treatments will retain or create structural complexity to enhance diverse forest characteristics and better integrate them with riparian areas to meet a broad set of objectives and values while simultaneously producing wood fiber. The aim is to promote conditions in extensive stands to obtain regeneration and sustain this complex forest structure through time. Extensive treatments will be implemented in stands representing a range of age classes on the forest.

Extensive alternatives are an opportunity to expand timber management's frontiers by testing the potential to simultaneously achieve biodiversity, carbon sequestration and sawtimber objectives at the stand scale. The Oregon Department of Forestry and Bureau of Land Management are implementing similar alternative approaches, making ESRF science findings from extensive treatments especially relevant.

Examples of research concepts that may be associated with extensive treatments include:

- Emulate and measure response of natural disturbance including reintroduction of complex early seral ecosystems that are being replaced by rapidly growing plantations.
- Tribal perspectives and traditions
- Level of retention of the existing forest canopy
- Distribution of retained trees in a dispersed or aggregated fashion
- Treatments across the spectrum of forest ages
- Thresholds of size and quantity of standing dead and downed wood
- Selective and no use of herbicides
- Tree and shrub regeneration
- Prescribed fire to generate pyro-diversity
- Riparian integration with upslope conditions

- Logging systems under varying levels of retention
- Economic thresholds and markets
- Monitoring objectives and protocols

**Reserve** stand-level research treatments will occur primarily in unlogged, naturally regenerated stands and also in former plantations in both the CRW and MRW. Reserve treatments have two long-term strategies. The first strategy involves restoration thinning in Douglas-fir plantations to diversify structure, accelerate growth of remaining trees and increase resilience as these stands transition to mature forest reserves. Research in these reserve stands will explore methods for increasing the likelihood of achieving old forest structure, increasing species diversity and creating complex early seral forests from dense single-species plantations.

The second treatment strategy is to conserve unmanaged mature forests as they move through natural succession and transition to old growth. These older forests are either unlogged or received a single-entry thinning approximately 20-60 years ago, and are ideal for monitoring ecosystem attributes such as biodiversity, recreation, carbon cycling, water, and climate change effects in unmanaged relative to actively managed forests. They serve as baselines for comparison with managed Triad research treatments and habitats.

Examples of research concepts and outcomes associated with reserve treatments include:

- Emulate natural disturbances
- Incorporate tribal perspectives and traditions
- Vary the level of retention of the existing forest canopy in plantations and riparian forests
- Vary distribution of retained trees (dispersed or aggregated) in plantations and riparian forests
- Apply treatments across the spectrum of forest ages up to age 65
- Natural thresholds of the size and quantity of standing dead and downed wood
- Carbon uptake and release with natural disturbance
- Climate impacts in unmanaged forests relative to actively managed forests
- Active management as compared and contrasted with natural disturbance processes

**Riparian conservation areas** (RCAs) will be managed with the goal to maintain and restore vital ecological processes that influence the aquatic ecosystem in the intensively managed and extensively managed treatments. Widespread riparian alteration has occurred in western Oregon as a result of land uses since Euro-American settlement. Thus, developing and evaluating methods to manage riparian areas to restore their ecological capacity will be an important component of the ESRF research program. See Chapter 7: *Aquatic and Riparian Systems* for further information.

Detailed descriptions of intensive, extensive, and reserve stand level research treatments are provided in Chapter 6: *Silviculture, Harvest Systems, and Operations Planning* and also in the ESRF Research Proposal (OSU College of Forestry 2021) Appendix 5. The Research Proposal includes potential research projects classified as *near-term* (0-10 years), *mid-term* (20-60 years) and *long-term* (70+ years). Potential near-term studies and projects are listed below. This is not an exhaustive list or directive to implement these studies, but rather provides examples of the types of research that could occur on the ESRF in the first decade.

Examples of near-term (0-10 years) research on the ESRF:

- Structured tests for tethered harvesting and grapple yarding on steep slopes (no one on the ground)
- Structured tests comparing short and longwood harvesting systems (stump to mill)
- Testing rock replacement strategies for forest roads
- Testing rock substitutes for forest roads
- Improving logistics for tree planting on steep ground
- Improving pole recovery from forest stands
- Testing non-mechanical methods of pre-commercial thinning (PCT)
- Optimizing thinning decisions in real-time
- Monitoring second generation genetically improved stock
- Testing all-electric trucks on steep forest roads
- Monitoring regeneration under alternative leave tree configurations for extensive
- Monitoring growth under extensive and intensive systems
- Monitoring biodiversity and individual species under extensive, intensive and reserve systems
- Monitoring soil productivity and function under extensive, intensive and reserve systems

### 4.3.3. Phased Research Implementation

Design and implementation of a research program of this magnitude and complexity requires deliberate and staged planning and implementation. Phased research implementation will be combined with adaptive management protocols, modeling, ecosystem assessment and monitoring, and stakeholder input to reduce uncertainty and ensure the viability and relevance of the research through time. Phased implementation of the Triad experimental design will begin with designating 16 subwatersheds in the MRW representing four replicates of the four Triad treatment types, where pre-treatment monitoring will be focused. Up to four subwatersheds in the CRW will be identified to serve as no-harvest controls, chosen in coordination with the CRW restoration experiment for plantations in reserve to avoid conflicts between experimental designs.

In 2022, researchers developed a process and set of criteria for selecting MRW early implementation subwatersheds

under the Triad experimental design, then selected the subwatersheds where pre-treatment monitoring will begin based on an analysis using 2015 ODF inventory data. Selection criteria included:

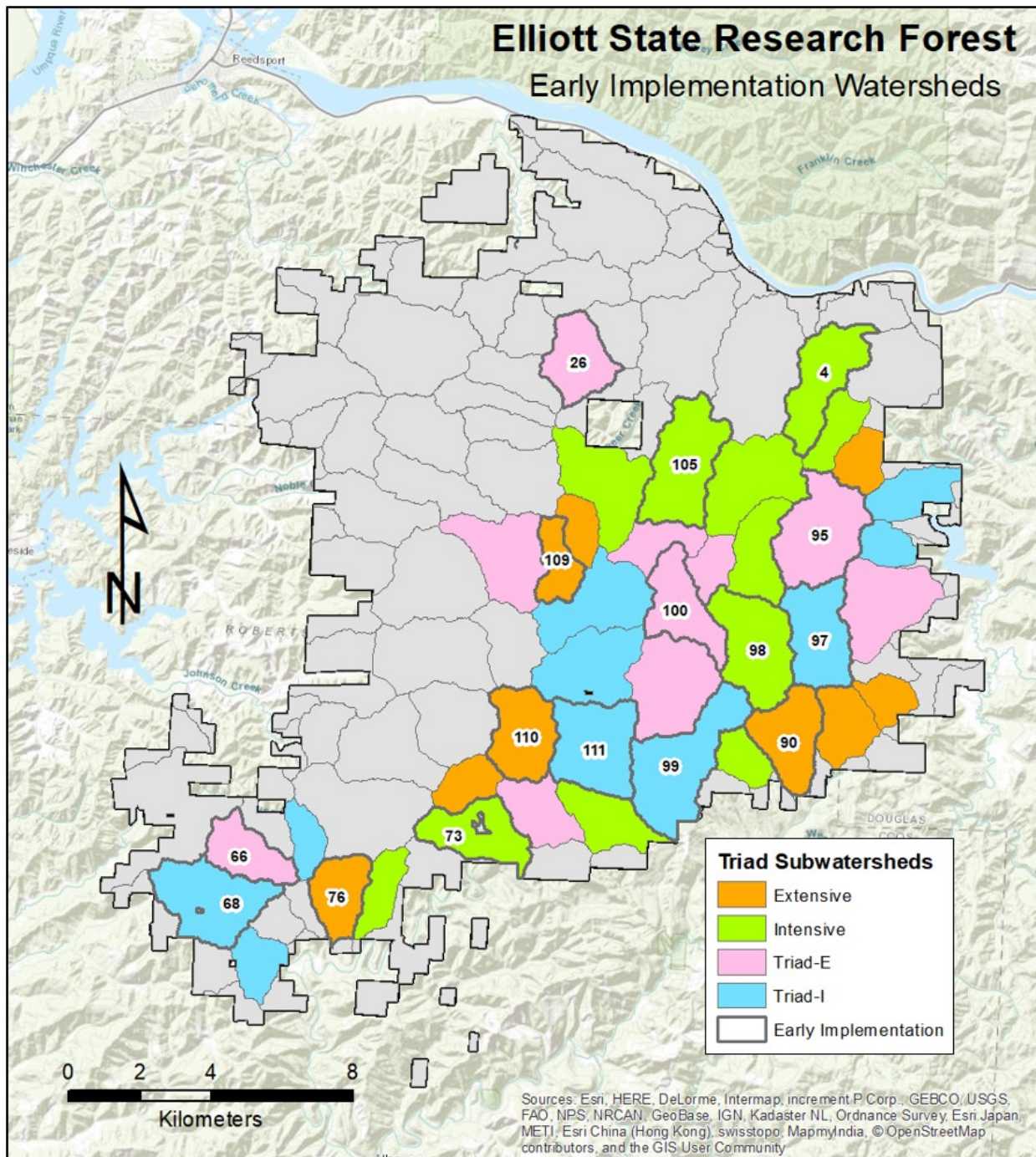
- Stand age,
- Topography,
- Arrangement on the landscape (i.e., representing the full geographic scope of the MRW),
- Integration with aquatic and riparian systems,
- Silvicultural priority (i.e., subwatersheds containing stands suitable for harvest in the near term based on guidelines for intensive and extensive treatments), and
- Subwatershed size.

The following MRW subwatersheds were identified for inclusion in the early implementation phase of the Triad experiment (Table 4.1, Figure 4.7):

**Table 4.1.** Triad Experiment Early Implementation Subwatersheds in the MRW

Subwatershed ID	Subwatershed Name	Treatment Allocation	Size (Acres)
4	Footlog Creek	Reserve with Intensive	1,031
26	Upper Dean Creek	Triad-E	792
66	South Fork Palouse Creek	Triad-E	674
68	Larson Creek	Triad-I	1,237
73	Stulls Falls	Reserve with Intensive	792
76	Totten Creek	Extensive	655
90	Howell Creek	Extensive	894
95	Cougar Creek	Triad-E	1,317
97	West Fork Millicoma	Triad-I	1,019
98	Panther Creek	Reserve with Intensive	1,224
100	Lower Elk Creek	Triad-E	829
105	Knife Creek	Reserve with Intensive	1,247
109	Joes Creek	Extensive	449
110	Trout Creek	Extensive	889
111	Rhombus Reach	Triad-I	1,135





**Figure 4.7.** Map of Triad early implementation subwatersheds, where early pre-treatment monitoring will occur for at least 5 years prior to implementation of harvest treatments to serve as a baseline for long-term data analysis.

Pre-treatment monitoring will occur in these MRW subwatersheds according to the framework described in Chapter 10: *Monitoring* for 5 years prior to implementation of harvest treatments within the Triad experiment, serving as a baseline for long-term data collection and analysis. Stands that are eligible for harvest in each decade under two different harvest scenarios are described in Appendix H. These are preliminary harvest scenarios rather than a final defined harvest schedule. Determination of the harvest schedule will involve stand visits by ESRF foresters and forest/research technicians and additional data analysis. Decisions about that harvest schedule, including timing, location, and specific plans for harvest units will occur during the biennial operations planning stage through collaboration with ESRF foresters, the Research Director (PI), and the Executive Director, and with approval from the ESRFA Board of Directors. Actual areas harvested and when they will be harvested will change from this scenario while remaining within the conditions of the ESRF HCP.

In addition to these 16 MRW early implementation subwatersheds, four subwatersheds will be identified in the CRW to serve as controls to compare against watersheds that receive treatments in the CRW and MRW. These benchmark subwatersheds will allow researchers to track changes through time that are independent of management actions, including climate change, disturbance from weather events, and insect or disease outbreaks. Controls are a crucial part of any experiment.

The four early implementation CRW subwatersheds will be chosen based on the following criteria. These subwatersheds will:

- Be widely distributed from north to south.
- Contain several of the control stands for the CRW restoration experiment (stands less than 65 years old as of 2020).
- Be in a similar size range of the treated subwatersheds, or 400 to 1500 acres.
- Not be dissimilar in elevation range, aspect or precipitation gradient, relative to the other subwatersheds in the experiment.

As planning of the CRW restoration experiment is finalized we will be able to determine the most appropriate candidates for subwatersheds to serve as controls based on the criteria above. These controls and 16 subwatersheds identified as early implementation in the MRW will be instrumented with key monitoring equipment and baseline

data collected for at least 5 years. At the end of 5 years, management will begin in the early-implementation subwatersheds according to harvest planning and stand eligibility for harvest based on treatment type. Early implementation control watersheds will not receive any harvest treatments.

## 4.4 Landscape Level Planning: A Modeling Approach

### Landis-II Modeling Team

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### Optimal Planning Team

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### 4.4.1 Modeling Objectives

Forest management planning implicitly requires estimating future stand conditions and forest development, but quantifying the cumulative effects of management and disturbance at large spatial scales and over long temporal durations is challenging using only field-based methods (Hong 2008). Forest landscape models, such as LANDIS-II and i-Land, allow managers to replicate the mechanistic processes that shape forest structure and composition and generate robust predictions under a range of future climate, disturbance and management conditions. Nevertheless, almost all landscape level models lack two aspects: optimality of the decision and realistic implementation. Alternatively, most optimal decision models lack the integration of fine ecological processes, whereas realistic implementation of forest activities lacks landscape perspective. To address the non-optimality or non-ecosystem weaknesses, the planning of the ESRF would integrate i-Land results into a landscape planning optimization platform, such as Remsoft Spatial Planning System (Remsoft 2023).

The primary objective of the modeling on the ESRF is to improve understanding of the integrated effects of the Triad



forest management and natural disturbance (e.g., wind, fire) on provisioning of key ecosystem services from the ESRF, including timber harvesting, carbon storage, and habitat for biodiversity. Data that these simulations generate can help refine the preliminary forest management strategy across the ESRF in order to achieve the desired set of timber, carbon and biodiversity outcomes.

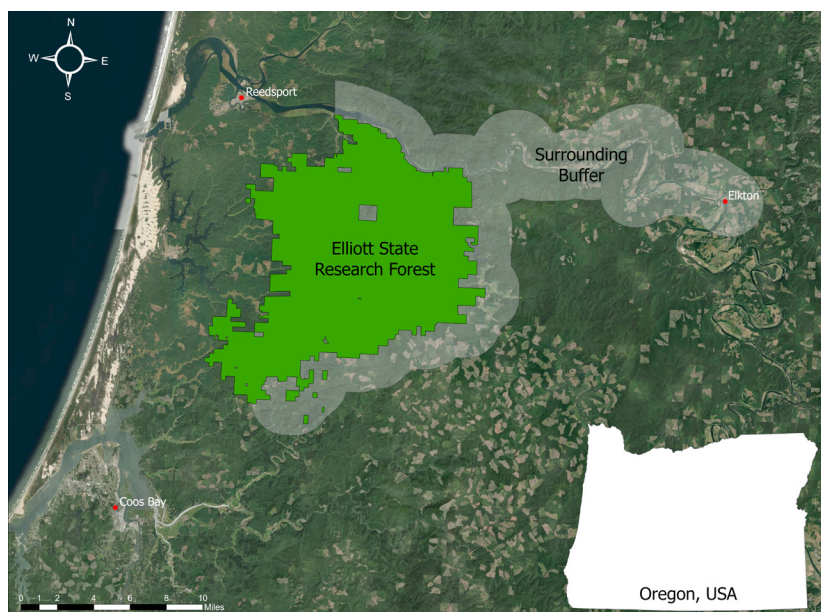
A secondary objective of this landscape modeling relates to future research data collection needs on the ESRF. Landscape simulations will be an important tool for forest management decision-making on the ESRF, but landscape models are data-intensive. Initial landscape modeling, described below, will highlight important data requirements for improving the capability of future landscape modeling. The simulation landscapes developed for modeling with LANDIS-II, iLand and the southwest Oregon (SWO) variant of Organon in this FMP do not align precisely with the ESRF planning area described in Section 1.3. Landscape modeling was initiated prior to the incorporation of East Hakki Ridge into the ESRF and treatment allocation adjustments and June 2023 ESRF HCP changes to allocations in Alder Creek, Upper Big Creek, and the MRW Partial Watersheds. Therefore, the spatial pattern of model results described in this section may differ slightly from the treatment allocations described elsewhere in this FMP.

#### 4.4.2 Rationale for Model Selection

Initially, three forest landscape models were selected for use in modeling forest and carbon dynamics on the ESRF: LANDIS-II, iLand, and Organon. LANDIS-II and iLand were chosen for their ability to model forest development and the effects of disturbance (harvesting and natural disturbance) over long time periods in a spatially-explicit fashion (i.e., the models capture the spatial nature of vegetation, landscapes and biophysical processes). Using models that employ different approaches to simulating complex forest landscapes and biophysical processes benefits from (1) the various strengths of different modeling approaches, and (2) allowing comparisons between models to identify areas of greater and lesser model certainty regarding potential future outcomes. Additionally, Organon is a non-spatial growth model with a long history of use with plantation forestry in Oregon's Coast Range and provides a reference for LANDIS-II and iLand results. These initial modeling efforts can be expanded to include other models, such as the Community Land Model (CLM).

#### 4.4.3 LANDIS II

The study landscape is the ESRF and surrounding area with a combined area of 172,428 acres (69,779 hectares, Figure 4.8). This landscape was defined to include the entirety of the ESRF



**Figure 4.8.** Depiction of the ESRF simulation landscape for LANDIS-II, which includes an exterior buffer in which natural disturbance and succession was simulated to allow disturbances to spread into the ESRF. Note that the buffer landscape is not included in any of the results.

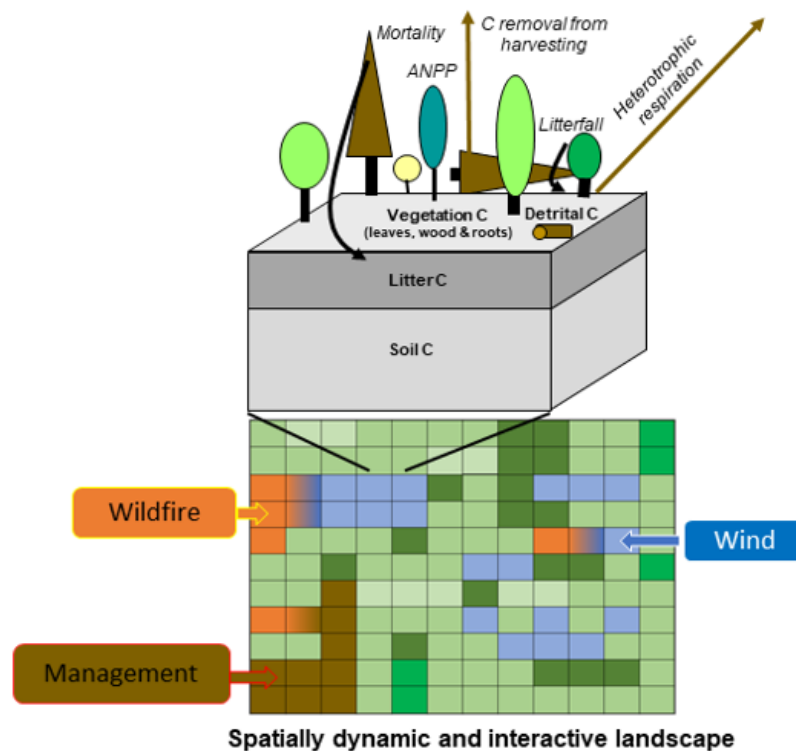


with a buffer to allow fire to ignite outside the boundary of ESRF and spread into the forest (a scenario that has occurred in the past), but also constrained to facilitate replicated simulation at our high spatial resolution (30 m x 30 m).

LANDIS-II is a spatially-explicit, process-based simulation model, optimized for large-scale spatial dynamics (Scheller et al. 2007). LANDIS-II allows for multiple ecological processes (e.g., growth, mortality, regeneration, decomposition, and disturbances) to overlap in space and time. This model has been widely adopted for use in climate change research in the U.S. (e.g., Loudermilk et al. 2014; Duveneck and Scheller 2016), including in the Pacific Northwest (Cassell et al. 2019, Creutzburg et al. 2016). The strength of LANDIS-II lies in its process-based approach to forecasting the interactive effects of climate, succession, and disturbances and its ability to simulate species-level succession as an emergent property of these processes and species' life history strategies.

The *Net Ecosystem Carbon and Nitrogen* (NECN) succession extension of LANDIS-II (Figure 4.9) simulates growth, mortality, reproduction/dispersal, and regeneration of

trees, shrubs, and grasses as a function of climate, soil, and life history strategies (Scheller et al. 2011, 2012). NECN simulates monthly changes in individual species growth as dictated by life history attributes (e.g., serotiny, vegetation regeneration, seed dispersal distance), biogeochemistry (e.g., C:N ratios of wood, leaves, and roots), and resource availability (e.g., light, nutrients). It tracks carbon (C) and nitrogen (N) in multiple pools of live biomass and detritus (leaves, wood, fine roots, coarse roots) and soil (Parton et al. 1988, 1994). NECN also simulates hydrologic processes (e.g. precipitation, snow accumulation and melt, evaporation, transpiration) and simulates feedbacks between soil water availability and plant growth. NECN simulates many facets of climate change, both direct (e.g., temperature, precipitation) and indirect (e.g. changes in growing season length, soil temperature, soil moisture, available N) on growth, mortality, and regeneration. This comprehensive tracking of species composition, hydrology, and biogeochemical processes in NECN is helpful for exploring different management and disturbance scenarios under a changing climate.



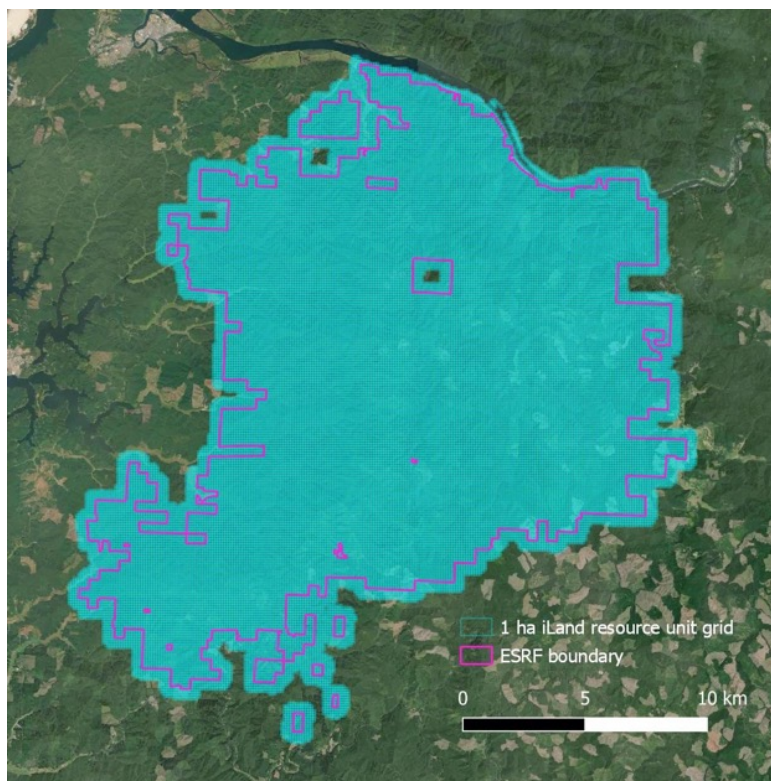
**Figure 4.9.** Conceptual figure of the NECN Extension of LANDIS-II.

Natural disturbances can have significant impacts on forest management outcomes; therefore it is important for managers to consider and incorporate natural disturbances in forest management planning. LANDIS-II allows for the simulation of natural disturbances, including wildfire, windstorms, insects, browsing by deer, and the interactions that may occur when these disturbances overlap. In all LANDIS-II simulations completed during development of the ESRF FMP, the ignition, spread, and impact of both natural and human ignited fire were modeled using the *Social-Climate Related Pyrogenic Processes and their Landscape Effects* (SCRPPLE) extension of LANDIS-II. This extension allows for the simulation of both natural and anthropogenic fire and captures the spatial and temporal pattern of fires, as driven by topography, fuels, climate, and human activity (Scheller et al. 2019). Stochastic windstorm events and associated mortality were also simulated using the Base Wind extension (Scheller and Domingo 2005), which uses age to calculate mortality risk with the oldest cohorts most vulnerable to wind-induced mortality (Mladenoff and He

1999). Both disturbance extensions were parameterized using empirical estimates of the mean disturbance regimes for the study area (distributions of event sizes, rotation period (time to disturb an area equal to the study area), and mortality rates).

#### 4.4.4 iLand

iLand is a spatial, process-based, individual tree growth model designed for large scale simulation. It differs from non-spatial, individual tree growth models currently in operational use primarily in its abilities to make greater use of information available from aerial LiDAR flights and to more completely represent climate change effects on future forest growth. iLand represents each tree's location with 2 m accuracy, tracks the amount of light each tree receives, and converts each tree's photosynthesis into annual growth. Soil properties, the water cycle, and their influence on tree growth are captured at 100 m resolution (Figure 4.10) and driven by monthly predictions of local weather under various climate scenarios (Seidl et al. 2012a, Wang



**Figure 4.10.** iLand grid of 41,809 100 x 100 m simulation resource unit cells (1 ha each) which extends 400 m past the ESRF boundary to minimize edge effects in the model. Each resource unit contains many individual trees, independent photosynthetic calculations, and a unique water cycle based on weather predictions and soil properties.

et al. 2016, Chaney et al. 2019, Poggio et al. 2021). iLand was originally developed for research use on Oregon's HJ Andrews Experimental Forest and has been rewritten and improved for use on the ESRF (West 2023). Among other similar growth models, iLand's selection was motivated by its open source availability, status as a well established variant within the widely used 3-PG model family (Gupta and Sharma 2019), successful prior use in western Oregon (Seidl et al. 2012b), and ability to simulate 100,000 acre landscapes (Hansen et al. 2020).

#### 4.4.5 Organon Southwest Oregon

The southwest Oregon (SWO) variant of Organon is publicly available in CIPSR 2.2.4 (Osborne 2015) with more recent versions available to members of the Center for Intensive Planted-forest Silviculture (Joo et al. 2020). Organon is a non-spatial, individual tree growth model which is not climate aware but is in operational use and directly accepts plot measurements from timber cruising, such as those from the 738 ESRF stands inventoried in 2016 (Dooley and Fairweather 2016). The updated version of Organon 2.2.4 used on the ESRF has been integrated with an individual tree harvest cost model (West 2022) which seeks to account for steep slopes and evolution in harvest equipment.

#### 4.4.6 How Landscape Models Contribute to Forest Management Planning

Forest management planning requires estimating future stand and forest development under different management practices, while recognizing the critical role of disturbance. However, forest managers are often limited in their ability to quantify the cumulative effects of management and disturbance at large spatial scales and over long temporal durations using field-based methods (Hong 2008). Ecological models offer a solution. However, models that rely on replicating how systems behaved in the past are unable to confidently project forest conditions under climate change (Gustafson 2013). Forest Landscape Models (FLMs) such as LANDIS-II and iLand allow managers to replicate the mechanistic processes that produce landscape effects without relying solely on statistical relationships between forest attributes. This allows for robust predictions under a range of future conditions.

Landscape modeling is able to project future spatial and temporal changes in tree and shrub species composition, carbon stocks, and age-class structure across the ESRF. Unlike the outputs of many timber-oriented growth and

yield models (such as Organon SWO) which do not account for disturbance, simulations from LANDIS-II illustrate the potential shape of future forest development under the influence of two large-scale natural disturbances in Oregon Coast Range forests—windstorms and wildfire. Simulations from iLand can provide detailed estimates of tree physiology and microsite responses at landscape scale.

##### 4.4.6.1 Incorporating Climate Change into the Forest Planning Process

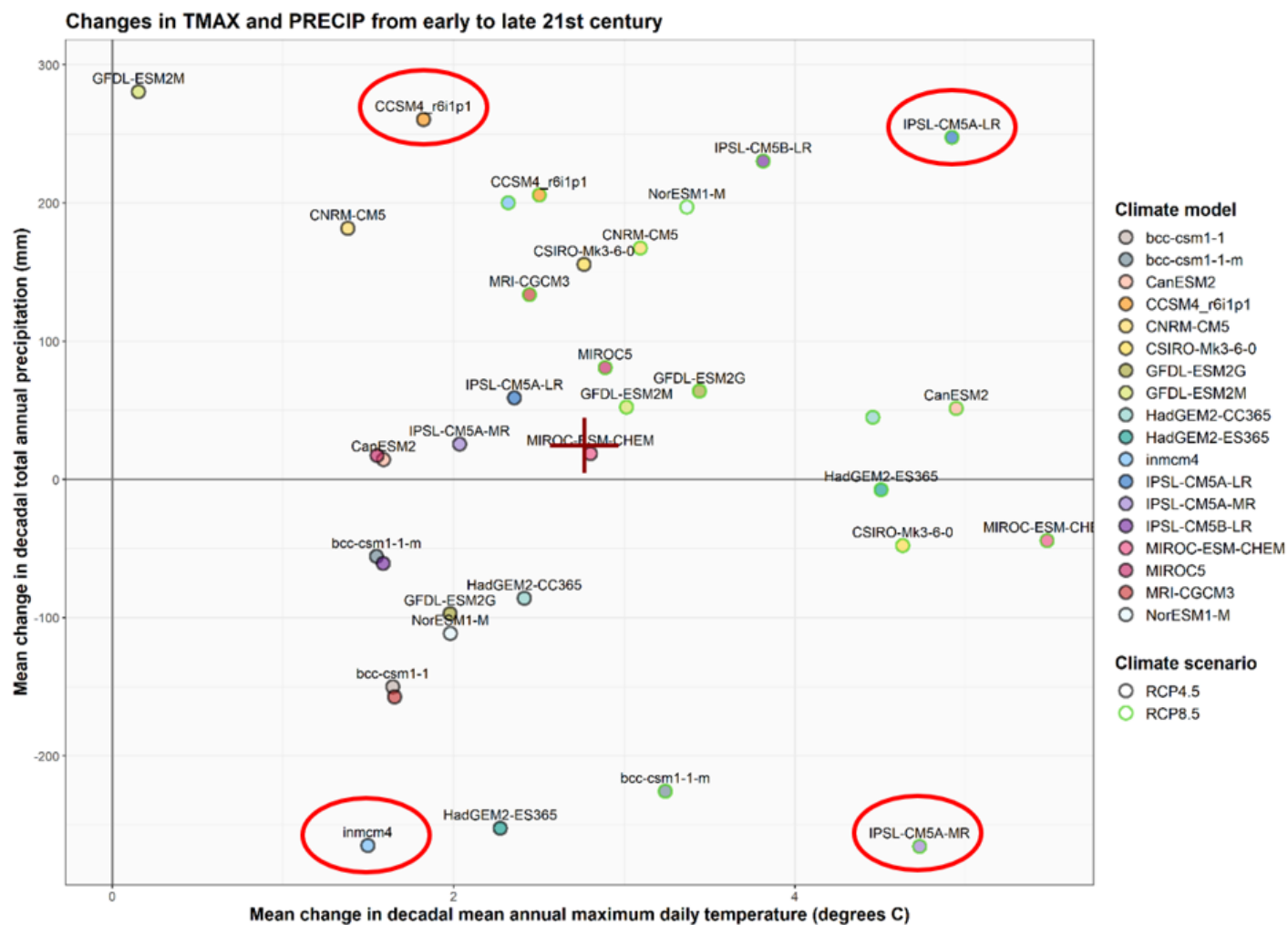
Although tree and shrub species have adapted historically to changing climatic conditions in the Pacific Northwest, future changes in climate may occur at rates that are beyond the natural adaptive capacity of forest ecosystems, leading to the loss of local species and important functions and services, including reduced forest carbon stocks. Forest managers are accustomed to planning over long time scales (i.e. 5- 15 years), but practices are often based on an implicit assumption that local climate conditions will remain constant, which may no longer be valid. Factoring climate uncertainty into management is critical for evaluating the long-term implications of timber harvesting, carbon stocks, and wildlife habitat.

Climate models and RCPs (Representative Concentration Pathways) for inclusion in the LANDIS-II model were developed using the “four corners” approach often applied in evaluations of climate change. Under this approach, models scenarios representing relatively “warm-wet” (CCSM4 RCP 4.5), “warm-dry” (CCSM4 RCP 4.5), “hot-wet” (IPSL-CM5A-LR RCP8.5), and “hot-dry” (IPSL-CM5A-MR RCP8.5) were selected (Figure 4.11). In addition to these four climate scenarios, a historical (i.e. no climate change) scenario was created using downscaled gridMET data from 1979 to 2021 (Abatzoglou 2013). For the sake of simplicity, the results shown here are from the historical, warm-wet, and hot-dry climate scenarios, though all climate scenarios were run in LANDIS-II.

##### 4.4.6.2 Model Outputs to Inform Treatment Levels and Timber Volume Projections

Forest management activities implemented in the LANDIS-II simulations were designed to emulate the type and spatial distribution of planned silviculture across the ESRF, given windstorms and wildfire. These activities were modeled across five “management areas”: the Conservation Research Watershed (CRW) and the four subwatershed-level Triad treatments (*Reserve with Intensive, Triad-I, Triad-E, and*





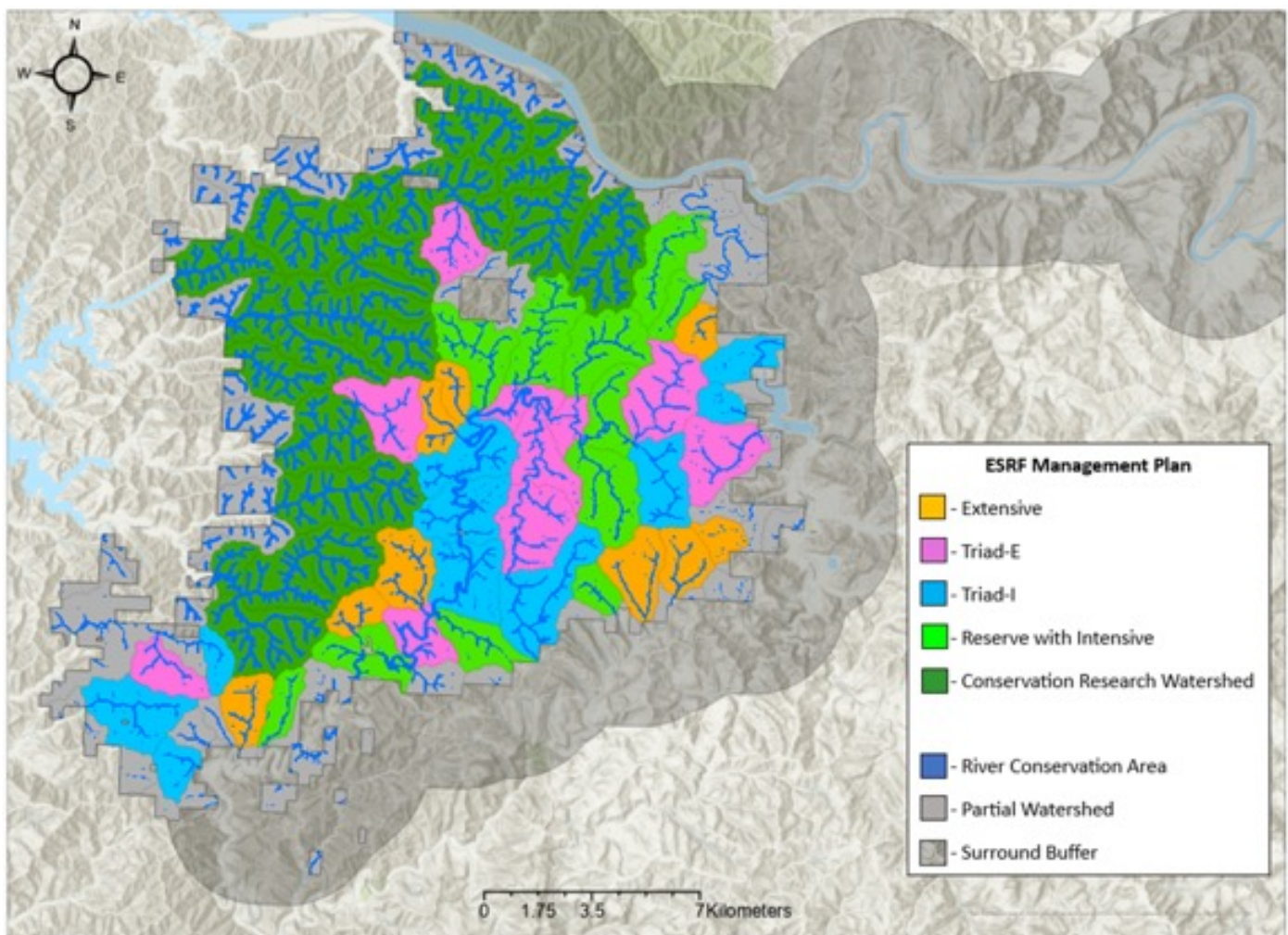
**Figure 4.11.** Projected change in decadal Tmax and precipitation: Late-century climate (2090-2099 decadal average) minus contemporary climate (2010-2019 decadal average). Models representing the “four corners” were identified visually after first ruling out potential outliers – model x scenario combinations that clearly differed in x- (Tmax) and y- (precipitation) space from other models.

*Extensive*; Figure 4.12). Harvesting in the CRW was limited to an initial thinning of young plantations with the goal of increasing structural complexity at stand- to watershed scales. The vast majority of simulated harvesting occurred in the Management Research Watershed (MRW), distributed between subwatersheds assigned to the four experimental treatments, and to partial watersheds outside the formal Triad experiment.

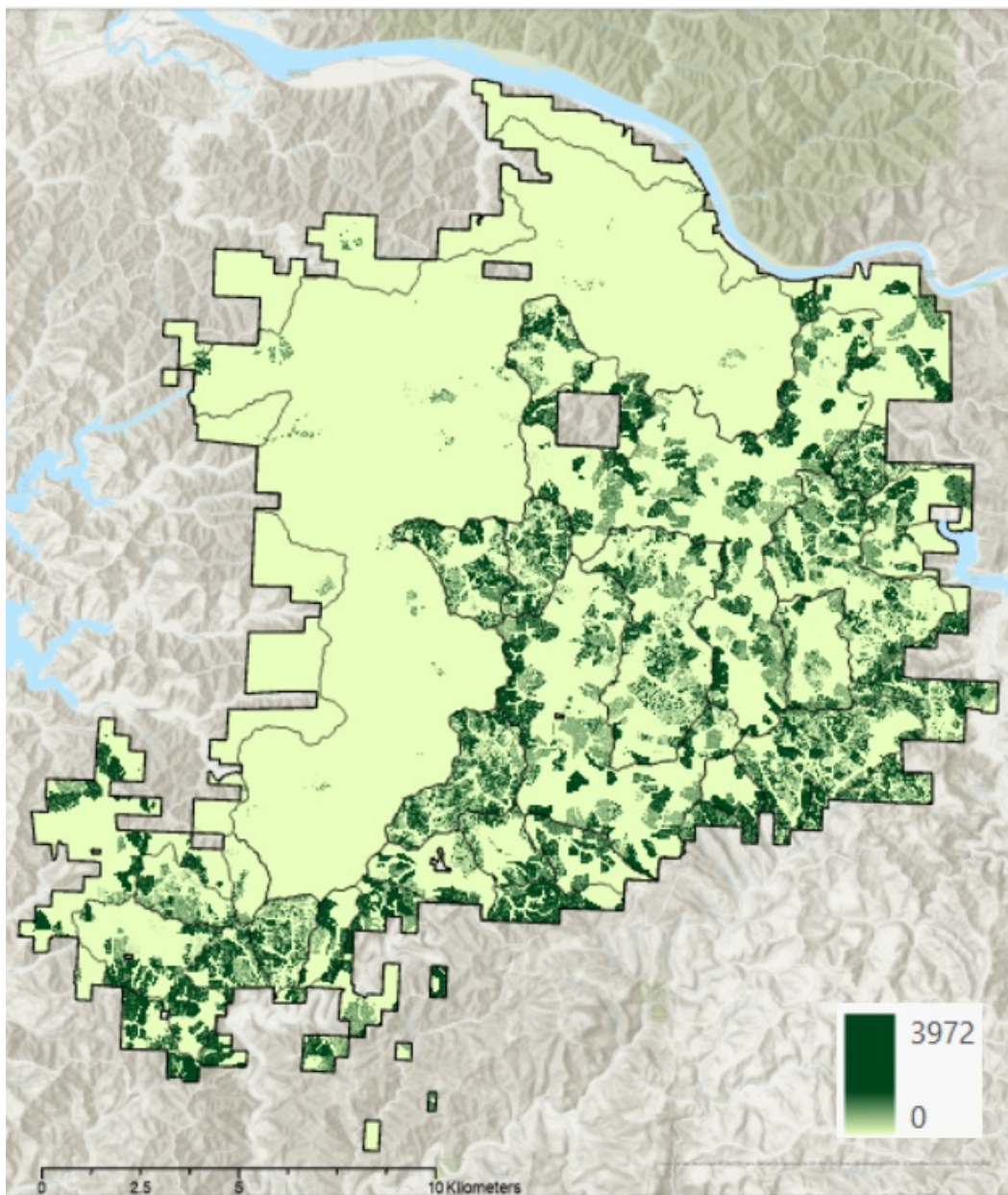
Harvesting was excluded from MRW Reserves in subwatersheds assigned to Reserve with Intensive, Triad-I and Triad-E experimental treatments. Over the long-term, this spatial segregation of active management between CRW and MRW, and within the MRW resulted in a complex

hierarchical spatial distribution of harvest biomass removals (Figure 4.13). This spatial patterning has important implications for wildlife habitat at the landscape scale (see Section 4.4.6.3).

As expected, the proportional area harvested annually within a subwatershed was largest in the Extensive subwatersheds, followed by the Triad-E, Triad-I, and finally the Reserve with Intensive subwatersheds (Figure 4.14). The proportion of subwatersheds managed within the Reserve with Intensive and Triad-I areas remains consistent throughout the simulations. However, higher variability was observed in year-to-year management extent within Triad-E and Extensive subwatersheds. The only harvesting modeled

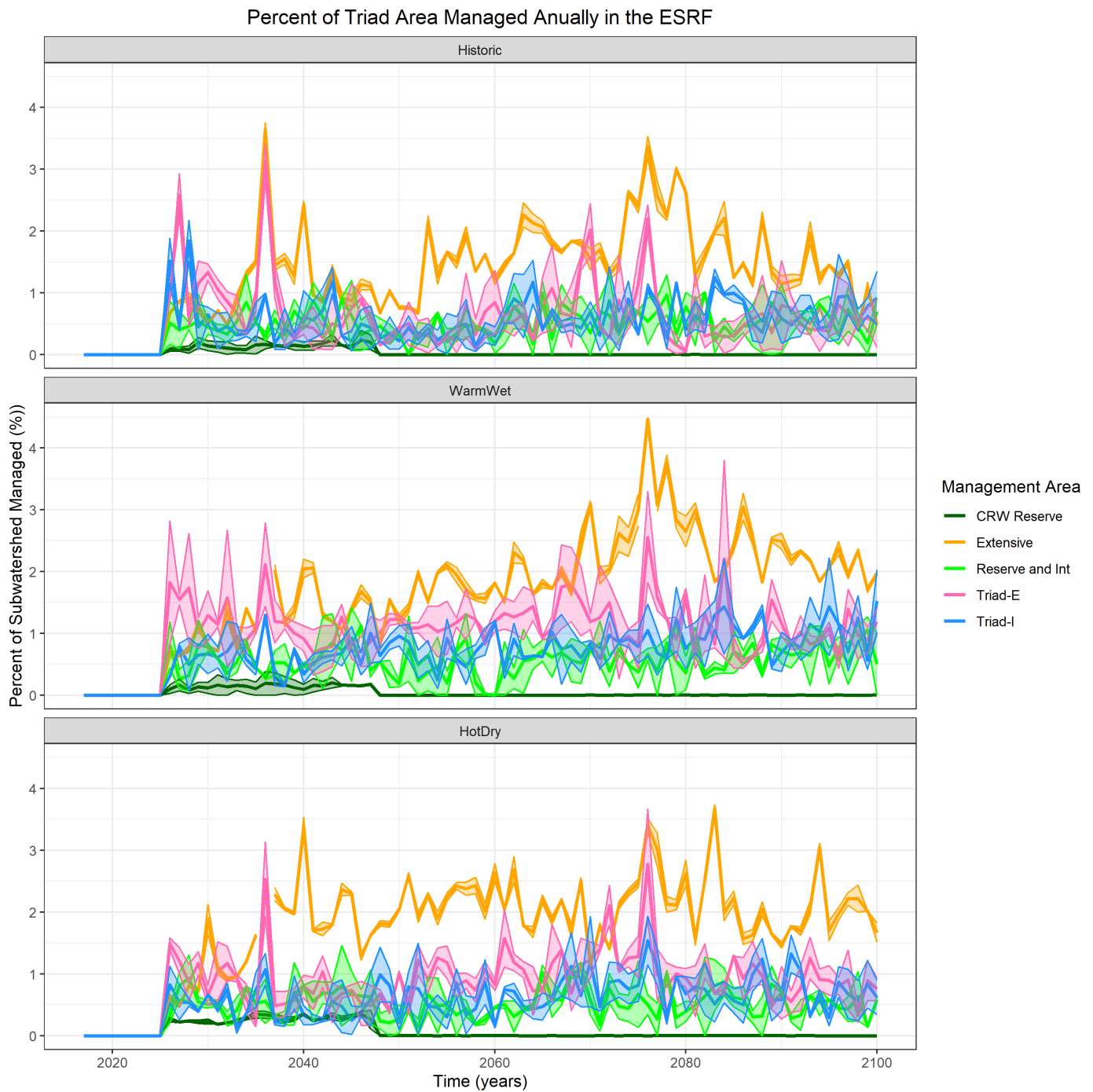


**Figure 4.12.** Map displaying Triad management allocations in the LANDIS-II model.



**Figure 4.13.** Amount of harvested carbon (Mg/ha) over the 85 year simulation period for one LANDIS-II replicate.





**Figure 4.14.** Annual proportion of management area managed under the five subwatershed-level treatments and three climate scenarios using LANDIS-II.

in the CRW was single-entry variable density thinning for the first 21 years within stands less than 65 years old for the purpose of promoting structural complexity. These patterns remained true under the three climate change scenarios.

Biomass removal was relatively similar between all four management research watersheds (Figure 4.15). Results indicate that the biomass removed from Extensive and Triad-E areas is far more variable than biomass removed from other treatment areas, with sporadic years of high timber production due to stand availability, given modeled wildfire and windstorms. However, despite higher initial values in modeled timber production, the average amount of biomass harvested remains relatively even between treatments through the end of the simulation, indicating that all four subwatershed-level treatments will be able to produce consistent levels of timber through the 21st century, even with wildfire and wind disturbances. Results also indicate an increase in year-to-year variability under climate change scenarios.

#### 4.4.6.3 Model Projections of Carbon Stocks and Species Composition

Succession, harvesting and natural disturbances in a modeled landscape affect carbon storage in the forest and in harvested wood products. LANDIS-II and iLand model outputs allow us to estimate changes in carbon storage in all major pools (or reservoirs) in the forest, including live trees (Poudel et al. 2019, Chojnacky et al. 2013) and shrubs (LANDIS-II only), dead wood, and forest soils.

Results from LANDIS-II indicate that while all management areas start with similar levels of aboveground carbon storage, these levels greatly change over the course of the 21st century depending on the management area (Figure 4.16). The aboveground carbon storage in these management areas arrange themselves based on proportional allocation of stand-level reserve treatment. The CRW stores the most, followed by the Reserve with Intensive, Triad-I, Triad-E and finally the Extensive subwatersheds. Under a warmer, wetter climate aboveground carbon storage decreases relative to the historic treatment. However, under a hotter, drier climate, aboveground carbon storage initially increases at rates similar to that of the historic climate scenario before plateauing and beginning to decline near the end of this century.

Similar to aboveground, the management areas start with similar levels of belowground soil organic carbon (SOC). Over time, soil carbon diverges between management

areas, arranging itself based on the proportional allocation of stand-level extensive treatments by the end of the century. Therefore, the Extensive subwatersheds store the most SOC, followed by Triad-E, Triad-I, Reserve with Intensive, and finally the CRW by the end of this century (Figure 4.17). This order remains the same under our climate scenarios. Under both climate scenarios, SOC remained at similar levels to historic for the first three decades before diverging and leveling off. By the end of the century, SOC in the Triad-E, Triad-I, Reserve with Intensive, and CRW subwatersheds was relatively constant. Conversely, SOC was still increasing within the Extensive subwatersheds at the end of the 21st century.

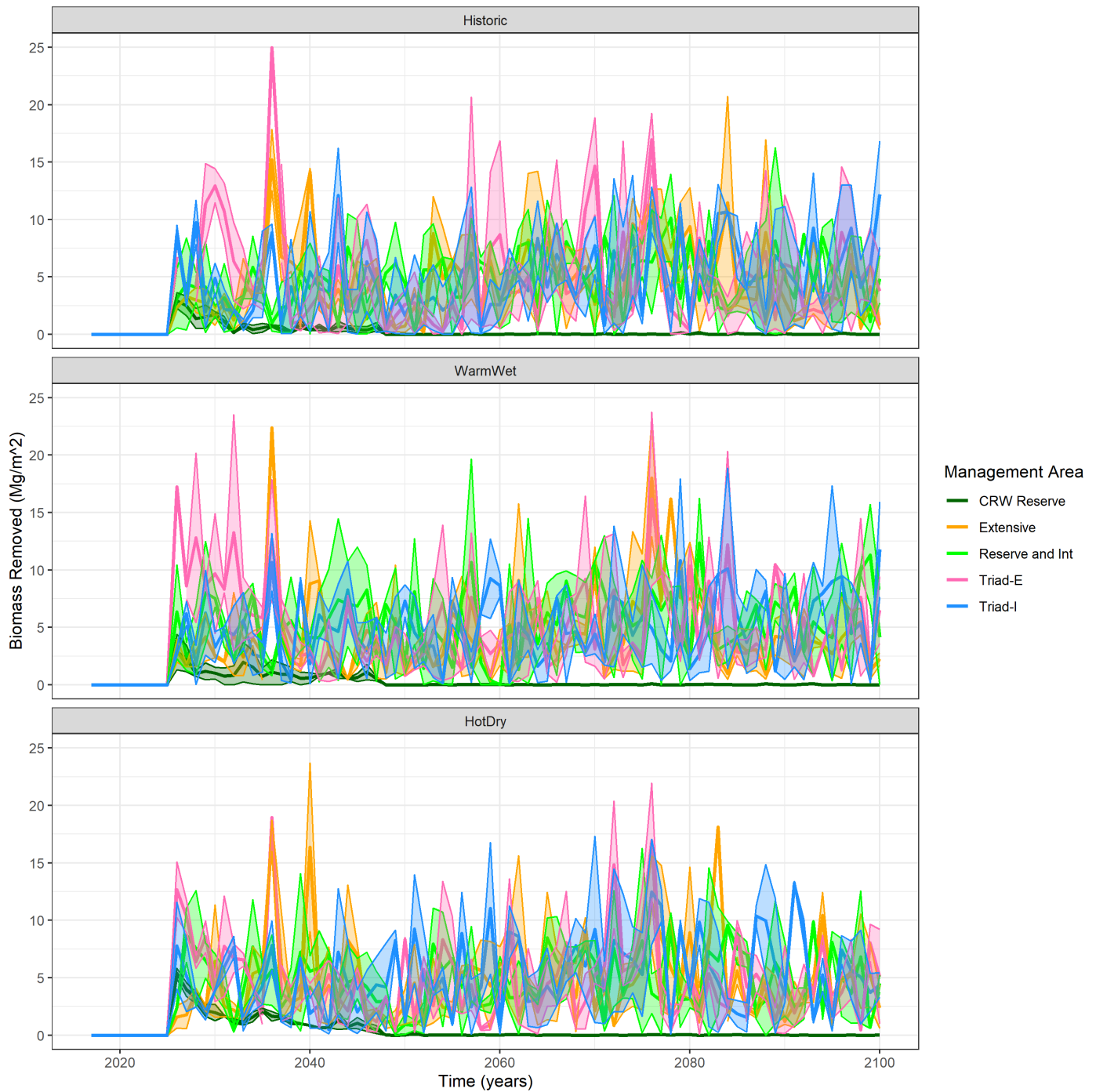
Under *historical climate*, carbon stored in Douglas-fir increases the most in the CRW and the least within the Extensive management area (Figure 4.18). However, the Extensive subwatersheds saw the largest increases in species other than Douglas-fir, particularly Western hemlock, and was the only management area to experience increases in shrub carbon, with the largest increases occurring in Evergreen huckleberry and Cascara buckthorn (Figure 4.19).

Under a *warmer, wetter* climate, total tree carbon increased at a slightly slower rate than under historic conditions. The largest contributor to tree carbon was Douglas fir. Other tree species experienced a smaller increase in carbon storage over the course of the simulation when compared to the historic climate scenario. Carbon stored within shrubs remained similar to the historic scenario, except in the extensively managed area, where evergreen huckleberry and cascara buckthorn experienced an increase in carbon storage near the end of the century.

The *hot dry* climate scenario saw initial increases in total tree carbon similar to the historic scenario. However, total carbon stored within trees plateaus near the mid 21st century before beginning to decline near the end of the simulation. The hot dry simulation also saw the smallest increase in non-Douglas fir carbon and large increases in shrub carbon within both the Extensive area.

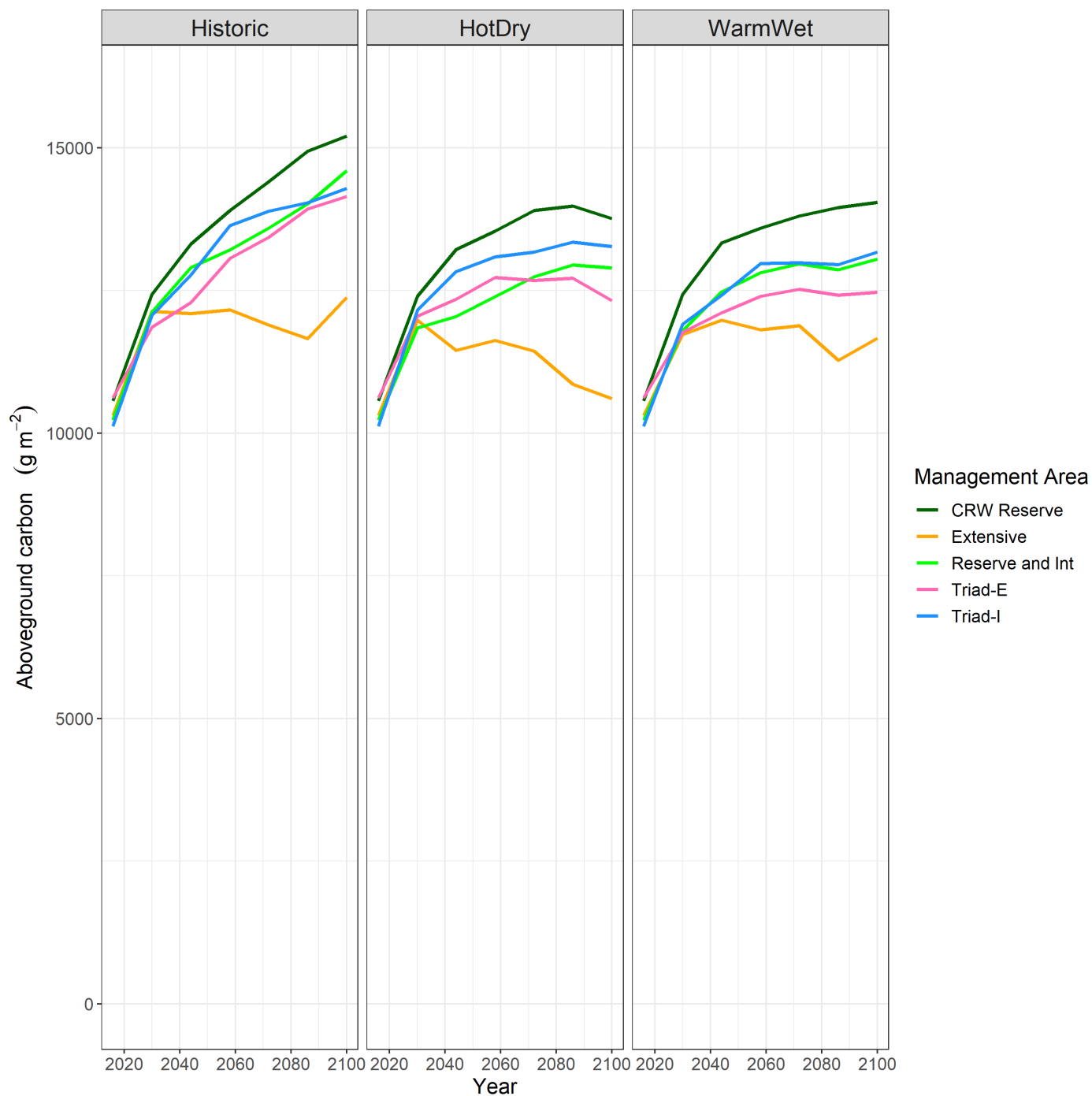
#### 4.4.6.4 Model Projections of Habitat

Landscape modeling with LANDIS-II and iLAND can help assess habitat suitability across the ESRF for wildlife associated with different successional stages and vegetation compositions, both through stand-level silvicultural guidelines (e.g. Harrington and Nicholas 2007) and finer scale approaches considering intra-stand variability (Hagar

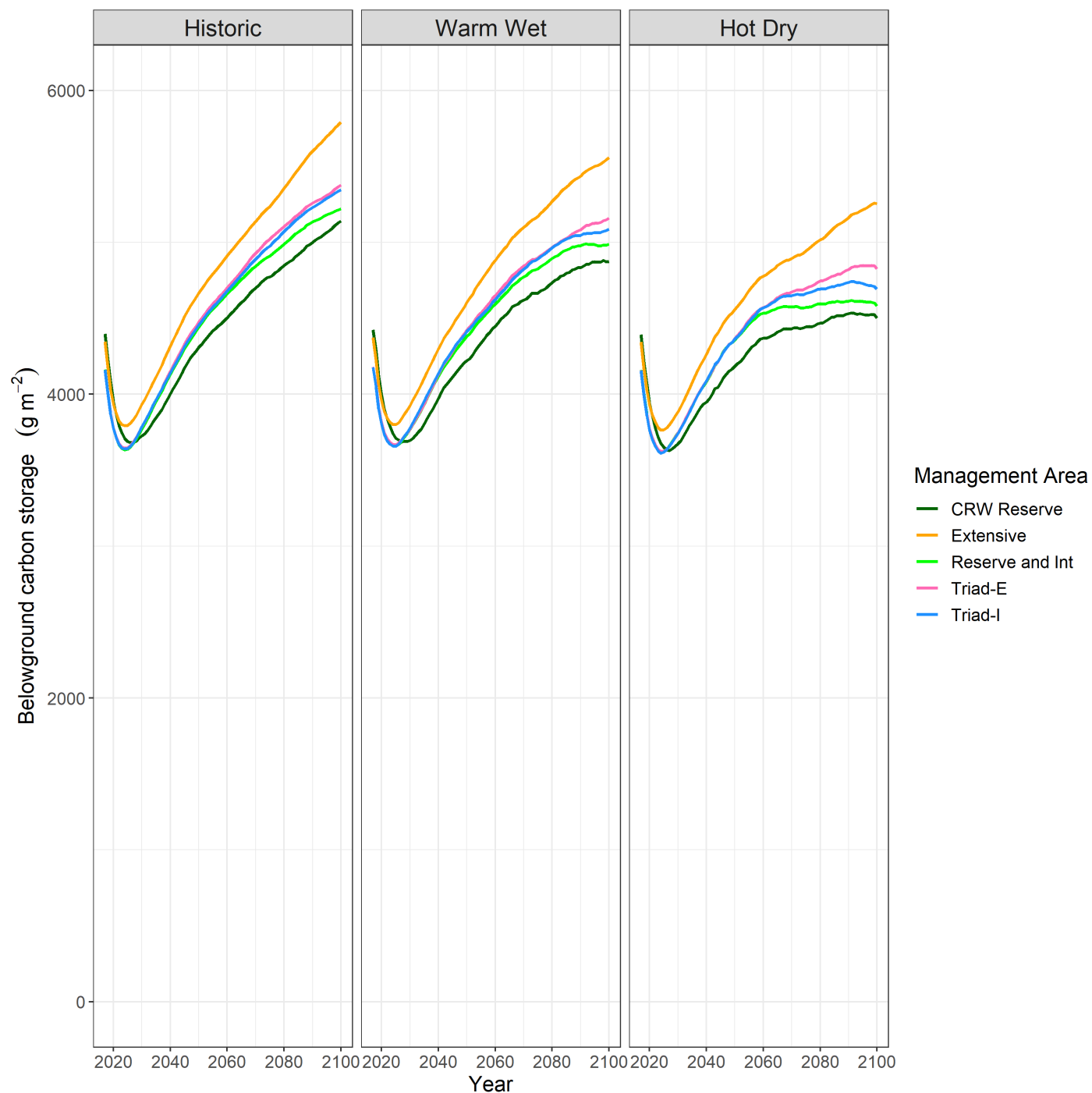


**Figure 4.15.** Annual biomass removed from management areas under the five subwatershed-level treatments and three climate change scenarios using LANDIS-II.

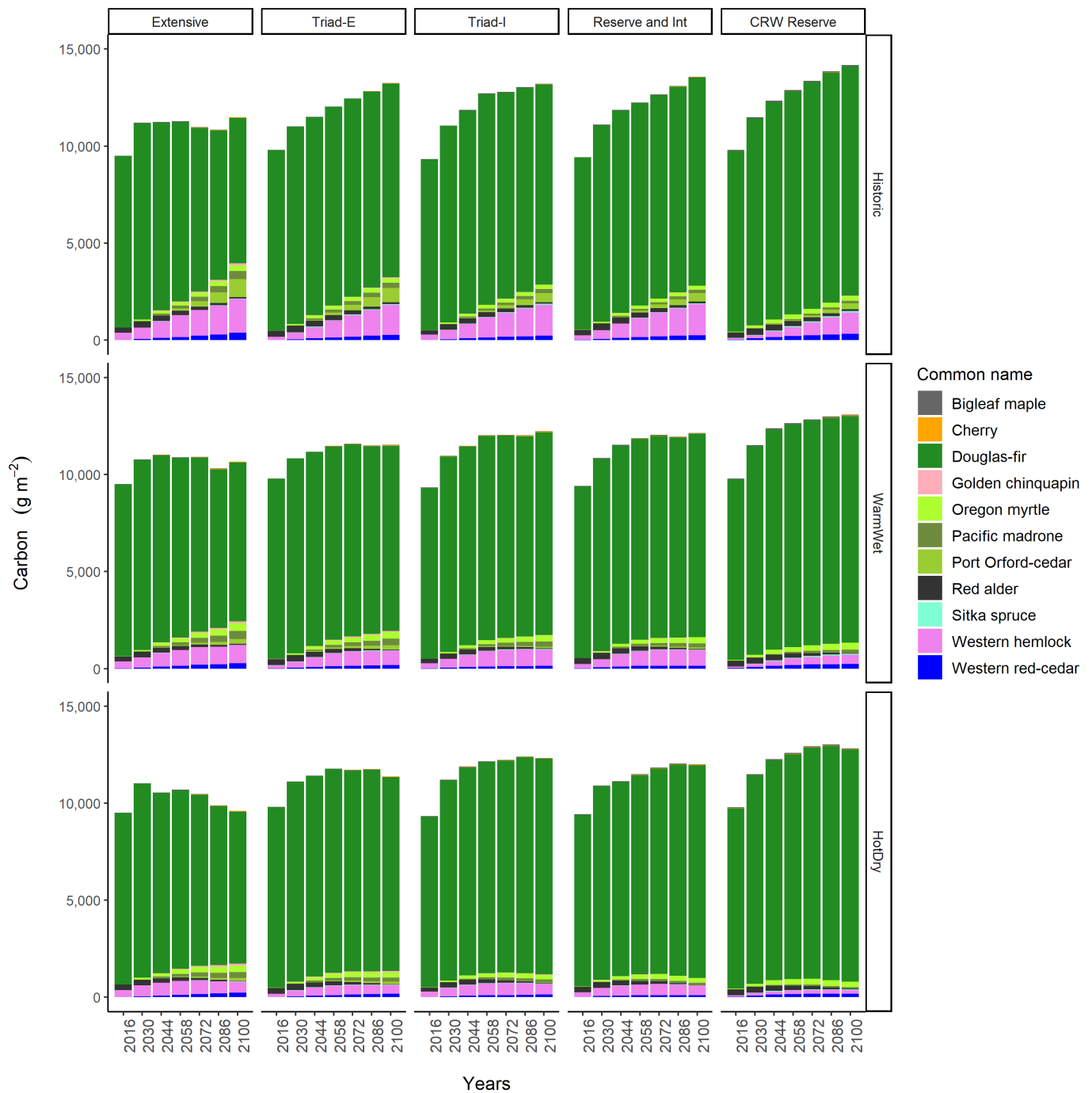




**Figure 4.16.** Aboveground carbon storage trends in the five management areas under three of the five climate scenarios using LANDIS-II.

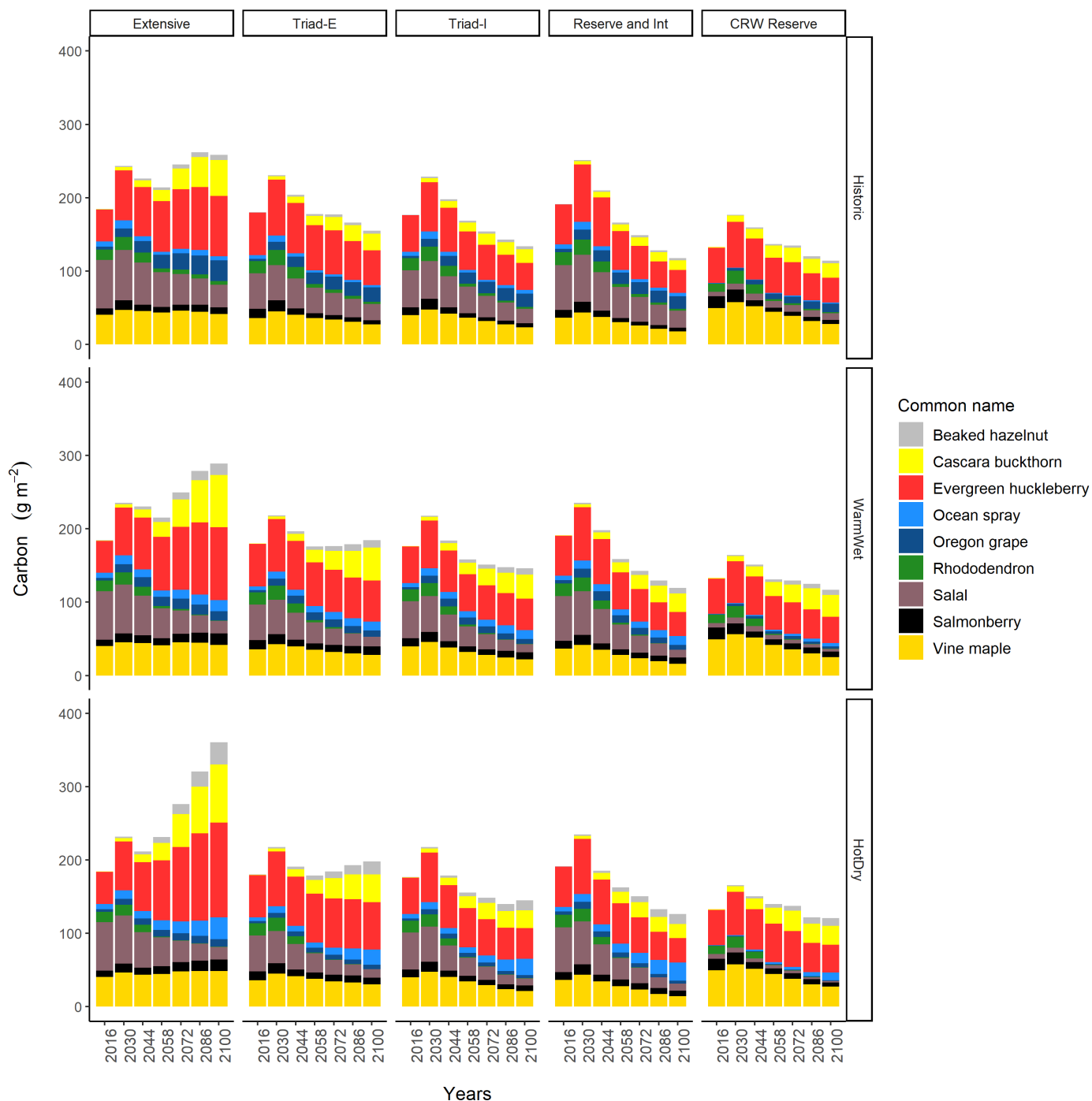


**Figure 4.17.** Trends in *belowground soil organic carbon storage (SOC)* in the five management areas under three of the five climate scenarios using LANDIS-II.



**Figure 4.18.** Trends in *tree carbon storage* at a species level within the five subwatershed-level treatments and under three of the five climate scenarios using LANDIS-II.



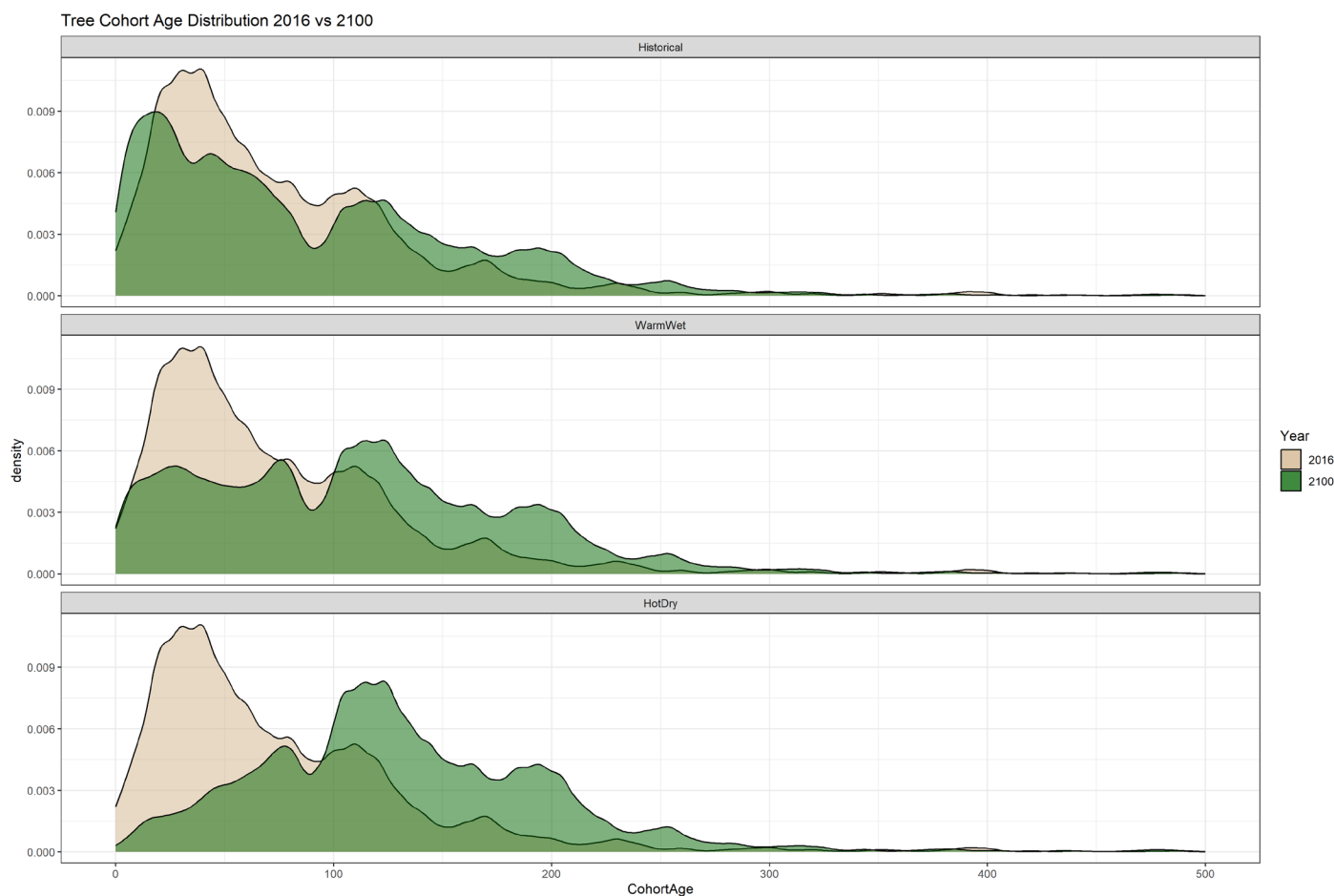


**Figure 4.19.** Trends in *shrub carbon storage* at a species level within the five subwatershed-level treatments and under three of the five climate scenarios using LANDIS-II.

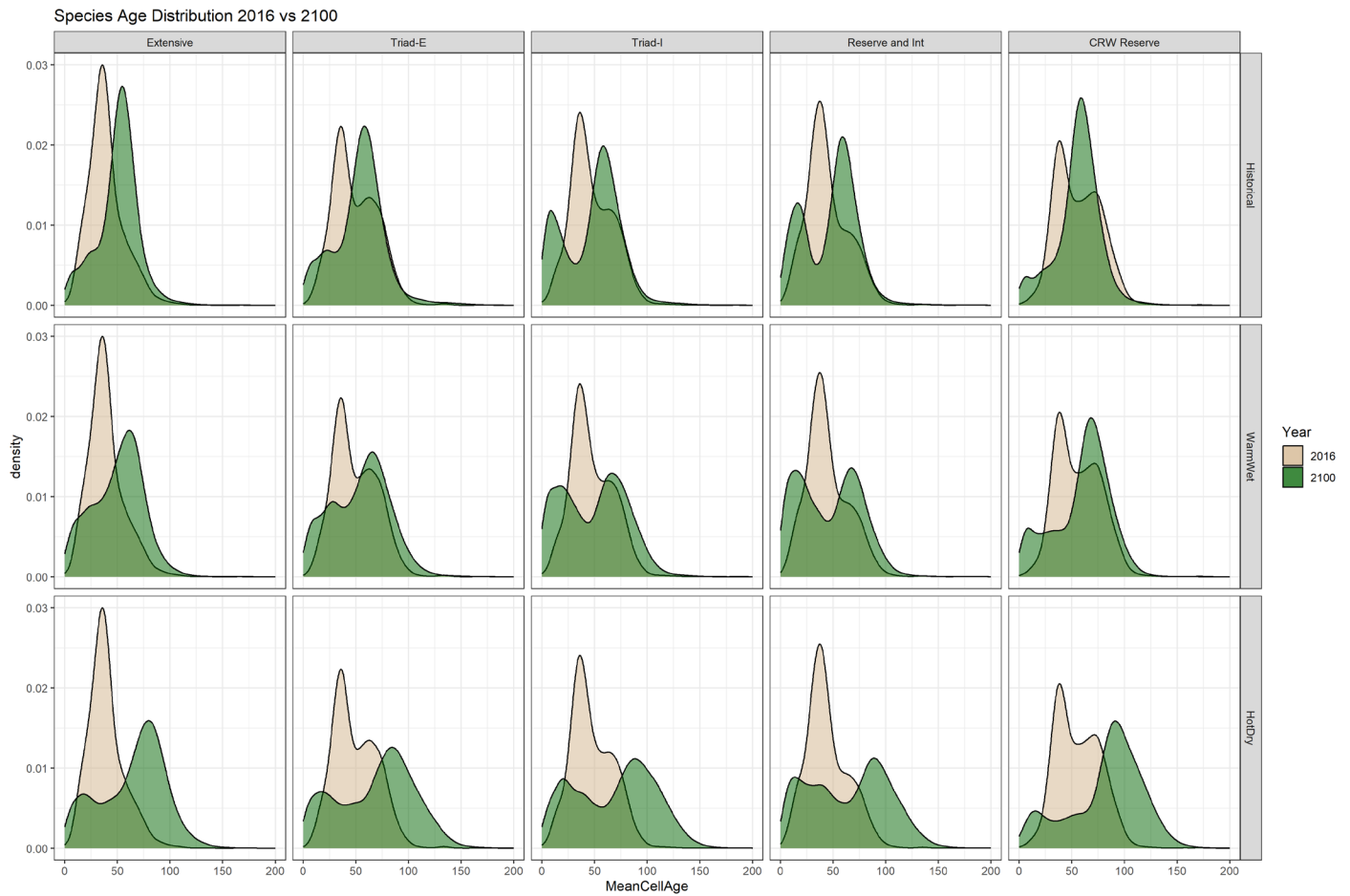
Cohort age distributions derived from LANDIS-II outputs indicate a relatively stable cohort age distribution in the ESRF over time under a *historic climate*, with decreases in the proportion of 20 to 40 year old trees and shrubs and an increase in the proportion of trees and shrubs over 100 years old (Figure 4.20). Under the *warm-wet* scenario, this trend was amplified with a larger decrease in the proportion of younger vegetation and an increase in the proportion of trees and shrubs over 60 years old. Finally the *hot-dry* scenario saw the largest shift. Under this climate there was a substantial decline in the proportion of trees and shrubs under 60 years old. This result coupled with the decrease in aboveground carbon storage near the end of the century could indicate a decrease in the establishment of tree and shrub species under this climate scenario.

Most management areas show some level of bimodality at the end of the 21st century, but to varying degrees. The degree to which cohort age distributions follow a bimodal distribution align based on the proportional allocation of intensive stand-level treatments within management areas, with the Reserve with Intensive treatment showing the two most distinct modes and the CRW showing the least (Figure 4.21). Modes become suppressed under climate change and the distribution becomes more uniform.

Using age as a predictor of abundance of early successional bird species (Harris and Betts 2022), preliminary results show that under all the climate scenarios in LANDIS-II, the CRW had the lowest abundance of early successional bird species and Extensive subwatersheds had the highest at the

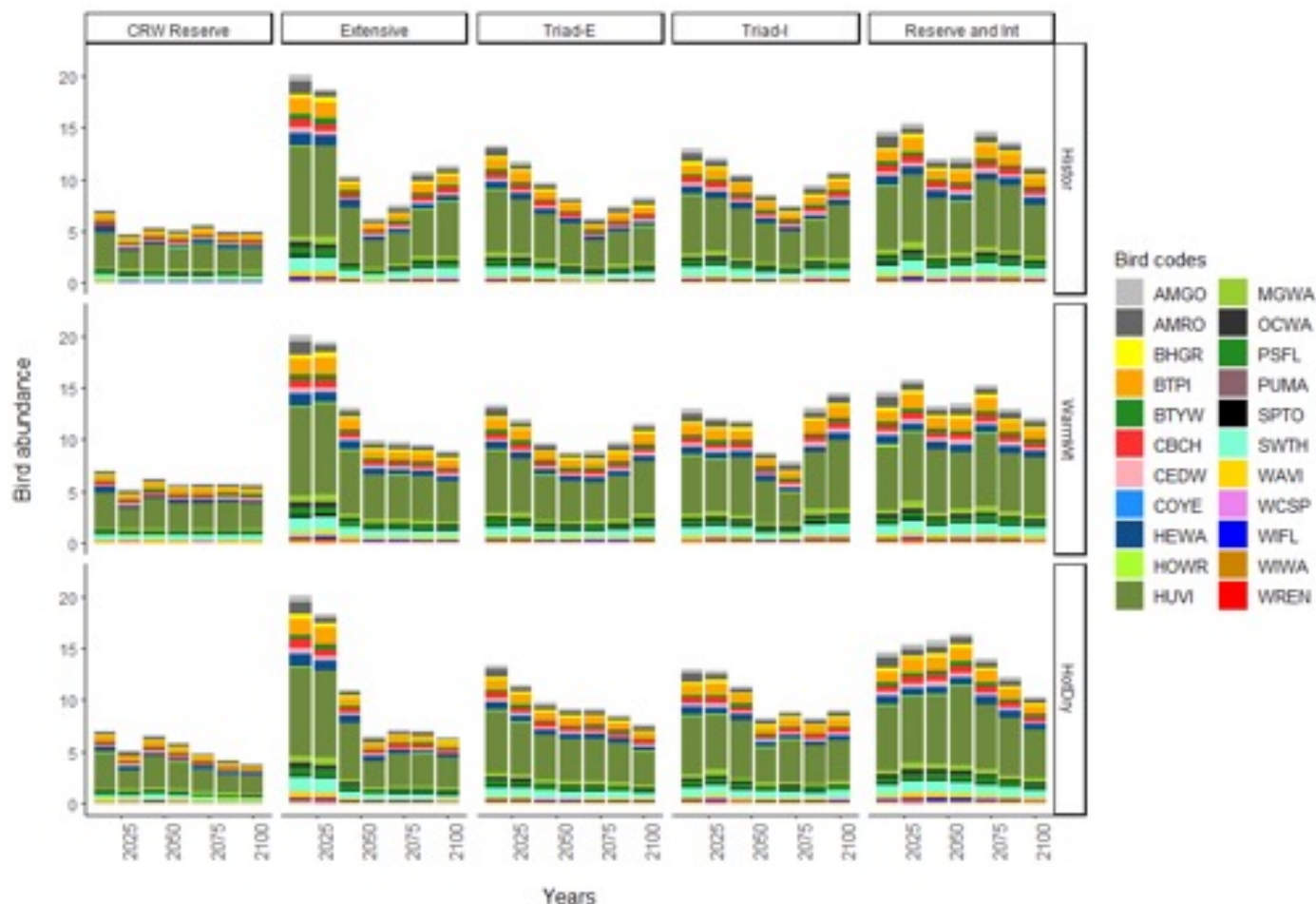


**Figure 4.20.** Shifts in cohort-level age distributions in the Elliott under three of the five climate scenarios as projected by LANDIS-II.



**Figure 4.21.** LANDIS-II results displaying shifts in cohort-level age distributions in the ESRF under three climate change scenarios and the five management areas.





**Figure 4.22.** Changes in early-seral bird abundance over time in the five management areas under three climate scenarios using LANDIS-II. Bird codes are defined in Harris and Betts (2022).

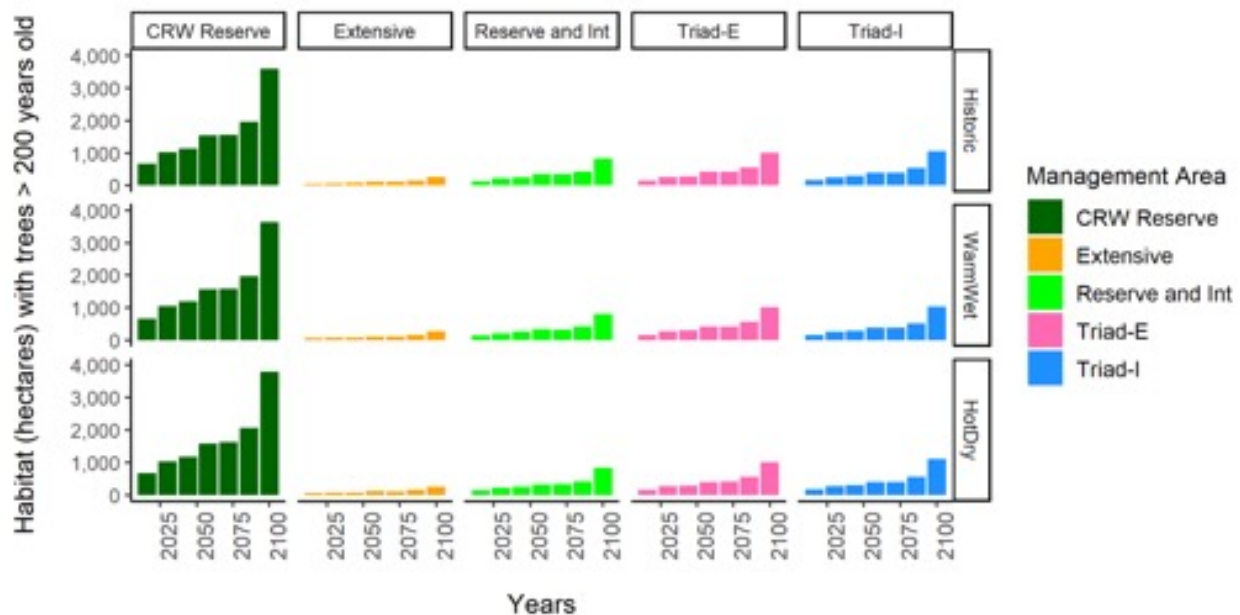
start of the simulation (Figure 4.22). Bird abundance was very similar between Triad-E and Triad-I. There was relatively large decadal variation in bird abundance, particularly in the Extensive management areas, with a dip in bird abundance in mid-century, followed by a plateau. Hutton's vireo (HUWI) had the greatest abundance of all the bird species, though it exhibited large decadal variation in abundance. Band-tailed pigeon (BTPI) and Swainson's thrush (SWTH) were also common in the ESRF.

Preliminary analysis shows that the CRW had the highest abundance of late successional bird habitat (sites with at least one cohort > 200 years old) across the next 85 years (Figure 4.23). Extensive had the least amount of late successional bird habitat, with the other management areas falling between

these extremes. Late successional bird habitat increased over time in all the management areas, but the reserve areas showed the greatest increases over time with a 5-fold increase in habitat by the end of the century.

#### 4.4.7 Using Scenario Analysis to Inform Research Management Decisions

Forest landscape models serve as powerful tools for management planning as they allow managers to explore different management and climate scenarios. Using scenario analysis, managers can forecast possible changes in the state of ecosystems, ecosystem services, and natural resources resulting from different scenarios of climate, management, or disturbance (Clark et al. 2001).



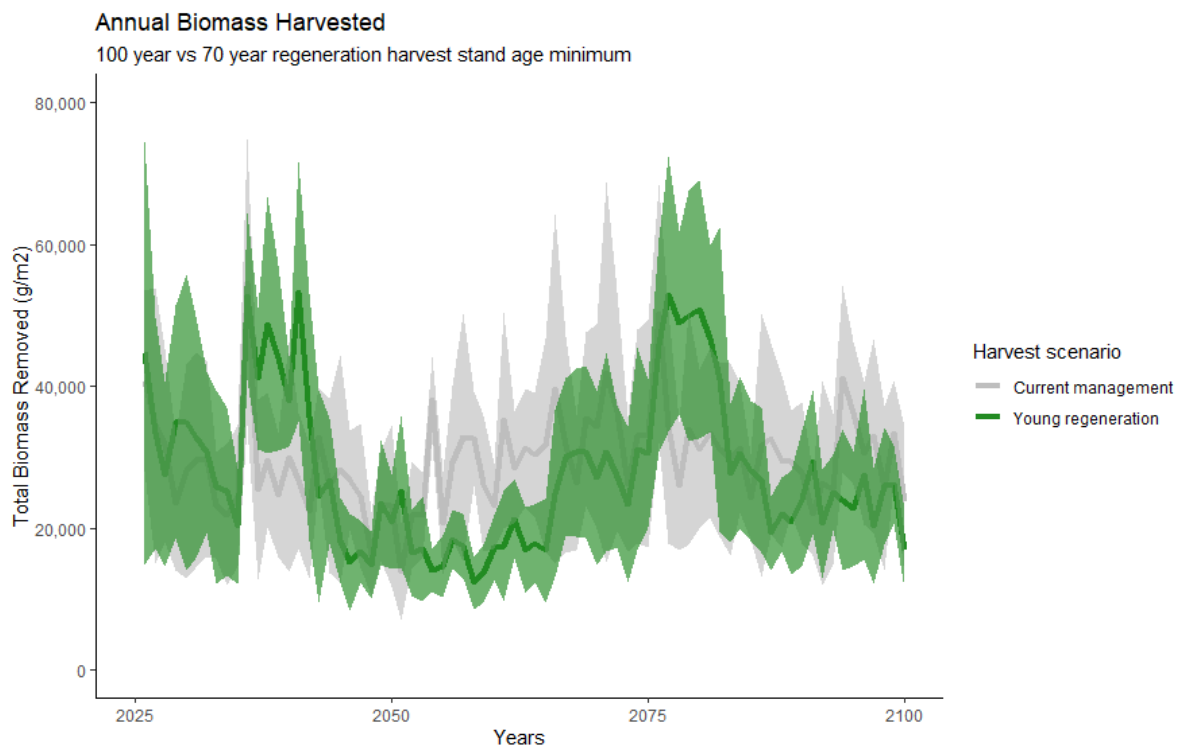
**Figure 4.23.** Preliminary LANDIS-II projections of bird habitat for species requiring late successional forests (> 200 years old) in the five management areas under three climate scenarios.

This is especially relevant in allowing managers to adjust management requirements or incorporate new treatments and observe the impacts that these changes have on key management objectives.

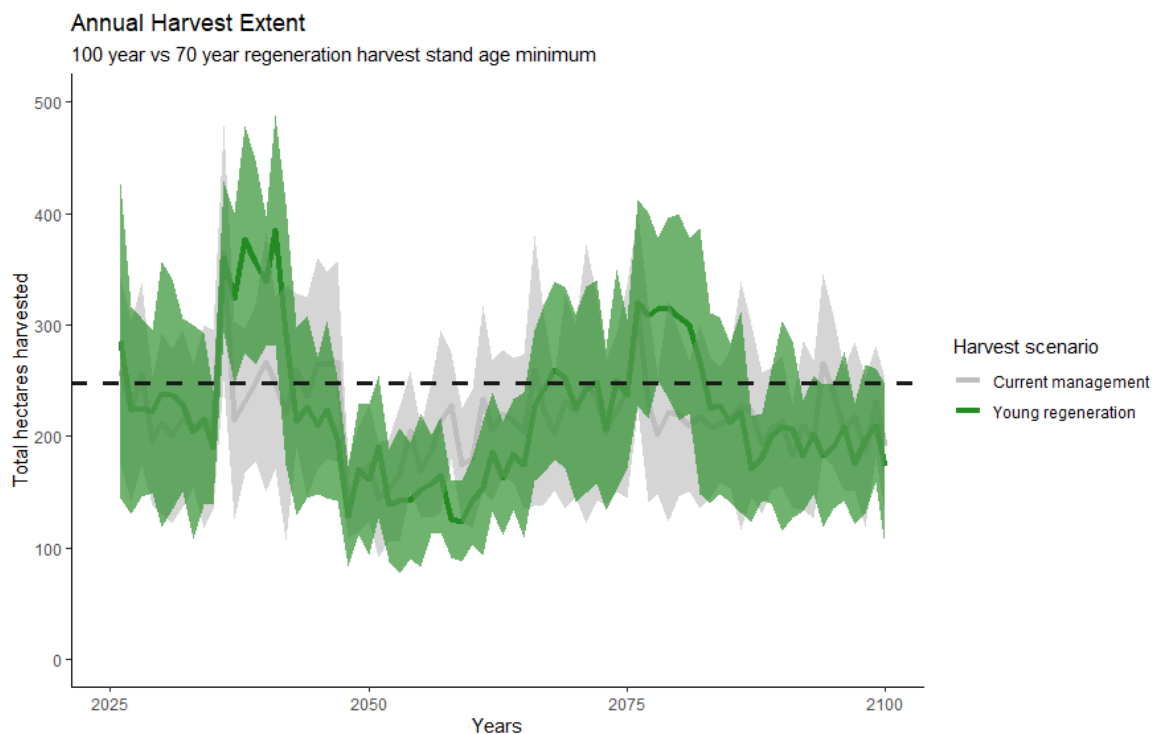
It is also increasingly necessary for managers to consider how climate change will affect the relationships between forest attributes. Current models often used for forest biomass accounting rely heavily on historical relationships between stand age, growth and climate, but as climate changes these relationships begin to break down (Crookston et al. 2010). Process-based models, such as LANDIS-II and iLAND allow for these relationships to change under different climate scenarios by capturing the mechanisms behind ecosystem processes, not just the statistical relationships derived from historic records. Projections that do not consider belowground nutrient cycling may also not be robust in the Coast Range, given that logging depletes soil nutrients. LANDIS-II simulates nitrogen cycling, but data from the Coast Range suggests nitrogen and calcium supply are tightly coupled (Hynicka et al. 2016). Also some soils in the Coast Range have very limited nutrient supply capacity and model simulations suggest these forests could become deficient in multiple nutrients (e.g. phosphorus, calcium) within only 1-2 harvest cycles (Siah et al. 2023). “Growth and yield” models that rely on statistical relationships and do not simulate nutrient cycling have predominated

until recently, but process-based models generate more robust projections about long-term changes in above- and belowground processes in forests, capturing how the spatial pattern of forest attributes change over decadal timescales.

In the ESRF, there have been discussions about the minimum stand age for harvesting. Changing the minimum stand age required for regeneration harvesting is likely to have important consequences for stand availability which constrains the amount of harvesting that can take place in any given year. Therefore, it is important to know both the amount of biomass removed and the extent at which harvesting can take place under different stand age requirements. The LANDIS team experimented with two different age minimums for regeneration harvest: a 100-year and 70-year minimum. Results indicate that while the 70-year harvest requirement produced higher peaks in timber output, the total biomass removed was lower at 2,101,470 g m<sup>-2</sup> compared to the 2,231,622 g m<sup>-2</sup> under the original 100-year stand age requirement (Figure 4.24). The extent of harvesting activities also remained similar between the two scenarios, with the 70-year requirement occurring over a larger area (16,681 ha) than under the original requirement (16,381 ha) (Figure 4.25). Therefore, we predict that under a younger stand age requirement, the extent of management increases while the biomass removed decreases.



**Figure 4.24.** Temporal trends in annual biomass removed under the proposed 100-year minimum for regeneration harvest and a shorter 70-year minimum harvest requirement.



**Figure 4.25.** Temporal trends in annual harvesting extent (ha) under the proposed 100-year minimum for regeneration harvest and an alternative scenario using a shorter 70-year minimum harvest requirement.



Other LANDIS-II projects that have used scenario analysis include Deak et al. (in review) comparing differing prescribed fire extents in the Siskiyou Mountains of northwest California and southwest Oregon. This work suggests that targeted thinning coupled with prescribed fire was effective in reducing fire severity on shallow north-facing slopes, but that prescribed fire was not enough to meaningfully reduce fire severity at a landscape-scale. Additionally, results indicate a negative impact of prescribed fire on carbon storage at a landscape-level with large decreases in total carbon storage under a 10x prescribed fire scenario (Figure 4.26). Future work with LANDIS-II could explore the use of prescribed fire and the reintroduction of cultural burning within the ESRF.

#### 4.4.8 Future Data Collection Needs

Establishing a comprehensive modeling, analysis, and forest planning capability on the ESRF requires the involvement of operations foresters, inventory foresters, and GIS analysts to update past forest inventory to the new management objectives of the ESRF. As this work will continue with the establishment of the ESRF and hiring of research management staff and contractors, many model results remain preliminary due to limitations in the best available input data and lack of operational results which could be used for model validation, calibration, and refinement.

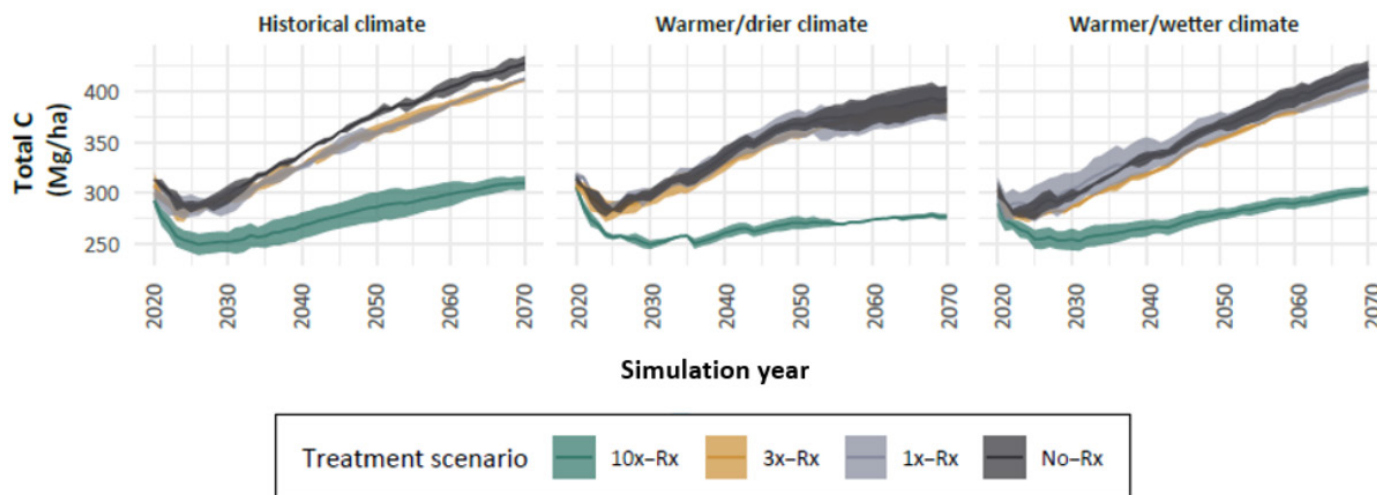
Components of the long-term monitoring plan (Chapter 10: *Monitoring*), including forest inventory plots and repeated

aerial and ground-based LiDAR, will contribute to future modeling and analysis to assist with forest planning. The initial model development completed as part of this FMP serves as a foundation for continued refinement based on new data, implementation of the FMP and biennial operations plans, and the adaptive research process.

As of September 2023, two major modeling limitations are lack of cruise data over 52% of the forest (Figure 4.27a) and lack of detection of about 50% of the trees present during individual tree segmentation (Figure 4.27b).

iLand is run over all 83,300 acres of the ESRF, avoiding Organon’s cruise data coverage limitations, but incurring remote sensing limitations instead. iLand is initialized with the heights of 9.4 million dominant and codominant trees segmented from LiDAR combined with DBH predictions from generalized models developed for the ESRF (West and Strimbu 2023). Ongoing research of methods for improving iLand modeling focuses on:

1. Increasing individual tree detection rates when processing LiDAR point clouds, performing more reliable species identification, and obtaining more accurate height measurements of trees on steep slopes.
2. Increasing the accuracy of initial stand descriptions by integrating LiDAR processing results and ground data to fill in missing trees which could not be detected within LiDAR point clouds.



**Figure 4.26.** Carbon storage trends (total, aboveground, and belowground) under four prescribed fire scenarios (10x, 3x, 1x, and 0x current prescribed fire extent) using LANDIS-II.

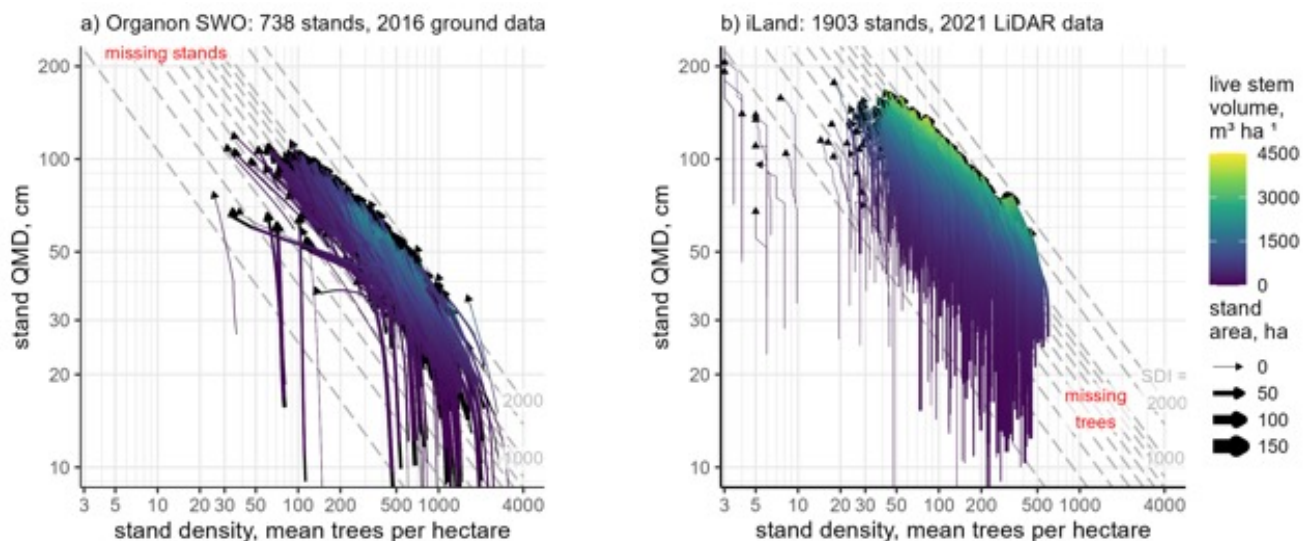
Many stands on the ESRF are at least two-aged and, particularly in younger intensively managed stands with large permanent retention trees, tracking the two cohorts separately is important to accurate characterization of top height, site index, and annual increments of merchantable wood. LANDIS-II already tracks multiple age cohorts within a cell, but more comprehensive estimates of tree age across the ESRF would be helpful for creating the map of initial conditions of species age and biomass.

As most carbon pools on the Elliott have received little study, local calibration data for models is lacking, especially soil C. Establishing a forest age chronosequence of soil C in the ESRF would be helpful for calibrating changes in soil C over time. Relevant data will be collected through the forest inventory and carbon monitoring program outlined in Chapter 10: *Monitoring*. In some cases model accuracy is also constrained by limited study of some species at other locations, particularly shrubs like Oregon myrtle and huckleberry.

Projections of bird abundance and habitat in LANDIS-II are only preliminary and will be revised when analysis of 2023 biodiversity fieldwork on the ESRF is completed. Better estimates of current bird abundance on the ESRF will improve future projections.

In the near term, optimizers attached to Organon SWO provide an ability to estimate optimal thinning intensities and rotation lengths for intensive management as well as, to some degree, extensive management. Once remote sensing capabilities are capable of fully initializing iLand, these optimizers will be transferred to iLand to obtain climate and spatially aware management guidance. Additionally, development of individual tree silvicultural decision support has been shown to be numerically feasible with Organon (West 2021). The long-term intent is to extend this capability to iLand to better inform management of forest structure and consider microsite effects on retention trees, avoiding Organon limitations which lead to spatially impractical harvest patterns.

Model outputs also include the amount of carbon removed from the forest during harvesting. However, conversion of harvested carbon into estimates of carbon storage in wood products is beyond the scope of modeling as it entails major assumptions concerning the wood product mix, product markets, and end-of-life disposal practices.



**Figure 4.27.** Stand trajectories predicted by Organon SWO (a) and iLand (b, ensemble mean for SSP370 climate scenario) from 2021-2100 CE, August 2023 modeling. Organon modeling is incomplete at this time because cruise data is available for only 738 of the 1903 stands delineated on the forest prior to transition to the ESRF. iLand modeling is incomplete primarily because intermediate and suppressed trees have low detection rates from remotely sensed data for tall and dense forests, leading to underestimation of trees per hectare and overestimation of QMD (quadratic mean diameter).





# Chapter 5

## Research Planning and Implementation

## 5.1 The Research Management Process: Proposing and Incorporating New Research

### 5.1.1 ESRF Scientific Advisory Committee (SAC)

The ESRF Research Director (PI) will oversee and coordinate with the ESRF Board on research planning and implementation. This includes convening a Scientific Advisory Committee (SAC) that will play a key role in the development and continuation of research activities at the Elliott State Research Forest. The purpose of this committee is to:

1. Review research activities and provide guidance in developing, updating, and implementing research and management plans.
2. Provide guidance about global science trends in the field and how these can be reflected in the work on the ESRF.
3. Investigate and encourage opportunities to set up related experiments and nested studies in other parts of the globe.
4. In coordination with the ESRF Research Director (PI), inform and encourage other researchers about opportunities for collaboration and co-stewardship with Tribal nations.
5. Be an advocate for the research forest and publicize ESRF efforts within their circles to increase the global visibility of the ESRF.

The SAC will include researchers working in the Pacific Northwest and in countries across the world. Individuals on the committee will bring expertise from biological, physical and human dimensions of western science and Indigenous Knowledge. The expertise on the committee will reflect the key research being done on the forest and membership will change with time. The ESRF Research Director will coordinate with the ESRFA Executive Director and Board of Directors to share information on the Science Advisory Committee's work and provide a clear line of communication with the committee and ESRFA.

### 5.1.2 Implementation and Adaptive ESRF HCP Management Committee

An Implementation and Adaptive ESRF HCP Management Committee (AMC) will be developed to participate in research and monitoring planning conversations as

they pertain to the ESRF HCP covered species and their habitat. The AMC will be created and managed by the ESRF HCP Permittee and may include, but not be limited to, participants from DSL, OSU, USFWS, NMFS, ODFW, two members of the Board of Directors of the ESRFA, and subject matter experts not affiliated with other entities represented on the committee. The Services may recommend that other federal, state, Tribal, and local governments and nongovernmental organizations be invited to participate in informing the AMC on research needs.

The AMC will receive annual reports, 6-year Summary Reports, 12-year Comprehensive Reviews, and other ESRF HCP-related information that may influence or inform work of the committee. The committee will provide input and advice to the ESRF HCP Permittee, ESRF Research Director, and ESRF staff on planning and management, effectiveness of past implementation of the FMP, and compliance with foundational documents, codified allowable activities, and public dispute resolution.

## 5.2 Nested Experiments within and alongside the Research Platform

All new research, including co-location of equipment or sampling efforts with existing research infrastructure, must be evaluated through the research proposal process.

### 5.2.1 Process for Proposing and Integrating Additional Research Projects

#### Requirements for Submitting Research Proposals

There is a clear goal that the forest will attract researchers. As the number of research projects grows, there will be unavoidable trade-offs between the opportunities for broader and more synthetic research made possible with co-located studies and the not insignificant impact that one project can have on the findings of another. Therefore it will be critical to establish core principles to guide consideration and balance of conflicting imperatives, including a process that ensures that the group making decisions about proposed new research has the detailed information/input needed to assess conflicts and to ensure that disciplinary and cultural bias is not influencing acceptance/rejection.



### 5.2.1.1 Core Principles

Researchers on the ESRF will be in alignment with the Mission, Vision and Guiding Principles of the ESRF, agree to open access to data (as allowable), and respect the ESRF community of leadership, ESRFA Board, ESRF staff and Tribal partners.

### 5.2.1.2 Structure for Decision-Making on New Research and Integration with Existing Projects

The first step to planning research at the ESRF is to submit a site use research proposal. All new project proposals will go through a review to determine potential conflicts with existing research, compatibility with ESRF research guidelines, and any potential impacts relevant to the Research Proposal, ESRF HCP or other regulatory document. The Principal Investigator will send the proposal to the appropriate reviewers including the ESRFA Board and Executive Director. All major manipulative experiments will be discussed with the ESRF research community with the intent of both increasing collaboration and maximizing field site utilization. Availability of funding does not ensure the research project will be approved. Requests should be made before obtaining funding.

### 5.2.1.3 Requirements for Submitting Research Proposals

Proposal forms will be developed where researchers will document study details including an abstract, the sites to which access is being requested, and methods and planned activities. Other information collected through the proposal process will include the project lead and contact; project title, research team members, titles, and affiliations; start date and planned end date; primary funding source; estimated total funding amount of the project; person responsible for dismantling the project (removing field equipment, flagging, PVC, etc.); and supporting maps and figures.

### 5.2.1.4 Field Work Guidelines and Requirements

Once a research proposal is approved, all researchers are required to:

- Ensure that all field crews/helpers have first aid training, use appropriate safety equipment, and carry a first aid kit. Please refer to the HJ Andrews field safety procedures for an example of the ESRF safety policies that will be developed once an Executive Director is hired.
- Notify the ESRF PI whenever substantive additions to or modifications of an ongoing research project are planned.
- Help prevent the spread of invasive species by washing the underside and wheels of all field-going vehicles at

vehicle wash stations and by scrubbing boots to remove soil and weed seeds. Before entering streams for the first time each visit, researchers will dry or freeze waders and use Virkon rinse for all gear.

- Help prevent unintended fire on the forest by complying with fire restrictions.
- Remove flagging, PVC, instrumentation, and any other research debris after their research project is completed.

## 5.3 ESRF Data Management

Data collected and results of research are some of the most important outcomes of all of ESRF efforts. The ESRF will be generating immense amounts of data, some of which will be readily available to the public and some of which will have limited or restricted distribution. Data should not be limited to western science practices and methods but woven together with Indigenous Knowledge and multiple ways of knowing. As examples, climate data will be readily available but data sovereignty guidelines rightfully restrict sharing of Indigenous Knowledge. Designing and implementing the full-scale data management plan will be the initial duty for the Data Manager when hired. Given the spatial breadth and desire for long-term research on the ESRF, this is a critical step and will take coordination between the Data Manager, Research Director (PI), Executive Director, Tribal Nations, and the ESRFA Board in fully drafting the plan. In the meantime, several components are provided to consider primarily based on the HJ Andrews Long-Term Ecological Research site that has been operating successfully for 75 years.

### 5.3.1 Data Stewardship and Information Management

Data collection, synthesis, and archiving must be able to be managed using ESRF staff capacity. A long-term monitoring (LTM) program must also be sustainable over time. It is important to note that expanding a LTM program by adding more observations, study plots, new data types, etc., to an existing LTM program has the same effect as adding an entirely new LTM program. If LTMs are explicitly monitoring programs in perpetuity (e.g., hydrology), then they must be sustainable in perpetuity. If measurements and monitoring are planned for a shorter time frame (e.g., 3 years) then they must be sustainable for that time frame within ESRF data management capacity. Therefore, the time frame must be made explicit, and cannot change without being reviewed by the Research Director (PI) and data manager.

In alignment with the mission and values of the Elliott State Research Forest, data will be maintained and made available to researchers, managers, and the public as outlined in Section 5.3. The *Findable, Accessible, Interoperable, and Reusable* (FAIR) data principles (Wilkinson et al. 2016) are one approach to increasing data usability and accessibility.

The FAIR principles can be summarized as:

1. Findable: Metadata and data are easy to find for both humans and computers
2. Accessible: Data are accessible, including protocols that are universally implementable
3. Interoperable: Metadata use a formal, accessible, shared, and broadly applicable language for knowledge representation
4. Reusable: Metadata and data are well-described so that they can be replicated and/or combined in different settings

However, use of the FAIR principles may potentially neglect the rights of Indigenous Peoples and Tribal Nations regarding cultural, spiritual, and ecological information. Therefore, the ESRF will also strive to apply the CARE Principles for Indigenous Data Governance to support ethical data stewardship (Jennings et al. 2023). Indigenous Knowledge, data related to these knowledges, and other sensitive information that is part of ESRF research will receive the appropriate protections using vetted protocols.

As outlined in Jennings et al. 2023, the CARE Principles of Indigenous Data Governance can be summarized as:

1. Collective Benefit: research and data that benefit community values, aspirations, and well-being
2. Authority to Control: recognizing Indigenous Peoples' rights to and interests in their knowledges and data, including
3. Responsibility: respect reciprocity, trust, capacity sharing, consent, and mutual understanding pertaining to Indigenous Knowledge and data
4. Ethics: align with Indigenous ethical frameworks, minimize harm and maximize benefits from the perspectives of Indigenous Peoples

#### 5.3.1.1 Planning, Preparation, and Submission of Data

A data submission system, protocols, and set of guidelines for planning, data preparation, and submission of data to the ESRF system will be developed once the Data Manager is in

place. These systems will help ensure that data is publicly available, accurate, and follows FAIR and CARE principles of data stewardship.

#### 5.3.1.2 Quality control protocols

The collection of high-quality data, in all of its forms, is an essential component of research programs worldwide. Core data collected from the ESRF must be collected and presented in a usable way, consistent with contemporary best practices and values inherent in western science and Indigenous Knowledge. Decisions about data quality will be informed by a representative group of potential users who are competent to evaluate and the Data Manager. These evaluators should include disciplinary experts who understand the measurements being made, logistics of maintaining specific measurements and the importance of multiple ways of knowing.

#### 5.3.1.3 Protecting Sensitive Information

##### ***Working with Indigenous Knowledge and Culturally Sensitive Sites***

As outlined in the OSU College of Forestry's Principles and Best Practices for Working with Indigenous Knowledge and Partnering with Tribal Nations and Indigenous Peoples (Appendix C), a Memorandum of Understanding or Data Sharing Agreement needs to be developed for any work that involves IK obtained from Tribal Knowledge. These are formal contracts *"that clearly documents the data being shared and the parameters under which those data may be used, or a Non-disclosure Agreement (NDA), defined as a contract by which one or more parties agree not to disclose confidential information that they have shared with each other as a necessary part of working together."*

*"At the conclusion of the research, the results should be reviewed by the partnering Tribe or Indigenous Peoples and shared in ways that are meaningful and useful to them and the broader scientific community. This includes having Tribal members and Indigenous Peoples as co-authors of published peer-reviewed literature."*

Information about the location of culturally sensitive sites and species will be protected according to state and federal regulations, using best practices for working with sensitive information, and in consultation with Tribes.

The ESRF will also work to apply the CARE Principles for Indigenous Data Governance as a foundational practice to support ethical data stewardship.

### ***Information on Sensitive, Threatened, and Endangered Species***

Information regarding threatened and endangered species, sensitive species, game species, or vulnerable species will be protected in consultation with ODFW and in accordance with Oregon statute, i.e. SB 2841 (2019) relating to the release of animal data.

Species considered to be “vulnerable” may include:

- Species with a history of harm to a local population from malicious or unlawful behavior, or accidental taking,
- Species where disturbance or harassment and the behavior or ecology of the species makes the species especially vulnerable to that harm;
- Species where there is known demand for illegally taking or harassing the species;
- Species that are limited in distribution and concentration or are endemic species

## **5.3.2 Data Repository**

The data repository system, including infrastructure and guidelines, will be developed once the Data Manager is in place. This system will be adapted over time based on currently available technology and data management needs.

### **5.3.2.1 Data Types**

A range of data types will be generated as part of research and long-term monitoring on the ESRF. This data includes but is not limited to real-time data from sensors and instrument stations, spatial data, images, maps, models, and software. ESRF data will be publicly available through an access portal using the approved protocols and guidelines that will be developed once the ESRF data manager is hired. Sensitive information, which may include details related to species, culturally important sites, Indigenous Knowledge, and unpublished research data will receive protections according to the appropriate protocols and best practices.

## **5.3.3 Communication, Outreach, and Information Management**

The ESRF will maintain a publication list to provide information for reporting efforts and to serve as a repository of knowledge generated on the research forest.

### **Types of publications**

Publications are written communications meeting the criteria below and that are stored in a reasonably permanent

and publicly accessible form. The following types of publication can be tracked:

- Peer-reviewed
  - Journals
  - Book chapters
  - Books
  - General Technical Reports
- Not peer reviewed
  - Theses and dissertations
  - Reports (e.g., Masters Projects, final project reports)
  - Grant proposals, Annual reports, Mid-term review reports, Final reports
  - Books
  - Book chapters
  - Proceedings
  - Communications about science to the public (e.g., magazine, newspaper)
  - Presentation abstracts
- Miscellaneous
  - Web documents
  - Software and model documentation
  - Published maps of the ESRF

## **Criteria and Categories of Elliott State Research Forest Publications**

ESRF publications meet at least one of these criteria:

- Research conducted at one or more study sites within the ESRF or using the ESRF as a subject in your research;
- Research using data collected on the ESRF;
- Research making use of ESRF infrastructure – living facilities, laboratory space such that the use of these facilities constituted a substantial investment of in-kind resources to the project

## **Protocol for Gathering, Tracking, and Reporting Publications**

All scientists conducting research or education activities at the ESRF agree to provide copies or citations for publications that arise from their work if allowed.





# Chapter 6

## Silviculture, Harvest Systems, and Operations Planning

This chapter details specific goals, objectives, silvicultural treatments and harvest systems that will be used to implement the Triad research design outlined in Chapter 4: *Research Platform and Experimental Design* and in the ESRF Research Proposal (OSU College of Forestry 2021).

## 6.1 Implementation and Operations Planning

Research management activities will comply with the Oregon Forest Practices Act (FPA). This may include a Stewardship Agreement (approved by ODF pursuant to FPA rules) to address research outlined in the ESRF Research Proposal, application of provisions of an ESRF Habitat Conservation Plan and Incidental Take Permit to activities on the forest. Research, silvicultural treatments, and management practices will be implemented according to the guidelines in the ESRF HCP and this FMP, including management guidance in this chapter, ESRF HCP Conditions and Conservation Measures.

### 6.1.1 Biennial Operations Plans, Harvest Planning, and Operations Reports

Biennial Forest Operations Plans (FOPs) consistent with the forest management plan will be developed that delineate active forest management actions to be conducted on the ESRF in the 2-year period following an FOP's finalization. The FOP includes:

- **Setting and Context:** A summary describing the scope and purpose of the biennial plan, planning process, and a review of previous period accomplishments. Also, an overview of planned activities in the context of the research plan, ESRF HCP and FMP.
- **Periodic Goals and Objectives:** Operational priorities and drivers for the current biennium within the framework of the FMP, ESRF HCP and research plan. Goals and objectives should focus on the current biennium while setting the stage for activities over the next 2-4 biennia.
- **Research Activities:** A summary of new and in-place research including ties to planned operations and linkage to overall research platform.
- **Planned Forest Management Operations and Treatments:** Descriptions of harvests, road management, young stand management, regeneration and other treatments and operations scheduled to occur during the biennium. Includes project objectives and expected outcomes as well as alternatives.
- **Forest Health Management:** Identification of disturbance agents, responses and management efforts. Includes descriptions of treatments related to invasive weeds, animal

damage, reduction of fire risk and other opportunities or needs to promote forest health and resilience.

- **Resource Inventory and Monitoring:** The status of and activities related to forest inventory, wildlife surveying, RTE surveys, monitoring, and other resource inventory efforts that will be initiated and ongoing taken during the biennium.
- **Contracting and Administration:** A description of administrative steps and processes necessary to achieve planned activities, roles and timelines.
- **Partnerships, Outreach and Education:** Anticipated public engagement processes related to operations implementation, community engagement plans, educational opportunities and objectives, and identification of roles and interactions with new and existing partners.
- **Recreation and Public Access:** Plans and strategies for management of recreational resources and public access considerations relative to planned forest operations.
- **Adaptive Research Implementation and Contingency Planning:** Considerations related to risk and uncertainty that may upset planned operations and approaches to research objectives.
- **Facilities, Infrastructure and Staffing:** Status of and anticipated changes in infrastructure, facilities and staff that will support operations and activities planned for the biennium.
- **Schedule of Operations:** Anticipated timing of planned operations as well as references to activities that will serve or support operations planned for subsequent biennia.
- **Biennial Budget:** A budget reflecting projected revenue and expenses associated with operations, administration, and research treatments and related projects on the ESRF over the biennium.
- **Appendices:** Summary tables, maps, and other details related to implementation and administration of planned operations.

### Timeline

Plan development should be initiated at least 16-18 months prior to the target date of adoption based on the steps and timing illustrated in Table 6.1. This timeline refers to plan development only. For timber sales identified and approved in the FOP, it is anticipated that a minimum of 9 months will be necessary to conduct the required layout, cruising, scoping, advertising and sale, assuming procedures are in place to support development of the projects.



**Table 6.1.** Estimated steps and timeline for ESRF Biennial Forest Operation Plan development once the forest staff is hired.

Step	Months															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Primary plan development																
Internal review																
Edits and revision																
Public review																
Edits and revision																
ESRFA review																
Edits and revision																
Final plan approval																

FOP development includes public review and comment, as well as input and advice from the ESRFA Board of Directors. Written materials related to the FOP will be provided to the public within 45 days before the ESRFA Board of Directors approves or denies a biennial operations plan (SB 1546).

Biennial operations reports will provide a review and summary of forest management and monitoring activities for the most recent biennium. Reports will be structured to reflect the biennial operations plan content described above. Biennial operations plans and reports will be developed by ESRF Research Director and research management staff through close coordination with the ESRFA Executive Director. For the first six years of ESRF implementation, ESRF managers will produce an annual operations report (rather than a biennial report), which the ESRFA Board of Directors will share with the State Land Board.

## 6.1.2 Plan for Alternate Practice and Stewardship Agreements

Under ORS 629-605-0100, forestland owners, managers, and operators must comply with the practices described in the forest practice statutes and rules unless approval has been obtained from the State Forester for a plan for an alternate practice. The State Forester may approve a plan for an alternate practice to waive or modify forest practice rules in several circumstances, including if the State Forester determines that a federal or state agency, a college or university, or a private landowner has submitted an application to the State Forester for a bona fide research project involving activities not in accordance with the rules.

The ESRF will comply with Oregon FPA regulations (meet or exceed), including through submission of an application for a plan for alternate practice where appropriate. Where needed, the ESRF Research Director (PI) and lead forester will submit a plan for alternate practice for research operations according to ORS 629-605-0173 and seek approval from Oregon Department of Forestry (ODF), Oregon Department of Environmental Quality (DEQ), Oregon Department of Fish and Wildlife (ODFW), and/or other agencies as appropriate.

Over the longer term, the ESRF may submit an application to Oregon Department of Forestry for a programmatic, forestwide stewardship agreement.

## 6.1.3 Estimated Timing and Amount of Harvest Based on the Research Design

A preliminary analysis to estimate the annual acres of intensive and extensive regeneration harvests and thinning in Douglas-fir plantations is shown in Appendix H. These estimates illustrate the potential spatial and temporal scale of harvest operations on the ESRF by decade when implementing the foundational Triad research design (2021 to 2080) using the assumptions in two different scenarios. Addition of further data, site visits, additional operational considerations and opportunities may cause actual harvest on the ESRF to differ from these scenarios.

### 6.1.3.1 Harvest Cap

The ESRF HCP requires a harvest cap for the ESRF that limits the acres sold (contracted) for commercial harvest by

treatment type and timeframe. These limits are approximations that do not account for changing habitat conditions due to naturally occurring events (e.g., fire, insect infestation).

Timber sales from all silvicultural treatments will not exceed 1,000 acres per year based on a four-year rolling average of contracted sales. Of the 1,000 acre cap, the limit on intensive regeneration harvests is 480 acres per year. This 1,000 acre overall limit will apply unless otherwise agreed upon with the U.S. Fish and Wildlife Service and National Marine Fisheries Service (collectively, the Services), pursuant to the adaptive management strategies in the ESRF HCP (ESRF HCP Section 6.6) and in conversation with OSU, the ESRF Authority Board of Directors, U.S. Fish and Wildlife Service, and National Marine Fisheries Service.

Separate from the limits stated above, there is a demonstrated need to implement time-sensitive ecologically-based restoration thinnings of plantation stands (less than 65 years of age as of 2020) in areas designated as CRW Reserve and Riparian Conservation Areas (RCAs) in order to facilitate development of more complex and resilient forest stands over time and enhance habitat for species covered in the ESRF HCP. To address this need, up to 400 additional acres per year of restoration thinnings may be allowed during the first 20 years of the permit term. Harvest of this acreage would only occur with concurrence of the Services and consultation with the ESRF HCP Implementation and Adaptive Management Committee. This provision allows for potential additional acres of restoration thinning above the overall 1,000-acre limit set forth for all treatments during the first 20 years of the permit term.

The use of acres sold for the harvest cap recognizes an important consideration of forest operations. Contracts for sale of timber routinely allow actual harvest to occur over a 2 to 3-year period following the sale at the discretion of the contractor. This standard practice can (and often does) result in a variable number of acres harvested in any given year of a contract. Extension of this contract period for execution beyond 3 years may be sought by the ESRFA in consultation with the Services when unforeseen circumstances arise related to contractor operations. ESRF forest managers will track contracted acres over a four-year rolling average as part of biennial operations plans and reports.

In addition to this harvest cap, no more than 3,200 acres of extensive treatments will occur in stands greater than 65 years old (as of 2020).

#### 6.1.4. Seasonal Restrictions

In addition to Oregon FPA regulations on seasonal restrictions, the following restrictions apply regarding HCP covered species on the research forest.

##### **ESRF HCP Condition 1: Seasonal Restrictions Around Northern Spotted Owl Nest Sites**

To minimize adverse effects on nesting northern spotted owl, covered activities will follow USFWS-recommended seasonal disturbance distances (U.S. Fish and Wildlife Service 2020c; Table 5-4). Seasonal disturbance restrictions will apply to the 22 northern spotted owl activity centers (19 pair sites, 1 unconfirmed pair site, and 2 resident single sites) centered within the permit area that had historical occupancy over several years and have had at least one northern spotted owl detection between 2011 and 2016 (within 5 years of the last full survey conducted in 2016; see ESRF HCP Chapter 2, Environmental Setting, for details).

The operational restrictions described in this condition also apply to actively nesting northern spotted owls that may become established on the ESRF. Activities will be restricted during the critical nesting season for active single and pair sites, and within the distances given in HCP Table 5-4 (ESRF HCP Section 5.5.2), unless it is determined that no nesting is occurring, or has failed, or until July 15, whichever is sooner. Determination of absence of nesting will be made following USFWS-approved survey protocols.

Exceptions to these restrictions will only occur in situations where either (1) applying these restrictions would compromise the safety of staff, contractors, or members of the public; or (2) applying a more limited restriction is clearly justified based on site conditions (e.g., topographic features on the landscape shield the nest site from the activities in question). Exceptions from these restrictions are expected to be rare and will be applied only after a site-specific review by a northern spotted owl expert and documentation of recommendations. Any exceptions will be summarized in annual reporting.

##### **ESRF HCP Condition 6: Seasonal Restrictions in Marbled Murrelet Occupied Habitat**

To avoid disturbance to nesting marbled murrelet adults and chicks, seasonal restrictions will apply in designated occupied marbled murrelet habitat, or other areas that have been determined to be occupied using surveys described in HCP Condition 7, during the murrelet nesting season (April



1 to September 15). Seasonal restrictions prohibit certain covered activities from occurring within a set distance of occupied habitat, using distances approved as adequate by the USFWS. Recommended distances identified by USFWS (2020c) for marbled murrelet—as applied to covered activities—are listed in HCP Table 5-5 (ESRF HCP Section 5.5.7). As noted in HCP Table 5-5, some activities have daily restrictions as well, which avoid disturbance during certain times of day later in the nesting season.

### 6.1.5 Supporting Management Activities

The following activities may be implemented to manage stands in support of the research platform, including pre- and post-harvest management actions. Supporting management activities will be undertaken as part of the research operations for the forest.

#### Mechanical Vegetation Control

Mechanical vegetation control will be performed in accordance with restrictions placed by the Oregon FPA and may include grading, hand cutting, using a brush hog-type mechanical device, steaming, and other experimental methods. Mechanical vegetation control provides an alternative to chemical control and may be appropriate in situations where use of herbicides is not appropriate or where mechanical removal of material is necessary or preferred. Use of herbicides may be paired with mechanical control (e.g., mow then spray) in some instances.

#### Prescribed Burning

Prescribed burns will follow Oregon FPA requirements and include single or multiple prescribed burns that incorporate Indigenous Knowledge (IK) to manage fuels and increase or maintain suitable conditions for species of cultural value to local tribal communities. Prescribed burning of slash piles on landings following harvest and broadcast burning of harvest units for site preparation prior to planting will also occur, where appropriate, as part of the research management program. Prescribed burns will not occur inside RCAs.

#### Slash Management

“Slash” is the residual woody debris that results from timber harvest and thinning. Slash may accrue within harvest units or on landings, depending on logging systems and log processing methods. Methods of slash management include piling and burning, mastication (chipping), lopping and scattering. Slash may also be left in place if it does

not conflict with other objectives and slash piles may be left unburned and allowed to decompose. Slash piles are generally built using heavy equipment or by hand. Within riparian areas, slash may be left in place. Methods that could be used inside riparian areas include hand piling, hand piling and burning, and lopping and scattering.

#### Reforestation

Trees may be planted as part of intensive, extensive, and restoration treatments. A mix of species may be planted as guided by the objectives for these three research treatments (see Sections 6.2, 6.3, and 6.4 below for guidance on species diversity for each treatment type). Cedar trees may be planted as part of efforts to manage for Indigenous cultural practices, in collaboration with Tribal partners. Seedlings planted for reforestation will be sourced from local nurseries, and grown from improved seed from the appropriate seed zones, defined by Oregon Department of Forestry’s Forest Tree Seed Zones for Western Oregon (1996). Wild or unimproved seed may be used for some species when improved seed is not available. Allowances may be made for adjustment to seed zone preferences as part of climate adaptation efforts and other research activities.

#### Animal Control

Many stages of tree regeneration are susceptible to animal damage and when the potential for damage or actual damage levels conflict with management or research objectives control of specific damaging wildlife species is necessary. Animal control techniques will follow ODFW standards and guidelines. Methods of animal control on the ESRF will not involve use of rodenticides. See Chapter 12: *Disturbance, Forest Health and Resilience*, Section 12.2.17 for more information on management options in response to animal damage.

#### Herbicide Use

As defined by the EPA, a pesticide is any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest, any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant, and any nitrogen stabilizer. Herbicides are included within the broader category of pesticides. Herbicide applications may be used to control competing vegetation over a rotation period in compliance with FPA regulations. Examples of uses include site preparation treatments prior to planting, release treatments following planting, management of invasive weeds or

control of roadside vegetation as part of routine road maintenance. Herbicides selected for use will be labeled for forestry application rates and methods will follow EPA rules contained in the product label. See Sections 6.2 and 6.3 below for guidance on use of herbicides in intensive and extensive treatments, respectively. The use of herbicides will be minimized within a research context while still ensuring successful reforestation and rapid young stand establishment. Herbicide application using either aerial application methods (i.e., fixed-wing airplane, helicopter, unmanned aerial system) or ground (e.g., backpack sprayer) is not a covered activity under the ESRF HCP. Herbicide applications will be conducted and supervised by licensed operators in accordance with Oregon FPA regulations and best practices, and with ESA requirements using a take avoidance strategy. Operational level details for herbicide use, as with any specific treatments or operations, will be contained in the Biennial Forest Operations Plans (FOPs) and project-specific design or prescriptions.

### **Pre-commercial Thinning and Pruning**

Pre-commercial thinning involves thinning where the trees cut are not sold commercially. This is generally used when stocking levels are higher than desirable and the tree size is too small to conduct a commercial thinning. Felled trees are typically left on site, although slash may be treated, as described under Slash Management above.

### **Landings and Log Hauling**

Timber harvest requires the use of landings for harvest and log hauling. Landings are generally permanent features of the road system and used intermittently as harvest operations require. There are no seasonal restrictions for log hauling on open roads relative to marbled murrelets and spotted owls (see Table 5-5 in the ESRF HCP).

### **Helicopters**

Helicopters are not expected to be regularly required for management of the ESRF. However, helicopters may be used as part of riparian restoration projects or other projects in remote locations where movement of heavy objects, such as large wood, is required. Occasional aerial reconnaissance using helicopters may also be necessary.

### **Small Fixed-Wing Aircraft (Cessna 185, etc.)**

Fixed-wing aircraft may be used infrequently for a variety of purposes, including collection of remote sensing imagery and related data.

### **Unmanned Aerial Systems (UAS)**

Commonly known as drones, unmanned aerial systems (UASs), are aircraft without any human pilot, crew, or passengers on board that can fly according to a predefined trajectory. An UAS is a flying vehicle capable to execute a task, such as carry equipment to acquire data, extract or deliver physical entities. Therefore, an UAS is the vehicle itself, the system executing the task (like a camera or scanner), and the system that coordinates the flight (controller, GPS, IMU, etc). UASs will be used as part of the monitoring program on the ESRF, including for ground-based LiDAR to collect data on forest inventory, landslides, and streams.

### **Heavy Equipment**

Heavy equipment of various configurations will be used for a variety of reasons on the ESRF, including logging, road construction, road repairs, bridge construction, culvert replacements, riparian restoration, and supporting infrastructure.

### **Tree Climbing**

Trees may be climbed as part of research, management, and monitoring on the forest. Tree climbing methods will generally be non-damaging, unless the intent is to create snags through topping or top-girdling.

### **Hazard Tree Removal**

A hazard tree is defined as a standing tree that presents a safety threat due to conditions such as, but not limited to, deterioration or physical damage to the root system, trunk, stem or limbs, and the direction and lean of the tree. Hazard tree removal will be done as a standard safety measure for maintenance of forested roads, trails, and developments, as well as during harvest and thinning operations, where hazard trees may pose a risk to workers.

### **Chainsaws/Tree Felling**

Chainsaw use and tree felling will be conducted as part of forest management and research treatments. Felling may also be accomplished using mechanized equipment such as harvesters or feller-bunchers.

### **Yarding**

Ground-based logging equipment and cable yarding systems will be used to yard logs from inside harvest units to roadside landings during stand treatments. Yarding systems

will be appropriate for the topography and project design and may include multiple approaches for a single project. Yarding is generally used for commercial logging activities but may be used for restoration or fuels management also.

### 6.1.6 Protections for Cultural Resources

Federal and state laws regulate cultural resource management, with OAR 690-51-240 (1991) and OAR 736-51-070 applying to cultural resources on state forestlands. Archaeological sites are defined as sites over 75 years old, with some sites over 50 years old also qualifying for limited protection. Oregon statutes do not mandate archaeological surveys, or mitigation of impacts by state agencies as part of conducting land management activities. However, artifacts and sites found on public lands must be protected from harm, alteration, or removal. If a sacred object is found, the State Historic Preservation Office and appropriate group or tribe must be notified. Anywhere in Oregon, state law protects Native American cairns and graves.

Management of the ESRF will:

- Preserve and protect archeological sites, or archeological objects in accordance with state law (ORS 97.740 to 97.760; 358.905 to 358.955; and 390.235).
- Conserve historic artifacts, and real property of historic significance in accordance with state law, in consultation with the Secretary of State and the State Historic Preservation Office (SHPO) (ORS 358.640 and 358.653). Protect additional cultural resource sites that are determined by the ODF to have special educational or interpretive value.
- Protect additional cultural resource sites that are determined to have educational or interpretive value through consultation with the Research Director (PI), ESRFA Executive Director and Tribal Nations, other relevant partners, and agencies.
- Contract with licensed archaeologists for cultural resource surveys prior to any groundbreaking activities with a determined need. This ensures that any historic or prehistoric resource is located prior to activities occurring in that location. When a resource is located, the ESRF will work with Tribal partners and coordinate with agencies to take steps that ensure sites of cultural significance are not compromised as a result of active forest management.

### 6.1.7 Access for Cultural Practices and Culturally Important Species

Following the principles and best practices described in Section 3.1.1 and Appendix C, the ESRF will work with Tribal governments to provide access for Tribes to harvest culturally-valued resources and follow Tribal cultural practices including through the corresponding authorities described within the MOU's between Oregon State University, the Elliott Tate Research Forest Authority, and Tribal governments. In particular, Extensive areas will be managed to promote culturally-valued resources over time as. Culturally-valued species, including plant species as well as animals such as deer and elk, will be identified through the Tribal consultation process.

#### Management of Cedar Trees for Indigenous Cultural Practices

Cedar restoration is one of the goals for riparian habitat restoration on the ESRF, considerations for cedar will be assessed as part of site selection for RCA restoration treatments, tree planting, and retention in prescriptions. The ESRF will work with Tribal partners through co-stewardship and/or other agreements to identify opportunities for promoting growth and management of cedar trees in riparian restoration treatments and other areas of the forest guided by Indigenous Knowledge.

As a covered activity in the ESRF HCP, removal or selective use of individual cedar trees over 65 years of age (as of 2020) may occur for Indigenous cultural practices. These cultural practices include cedar bark peeling and/or cedar tree removal for cultural purposes, including canoe building, providing material for plank houses and stakes for ceremonies, basket weaving, or other cultural practices.

Removal of cedar trees on the ESRF may occur through a permit process that is in compliance with ESRF HCP intent and conditions (see ESRF HCP Section 3.8). An application process will be established by the ESRFA to receive applications through biennial operations planning or other process avenues from Tribal governments or related Indigenous entities with ancestral connections to the lands that are now known as the Elliott State Research Forest.

The ESRF HCP outlines specific requirements for the application process and removal of cedar trees by Tribal Nations and Indigenous Peoples as approved by the ESRFA.



Removal of cedar trees as approved by the ESRFA may occur in any treatment allocation on the ESRF. Cedar use and removal will not be advanced for purposes of harvest objectives or revenue. Additional individual cedar trees could be removed in areas outside of RCAs if consistent with the following:

- Removal of individual cedar trees meets with research operations and stand or landscape scale objectives. ESRF managers will assess cedar as part of inventory efforts and include cedar management in relevant objectives in biennial operations plans. The ESRF will work with Tribes to weave Indigenous Knowledge into research operations and management objectives for cedar on the forest.
- Cedar trees identified are within areas of:
  - Blowdown/windthrow, tree mortality from wildfire or other factors;
  - Roadside clearing, construction, or maintenance;
  - Management to address human safety protection; and/or
  - Planned research or other treatments within the treatment allocations (e.g., extensive, intensive, restoration thinning) where the tree removal would not be inconsistent with retention or other objectives for the planned treatment.
  - Planned research treatments within allocations (e.g., extensive, intensive, restoration thinning) where the tree removal would not be inconsistent with retention or other objectives for the planned treatment. ESRF staff may work with Tribal partners to develop and adjust prescriptions in these cases.

In accordance with the ESRF HCP, cedar trees will not be removed for cultural use if a tree is:

- Within marbled murrelet occupied habitat or northern spotted owl core area,
- Situated on landslide-prone slopes or likely to destabilize conditions and promote landslide effects, and/or
- Leaning or situated in a way that is likely to become an instream log.

In order to address the range of potential cultural uses, tree size would not be limited, but tree selection would be limited by compliance with the above criteria.

## 6.2. Intensive Research Treatments

Currently, approximately 42,100 acres or approx 50% of the ESRF are Douglas-fir plantations, established primarily between 1955 and 2015. These stands reflect conventional even-age forestry practices over the past six decades. As described in Chapter 4: *Research Platform and Experimental Design*, intensive treatments have currently been allocated to a subset of 9,860 acres of Douglas-fir plantations in the Triad MRW experiment.

Within the Triad design, the primary objective of intensive research treatments is to maximize wood productivity per acre and explore management practices relevant to industrial forestland management. Concurrently, ESRF research will assess methods to reduce the impact of intensive harvest regimes on other attributes such as biodiversity, habitat, carbon cycling, recreation, and rural well-being. These intensively managed forest stands within the ESRF and will serve as benchmarks for wood production potential and tradeoffs relative to extensive and reserve treatments.

**Goal 1. Promote opportunities for research, within a Triad design (see Chapter 4: Research Platform and Experimental Design, Section 4.3), focused on long-term monitoring and assessment of current and emerging approaches to intensive management with an emphasis on wood production.**

### **Relevant Objectives and Management Direction**

**Objective 1.1.** Provide opportunities to analyze effectiveness of current and novel silvicultural practices for even age management designed to maximize wood yield.

- Design and implement even age management treatments using suitable harvest techniques and equipment.
- Intensive treatments may vary in rotation length (with an approximate minimum of 60 years), type of site preparation, and species planted based on harvest-level conditions, research objectives, and operational considerations. Rotation lengths and other forest management practices will be consistently applied in all subwatersheds to maintain replication among treatments. This minimum 60-year rotation applies in all intensive treatments, including MRW Research Watersheds Flexible/Partial watersheds.

- Serve as a benchmark for wood production potential and tradeoffs associated with wood production, in comparison with extensive treatments and reserve restoration treatments. Under the ESRF Research Proposal, on average at the subwatershed level the harvest volume goal of extensive treatments is approximately 50% of the volume produced by intensive treatments (i.e., the benchmark provided by intensive forest management is used to assess the harvest volume of extensive treatments in meeting this experimental goal).
- Conduct research on intensive forest management practices and outcomes while complying with the Oregon Forest Practices Act (FPA). This may include a Stewardship Agreement (approved by ODF pursuant to FPA rules) to address application of provisions of an ESRF Habitat Conservation Plan and Incidental Take Permits to forest management.

**Objective 1.2.** Assess methods to better understand the long and short-term impacts of intensive forest management on other attributes, including biodiversity, habitat, carbon cycling, recreation, water quality and quantity, and rural economies and communities. Monitor and analyze outcomes of intensive forest practices on the economy, environment, and community, which may include (but not be limited to):

- Log volume and value as rotation length changes (i.e., results of increasing rotation on log value, log quality, higher value end products, logging cost)
- Harvesting equipment selection and efficiency, including use of emerging technologies
- Silviculture and logging costs
- Standing leave tree, snag and down wood amount, location and arrangement
- Approaches for promoting growth and vigor and resilience of regeneration
- Vegetation control measures, including herbicide application and alternatives
- Harvest innovations, efficacy, and safety
- Provisioning of culturally-valued resources
- Recreational use and value
- Habitat for fish and wildlife, particularly species found in early-seral and mid-seral forests.
- Responses to disturbances, such as climate change, fire, wind, landslides, forest pests, pathogens, and invasive species.

- Continuity between riparian and upland forests
- Carbon storage and sequestration rates

**Objective 1.3.** If determined to meet mutual goals, partner with Tribes through co-stewardship to promote research on the implementation and effects of contemporary Tribal forest management practices as compared to both current and emerging intensive forest management practices. Recognizing that Tribal forest management is not a monolith, any potential opportunities that are identified as a shared interest will be explored through early and sustained engagement that braids Indigenous Knowledge with western science (see Chapter 3: *Managing a Research Forest for Multiple Values*, Section 3.1.1).

**Objective 1.4.** Partner with research cooperatives, industry, and other stakeholders to experimentally test current and emerging intensive forest management approaches to meet ecological and economic forest management goals while taking into account changing climatic conditions (see Chapter 3: *Managing a Research Forest for Multiple Values* for information on partnerships).

**Objective 1.5.** Experimentally test aggregation and retention alternatives, in alignment with the ESRF HCP and Oregon FPA, that seek to support and improve slope stability while meeting objectives for structural composition, wood production, and diversity of adjacent riparian areas.

**Goal 2. Provide high quality, sustainable forest products and ecosystem services to meet the needs of society.**

#### **Relevant Objectives and Management Direction**

**Objective 2.1.** Determine timing and selection of intensive stands for regeneration harvest and thinning (pre-commercial and commercial, if warranted) by growth patterns (mean annual increment), vulnerability to disturbances, and markets, with an approximate minimum final rotation age of 60 years and consistent with Objective 1.1.

- Design intensive forest harvests to provide a predictable volume of wood fiber to support manufacturing facilities in the region under the goals and objectives described in this chapter.
- If thinning, maintain annual contracted acres of commercial harvests within the limits specified in Section 6.1.2 above.

**Objective 2.2.** Establish plantations at densities that ensure relatively quick canopy closure, using species and seed

sources that are best suited for predicted climate conditions (see Chapter 8: *Climate Change, Adaptive Silviculture, and Forest Carbon* for more details).

**Objective 2.3.** Utilize commercial and non-commercial harvest treatments as well as pre- and post-harvest management actions to maximize wood fiber yield on a per acre basis.

- Regeneration (clearcut) harvests will occur on an approximate minimum rotation of 60 years. Current stands in intensive treatment allocations will be eligible for a regeneration harvest when they reach 60 years old as of 2020.
  - Retain older trees carried from retention in prior clearcut harvests as biological legacies except when there is a need to occasionally remove such trees for safety and operational reasons.
- Intensive forest management treatments will include no more than two herbicide applications to control competing vegetation over the rotation period. The use of herbicides will be minimized within a research context while still ensuring successful reforestation and rapid young stand establishment. Aerial application of herbicides may be used: (1) only when necessary as determined by the reforestation forester, (2) if in compliance with Oregon FPA, and (3) when other types of herbicide application are operationally impractical as determined by the reforestation forester. The ESRF will monitor water quality (see Chapter 10: *Monitoring*) for presence of herbicides and based on results will adjust practices through the adaptive strategy outlined in Chapter 11: *Adaptive Research Strategy and Implementation*.
- Additional intensive management activities that may be prescribed include: animal damage control, slash abatement, prescribed burning (outside of RCAs), tree planting, fertilization, and pre-commercial and commercial thinning. Post-harvest application of site preparation and vegetation control practices are further described in Section 6.1.3 above, with the goal of ensuring seedling establishment and rapid initial seedling growth.
- Animal control techniques will follow current Oregon Department of Fish and Wildlife (ODFW) standards and guidelines. Rodenticides will not be used to control species (e.g., mountain beaver) on the ESRF.
- Pre-commercial and commercial thinning may be used to maintain stand densities at levels that provide vigorous tree growth and maintain high wood production.

Intensive stands may receive zero to up to 2 commercial thinnings, typically between 30 and 50 years of age. Decisions about timing and thinning strategy will be made at the stand level to support the goals of ESRF intensive silviculture and detailed in biennial operations plans.

- Salvage harvest may occur in intensive stands affected by natural disturbances such as fire, drought, disease, wind, and insects.

**Objective 2.4.** Partner with Tribal Nations and Indigenous Peoples to promote cultural practices and harvesting of culturally significant forest products and wildlife using the principles and practices outlined in Chapter 3: *Managing a Research Forest for Multiple Values*, Section 3.1.1.

**Objective 2.5.** Provide continued recreational access and promote recreational experiences across the Triad, including intensive management areas.

- Recreation resource management in intensive management areas will follow the Recreation and Public Access Plan section of the FMP (see Chapter 3: *Managing a Research Forest for Multiple Values*, Section 3.1)
- Initial levels of recreational user satisfaction ratings on the ESRF and ongoing levels in intensive management areas will serve as baselines for measuring the objective to maintain or improve user satisfaction.
- To protect public safety, temporary area closures may occur around management units undergoing active forest operations.

**Goal 3. Incorporate ecological considerations and research short and long-term outcomes related to ecosystem and forest resilience within intensive treatment.**

#### **Relevant Objectives and Management Direction**

**Objective 3.1.** Measure the interaction and response of fish and wildlife to intensive treatments. This may include assessing (1) temporal variation in use by species, both over short time frames (seasons) and larger time frames (decades), and (2) fish and wildlife interactions with and use of other nearby habitat types.

**Objective 3.2.** Research the interaction between riparian, aquatic (See Chapter 7: *Aquatic and Riparian Systems*) and upslope intensive silviculture treatments and efficacy of strategies to support ecosystem function of fish-bearing streams, non-fish bearing perennial streams, and seasonal and intermittent streams.

**Goal 4. Conduct long and short-term monitoring and data analysis to better understand the effects of intensive management treatments on a wide range of biophysical and human ecosystem responses and inform an adaptive management process and further Goals 1-4.**

**Relevant Objectives and Management Direction**

**Objective 4.1.** Assess and monitor the effects of current and emerging forest management practices in a Triad framework on a variety of responses including, but not limited to those listed in Objective 1.1. The variables monitored for this objective will be determined by individual research projects designed around intensive management treatments. Baseline data will be collected prior to treatments to ensure a complete analysis of experimental treatment response.

**Objective 4.2.** Utilize monitoring indicators and target levels to evaluate the efficacy of current objectives and management direction for intensive management areas at meeting or making progress to Goals 1-4. See Appendix K for monitoring indicators and initial target levels associated with individual research and land management objectives in Intensive Areas.

**Objective 4.3.** Review the list of monitoring indicators and associated target levels at intervals not to exceed 10 years to determine if they are supported by ongoing scientific discovery and adequately characterize achievement of research goals for intensive management areas.

**Objective 4.4.** Compare current levels of the monitoring indicators listed under Objective 4.2 to targets at intervals not to exceed 10 years in accordance with the adaptive management plan outlined in Chapter 11: *Adaptive Research Strategy and Implementation*. Engage in a revision of the objectives and management direction for intensive management areas when multiple decision criteria indicate that current management is not meeting or making progress towards the experimental and land management goals for intensive management areas.

## 6.3 Extensive Research Treatments

### 6.3.1 Purpose and Primary Principles of Extensive Treatments

The purpose of *extensive* research treatments is to explore a set of new and existing alternatives along a continuum between intensive plantation management and unmanaged reserves. Principles of *ecological forestry* (Seymour and Hunter 1999, Franklin et al. 2018) will guide the delineation of desired conditions at landscape scales. Principles of *ecological silviculture* (Palik et al. 2021) will guide the development of silvicultural prescriptions and desired treatment outcomes for individual stands. Extensive treatment alternatives aim to accomplish diverse forest characteristics to meet a broad set of research and resource management objectives and ecosystem services while simultaneously achieving wood production.

A management approach rooted in ecological forestry relies on an understanding of the structure, function, and dynamics of natural ecosystems to provide a wide range of ecosystem services by developing land management activities to follow natural patterns and processes of forest disturbance and succession (Seymour and Hunter 1999, Franklin et al. 2018). Key elements of ecological forestry include: (1) maintaining a full array of ecosystem structures, functions, and associated species, (2) developing silvicultural prescriptions based on an understanding of natural disturbance and stand development processes, (3) promoting complexity and heterogeneity at stand to landscape scales, and (4) promoting ecosystem resilience to reduce the risk of major disruptions in ecosystem functioning associated with disturbances and environmental change (Franklin et al. 2018, Palik et al. 2021). Achieving these outcomes requires land managers to plan for landscapes with a diverse array of successional stages including early-successional and older forest structures, promote spatial heterogeneity with management actions in individual stands, and plan for the continuity of ecosystem structure, functioning, and biota by retaining ecological legacies during harvest operations in order to promote the maintenance of ecosystem components and processes over time.

Following ecological forestry principles, the extensive treatments in the moist, Douglas-fir/western hemlock forests characteristic of the ESRF incorporate several



key elements. First, management objectives for extensive treatment areas focus on promoting landscapes with a diverse array of successional stages, including an emphasis on promoting increased representation of complex, early-successional forest and mature to late-successional forest over multiple decades. Complex, early-successional forests and older forests are under-represented across both the current ESRF and western Oregon landscapes in general relative to their historic levels (Wimberly et al. 2000, Spies et al. 2007, Franklin and Johnson 2012). Several wildlife species associated with complex-early seral and mature to late-successional forest conditions have declined over the last 25+ years in the Coast Range and western Cascades (Phalan et al. 2019), and a review of species associated with early-seral forest conditions concluded that land managers should incorporate plans for the creation of complex, early-seral habitat directly into their land management planning efforts in order to meet biodiversity conservation objectives (Swanson et al. 2014). Given the current dominance of dense, young plantations in extensive treatment areas, increasing the representation of early-successional and mature to late-successional forest conditions is critical to meeting both biodiversity conservation objectives, and to providing the wide range of cultural resources associated with historical landscape conditions in the southern Oregon Coast Range.

Creation and maintenance of a shifting mosaic of complex, early-seral habitat within extensive management areas is a particular priority because management activities in intensive treatment areas, RCAs, and reserves are not expected to generate significant levels of complex, early-seral habitat. In contrast, the large reserve network on the ESRF coupled with the protections of older forests within ESRF HCP-designated occupied marbled murrelet habitat and northern spotted owl core use areas, and a prohibition on harvest in stands that established prior to the 1868 fire are already projected to increase the availability and quality of mature to late-successional forest habitat for older-forest associated species (ESRF HCP). Current management activities on private and federal lands are also projected to promote continued declines in complex, early-seral habitat across the Oregon Coast Range (Spies et al. 2007), emphasizing the value of conducting research in extensive treatment areas that examines the effectiveness of silvicultural treatments designed to foster complex, early seral habitat for conserving early-seral associated wildlife and vegetative species, many of which have significant cultural value.

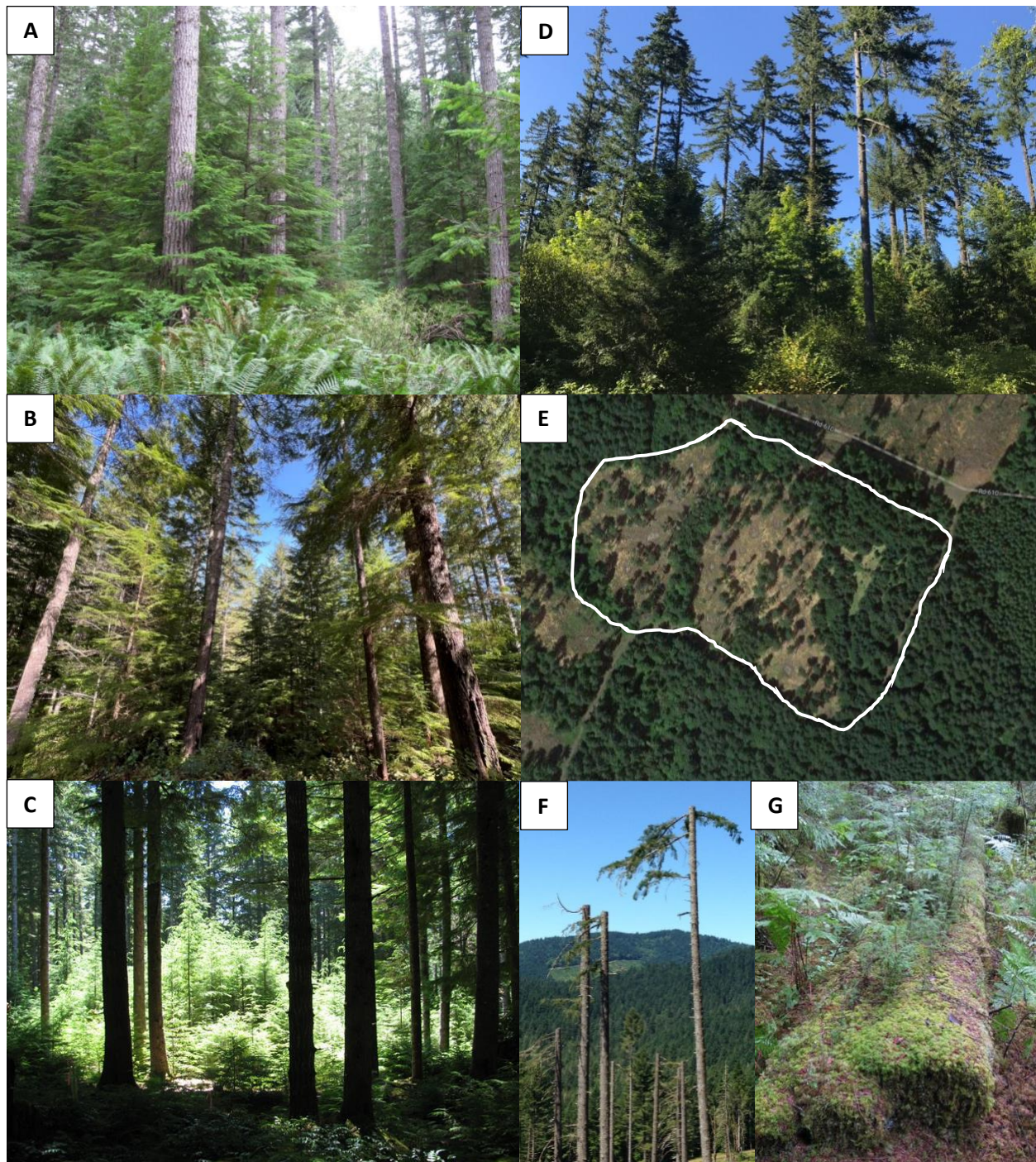
In addition to promoting the development of an array of successional stages, silvicultural treatments in extensive

areas will be designed to promote structurally complex, multi-aged stand structures with varied retention levels and patterns (Figure 6.1). Natural disturbance regimes in forests of the southern Coast Range historically included a combination of infrequent, high-severity fire near the coast with moderately frequent, mixed-severity fire regimes becoming more common inland of the coastal fog belt (Spies et al. 2018, Appendix J). More frequent, but smaller-scale gap-generating disturbances associated with wind, snow, ice, insects, and fungal pathogens also occurred, contributing to the development of structural heterogeneity in mid-to late-successional forests (Franklin et al. 2002, Spies et al. 2018).

These disturbances fostered a mosaic of mature and late-successional to old-growth stand structures characterized by varied tree ages and sizes interspersed with patches of early-seral vegetation that included varying densities of residual live trees in both dispersed and aggregated patterns. This in turn fostered increased vegetative diversity relative to the current plantation-dominated landscape (Franklin et al. 2002). Multi-aged regeneration harvests that intentionally incorporate varied retention levels and patterns both within and among individual stands foster many aspects of the natural stand development pathways and landscape mosaics characteristic of these infrequent to moderately frequent, mixed-severity disturbance regimes (Franklin and Johnson 2018, Palik et al. 2021). Multi-aged and mixed-species stand development pathways also foster increased resistance and resilience to many biotic and abiotic disturbances (O'Hara and Rammage 2013), suggesting that multi-aged silvicultural approaches may foster adaptation to drought, wildfire, insects, and fungal pathogens in extensive treatment areas.

As a part of promoting complex stand structures, land management objectives for extensive treatment areas emphasize the creation and retention of biological legacies that help to provide continuity in ecosystem functioning through both harvest and natural disturbance cycles (Franklin et al. 2018, Palik et al. 2021). Retention of live trees in varying sizes, species, and conditions, snags, down deadwood, and undisturbed patches of vegetation dramatically reduce harvest impacts on biodiversity, contributes to the persistence of functionally important taxa such as ectomycorrhizal fungi, and promotes more rapid recovery of disturbance-sensitive taxa following harvest activities (Rosenvold and Lohmus 2008, Bauhus et al. 2009, Beese et al. 2019). Management direction for extensive areas calls for land managers to preferentially retain live





**Figure 6.1.** Examples of complex stand structures generated through silvicultural activities including multi-layered canopy structures promoted through thinning and gap creation (a-c), multi-aged structures generate through retention harvests that include a mix of dispersed retention of large residual trees (d), and aggregated retention interspersed with larger openings to foster complex, early-successional forest conditions (e), and deadwood creation through topping or girdling trees (f) and leaving logs on site (g).



trees containing structural features associated with the conservation of northern spotted owls, marbled murrelets, and other taxa associated with older forests. Examples of these structural features include larger diameters and heights, complex crown and branching structures such as broken tops, epicormic branches, platform structures, and large-diameter limbs, and bark with deep furrows or crevices.

In addition, land managers planning harvests in extensive areas are directed to maintain varied tree species and sizes, and retain dead and dying trees along with down deadwood within individual management units. Where deadwood is lacking in extensive areas, such as in the existing network of plantations, land managers are directed to promote deadwood creation through both active means such as snag creation via topping or girdling and leaving some felled trees on-site to provide down deadwood and through passive means such as the retention of unharvested leave islands or “skips” and declining trees as sources of future deadwood recruitment. The use of extended rotations in extensive areas will also allow for recovery of key structural and compositional attributes between harvest entries that represent higher severity disturbances (Franklin et al. 2002, Franklin et al. 2018).

Other key elements of the management direction for treatments in extensive areas include promoting increased broadleaved tree and shrub cover relative to baseline conditions in extensive areas and promoting regeneration of diverse vegetative communities including culturally important plants. Broadleaved cover has disproportionate importance in supporting wildlife diversity in the conifer-dominated forests of the Pacific Northwest (Hagar 2007), and several dozen species of broadleaved plants represent culturally-important resources for Indigenous Peoples of the southern Coast Range (Whereat Phillips 2016). The importance of broadleaved cover to wildlife diversity is particularly strong in early-seral forests where broadleaved cover is closely linked to songbird diversity (Betts et al. 2010, Ellis and Betts 2011, Ellis et al. 2012) and to increased levels of floral resources, which are associated increased pollinator abundance (Galbraith et al. 2019). Recognizing the importance of providing diverse broadleaf communities to biodiversity conservation and the provisioning of cultural resources, management direction for extensive areas encourages increased broadleaved cover and vegetative species diversity through both regeneration activities and the retention of minor tree species and patches of intact vegetation within harvest units.

The management approaches described above are intended to provide for a wide range of resource management outcomes including the conservation of biodiversity, the provisioning of cultural resources for local tribes, providing a range of forest conditions to support varied recreational activities, increasing ecosystem resistance and resilience to disturbances, insects, pathogens, and promoting adaptation to climate change. In addition to these outcomes, extensive areas will be managed to provide a sustainable supply of renewable materials to help meet society’s demand for biomaterials and to support local economies. In ecological forestry approaches, sustained yield wood production is balanced against ecological and social objectives, rather than serving as the primary driver of resource management decisions. Guidance for annual harvest levels described in the management goals and objectives section below are based directly on the ESRF Research Proposal (OSU College of Forestry 2021) and ESRF HCP. Average annual harvest levels in extensive treatments will adhere to acre-based harvest caps described in the ESRF HCP and in Section 6.1.3 and retention objectives described below. An experimental hypothesis to be tested is that extensive treatments produce average harvest volumes that are approximately 50% of the fiber production of stands managed according to intensive experimental treatments, recognizing that relative yields of individual, stand scale treatments will vary based on retention level. No more than 3,200 acres of extensive treatments will occur in stands greater than 65 years old (as of 2020).

### 6.3.2 Goals, Objectives, and Associated Management Direction for Extensive Treatments

**Goal 1. Promote opportunities for experimental research, focused on the use of a broad variety of innovative approaches to active management to create stands that provide a diverse array of ecosystem goods and services to meet societal values (see Appendix L).**

#### *Relevant Objectives and Management Direction*

**Objective 1.1.** Provide opportunities to assess the effectiveness of existing and novel silvicultural practices designed to promote and retain diverse forest characteristics and management outcomes.

- Develop extensive (i.e., ecological forestry) treatments based on initial site-specific and landscape level conditions to ensure that each treatment is best suited to support research questions.

- Size of the management units should represent the ecosystem's natural disturbance patterns, including the appropriate mix of clumps and open patches, snags, and downed wood while recognizing operational constraints in order to assess the effects of varying levels of fragmentation on responses including, but not limited to: conserving biodiversity; population dynamics and habitat of northern spotted owls, marbled murrelets, Oregon Coast coho, and other at-risk wildlife species; harvest efficacy and safety; provisioning of culturally-valued resources; recreational use and enjoyment; responses to natural disturbances, climate change, forest pests, pathogens, and invasive species; continuity between riparian and upland forests.
- Return intervals for harvest will depend on monitoring growth, meeting the objectives of individual research projects, and providing for a range of conditions across Extensive management areas including complex early-successional, complex mature, and late-successional forest structures.
- Retention of live trees, standing and down deadwood, patches of intact, unharvested forest, and other biological legacies should be driven by initial site conditions and experimental objectives while adhering to the objectives and management direction outlined under Goal 2.

**Objective 1.2.** Provide continuing opportunities for the development and implementation of new research examining the effects of Extensive (i.e. ecological forestry) silviculture approaches on forest ecosystems, including the social, ecological, and economic outcomes of forest management.

**Objective 1.3.** Through experimentation, seek ways to optimize synergies and analyze tradeoffs and conflicts across a diverse array of resource values.

- Utilize a structured tradeoff assessment model to examine tradeoffs among a wide range of social, ecological, and economic outcomes of forest management in Extensive management areas (e.g., Bradford and D'Amato 2012).

**Objective 1.4.** Partner with Tribal governments to promote research on the implementation and effects of contemporary Tribal cultural practices and ecological knowledge related to forest management using the principles and best practices described in Section 3.1.1 of this FMP.

**Objective 1.5.** Experimentally test if aggregating retention on unstable slopes is critical to providing attributes including mitigation of landslides, delivery of large wood to streams, habitat for owls, murrelets, and other terrestrial species, and corridors for movement within and among watersheds.

**Goal 2. Generate sustained yields of high-quality forest ecosystem goods and services to support biodiversity and the bioeconomy.**

#### ***Relevant Objectives and Management Direction***

**Objective 2.1.** Support the conservation of biodiversity by providing diverse forest characteristics encompassing a range of stand structures, successional stages, and wildlife habitat features across Extensive management areas.

- Through the combination of silvicultural treatments and natural disturbances, aim to develop and maintain a managed forest landscape that provides a variety of stand structures, successional stages, and wildlife habitat features distributed in time and space.
- Conduct commercial and non-commercial treatments to promote the development of complex early-successional forest habitat. Manage Extensive areas to provide complex early-successional habitat consistent with target levels defined under Objective 3.2. Target levels represent subwatershed-scale averages and shall be periodically reviewed and updated based on research outcomes and the best available science regarding the conservation of taxa associated with early-successional forests as a part of the adaptive management process described in Chapter 11: *Adaptive Research Strategy and Implementation*.
- Conduct commercial and non-commercial treatments to promote the development of complex mature and late-successional forest habitat. Manage Extensive areas to provide complex mature and late-successional habitat consistent with target levels defined under Objective 3.2. Target levels represent subwatershed-scale averages and shall be periodically reviewed and updated based on research outcomes and the best available science regarding the conservation of taxa associated with early-successional forests as a part of the adaptive management process described in Chapter 11: *Adaptive Research Strategy and Implementation*.
- Return intervals between harvests will vary depending upon treatment objectives and research needs.



- Return intervals for future harvest treatments that promote complex early-successional habitat conditions across greater than 50% of the total area in the management unit (i.e., management-unit-scale regeneration harvests) should average 100 years or more.
  - » Management-unit-scale rotation lengths should average 100 years or more over the long term, therefore contracted acres covering management-unit-scale regeneration harvest treatments will not exceed an average of 1% annually of the eligible Extensive area after each three-decade period of plan implementation.
- Return intervals for harvest treatments designed primarily to tend existing stands and/or accelerate the development of complex mature and late-successional forest habitat characteristics will be determined based on the needs of ongoing research.
- Through the combination of silvicultural treatments and natural disturbances, aim to develop management units that include substantial vegetative species diversity and structural complexity.
- After timber harvest and natural disturbances, utilize natural or artificial regeneration or both to regenerate a mixture of species at a sufficient density to support research activities and resource management objectives.
  - » Utilize site preparation methods such as mechanical, chemical, manual, and prescribed fire to prepare newly harvested or inadequately stocked areas for regeneration of desired vegetative species.
  - » Encourage natural regeneration of desired vegetative species to the extent practicable and consistent with research activities.
  - » Utilize artificial regeneration of desired vegetative species when natural regeneration is unlikely to fully meet the needs of research activities or adequately contribute to resource management objectives.
  - » When consistent with research activities:
    - Design regeneration activities to introduce variability in vegetative species composition and density at the stand level, rather than uniform conditions.
    - Artificial regeneration should not be limited to commercial tree species, but should also include non-commercial trees and other ecologically and culturally valuable vegetation consistent with site conditions and broader resource management objectives.
- Utilize integrated vegetation management practices to promote successful regeneration of desired vegetation and enhance vegetative biodiversity and productivity.
  - » Herbicides should not be applied solely to maximize the growth of commercial tree species, or in a manner that reduces the overall diversity or productivity of culturally or ecologically desirable plants at the subwatershed level.
  - » Selective application of herbicides may be used to target invasive species and when necessary to promote the successful establishment and growth of desirable vegetative species.
    - Rodenticides and other chemicals targeting vertebrates will not be utilized in Extensive treatments.
    - Fixed-wing planes and helicopters will not be utilized for herbicide application in Extensive management areas. Drones may be used for targeted application of herbicides when consistent with research activities and resource management objectives.
- When consistent with research activities, design treatments to encourage increased broadleaf tree and shrub cover relative to baseline conditions in Extensive management areas and ongoing conditions in Intensive management areas. Treatments should promote progress towards meeting broadleaf cover target levels as defined in Objective 3.2 below. Target levels represent subwatershed-scale averages and shall be periodically reviewed and updated based on research outcomes and the best available science regarding the conservation of taxa associated with early-successional forests as a part of the adaptive management process described in Chapter 11: *Adaptive Research Strategy and Implementation*.
- Silvicultural treatments should be designed to promote multi-aged stand structures with varied tree sizes and multi-layered canopies at varying scales ranging from within individual stands to across the subwatershed.
- Treatments in Extensive management areas are limited to stands established after 1868.
  - When silvicultural activities are conducted in stands established after 1868, individuals or small groups of trees established prior to 1868 that may exist in

those stands will be retained to the greatest extent practical, recognizing limitations on tree aging and the need to occasionally remove such trees for safety and operational reasons.

- If trees established prior to 1868 must be cut for safety or operational reasons, those trees will be retained on site or relocated to function as downed wood or instream structures.
- Details regarding the cutting of any trees established prior to 1868 will be recorded as part of the compliance monitoring process contingent with Sec. 6.2.3 of the draft ESRF HCP.

**Objective 2.2.** Retain live trees and deadwood as needed to meet various experimental goals.

- Retain 20-80% of pre-harvest live tree relative density (Appendix I) immediately post-harvest, on average across the treated portion of the management unit.
  - When dispersed retention is used, retention is measured as the percentage of pre-harvest live tree relative density.
  - When aggregate retention or patch cutting is used, the percentage of area retained or percentage of area planned for removal in patch cuts will be treated as equivalent to the percentage of pre-harvest SDI retained in aggregates or removed in patch cuts.
    - » In cases where significant spatial variability in stand density exists, remotely-sensed data or cruise data may be used to generate area-weighted estimates of pre-harvest SDI encompassed within planned aggregates or patch cut locations.
  - Retention will be 80% of pre-harvest relative density when harvests occur in areas identified as occupied murrelet habitat
  - Retention levels around the 22 northern spotted owl nest sites identified in the ESRF HCP will follow relevant standards outlined in Condition 2 and Condition 3 of the ESRF HCP.
  - Incorporate occupied marbled murrelet habitat and northern spotted owl core use areas around active nesting centers in Extensive management areas that fall outside of Riparian Conservation Areas into high retention up to 80%, and follow additional species-specific management direction for occupied habitat described under Objectives 2.5 and 2.6.
  - Outside occupied marbled murrelet habitat and northern spotted owl core use areas, retention

levels will vary in accordance with research and land management needs. Retention levels across harvests in Extensive management areas do not have to average 50%.

- Retained trees should be left in a variety of spatial patterns tailored to the unique conditions in the management unit and research questions related to the effects of retention pattern on various ecosystem processes and resource values. Retention patterns may include various combinations of stringers, individual trees, small and large retention aggregates (clumps of 2-5 trees to several acres in size), or a retained matrix between gaps and larger openings.
- Test approaches to create standing dead and down trees when their abundance is low relative to unmanaged reference units representing comparable successional stages.
- Prioritize the retention of large live trees, standing dead trees, and down deadwood with wildlife habitat features that contribute to the conservation of northern spotted owls, marbled murrelets, and other taxa associated with structural features that require multiple decades to develop including, but not limited to:
  - larger tree diameters and heights,
  - complex crown and branching structures such as broken tops, epicormic branches, platform structures, and large-diameter limbs,
  - bark containing deep furrows or crevices.
- Select retention trees and aggregate locations to maintain varied tree species and sizes within the management unit.
- Additional priority features for selecting retention trees and aggregates will be identified through a landscape analysis focused on limitations to biodiversity.
- Yarding and skidding through unharvested aggregates that are retained to contribute to live tree retention targets within management units in extensive treatment areas may be allowed for safety and operational reasons; if no practicable alternative exists. Any such yarding and skidding corridors will not count towards the total amount of live tree retention (i.e., the 20-80% retention target) for the management unit.
- Implement salvage harvest after disturbances as needed to contribute to harvest volume objectives and to reduce commercial loss or deterioration of trees where it would be economically viable to do so.

- Retain dead and dying standing and down trees during salvage operations as needed to meet research objectives and provide ecological function.
- Salvage treatments may be integrated into regeneration harvest and thinning treatments to accomplish multiple purposes.

**Objective 2.3.** Manage the lands allocated to Extensive management to help meet society's growing demand for sustainably-produced, renewable resources, while:

- An hypothesis to be tested is that on average, extensive treatments produce harvest volumes that are approximately 50% of the fiber production of stands managed according to intensive experimental treatments. Average harvest volumes should be calculated as rolling, ten-year average across all extensive and intensive treatment areas, including those in subwatersheds assigned to triad treatments.
- Maintaining annual contracted acres of commercial harvests within the limits specified in Section 6.1.2.1 (see also Section 3.4.1 of the ESRF HCP). Priorities for assigning silvicultural treatments and timelines to individual stands will be developed in a decision support matrix for Extensive treatment areas (Section 6.3.3). The planning and implementation of individual stand-level treatments within individual years will be finalized within the ESRF's biennial operations plans based on this decision support matrix and revised based on assessments of changing landscape-scale conditions that incorporate the ongoing effects of succession in response to past treatments and natural disturbance events.
- Allowing for necessary variation in decadal outputs to accommodate practical constraints.
- Ensuring or improving wood product quality and maximizing value recovery.
- Ensuring or improving economic and operational feasibility of commercial harvest treatments.
- Allowing for experiments, development, and applications of novel timber harvesting technologies and wood supply chain solutions for safer, more efficient and environmentally responsible forest operations and wood supply.

**Objective 2.4.** Support rural economies and communities.

- Support local forest industries and create job opportunities through sustainable timber production and reliable supplies of timber and other renewable resources.

- Support local workforce development and embrace state-of-the-art forest technologies to retain and diversify the workforce in rural areas.
- Ensure local communities have access to benefits of the expanded bioeconomy through employment, financing and direct investment by local people, profitable entrepreneurship, and local leverage of the economic multiplier effect.

**Objective 2.5.** Increase nesting, roosting, and foraging habitat for northern spotted owls, relative to baseline levels in Extensive management areas, through the use of extensive/ ecological forestry treatments. Note that the management direction summarized in the bullet points below should be interpreted as subordinate to conditions of the ESRF HCP. In situations where discrepancies exist, the requirements of the conditions in the ESRF HCP will take precedence.

- Conduct silvicultural treatments to promote structural features associated with nesting, roosting and foraging habitat for northern spotted owl (as described in Sec 2.3.1 of the ESRF HCP) in closed-canopy stands lacking such features.
- Operational activities around active northern spotted owl nest sites within the 22 activity centers identified in the ESRF HCP will follow the seasonal restrictions described in Condition 1, as described in Sec. 5.5.2 of the ESRF HCP.
- Treatments around the 22 activity centers identified in the ESRF HCP will maintain a 100-acre nesting core area around the northern spotted owl nest tree or designated activity center that includes 100% retention in accordance with all provisions of Condition 2, as described in Sec. 5.5.3 of the ESRF HCP. Core areas should maintain the best 100-acres of contiguous habitat and do not need to be circular in shape, but the edge of the nesting core area will be no less than 300 feet from the nest tree or designated activity center. Designation of nesting core areas must be completed prior to any harvest occurring in the surrounding core use area.
- When planning treatments around any of the 22 northern spotted owl activity centers identified in the ESRF HCP, core use areas of at least 502 acres of the best contiguous habitat will be established around active northern spotted owl nest sites in accordance with all provisions of Condition 3, as described in Sec. 5.5.4 of the ESRF HCP. The 502 acres does not need to be in a circle but will be contiguous and the edge of the core use area will be no less than 300 feet from the nest location.



Within the core use areas, at least 50 percent (more than 251 acres) will be retained as nesting, roosting, or and foraging habitat, at the same or better quality as pre-treatment conditions, at all times. For core use areas that extend beyond the permit area the permittee will be responsible for maintaining retaining nesting, roosting, or and foraging habitat on at least 50 percent of the total area inside the core use area (which is also inside the permit area). For core use areas that are currently below the 50 percent threshold no harvest will occur until the minimum habitat threshold is met.

- At least 40% of the home range of the 22 northern spotted owl activity centers identified in the ESRF HCP (a 1.5-mile radius circle centered on the activity center) will be retained as nesting, roosting, and foraging habitat in accordance with all provisions of Condition 4, as described in Sec 5.5.5 of the ESRF HCP. For home range areas that are currently below the 40 percent threshold no harvest will occur until the minimum habitat threshold is met.
- Management activities in Extensive treatment areas will contribute to maintaining at least 40% of the MRW as dispersal habitat in accordance with all provisions of Condition 5, as described in Sec. 5.5.6 of the ESRF HCP.
- If new owl nest locations are discovered in the future, outside of those shown in Figure 2-6 of the ESRF HCP, the retention standards described in this objective would not be required in those locations. Those stands may be subject to removal of 20-80% of the pre-harvest relative stand density, though retention would be clustered around known northern spotted owl core areas including known nest trees, and trees immediately surrounding known nest trees.

**Objective 2.6.** Increase suitable marbled murrelet nesting habitat (as described in Sec. 2.4.1 of the ESRF HCP) relative to baseline levels in Extensive management areas through the use of extensive/ecological forestry treatments. Note that the management direction summarized in the bullet points below should be interpreted as subordinate to conditions of the ESRF HCP. In situations where discrepancies exist, the requirements of the conditions in the ESRF HCP will take precedence.

- Conduct silvicultural treatments to promote development of structural features associated with nesting habitat for marbled murrelet (as described in Sec. 2.4.1 of the ESRF HCP in closed-canopy stands lacking such features).

- Silvicultural activities occurring in or near areas designated as occupied habitat in Figure 2-11 of the ESRF HCP will follow all seasonal restrictions described in Condition 6, or other areas deemed to be occupied based on the survey processes described in Condition 7, as described in Sec. 5.5.7 of the ESRF HCP.
- Surveys for marbled murrelet nest sites will be conducted prior to treatment for all extensive treatments in designated occupied or modeled potential marbled murrelet habitat as designated in Figure 2-11 of the ESRF HCP. These surveys will follow all provisions of Condition 7, as described in Sec. 5.5.8 of the ESRF HCP.
- Extensive treatments in designated occupied and modeled potential marbled murrelet habitat, which are found to be occupied pursuant to the survey process described in Condition 7, Sec 5.5.8 of the ESRF HCP will follow all limits on harvest acreage totals, corresponding timelines, and retention provisions described in Condition 8, Sec. 5.4.9 of the ESRF HCP.
- Harvest treatments will not contribute to a temporal loss of the aggregate number of acres of designated occupied marbled murrelet habitat as designated in Figure 2-11 of the ESRF HCP and will follow all provisions of Condition 9, as described in Sec. 5.5.10 of the ESRF HCP.
- Any harvest areas outside of designated occupied and modeled potential marbled murrelet habitat as designated in Figure 2-11 of the ESRF HCP do not fall under the limitations described in Condition 9 (Sec. 5.4.10) of the ESRF HCP, regardless of occupancy status.

**Objective 2.7.** Promote the development of riparian forests that emulate their critical roles in natural disturbance, are fully integrated with upland management, and maintain critical ecological processes that will benefit Oregon Coast coho and other riparian-associated fish and wildlife species.

- Conduct long-term monitoring and surveys of landforms prone to shallow landslides and high-mobility debris flows (e.g. colluvial hollows) and intermittently active deep-seated landslides to constrain the influence of a spectrum of management practices on landslide activity and consequently sediment delivery. Sufficiently long monitoring of a number of replicate test sites will help isolate the importance of management practices versus disturbance events (e.g. rainstorm) and the thresholds by which management activities result in similar wood recruitment and sediment delivery to natural reserve systems.

**Objective 2.8.** Provide sustained yields of culturally valued resources for local tribes, and opportunities for tribal governments and tribal members to harvest traditional forest products and engage in traditional tribal cultural practices.

- Utilize the formal consultation process outlined in Chapter 3: *Managing a Research Forest for Multiple Values* and the corresponding authorities described within the MOU's between Oregon State University and tribal governments to identify culturally-valued resources and consult on the potential impacts of silvicultural activities in Extensive areas on natural, cultural, and traditional resources.
- Provide access for Tribal governments and members to harvest traditional forest products and follow Tribal cultural practices and the corresponding authorities described within the MOU's between Oregon State University and Tribal governments (see Section 3.1.1 and 6.1.7).
- Manage Extensive areas to promote increased yields of culturally-valued resources over time.
  - Cover and biomass production of culturally-valued plant species identified through the Tribal consultation process increases over time relative to baseline conditions and ongoing conditions in intensive management areas.
  - Deer and elk populations increase relative to baseline conditions in Extensive management areas.

**Objective 2.9.** Promote adaptive responses to changing climatic conditions, disturbance regimes, and biological conditions to ensure continued provisioning of a wide range of forest ecosystem goods and services.

- Increase tree species diversity relative to baseline conditions in Extensive management areas and ongoing conditions in intensive management areas.
- Increase the proportion of overstory BA and understory cover represented by species with adaptations to increased drought and wildfire (e.g., drought-tolerant conifers, sprouting hardwoods and shrubs, and species that develop thick bark and higher canopies as they mature) relative to baseline conditions in extensive management areas and ongoing conditions in intensive management areas.
- Treat both activity and natural fuels to reduce wildfire hazard and risk to acceptable levels, as necessary depending on local context (e.g. more intensive fuel reduction near structures and in the wildland urban interface, less intensive fuel reduction in more remote areas).

- Utilize density management techniques to maintain stand densities below levels associated with increased risk of mortality associated with synergistic relationships between drought and insects or diseases.

**Objective 2.10.** Provide continued recreational access and promote high-quality recreational experiences across Extensive management areas.

- Recreation resource management in Extensive management areas will be consistent with the ESRF Recreation Plan (Chapter 3: *Managing a Research Forest for Multiple Values*, Section 3.1).
- Maintain or improve recreational user satisfaction ratings relative to baseline levels and ongoing levels in Intensive management areas.
- To protect public safety, temporary area closures may occur around management units undergoing active forest operations.

**Goal 3. Collect data to monitor the effects of extensive management treatments on a wide range of ecosystem responses and inform an adaptive management process designed to further Goals 1-3.**

#### **Relevant Objectives and Management Direction**

**Objective 3.1.** Assess and monitor the effects of the level of retention, spatial pattern of retention, harvest unit size, and connectivity of upland forests with riparian forests on a variety of responses including, but not limited to:

- population dynamics of northern spotted owls, marbled murrelets, Oregon Coast coho, and other at-risk species,
- maximizing opportunities for biodiversity,
- promoting complex early successional habitat conditions,
- promoting complex mature and late-successional habitat conditions,
- providing a sustainable supply of renewable materials,
- supporting local economies,
- efficiency of harvesting activities
- provisioning of culturally valued resources,
- aesthetics and recreational user satisfaction,
- use and costs of harvesting systems,
- resistance and resilience to wildfire, insects, diseases, wind damage, landslides, and other disturbances, and
- carbon storage and sequestration rates.

The variables monitored for this objective will be determined by individual research projects designed around extensive management treatments.

**Objective 3.2.** Utilize the monitoring indicators and target levels to evaluate the efficacy of current objectives and management direction for Extensive management areas at meeting or making progress to Goals 1-3 (See Appendix M).

**Objective 3.3.** Following the adaptive experimental design process outlined in Chapter 11: *Adaptive Research Strategy and Implementation*, review the list of monitoring indicators and associated target levels at intervals not to exceed 10 years to determine if they are supported by ongoing scientific discovery and adequately characterize achievement of research goals for Extensive management areas.

**Objective 3.4.** Compare current levels of the monitoring indicators listed under Objective 3.2 to targets at intervals not to exceed 10 years in accordance with the adaptive management plan outlined in Chapter 11: *Adaptive Research Strategy and Implementation*. Engage in a revision of the objectives and management direction for Extensive management areas when multiple decision criteria indicate that current management is not meeting or making progress towards the experimental and land management goals for Extensive management areas.

## 6.4 Reserve Research Treatments

The goal of *reserve* research treatments is limited intervention and management, with a targeted set of treatments focused on restoration, enhancing conservation, and cultural values that are in alignment with these goals in even age stands that regenerated following clearcut logging (i.e., Douglas-fir plantations less than 65 years old as of 2020). Treatments in the CRW and MRW reserves include restoration based thinning in Douglas-fir plantations, recognizing that past management in the CRW area and MRW reserves has created dense plantation stands in areas including riparian zones and that the need exists for a focused effort to recruit future old stands and unlogged naturally regenerated older forests (Figure 6.2; OSU College of Forestry 2021). The CRW restoration experiment (Section 6.4.1) describes the objectives and framework for this experiment. Stands older than 65 years old (as of 2020) and

controls within the plantations in reserve (both MRW and CRW) will follow natural processes and respond unmanaged to disturbances (with the exception of fire suppression). Reserve stands are located as a contiguous block in the CRW, and embedded in the matrix of Triad treatments in areas of older forest.

The following operational standards will be used to guide management in reserve treatments under the FMP and ESRF HCP:

1. Retain the CRW as a contiguous reserve in the southern Coast Range.
2. Assess CRW plantation conditions (forests 65 years and younger) in the first few years of implementation using the decision tree and guidelines for implementation below in Section 6.4.
3. Design and implement experimental restoration treatments in plantation stands 65 years or younger (as of 2020) during the first 20 years of ESRF implementation to explore methods for increasing and maintaining structural complexity and diversity from dense single-species plantations (see Section 6.4.1 Restoration Experiment for Plantations in Reserve and Appendix N). These objectives include promoting complex mature forest structure and habitat conditions for covered species as well as creating complex early seral habitats from current dense single-species plantations. Existing mature forest and other functioning complex habitat will be conserved.
4. Restoration operations will consist of single-entry restoration treatments within the first 20 years of the permit term. Indigenous knowledge, including related to prescribed fire, native planting, and invasive species removal (Section 3.5), may be used in combination with thinning techniques to create and maintain habitat conditions consistent with restoration and research goals.
5. Following initial treatments, use of supporting activities may occur (e.g., prescribed fire, native planting, invasive species treatments) whether planned in coordination with the thinning or separately. No additional logging or development of infrastructure will occur after the initial treatment unless, following the initial 20 years of the permit term, it is determined additional thinning would benefit the covered species, support goals for forest habitat complexity, and align with the research design. The CRW may also be managed for cultural practices compatible with restoring and conserving





**Figure 6.2.** Dense plantation stand of Douglas-fir on the ESRF. A range of restoration-focused silvicultural treatments are proposed for stands of this type, to diversify structure and accelerate development of mature forest characteristics.

- terrestrial, riparian, and aquatic habitat conditions (ESRF HCP Section 3.2.2). Subsequent entries will only be permitted contingent on input from the Implementation and Adaptive Management Committee (ESRF HCP Section 7.2.4), and concurrence from the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS). Infrastructure repairs or developments may be made if public safety or access for research, management, cultural resources, recreation, or education is compromised by unforeseen events or circumstances.
6. Impacts from natural disturbances such as fire, drought, disease, wind, and insects will occur in the CRW. Wildfire will be suppressed across the research forest, including in the CRW. Salvage harvest will not occur in the CRW with the following exceptions: (1) limited roadside tree removal needed to maintain public access and forest operations, (2) selective removal of cedar trees for Indigenous cultural practices as outlined in ESRF HCP Section 3.8 and Section 6.1.5 above, and (3) if an introduced nonnative insect or disease is found and removal of dead trees can help with control.
  7. Riparian Conservation Area (RCA) stands may be thinned to reduce density and promote the development of healthy native riparian ecosystems (see the riparian restoration experiment description in Chapter 7: *Aquatic and Riparian Systems*, Section 7.4.1).

#### 6.4.1 Restoration Experiment for Plantations in Conservation Research Watersheds

The Conservation Research Watersheds (CRW) in the ESRF provide exceptional opportunities to research novel approaches to conservation and ecosystem restoration. In this section, traditional definitions of restoration and



conservation of ecological systems are framed through a sustainability lens and broadened to include the restoration of a whole socio-ecological system that coalesces conservation of habitat with conservation of cultural values and cultural resources. This foundation reflects the human presence in this landscape for thousands of years and the associated impacts on forests mainly through fire and cultivation. The restoration experiment focuses on novel establishment of a sustainable research template that will provide compelling opportunities for investigators with diverse backgrounds including Indigenous, multi-cultural backgrounds, and those with diverse values and ethnicities, to ask questions that will be relevant for decades to come under the influence of global change (Dawson et al. 2021). A sustainable research template can be interpreted here to mean treatments are designed to support natural processes while also allowing for cultural practices based on value-driven holistic sustainability models, and provide diverse research opportunities.

Guided by the role that the CRW will play in addressing conservation goals and objectives articulated in the ESRF Research Proposal (OSU College of Forestry 2021) and ESRF HCP, this experiment will test how to rapidly restore conditions in coastal forests suitable for threatened and endangered species and associated biodiversity. Specifically, the intention is to accelerate development towards forests that support fish (e.g., salmon and lamprey) and associated fauna habitat through viable, resilient and disturbance driven connections between upland forest and lowland riparian areas.

A diversity of seral stages will be sought through restoration that reflect emerging fire history data on the Elliott (see Appendix J) and support culturally important flora and fauna, Indigenous Knowledge and educational accessibility. In addition to early and mid seral forest structure, restoration treatments will also establish opportunities to study methods aimed at accelerating old-growth forest conditions that support potential habitat for marbled murrelet and spotted owl populations and associated biodiversity. The aim is to apply treatments designed to steward long-term natural disturbance-driven natural regeneration that operates in union with the natural topography of the CRW landscape. The focus on biodiversity, habitat for species covered by the ESRF HCP, and cultural resources will drive the management entries in the CRW. The restoration and conservation activities of the CRW involve Indigenous co-stewardship as well as educational and research opportunities for maintaining and conserving seral diversity and old-growth features.

In the spirit of co-stewardship, special emphasis is placed on culturally valuable resources whose populations will be monitored as part of the plan outlined in Chapter 10: *Monitoring*. If deemed necessary to maintain conditions that reflect the restoration goals, additional treatments will be designed and implemented with special attention to resilience and sustainability of cultural resources. Subsequent entries will only be permitted contingent on input from the Implementation and Adaptive Management Committee and concurrence from the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) as described in (ESRF HCP Section 7.2.4).

Currently the CRW is dominated by a mix of stands that naturally regenerated after fire events throughout the 1800s (see Chapter 12: *Disturbance, Forest Health and Resilience*, Section 12.1.1 and Appendix J), and plantations that were established after initiation of harvest operations starting in about 1955. The major goal of the proposed experiment is to test whether and how to best treat the plantations in these subwatersheds to achieve the conservation goals set forth in the ESRF HCP and associated goals described in the ESRF Research Proposal (OSU College of Forestry 2021).

Restoration treatments will only be applied in plantations younger than 65 years as of 2020. Reflecting the large impact of past management practices, the first restoration operations, to be implemented during the first twenty years of the ESRF, will focus on moving the forest closer to conditions where natural processes, including cultural practices, become more influential in driving forest development towards the desired outcome. This provides a unique challenge, but also allows for exploration of questions regarding the impact of disturbances in unmanaged forests. For example, after the initial treatment, are natural disturbances sufficient to achieve the restoration goals and maintain those conditions over the long run, especially in the context of global change (Agne et al. 2018; Chmura et al. 2011)?

The experimental design will account for the fact that processes acting at multiple spatial scales influence forest development (e.g., regeneration, Dodson et al. 2014) making it possible to assess processes and responses at the individual tree scale, patch scale, stand scale, subwatershed scale, and at the landscape scale (Powers et al. 1999; Wilson and Puettmann 2007). The initial treatments aim to avoid the need for future “corrections” or “additions”. However, appreciating the unpredictability of future conditions (especially in the context of global change) and respecting the dynamic nature of these forests, it is

understood that the initial treatment may not steer the ecosystem development in the direction of restoration goals indefinitely. In cases when major restoration goals are clearly missed, future activities in the spirit of co-stewardship can be implemented to encourage the ecological, social, and cultural values in accordance with the ESRF HCP conditions noted in Section 6.4 above.

The heavy emphasis on the initial treatment has several implications:

1. Restoration treatments are limited to plantations i.e., stands that are imprinted by past management efforts to the point that they are outside the set of conditions historically found in the region.
2. Restoration treatments will be designed to achieve a high-variability in conditions among treated stands. We aim to treat 40, 40, and 20% of the treated stands to residual densities that are 20-40, 41-60, 61-80% of pre-treatment densities, respectively. Note, that control stands will fill in data on the upper bounds of stand densities.
3. Treatments are limited to efforts necessary to remove part of the recent human footprint, specifically impacts of fire protection, clearcuts, and associated reforestation efforts, and put stands on a trajectory allowing natural disturbances to influence ecosystem development towards restoration goals.
4. The planning horizon in terms of the effectiveness of that single treatment is long-term (unlimited).
5. Special attention should be paid to small scale variability inherent in the landscape, as it impacts future succession and disturbance patterns.
6. It is necessary to accept uncertainty about the type, frequency, and severity of disturbances as an inherent part of ecosystems, especially in the context of global change. Restoration treatments can only partially account for selected aspects of natural disturbances (e.g., those that are more predictable, such as differences in fire probability on north versus south-facing slopes, increased probability of windthrow with increasing tree height and slope).

These implications have inherent conceptual consequences. Many expectations associated with the “command and control approach” (e.g., the ability to model future tree and stand growth; Holling and Meffe 1996) will need to be modified, including respect and appreciation for the value of a certain unpredictability when natural processes play out in the forest. This will complicate other components such as carbon accounting (Prichard et al. 2019), and wildlife habitat

modeling (Williamson et al. 2021), especially in the context of global change (Hotta et al. 2019).

In the CRW, the sideboards on management add challenges to achieving this goal as treatment options are limited. However, the primary objective here is to test if the ESRF can provide an innovative natural disturbance driven restoration template that provides opportunities for investigators to pose questions relevant to the context of global change well into the future. Several ideas for research initiatives are suggested only as a starting point to incubate hypotheses:

1. Identify differences in stand conditions that accelerate habitat conditions for a variety of species, including species of conservation concern, cultural value, and ecosystem resilience (Ares et al. 2010; Neill and Puettmann 2013).
2. Partner with Tribal Nations, Indigenous Peoples, and affiliated researchers to explore questions related to cultural burning and other practices common prior to colonial timber use (Marks-Block and Tripp 2021).
3. Understand the connection between natural disturbance and cultural practices in upland areas and the positive and negative impacts on lowland riparian conservation zones and species of interest, especially salmon and lamprey (Hankins, 2013).

The proposed experiment has a nested structure, but all scales are linked (Levin 1992) in that they have the overall goal to encourage greater compositional, successional, and structural diversity to maintain functional habitat networks for ESRF HCP species (McGarigal et al. 2016), increase overall biodiversity, and restore resources of high cultural value as identified by Tribal partners and local communities (and described in the ESRF Research Proposal [OSU College of Forestry 2021]). At the stand scale, the impact of restoration treatments will be evaluated in terms of whether they direct and/or accelerate stand development towards these desirable conditions compared to stands that received no treatment.

The subwatershed scale is used to assign treatments. At this scale, the question of whether treating plantations when they are intermixed with natural, older stands (those established after the 1868 fire) is more effective in providing desirable habitat conditions than in untreated subwatersheds will be assessed. The assessment will be based on a comparison of subwatersheds along a gradient, from a low to high proportion of the subwatershed being in plantations and respective proportions of older, natural stands. At the landscape scale, the question of whether having a blend of treated and untreated subwatersheds, all of which will have a

mix of plantations (treated or not) and natural, older stands, achieves the desired conditions will be evaluated.

Last, but not least, at the ESRF scale, the landscape will provide crucial information for the Triad experiment in the MRW. The CRW restoration experiment will act as a control and allow testing of whether the smaller reserve areas in the MRW subwatersheds are effective in terms of conservation or whether their smaller size provides specific limitations. At the same time, the CRW allows small scale (e.g., tree, patch) studies within the proposed experiment, as long as the overall goals are not compromised. Examples include investigations on how to accelerate crown development (single trees) suitable as marbled murrelet or spotted owl nesting habitat or trials investigating novel regeneration techniques or current regeneration techniques in new settings, such as in understories (single seedlings).

#### 6.4.1.3 Reserve Restoration Goals and Objectives

The restoration experiment in the CRW has two goals at the stand (Goals 1 and 2) scale and one each at the subwatershed (Goal 3) and forestwide (Goal 4) scale:

**Goal 1: Ensure ecosystem development are driven by succession and natural disturbances to achieve and maintain desirable conditions over the long-term (i.e., successional diversity to maintain functional habitat networks for ESRF HCP species, functional drivers and associated biodiversity, and resources of high cultural value as identified by Tribal partners) that contribute to the landscape level success of providing:**

- *Desirable conditions* as quantified by Habitat Suitability indicators for the ESRF HCP species, and associated biodiversity and culturally valuable goals, as described in the ESRF Research Proposal (OSU College of Forestry 2021).
  - Habitat conditions that support roosting and foraging habitat for northern spotted owl (as described in ESRF HCP Sec. 2.3.1.1 and 2.3.1.2).
  - Habitat conditions that support marbled murrelet nesting habitat (as described in ESRF HCP Sec. 2.4.1).
  - Habitat conditions that support coho salmon (as described in ESRF HCP Sec. 2.5.1).
  - Conditions that support vegetation and animals of historical and current importance for Tribal members in the region (i.e., including spiritual, material, and other uses).
  - Broader biodiversity associated with Goals 1 through 4, with a special emphasis of functional biodiversity that

encourages resistance, resilience, and adaptive capacity to disturbances, especially to global change agents.

- Broadly the restoration activities are designed to set the CRW on a path to *successional stage diversity* reflective of past conditions at the landscape scale which supported viable populations of a range of species (including species listed under the ESRF HCP) and cultural values. Based on these goals, targets for successional diversity are envisioned as categories framed in a way to allow for continuous adjustment in experimental design as disturbances act upon the CRW landscape (see Chapter 11: *Adaptive Research Strategy and Implementation*). These broad targets pertain to successional stage diversity only and nuanced patterns, functional diversity, and species level composition are described in detail in the ESRF HCP. As more climate modeling data emerges, these values may be adjusted to greater accuracy but provide a starting point to initiate treatment.

**Goal 2: Compare restored plantations and unrestored plantations to allow comparisons aimed at improving our understanding of conditions that support Goal 1. These approaches are:**

1. Restoration treatments aimed at setting up the stand so that natural disturbances can act on the ecosystem and lead to the development of desirable conditions.
2. Unrestored and unmanaged plantations left in their current condition with no treatment application.

**Goal 3: Test how the effectiveness of supporting viable populations of ESRF HCP species, a range of biodiversity, and cultural values using the two experimental treatments varies as a function of initial conditions (i.e., as a function of the proportions of subwatershed areas currently in plantations). This will provide guidance for efficient implementation of future restoration plans in other areas.**

**Goal 4: Provide a reference for assessment of the Triad experiment on the MRW, specifically whether responses in similarly treated areas scale up to larger areas. As progress is made toward achieving the restoration goals, more information about, e.g., the population development of ESRF HCP and other species in a variety of settings will be available. Comparing this response at the landscape scale (i.e., the entire CRW area) with the smaller reserve areas in the MRW will provide information on how the size of reserves influences restoration success in relation to the “restored” CRW.**



Measurements of variables important for Goals 1 and 2 will be taken at the stand scale (in plantations that are either treated or untreated controls). Measurements of variables necessary to achieve Goals 3 and 4 will in addition be taken in the naturally regenerated older stands (after the 1868 fire, etc.). Data analysis will not just focus on central values (e.g., means or regression lines), but indicators of variability likely to provide more relevant information. Such indicators could include standard deviation and coefficient of variation. Other information, such as the data distribution (e.g., Poisson versus normal) and skewness may provide information about shifts in characteristics (e.g., towards more species adapted to changing climate conditions). In addition, spatial data, including patch sizes, fragmentation, and connectivity indicators will provide relevant information to assess treatment success.

#### 6.4.1.4 Reserve Restoration Experimental Design

Two basic treatments (untreated control or restoration treatments) will be assigned at the subwatershed scale, to all plantations in a subwatershed that meet established criteria (i.e. stands less than 65 years in a complete subwatershed). Given the relative homogeneity of plantations, less variation in ecosystem development is expected over time in the untreated control stands, as compared to the treated stands. To reflect this in the experimental design, it is proposed that a minimum of 20 % of the acres/hectares in the CRW be assigned as untreated controls and up to 80% of acres/hectares receive the restoration treatment.

##### **Control**

Controls provide a reference point to assess the effectiveness of the CRW treatment for the perpetuity of the ESRF. In experiments, no-treatment controls are typically chosen as standard or reference that provide the basis for interpretation of treatment responses, especially when a do-nothing option is considered by practitioners. In this experiment, in the control subwatersheds neither plantations nor naturally regenerated stands will receive a restoration treatment. This allows an assessment of the effectiveness of the treatments (i.e., what is gained and lost in regards to achieving the restoration goals by implementing treatments). Subwatersheds in the CRW that meet the criteria (see Section 4.3.3 *Phased Research Implementation*) will be designated as controls depending on forthcoming sub-watershed inventory and compositional analysis.

##### **Reserve Restoration Treatments**

These treatments are aimed at setting up the stand so that natural disturbances can act on the ecosystem and lead to the development of desirable conditions (as outlined in Goal 1). This approach is based on the assumption that natural disturbances are an important driver of ecosystem development, and allowing or facilitating natural disturbances will lead to a set of future conditions that more effectively support Goal 1. Thus, stand development following the initial treatment is driven by a combination of the restoration activities, natural disturbances, and successional patterns, whereby the restoration activities are mainly aimed at reducing the human footprint to encourage the positive effects of natural disturbances that are supportive of Goal 1. Because of the inherent variability and unpredictability, careful monitoring will be used to assess whether further treatments are necessary in the future. Treatment implementation and monitoring are designed to address the question: *If we prepare the landscape so succession and natural disturbances are the major drivers of future forest development, is the system more resistant (i.e. measurably less “damaged” than Control), more resilient (i.e. recovery of biodiversity to similar state occurs more quickly than in Control), and adaptive (based on long term indicators that system components are reorganizing)?*

The residual densities of trees and other vegetation after the restoration treatments are designed to allow natural disturbances to impact stands and thus become a critical driver of future vegetation development and adaptive capacity. Compared to typical restoration treatments (as applied in the MRW), this may mean leaving less, more, or different trees during harvest operations in selected places and basing such decisions on our current understanding how topography, elevation and aspect, and current stand structures and species mixtures at different spatial scales influence future forest development. Because the location and layout of the plantations typically do not match the topographic template as relevant for disturbances that drive inherent forest heterogeneity (Puettmann et al. 2009; Wilson and Puettmann 2007), this treatment will focus on restoring stand structures and composition that allow disturbance to further shape the forest in the ecologically “appropriate” location (e.g., more open canopies with grass, forb, shrub understory on south aspects and ridgetops; treatments in valley bottoms and north aspects could result in restoration of closed canopies and multi-layered tree characteristics).

Specific location of the management actions under the research design will be determined by current stand conditions, such as structure, composition, and spatial patterns, in addition to topography, soil and understory vegetation conditions, so as to tailor the experimental design to the landscape. Restoration treatments may incorporate the following activities:

- Variable density thinning that:
  - Are aimed at reducing tree densities, as reforestation efforts have resulted in current density that are higher than historic densities of younger stands (Tappeiner et al. 1993),
  - Leave trees of various sizes and shapes (qualities) to encourage presence of large trees and increase the Diameter Diversity Index (DDI) (Davis et al. 2007; Dodson et al. 2012) and a diversity of microhabitats (Asbeck et al. 2020),
  - Leave trees in various spatial patterns to mimic wind, ice, diseases and other natural mortality agents (Spies et al. 1990),
  - Favor “minority” tree and shrub species to encourage species diversity (Davis et al. 2007),
  - Create, maintain, and enlarge gaps to encourage a diversity of seral conditions, including early successional stages (Gray and Spies 1996),
  - Retain leave islands as refuges for animals and plants that prefer dense forests (e.g., flying squirrels; Manning et al. 2012),
  - Create snags and downed wood of various sizes and decay classes to encourage habitat heterogeneity and wildlife diversity (Pollock and Beechie 2014).
- In appropriate conditions, including in understory settings and gaps: seeding and planting of tree species necessary to encourage desired species composition (using species that are naturally present on the larger ESRF landscape or from nearby predicted to tolerate future conditions, Dodson et al. 2014; Urgenson et al. 2012).
- Weed control (non-chemical only) where absolutely necessary to ensure seedling survival (not to maximize growth) of selected seedlings, encourage specific habitat conditions as per ESRF HCP, or reduce the impact of invasive species (Hanley et al. 2007).
- Single or multiple prescribed burns to manage fuels and promote desirable species density and food production. Ecocultural burns shall be repeated over time as

appropriate as part of a co-stewardship agreement with the Tribal partners (Mucioki et al. 2021).

#### **6.4.1.5 Incorporation of Natural Disturbances into Reserve Restoration Treatment Design**

Natural disturbances are expected to be part of reserve restoration treatments whose role in driving ecosystem development will increase over time. The following section provides guidance for incorporating disturbances into the design of single-entry reserve restoration treatments.

- Wind, which can result in tree fall with uprooting (i.e., tip-up mounds), and stem/top breakage with potential for crown regeneration and specific decay patterns at individual tree and patch scales (Mitchell 2013).
- Guidance
- Leave trees of different sizes (height/diameter ratios)
  - Leave trees in different topographic locations (e.g., ridge, valley)
  - Leave trees in different spatial arrangements (e.g., single trees versus clumped)
  - Leave unstable trees as individuals and in groups.
- Swiss Needle Cast, which reduces Douglas-fir growth in stands near the coast (~15 miles) (Agne et al. 2018; Lee et al. 2016).

##### Guidance:

- Discriminate against Douglas-fir in terms of leaving residuals and regeneration, at least in patches
  - Promote regeneration and growth of disease-resistant associates, such as western hemlock, western redcedar, and hardwoods
- Fire: Because large wildfires will be suppressed in the CRW, treatments may emulate effects of the mixed severity fire regime found (or expected to be found in the future) in these forests and establish conditions for resistance, resilience, and adaptive processes (A. Merschel, pers. communication).

##### Guidance:

- Prescribed burn of selected patches as part of initial restoration treatments to create heterogeneity consistent with historic mixed severity fire regime and with cultural values and practices of tribal communities (Mucioki et al. 2021):

- » Small and large openings, especially on south facing slopes
- » Irregular spacing among trees
- » Multiple species, including sprouting species
- » Select burning schedule for repeated treatment to:
  - » decrease fuel loads across successional patches,
  - » increase species of historical and cultural values
  - » restore fire to the soil and understory in mid and late seral forests
  - » maintain open patches in early seral conditions
- Choose locations and encourage stand structures that are less likely to burn in stand replacing fire (i.e., emulate fire refugia).
- Choose locations for burns that accommodate cultural and spiritual use of the Indigenous community.
- Drought. ESRF moisture inputs will be part of the ESRF monitoring program. It is expected that droughts would have a higher influence in the eastern portion of the ESRF (Bansal et al. 2016; Beckmann et al. 2021).

Guidance:

- Encourage selection of more drought tolerant species, especially on south aspect slopes (e.g., Douglas-fir, Pacific madrone, giant Chinquapin, Oregon white oak)
- Encourage tree vigor (i.e., lower densities)
- Encourage species that are more adapted to drought conditions, especially on south west aspects (e.g., through planting or seeding). For example, one could establish mixtures including Douglas-fir, Pacific madrone, golden chinquapin and tanoak. In contrast, maintain less drought tolerant species in more mesic patches.
- Retain and encourage diverse understory structure with species adapted to drought conditions (Neil and Puettmann 2013).
- Ice/snow: minor damage may lead to desirable vegetation development (e.g., creation of selected canopy structures, Priebe et al. 2018).

Guidance:

- Spatial variability to prevent larger areas of canopy damage (i.e., unsuitable habitat for ESRF HCP covered and other species)
- Encourage species mixtures

- Encourage tree vigor (e.g., deep crowns so trees can recover from loss of tree top)
- Complex live crown structures with broken tops, forked stems, and pockets of decay.
- Other diseases (root rot, fir borer, etc.) can lead to small scale patchy mortality (or larger die-off, Agne et al. 2018).

Guidance:

- Leave trees of different vigor
- Encourage species mixtures
- Interrupt continuity through spatial variation of within patch structure and composition
- Landslides

Guidance:

- Encourage wood delivery to riparian areas (see Chapter 7: *Aquatic and Riparian Systems*).
- Thin to encourage this disturbance in pockets

## 6.5 Riparian Conservation Areas

The goal of the *Riparian Conservation Areas* (RCAs) is to maintain and restore vital ecological processes that influence the aquatic ecosystem in the intensively managed and extensively managed research treatments. The aquatic and riparian conservation component of the system-based research strategy will rely on a set of designated RCAs, conservation measures, and experimental treatments for riparian restoration and in-stream habitat enhancement as outlined in Chapter 7: *Aquatic and Riparian Systems*.

## 6.6 Forest Roads

Forest roads provide critical access to the ESRF for research, management, recreation, and fire protection. They also represent a significant human impact on the larger forest system in terms of chronic long-term disturbance, habitat fragmentation, sediment yield, and access for invasive species. Natural sediment processes are critical for stream ecosystem function. However, additional anthropogenic sediment inputs from episodic road-related landslides and washouts, and chronic sediment eroded from unvegetated cut banks, ditches, fill slopes and road surfaces can be harmful to many aquatic species including listed salmonids.



An overview of the ESRF road network is provided in Chapter 1: *Background*, Section 1.3.1. More details on the history of road construction and associated forest management are provided in Section 1.9.2.

Since the 1990s, the number of miles of streamside roads on the Elliott has decreased through rerouting and decommissioning. Upgrades and Best Management Practices (BMPs) have improved fish passage and the environmental performance of remaining roads. Despite this important progress, understanding impacts of and reducing sediment production from forest roads and their hydrologic connections to streams remain key facets of sustainable forest management and aquatic and riparian resource protection on the ESRF. An ongoing priority for managers will be to monitor and mitigate sediment and other impacts stemming from roads while maintaining the road system and the access it provides for research, active management, and recreation. This section discusses how roads on the ESRF will be managed to meet these objectives in alignment with the ESRF HCP.

### 6.6.1 Road Upgrading, Decommissioning and Maintenance

A majority of ESRF roads are located on ridges and are hydrologically disconnected from riparian areas. However, most roads in the forest were built decades ago, prior to the development of modern BMPs. The outdated practice of side-cast road construction with relatively few cross-drain culverts has made some roads on steep slopes subject to washouts or landsliding during intense rainstorms. Over time, many of these vulnerable road segments failed and were repaired using best practices at the time. Others were modified prior to failure or were relocated or decommissioned (Biosystems et al. 2003).

Significant investments in maintenance and upgrades from the 1980s into the 2010s have improved the stability of the road network on the Elliott and the primary road system (ESRF HCP Figure 3.3 and FMP Section 1.3.1) is considered stable as of 2023. Improvements have been focused on roads near stream channels and riparian areas, toes of past landslide deposits, and steep, dissected slopes not conducive to full bench and end haul construction methods. Another priority has been to upgrade and replace culverts at stream crossings – often in coordination with local NGOs and watershed councils – to facilitate salmonid fish passage. Biosystems et al. (2003) identified 14 large stream crossings as fish passage barriers, most of which had been

replaced by 2015. All mainstem areas of the WF Millicoma River and Elk Creek have been upgraded with either bridges or large culverts (CoosWA 2015). Numerous road cross-drains have also been added throughout the primary road network (ODF 2016).

Biosystems et al. (2003) found that the Elliott road system reflected a high standard of maintenance at the time. Until about 2015, ODF maintained an average of 320 miles of road on the Elliott annually, primarily grading and augmenting of road surfaces, cleaning of ditches, catch basins and culverts, and monitoring of potential problem areas such as cut and fill slopes. This work was contracted at an average annual cost of approximately \$250,000, not including supplies of rock surfacing material. In a typical year, several miles of road were improved by upgrading drainage structures, adding new cross drains, and resurfacing with hard crushed quarry rock (ODF 2016).

*Decommissioning* is a term commonly used by forest management agencies and industry in reference to the closure to motorized travel, stabilization and restoration of unneeded forest roads to a more natural state, usually with a primary goal of minimizing risks of sediment delivery and damage to waterways.

Road decommissioning treatments include:

- blocking the road entrance
- revegetation and water barring
- removing fills and culverts
- establishing drainageways and removing unstable road shoulders
- full obliteration recontouring and restoring natural slopes.

These treatments are used in a wide range of combinations depending on road location, and the scope and scale of the objectives for decommissioning. In some cases, restoration may be achieved by blocking a road entrance. In other situations, objectives to restore hillslope hydrology may require full obliteration recontouring. Short of full decommissioning, roads with future needs but no current needs may be placed in *storage*- closed to motorized travel but preserved for future use (Apodaca et al. 2018). The ODF (2000) and updated 2022 Oregon FPA rules use the term *vacating* in reference to forest road closure, stabilization and restoration.

As of approximately 2010, most roads on the Elliott deemed suitable for decommissioning up to that time

had been decommissioned (Oregon DSL and ODF 2011). An assessment of roads in the WF Millicoma- Elk Creek subwatershed (CoosWA 2015) resulted in recommendations for decommissioning some additional roads in that area of the forest. With the shift to a research focus under the ESRF HCP, more roads or road segments on the ESRF are likely to be considered for decommissioning (vacating) in the future. These decisions will balance resource protection and conservation with the need to provide adequate access for management, research, fire protection, and recreation.

Despite being well-maintained, roads to access the ESRF for management, recreation and fire protection traverse steep terrain and cross many streams. Recent management (since approximately 2017) by the Department of State Lands has focused primarily on road maintenance and improvements, security, and maintaining public access. Owing to the steep terrain and historic nature of the road network, regular monitoring and maintenance, as well as continued investments in selective upgrading and road decommissioning (vacating), will continue to be needed to ensure that roads on the ESRF can provide necessary access, while impacts to water quality and riparian areas are minimized in accordance with the ESRF HCP.

### 6.6.2 Alignment with the ESRF HCP and Oregon FPA

Under the ESRF HCP, all road construction, maintenance, and vacating within the ESRF will be performed in accordance with restrictions placed by the Oregon FPA (OAR 629) and other applicable statutes, except for certain instances described in ESRF HCP Chapter 5, *Conservation Strategy*. As described in ESRF HCP Conservation Measure 3, the density of the forest road network on the ESRF will be reduced relative to current density. ESRF HCP Condition 12: *Road Construction and Management* (Section 5.5.13) includes a list of measures to be taken and guidelines to follow during construction of new roads and maintenance of existing roads on the ESRF.

No primary or secondary road construction, relocation, or vacating is currently proposed on the ESRF but under the ESRF HCP, many existing spur roads constructed to access prior cutting units are expected to be vacated in the future. Some new road spurs may be constructed to facilitate research-related stand management activities and some road segments may be relocated to disconnect them from aquatic features. Construction of up to 40 miles of new permanent roads are allowed over the 80-year ESRF

HCP permit term. Road locations and standards will be suitably matched to the terrain and type of access needed, with a focus on minimizing impacts to aquatic and riparian systems. Road crossings will be constructed to meet NMFS and ODFW fish passage requirements.

Under the 2022 Oregon FPA rules, to vacate a forest road landowners must close the road to vehicles and restore it to a condition where road-related damage to waterways is unlikely by:

1. Using outslowing, water bars, or storm-proofing to leave roads in a condition suitable to control erosion and maintain water movement within wetlands and natural drainages,
2. Leaving ditches in a suitable condition to reduce erosion, and
3. Removing water crossings.

To vacate a water crossing, landowners must remove all crossing structures and imported road fill, re-establish channel connectivity to meet ODFW fish passage requirements, and align the restored streambed and banks with the original natural upstream and downstream geomorphology as closely as possible. Restoration should ensure zero or near-zero road related hydrologic connectivity across the entire site, incorporate large wood, if appropriate, to expedite restoration of the channel and fish habitat, and include planting of exposed stream banks or valley walls with native trees or shrubs to promote development of a functioning riparian condition (OAR 629-625-0650.)

Under ESRF HCP Conservation Measure 3: *Reduce Road Network Density in the Permit Area*, the road network density will be reduced relative to current road density on the forest in 10-year increments by the end of the 80-year permit term. The ESRF HCP describes road vacating as making the road impassable and effectively closed, including stabilizing the roadbed surface and removing stream crossing structures and associated fill materials. This may include ensuring proper drainage, mulching or seeding exposed soil, and blocking road entrances using gates, excavation, boulders, or other means. Under the ESRF HCP, roads on the ESRF may be vacated if deemed non-essential to near-term future management plans, where access would cause excessive resource damage, or where existing resource concerns or ecological values including hydrologic connectivity can be improved. ESRF managers will determine which roads to vacate during project-level analysis. The location, method, specific timing, and rate of road density decreases will be based on actions set forth in Biennial Operations Plans

consistent with this HCP, the forest management plan, and 10-year planning projections reviewed and adopted by forest managers in coordination with the HCP Implementation and Adaptive Management Committee. The first 10-year planning period will begin after completion of the required road system assessment to be completed during the first 12 years of ESRF management. Vacated roads are to be left stabilized and with adequate drainage.

Decisions regarding roads to be vacated will depend on their utility and degree of resource concern and/or potential benefit, and will consider access for firefighting and recreation, active forest management, and the conservation goals and multiple management objectives associated with the ESRF. Temporary roads that have not been vacated after 5 years will be considered part of the permanent road network and count toward the 40-mile limit.

The updated 2022 Oregon FPA rules define four road types:

- *Abandoned roads*: Roads that were constructed prior to 1972 and do not meet the criteria of active, inactive, or vacated roads. This does not include skid trails.
- *Active roads*: Roads currently being used or maintained for the purpose of removing commercial forest products.
- *Inactive roads*: Roads used for forest management purposes exclusive of removing commercial forest products.
- *Vacated roads*: Roads that have been made impassable and are no longer to be used for forest management purposes or commercial forest harvesting activities.

The ESRF and its roads have a different and more diverse suite of purposes compared to most forest lands. The following four ESRF road classifications, with definitions tailored for management goals and to be consistent with the ESRF HCP, are proposed:

- *Primary roads*: Mainline roads that receive a high degree of use either by the public for recreation access, or by researchers, fire safety personnel, or for hauling forest products. These roads are primary arterial connectors in and out of the forest and receive routine maintenance.
- *Secondary roads*: Lightly trafficked roads that receive periodic public use and occasional use by researchers or for hauling forest products. These are either dead-end roads or connectors between primary roads and receive periodic maintenance as needed.

- *Stored roads*: Roads closed to regular motorized travel but stabilized and preserved for intermittent research use, or regular use in the future.
- *Vacated roads*: Roads that have been made impassable and are no longer to be used for forest management or research purposes or commercial forest harvesting activities.

These road classifications are provisional and subject to revision, both in allocation and definition, as the ESRF road inventory and phased adaptive implementation of the Triad research design progress.

Under the ESRF HCP, during the first 12 years of ESRF management, a formal assessment of the degree of hydrologic connections of current and legacy roads and their primary locations in the forest will be developed. Monitoring will identify candidate roads for modification to test methods for reducing hydrologic connections, restoring ecological function, and long-term monitoring of subsequent habitat impacts. In support of this, ESRF managers will: (1) maintain an inventory of the ESRF road network to identify current and legacy roads that present a risk to the aquatic and riparian system, (2) seek to implement modifications to the road system prioritizing segments that pose the highest risk to aquatic resources and, (3) use the inventory to track current and future road density.

Oregon FPA amendments of 2022 to implement the Private Forest Accord (PFA) also include rules regarding the *Forest Road Inventory and Assessment* (FRIA) process for existing roads. The goal for the FRIA is to reduce chronic and catastrophic sediment entry to waters of the state of Oregon and to ensure passage for PFA-covered species during all mobile life-history stages. This will be accomplished by identifying existing roads not meeting the Oregon Forest Practices Administrative Rules (FPR) and bringing those roads into compliance with the FPR by hydrologically disconnecting roads from waterways and mitigating barriers to fish passage.

The FRIA process provides a framework to address goals and objectives for roads that aligns well with ESRF HCP requirements for roads in the ESRF. The FRIA process includes several specific steps and deadlines, including:

- *Road pre-inventory*: Landowners shall submit a pre-inventory of high conservation value sites on each road management block to the State Forester no later than January 1, 2025 including (1), areas of known chronic sedimentation; (2) fish passage barriers known to be of significant concern; (3) ongoing stream diversions

at stream crossings and areas with stream diversion potential and; (4) areas of known hydrologic connectivity.

- **Road inventory:** Landowners shall submit an initial inventory of all active, inactive, and known vacated or abandoned roads no later than January 1, 2029 including:
  - A. Maps showing the roads within each road management block;
  - B. A work matrix documenting actions necessary to bring all roads into compliance with the FPR. The document shall include prioritization of work; and
  - C. A FRIA initial inventory plan describing how the landowner intends to bring the road network into compliance no later than January 1, 2044.
- **Road improvements:** Landowners shall improve all road segments identified in the initial inventory as not meeting the FPR so that those segments either meet the FPR or are vacated no later than January 1, 2044.

### 6.6.3 Road Inventory Methods and Baseline

The ODF will publish *Forest Practices Technical Guidance* for compliance with the FRIA process, currently anticipated in late 2023. CoosWA and partners utilized the *Geomorphic Road Analysis and Inventory Package* (GRAIP; Black et al. 2012, <http://www.fs.fed.us/GRAIP>) to inventory roads in the WF Millicoma River-Elk Creek subwatershed, quantify sediment production potential for each road segment, and support prioritization of road improvement projects (CoosWA 2015).

Developed by the USDA Forest Service and Utah State University, the GRAIP combines a road inventory with a powerful GIS analysis tool set to predict sediment production and delivery by individual road segment, mass wasting risk from gullies and landslides, stream diversion potential, culvert maintenance, and fish passage at stream crossings. Roads are systematically field inventoried using a hand-held GPS, a specific data dictionary and automated forms. Quality checked and corrected data are then imported into ArcGIS as shapefiles and analyzed.

The GRAIP tool estimates the quantity of sediment generated for each road segment by modifying a base erosion rate with road slope, segment length, flow path vegetation, and road surface type. Sediment at each road drain point is output as accumulated sediment in the entire network, direct sediment for each stream segment, and specific sediment per unit contributing area. Observations

of delivery at each drainage feature can also be used to calculate road-stream hydrologic connectivity.

The GRAIP model outputs are primarily useful for comparing differences between road segments and potential effects to streams when those road segments are directly connected. The GRAIP could be used to inform an expanded and updated road assessment on the ESRF, with the benefit of providing data consistent with that already obtained for the WF Millicoma River and Elk Creek and meeting or exceeding Oregon FPA requirements.

#### 6.6.3.1 ESRF Road Inventory Baseline

The ODF maintained a road inventory for the Elliott and analyzed roads in the late 1990s to support technical guidance on road-landslide interactions (Robison et al. 1999). Biosystems et al. (2003) included detailed assessment of forest roads and recommendations to reduce their potential to impact water quality. More recently, CoosWA and partners surveyed roads in the WF Millicoma River-Elk Creek subwatershed, as described above (CoosWA 2015).

Prior road inventory studies, monitoring and projects implemented within the Elliott provide a strong knowledge base regarding problems areas, maintenance backlogs, remedial actions, and priorities for road improvement. This baseline knowledge will be used to support the updated formal ESRF road inventory which will then guide the ESRF road strategy. A key focus of the ESRF road inventory will be to verify and build on earlier findings and recommendations for roads, and to assess the stability and effectiveness of previous improvements.

The 2003 Elliott State Forest Watershed Analysis (Biosystems et al. 2003) was a comprehensive study that included recommendations for specific roads and actions. Some, but not all of this work backlog was subsequently addressed by ODF managers in collaboration with local watershed councils.

The 2015 Coos Model Watershed Program Supplemental Action Plan (SAP) for the Millicoma Forks Coho Restoration Partnership (CoosWA 2015) provides analysis of salmonid habitat and road conditions to support restoration strategies for the East and West Forks of the Millicoma River. The SAP supplements the 2003 Elliott Watershed Analysis (Biosystems et al. 2003), the 2008 Coos Model Watershed Program (Souder 2008; Reeve and Warren 2015), and the CoosWA 2005-2015 Strategic Framework. The roads assessment focused on the WF Millicoma-



Elk Creek subwatershed and combined GRAIP analysis with measurements of culvert characteristics (perching, condition, fill volumes, etc.). Findings and processes used in the 2015 SAP for prioritizing road modifications to protect aquatic habitat within these drainages can inform similar work elsewhere on the ESRF and are summarized below.

### ***Hydrologic Connectivity***

According to CoosWa 2015, 17.8% of road segments in the WF Millicoma-Elk Creek subwatershed had drain points leading directly to a live stream. Road segments that end at a stream crossing are fully hydrologically connected. Of 4,452 drain points measured, only 804 (18%) were found to be directly connected to the stream system; with stream crossings and ditch relief points accounting for 60% of all connected points. Ditch relief culverts were found to have the most connected drainage points (26.9%), followed by water bars (15.1%), non-engineered (9.7%), and diffuse drains (8.3%), broad base dip (4.6%), and lead-off ditches (3.9%). The percentages of road segment length connected and drain points connected were nearly the same, 17.8% and 18% respectively.

### ***Road sediment***

The 8200, 7200, 8100, 7400, 1600, 8000, County (WF Millicoma Road), and 9000 had the greatest distances of road connected to a stream. These are all riparian roads (valley) adjacent to streams where there are usually very limited filtering zones. The 1000, 2600, 7200, 8000, 8100 and 8800 roads contribute the most sediment to streams.

### ***Stream crossing/culvert failure***

Stream crossing failure is a common source of catastrophic sediment input to streams, usually caused by undersized culverts. When prioritizing culverts for replacement, both failure risk and fill volume should be considered, since the fill becomes the sediment source upon failure of the crossing. Out of 131 stream crossing culverts in the WF Millicoma River-Elk Creek subwatershed ranked for ability to properly drain the area upstream during a 100-year flood, eighteen (12.3%) are considered at-risk for improper drainage or failure due to being undersized. Two culverts (on spurs of the 2000 and 7000 roads) have very high risk of failure, but minimal fill (10 yds<sup>3</sup>); six culverts have high risk, potentially releasing 414 yds<sup>3</sup> of fill; and five ranked moderate, potentially releasing 150 yds<sup>3</sup> of fill. The greatest number and fill volume of at-risk culverts are on the 1000 road adjacent to Marlow Creek. Two are at the headwaters

of Elk Creek on the 9000 road. Three more are in the headwaters of the WFMR, on the 8000 and the 8700 roads. The 7400 road has one culvert with a moderate risk of failure.

### ***Culvert plugging and water diversion***

Undersized culverts can also plug and divert water down the road surface, resulting in both surface erosion and the potential for fills to become saturated, then fail in a landslide. In these situations, there is a likelihood of more erosion from a failed stream crossing than just the road fill at the crossing.

### ***Fish Passage***

Fish passage restoration usually involves replacement of perched, undersized, or poor condition culverts. However, artificially steepened channels can also be barriers or impediments to passage. There are currently 12 impassable fish barriers and 22 partial barriers identified on the ESRF, with most of the barriers overlapping the Coos independent population of Oregon Coast coho (Oregon Department of Fish and Wildlife 2019). Approximately 16 miles of additional modeled fish habitat is available on the forest upstream of impassable culverts.

## **6.6.4 Road Maintenance and Fish Passage Prioritization**

Fundamental questions used to determine relative priorities for road improvement in the 2015 SAP that can be applied more broadly on the ESRF include:

- Is the road currently needed for current or future management? If not, then decommissioning would be indicated, and would be a relatively high priority.
- Does the road currently meet Oregon FPA rules for stream crossing culvert sizing and cross-drain spacing? If so, there is low priority for drainage-related road improvements.
- What is the road's slope position? Roads in different locations have different watershed impacts:
  - Roads along ridgelines typically are stable (unless they traverse colluvial hollows or headwalls)
  - Mid-slope roads are often at high risk for catastrophic fill failures because of culverts plugging and diverting flows
  - Riparian roads are more likely to be sources of chronic sediment delivery.

For *riparian-adjacent* roads, the following considerations affect relative project priority:

- What is the traffic level on the road? This is important because traffic breaks down the road surface and—during rain events—mobilizes and transports sediment off the road surfaces. Roads without traffic are more likely to be stable and vegetated.
- How much hydrologic connectivity is there between the road and streams? For riparian-adjacent roads, if there is no connectivity there is little risk of sediment entering streams, although there could be other effects (debris flow interruption; reduced riparian buffer; OHV access, etc.) that could potentially be mitigated with road upgrades.

For *mid-slope* roads, important prioritization considerations are:

- Can existing culverts pass 100-year storm flows as required by Oregon FPA? Climate change predictions are that winter storms will be more intense and frequent. One of the best—and most cost-effective—ways to reduce the risk of culvert failure is to upsize them.
- What is the fill volume at risk if the culvert fails? Upgrading culverts where large volumes of fill are at risk is a higher priority than those with little fill. Fill failure risk can be categorized into three fill classes: Less than 10 cubic yards; 11 – 99 cubic yards; and 100 cubic yards and greater.

Based on the GRAIP analysis and culvert surveys, the 2015 SAP developed a list of priority road improvement projects. Several involve road *stormproofing*, a suite of actions to reduce sediment production during heavy precipitation events. These actions include the addition of appropriate levels and placement of cross-drains, adequately sized stream culverts, including for seeps separate from road drainage, and high-quality aggregate surfacing along with appropriate road grading. Stormproofing also includes maintenance of roadside ditches with appropriate frequency—vegetation in ditches is beneficial up to a point, but not to the degree that it impedes and redirects flows onto the road surface. Cross-drains need to be maintained and marked so that they don't get crushed by the graders when the ditches are cleaned.

Questions used to determine relative priorities for restoring or enhancing fish passage in the 2015 SAP that can be applied more broadly on the ESRF include:

- Can the crossing be removed? If the crossing is not needed for current or future management, it is generally best for it to be removed and the fill stabilized.
- Does the crossing currently meet ODFW fish passage criteria? If it does, it is unlikely to be a high priority for replacement.
- Is there more than 0.1 miles of accessible habitat upstream from the crossing? In general, there should be sufficient habitat upstream to make the replacement cost effective if it's an isolated site. However, during road system upgrades any fish passage barrier or impediment should be removed as part of the project.
- Is the potential habitat quality in the stream above the crossing sufficient for high quality habitat (HQH) to potentially be restored? Similarly with the amount of habitat upstream, the habitat should be of sufficient quality to make the replacement cost effective, but the crossing could be included as part of a larger, systematic road upgrade project.
- Is there a significant volume of gravel and cobble bedload stored above the crossing? Undersized and perched culverts frequently store significant upstream bedload, which is usually liberated through head cutting after the crossing is replaced. This can then provide material needed for restoration of in-stream habitat complexity downstream.
- Can the project be combined with instream habitat restoration? Leveraging the availability of bedload, is the question about whether the fish passage project can be linked with either existing downstream instream habitat restoration, or if these projects can be installed simultaneously so that the bedload benefits are not lost.

#### **ESRF Roads Strategy: Near term (5-10 Years):**

- Initiate process to update forest road inventory, consistent with guidance in ESRF HCP and FPA (i.e., the FRIA and ODF technical guidance for complying with it), including identification and implementation of high conservation value projects in the first 5 years of FRIA. Utilize findings and recommendations from Biosystems et al. 2003 and CoosWA 2015 as a guide to highest priority areas for inventory and subsequent improvements.
- Develop or improve road inventory and data management systems such as GIS and other database applications to meet needs of ESRF HCP and FPA.
- Implement a road maintenance program based on known needs, resources and opportunities. Establish priority

actions that can be implemented prior to development of a complete forest road inventory.

- Consult with DSL forest staff, road maintenance contractor, Douglas Forest Protective Association and local WCs to identify and address any critical or urgent maintenance or ESRF road repair needs, prioritizing roads and segments necessary for fire protection.
- With partners (e.g., CoosWA), identify any critical, time-sensitive road restoration funding/projects already “in the pipeline”. Develop action plans for completing any such projects in ways that do not interfere with establishment of riparian restoration studies on the ESRF. Identify road segments that remain hydrologically connected to streams and prioritize these for modifications to reduce or eliminate those connections, starting with segments identified in CoosWA 2015.
- Review additional road restoration, maintenance, improvement priorities identified in 2003 and 2015.
- Identify additional candidate roads for decommissioning, starting with recommendations in 2003 WA, 2015 SAP and focusing on roads within the CRW. Consider the context of a research forest when reviewing candidate road segments.
- Identify and implement high priority maintenance or construction needs for scheduled harvest operations. Assess long-term harvest scheduling to ensure road access is available and sufficient to maintain flexibility in timing of harvest operations and responsiveness to opportunities or needs (e.g., markets, disturbance events, etc.).
- Develop a long-term road maintenance plan based on findings of road inventory. Plan will follow requirements and priorities outlined in ESRF HCP and FPA, including completing required road improvements within the allowable timeframe of the Oregon FPA.
- Establish contracting, budgeting and administrative processes for implementation of road projects.
- Identify, with partners, additional funding opportunities or partnerships for road improvements and mitigation of road impacts to resources.

## 6.7 Harvest Systems

This section provides an overview of equipment used in forest operations such as restoration, pre-commercial and

commercial thinning treatments, and variable retention or regeneration harvests. Several types of specialized machines are used in different combinations and configurations to make up the *harvest system*. Treatment objectives, stand structure and location, topography, environmental protection, safety, and economic considerations all come into play when designing the system. Decisions about the appropriate harvest system to use for individual silviculture treatments will be determined at the operational planning level based on the criteria above.

Timber harvesting typically includes tree *felling* then *processing* to remove branches and cut into logs of desired lengths, *extraction or yarding* of logs from the stand to the landing, *loading* of logs, usually onto a truck, and *transportation* of the logs to a mill or transfer point. (USDA Forest Service 2022.) Depending on treatment prescriptions, some restoration treatments may only involve felling of trees and sometimes moving them short distances, but rather than being transported offsite and utilized, the downed trees may be left onsite to provide ecosystem benefits.

### 6.7.1 Harvest Equipment

The principal types of equipment used in harvest systems are described in USDA Forest Service (2022) and below for each step in the harvesting operation:

#### 6.7.1.1 Felling and Processing

A *harvester* is a self-propelled machine with either wheels or tracks, and a cutting/processing head used to fell trees then delimb and cut them into desired lengths. Wheeled harvesters have four to eight wheels on a two-section, articulated chassis. The operator cabs on some harvesters have self-leveling capabilities and some are capable of rotating like an excavator style cab, while others are fixed in place. The boom may have a telescoping function to extend its reach. Tracked harvesters can operate on slopes up to 55%, while wheeled models are generally limited to less than 40% slope depending on soil conditions. Rough, broken terrain will reduce the slope angles on which harvesters can operate. One new hybrid design has an articulated chassis like wheeled harvesters but instead has two sets of tracks and can operate on much steeper slopes.

Harvesters operate on a slash mat of branches and tops that they generate and lay down as they work, allowing their use on wet or loose soils that would otherwise restrict operations. Wheeled harvesters can be fitted with a ‘track’ over the drive wheels, increasing traction and decreasing

ground pressure. The size of tree that can be harvested is limited by the capacity of the cutting head and weight of the machine. Harvesters can operate in any type of treatment that allows them enough room to maneuver and cut trees. Compared to smaller tracked harvesters, wheeled harvesters are less nimble but have longer booms and can reach further into the stand. Stand density and the size of trees being cut must be aligned with the appropriate type of harvester. In general, if the harvester can move between the trees it can operate safely and with little damage to residual trees.

A *feller buncher* is a self-propelled machine (wheels or tracks) with a cutting head that can hold more than one tree at a time. Feller bunchers do not have processing (e.g., delimbing and bucking) capabilities. The cutting head is used strictly for cutting, holding, and placing tree stems on the ground. Tracked machines are slower than wheeled machines but are often more stable on steep slopes. Tracked feller bunchers can also operate on wet and loose soils where rubber-tired machines would be prevented from operating. Feller bunchers may have self-leveling cabs that allow operation on steeper slopes. A *drive to tree* feller buncher is a rubber-tired machine with the cutting head mounted directly to the carrier. The whole machine drives up to each tree to cut it. A *swing boom* feller buncher is a tracked machine with the cutting head mounted on a boom and does not have to drive up to each tree to cut it.

Tracked feller bunchers with self-leveling cabs can operate on slopes up to 50%. Wheeled feller bunchers should be restricted to slopes below 25%. Tracked machines have a lower ground pressure than wheeled equipment and are less prone to rutting and compaction. Feller bunchers are a good option where removal of biomass is desirable and stems to be removed fall within the suitable range of the bunching head.

*Manual chainsaw felling and processing* is generally not limited by slope, tree size, or soil conditions and is considered feasible for any type of treatment. Its major disadvantages are the high risk of serious accidents and low productivity compared to mechanical options. Chainsaw operators are in danger from falling objects and fatigue. Fatigue can be caused by the vibration and noise produced by the chainsaw as well as constantly walking and working in rough terrain. Falling objects include not only the tree itself, but also limbs and small trees knocked down by the falling tree. Operating in windy conditions increases this danger to the operator.

### 6.7.1.2 Extraction/Yarding

A *skidder* extracts whole trees or processed long logs from the stand by dragging them to a landing or roadside. *Wheeled* skidders have an articulated chassis with the cab and engine mounted on the forward articulation and either a cable drum and arch or grapple on the rear articulation. *Tracked* skidders may be modified construction crawlers or purpose-built. They use either a grapple or cable to skid trees. Compared to wheeled skidders, tracked skidders have more pull per horsepower and lower ground pressure. Tracked skidders are generally used where large loads are being pulled up steeper slopes.

*Forwarders* are articulated machines that extract processed short logs from the stand fully suspended in bunks. They are essentially tractors pulling a wagon load of wood. Forwarders have up to eight wheels and many have a boom-mounted grapple for loading and unloading logs. The cab may be fixed or able to rotate on the chassis. Traction and flotation can be increased by adding tracks that slide on over the dual wheels or by opting for wider tires. Forwarders are typically operated with a harvester capable of producing cut to length material. The harvester is also capable of stacking the processed logs near a skid trail accessible to the forwarder. Forwarders are in general more expensive than skidders. Forwarders are usually used in fully mechanized systems where all workers are enclosed in cabs and generally protected from falling or flying debris.

*Track mounted log loaders or “shovels”* are used to move logs from the woods to landings by making multiple passes through a harvest unit, using a large boom and grapple to pick up and swing logs toward the landing with each pass. Shovel logging is often paired with feller-bunchers, which allows the shovel to move large bunches of logs without requiring excessive machine travel. Shovel logging avoids ground disturbance associated with skidding of logs.

*Cable yarding* involves the use of a cable-based system to transport logs from the stand to the landing. Cable yarding systems are typically used where steep slopes do not allow ground-based extraction equipment to operate safely or where ground conditions do not permit travel by ground based extraction equipment. The cables are strung in corridors through the stand. Logs may be fully or partially suspended for all or a portion of the yarding distance. No yarding equipment other than the cables and a carriage are operated within the stand itself. Cable yarding consists of many components that affect the planning and design of an operation. The basic components are the yarder and



the carriage. The type of yarder and carriage available will determine the type of cable system that can be used. Manual felling is often used with cable extraction due to the inability to operate mechanical equipment in the stand. In some cases, mechanical felling and processing with tethered equipment may be used where soil conditions and terrain permit.

### 6.7.1.3 Helicopter Yarding

*Helicopter yarding* is incredibly versatile and mitigates or avoids many challenges associated with ground-based and skyline yarding systems, including site sensitivity and environmental impacts, lack of access, and slope of the terrain. The main drawbacks to helicopter logging are high operational costs, and fixed costs to move helicopter support in and out of the harvest unit. Thus, use of helicopters is often not cost effective for harvests that do not efficiently produce significant volumes of high-value merchantable timber.

### 6.7.1.4 Log Loaders

Log sorting, stacking and loading are usually accomplished using a hydraulic *loader*. Wheeled loaders can move quickly around the landing area. Tracked loaders are slower but more stable. Trailer mounted loaders are moved into place by tractor then remain in place for the duration of the harvest. *Knuckleboom* loaders are swing machines with specially designed booms for handling logs and may be tracked, wheeled, or trailer mounted. Knuckleboom loaders have fast hydraulics for quick swing and boom movement. The grapples are pin mounted with a rotator to help position logs for loading.

### 6.7.1.5 Harvest Systems

The types of equipment described above are used in various combinations of harvest systems tailored to ground conditions and treatment prescriptions. Systems that could potentially be deployed on the ESRF include:

Ground-based whole-tree systems

- Feller-buncher (felling) + skidder (extraction)
- Feller-buncher (felling) + shovel (extraction)

Ground-based cut-to-length system

- Harvester (felling) + forwarder (extraction)
- Harvester (felling) + skidder (extraction)

Whole-tree cable systems for steep slopes

- Chainsaw (felling) + cable yarder (extraction)
- Tethered feller-buncher (felling) + cable yarder (extraction)

Tethered cut-to-length systems for steep slopes

- Tethered harvester (felling) + tethered forwarder (extraction)

### 6.7.1.6 Tethered Logging Systems

*Tethered* logging systems utilize cable winch systems on harvesters, feller-bunchers, forwarders, log loaders, and skidders to stabilize and assist equipment operations on steep slopes. These tethered systems improve traction and reduce wheel or track slip on forestry machines by shifting some of the propulsive or braking force from the wheels or tracks to the winch cable that is attached to an anchor further upslope. The cable system allows the equipment to operate on slopes that would normally be considered unsafe for equipment or damaging to soils. Drums on currently available winch systems hold 1,000-2,000 feet of cable, roughly the distance that equipment can be lowered into the stand.

Over the past decade, tethered logging systems have been rapidly developed and adopted and are now considered one of the major recent innovations in steep terrain harvesting. At first, efforts to improve soil protection and the ability of harvesting equipment to move on steep terrain motivated development of tethered systems. However, increased worker safety and cost reduction have now emerged as primary drivers in the rapid expansion of the technology. A recent comprehensive review (Holzfeind et al. 2020) found that the extent of rutting, subsequent erosion, and soil compaction after working with tethered systems was similar to operations on gentle terrain or cable logging. They also found that tethered systems are often more productive than conventional systems and could allow economically and environmentally viable harvesting in areas previously considered to be marginal for it. Holzfeind et al. (2020) concluded that because tether technology is quite new and still evolving, there are major knowledge gaps regarding its social, environmental, and economic benefits and limitations and an urgent need for research to address these gaps.

#### *Tethered Logging and Research on the ESRF*

These findings and trends regarding tethered harvest systems are highly relevant to the ESRF for at least three reasons. First, the forest has abundant steep terrain, so the technology is likely to be an excellent option in many stands

where restoration treatments and harvests are planned. Second, tethered systems allow the use of mechanical equipment on slopes that normally require manual chainsaw felling. The system keeps personnel in a cab with its associated safety features, minimizing exposure to unsafe conditions encountered when manual felling. Third, in view of evidence that tethered harvesting is being rapidly adopted in the industrial forestry sector, including in the Oregon Coast Range and elsewhere in the PNW, use of the technology on the ESRF would offer a range of opportunities for research to fill the critical knowledge gaps regarding its use outlined above. Research of tethered harvest systems on the ESRF to look at their safety and economic benefits as well as environmental impacts could fairly quickly start expanding the frontiers of knowledge to optimize the use of this emerging and increasingly important technology.

In addition, steep slope mechanized harvesting through tether technology will allow us to take advantage of other smart technologies that are currently being built, such as machine vision and sensor technologies for real-time tree detection and measurement. We plan to customize our machine vision technology (patent pending by OSU and USDA Forest Service) to detect tree species and knots and incorporate available acoustic sensors to measure wood stiffness during tree harvest. This real-time information on wood properties will facilitate segregation of eligible trees for different wood products (e.g., mass timber and structural-use panels), optimizing wood handling and transport logistics. These technological advances will promote climate resistance and resilience by modernizing and expanding active forest restoration - often not cost effective under existing practices – and the marketing of resulting wood fiber.

### 6.7.2 Equipment Limitation Zones (ELZs)

Use of ground-based and cable yarding equipment will be limited within 35 feet of Oregon FPA-defined stream types (OAR 629-600-0100; Type F, SSBT, N, Np, and Ns streams) in accordance with Oregon FPA and to further promote the ecological function of RCAs and streamside processes. ESRF stream delineations extend beyond the distal extent of Oregon FPA stream definitions, and approximately 900 miles of XNFB streams do not meet the Oregon FPA-defined stream type definitions for Type F, SSBT, N, Np, and Ns streams (ODF State Flow Line digital map, June 30, 2023). XNFB streams that do not meet Oregon FPA stream definitions are not subject to the Oregon FPA ELZ requirement.

ELZs along Oregon FPA-designated stream types are intended to protect ecological functionality by limiting ground disturbance from equipment operation directly within these zones. The limitation on equipment operation includes yarding operations, but does not exclude the direct cutting and removal of trees from this zone. The ELZ will cover the areas within 35 feet of the stream types and will be maintained on both sides. ELZs will comply with the following measures to minimize ground disturbance and associated impacts to aquatic systems.

- Operators shall minimize disturbance from cable yarding and ground-based equipment operations near Oregon FPA-defined streams. When soil disturbances from cabled logging and ground-based operations exceed 20 percent and 10 percent, respectively, of the total area within any ELZ associated with an Oregon FPA-defined stream in an operational unit, operators shall take corrective actions consistent with Oregon FPA regulations and technical guidance.
- Disturbed areas shall be visually estimated in the field by operators or foresters; a specific monitoring or reporting protocol will not be required for disturbances in ELZs requiring corrective actions. However, disturbance exceedances will be monitored and reported consistent with Oregon FPA standards, summarized as part of biennial reports, and recorded during general ESRF HCP compliance monitoring efforts.
- Corrective restoration actions shall be designed to replace the equivalent of lost ecological functions. Examples include, but are not limited to, water bars, grass seeding, logging slash, mulching, and downed log placement. Onsite materials will be utilized whenever possible.





# Chapter 7

## Aquatic and Riparian Systems

Streams, lakes, wetlands, and springs are the lifeblood of forested watersheds, and the riparian ecosystems in which these features are embedded are among the richest and most productive areas of the forest. Streams transport nutrients, sediment, and large wood from the forest headwaters to downstream ecosystems, supporting connectivity and vital ecosystem functions across the watershed.

This chapter provides details on how aquatic and riparian systems in the ESRF will be classified, protected, and restored through experimental and adaptive approaches, and includes guidance for implementation. Sections include (7.1) stream network delineation; (7.2) ESRF riparian conservation strategies; (7.3) roads and aquatic systems, (7.4) descriptions of proposed aquatic and riparian restoration experiments, and (7.5) additional stream restoration and stream assessment activities.

Examples of proposed riparian and aquatic systems research (pending adequate funding) are provided in Appendices 2, 3, and 6 of the ESRF Research Proposal (OSU College of Forestry 2021). These research examples are not an exhaustive list, but rather an overview of priority research identified during the initial research platform design phase. Over time, it is expected that additional riparian and aquatic system research questions will be identified that address emerging or heretofore unrecognized issues and research subjects, including research topics identified through partnerships with Tribal Nations and through application of the adaptive research implementation strategy.

Monitoring of changes in aquatic and riparian ecosystems over time in response to natural processes and upland management is critical to the mission of the ESRF. The details of long-term aquatic and riparian monitoring to assess ecosystem changes and to meet ESRF HCP requirements are provided in Chapter 10: *Monitoring*.

## 7.1 ESRF Stream Network Classification and Riparian Buffer Delineation

The availability of LiDAR and LiDAR-derived products have transformed the mapping and inventory of forest landscapes and ecosystems, and this field continues to develop. Although older mapping products are still in use, such as optically derived topographic maps and the associated stream delineations that have until recently been used for administration of the Oregon FPA, these products are being replaced by LiDAR-derived products as LiDAR becomes more widely available. Similarly, currently available LiDAR products are expected to be replaced by higher-resolution LiDAR data and new remote-sensing technologies. For example, aquatic and riparian planning for the ESRF Research Proposal (OSU College of Forestry 2021) was performed using LiDAR products from the 2009 South Coast LiDAR acquisition (DOGAMI 2009). LiDAR data acquired in 2021 (DOGAMI 2021) offer both higher spatial resolution and additional data elements, and the ESRF stream network will be refined using these newer data.

### 7.1.1 Stream Network Delineation

OSU's current (as of 2023) delineated stream network is based on a 2-meter bare earth digital elevation model

(DEM) derived from the 2009 LiDAR data. The DEM was conditioned to eliminate spurious water flow barriers (e.g. roads at stream crossings), and the stream network delineated following the methodology described by Miller et al. (2015). In nearly all cases the delineated stream network extends further upslope than do administrative delineations, such as Oregon Department of Forestry (ODF) and National Hydrography Dataset (NHD) stream delineations. The extended stream network employed here is intended to identify areas of convergent topography susceptible to debris flow traversal, including features such as zero-order basins and bedrock hollows that may show little or no evidence of fluvial erosion. In the context of debris flow processes these upper reaches of the delineated stream network represent debris flow traversal corridors, whereas adjacent un-delineated hillslopes represent potential shallow translational landslide (STL) source areas.

As currently modeled, the ESRF delineated stream network has a total delineated stream length of 2,108 miles. It is important to recognize the difference between OSU's delineated stream network described here and other administrative or regulatory stream definitions, such as the ODF stream layer used for administration of the Oregon FPA. For example, the recently revised (June 30, 2023) ODF stream layer encompasses approximately 1,192 miles of stream on the ESRF, 916 fewer miles than OSU's stream layer. Most of this difference is attributable to first-order and zero-order streams at the distal ends of the stream network that are identified in the OSU stream layer as XNFB streams, but are not identified in the regulatory ODF stream layer. Although the ODF regulatory stream layer has been updated using LiDAR-derived stream delineations, the regulatory definition of a stream (e.g. a defined stream channel created by fluvial action) nevertheless constrains the regulatory stream network to a subset of streams recognized in the OSU stream layer. Moreover, stream classifications used for administration of the Oregon FPA (e.g. fish presence, perenniality, debris flow probability) may not coincide precisely with classifications employed by OSU.

### 7.1.2 ESRF Stream Classifications

Each stream segment of the ESRF stream network is assigned attributes according to relevant biophysical and administrative characteristics. Biophysical characteristics include attributes such as stream gradient, mean annual streamflow, taxa present, or habitat suitability indices. Administrative classifications are often based on biophysical stream attributes, but are modified or constrained to serve



administrative purposes. It is important to be clear about the construct classifications represent and the purposes they serve. For example, fish presence may be an observed biological attribute, a modeled biological attribute, or a regulatory (administrative) attribute. Regulatory attributes, such as Type F and Type SSBT streams of the Oregon Forest Practices Rules (OFPR; OAR 629-600-0100) may be based on observed or modeled fish presence, but have specific regulatory definitions and applications, and may not be equivalent to other definitions of fish presence. By comparison, modeled fish presence employed during planning for the ESRF is intended to represent both observed fish presence and potential fish habitat, recognizing that fish may not be present in a given stream reach at all times, but does not have the same regulatory function as do the OFPR stream definitions.

Two key administrative stream attributes used for the specification of Riparian Conservation Areas (RCAs) are watershed protection zone (described below in Section 7.1.2.1), which reflects the research and protective status of the watershed in which a stream segment is located, and stream protection class (described below in Section 7.1.2.2), which is based on biophysical attributes of each stream segment.

### 7.1.3 Watershed Protection Zones

In the ESRF Research Proposal, *Stream Protection Zones* were organized primarily with respect to delineated watersheds of the ESRF, and were classified according to (1) whether they are part of the Conservation Research Watersheds (CRW) or the Management Research Watersheds (MRW); (2) whether they are a full research watershed or a partial (i.e. partial ownership) watershed and; (3) whether they are, or are not, tributary to the mainstem of the WF Millicoma River downstream of Elk Creek. This classification structure was modified to account for allocation changes made during development of the ESRF HCP and addition of the Hakki Ridge parcel to the ESRF planning area. The resulting six *Watershed Protection Zones* characterize the general land allocation structure of the forest and define protections afforded to streams within each Watershed Protection Zone (Figure 7.1).

The Triad research watersheds comprise 40 watersheds fully within ESRF boundaries that support the core Triad research platform. There are two Watershed Protection Zones within the Triad research watersheds; one zone comprises 16 Triad research watersheds tributary to the mainstem of the WF Millicoma River downstream of Elk Creek, and the other

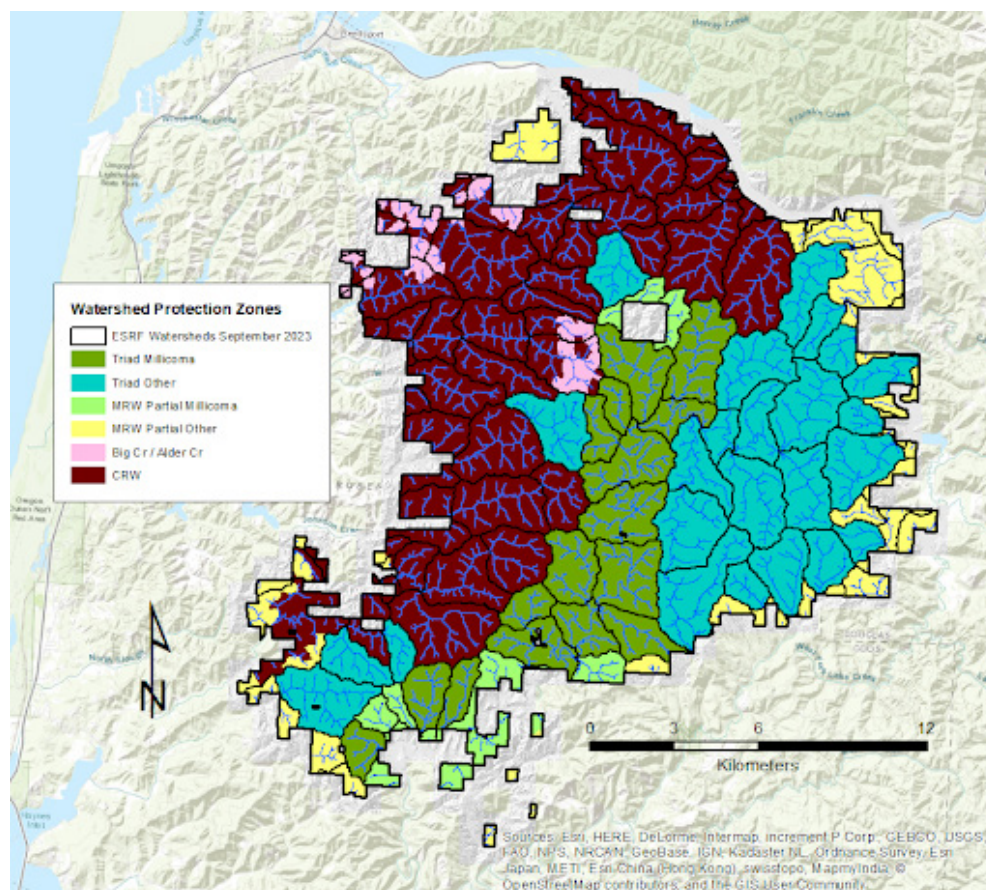
comprises the remaining 24 Triad research watersheds that are not tributary to the WF Millicoma River downstream of Elk Creek. The Conservation Research Watersheds (CRW) comprise a third Watershed Protection Zone, and include both full and partial-ownership watersheds. Within the general boundaries of the CRW are the Upper Big Creek and Alder Creek allocations, which together form the Big Creek/Alder Creek zone. Partial-ownership watersheds in the Management Research Watersheds tributary to the WF Millicoma River form the MRW Partials-Millicoma zone. The balance of the MRW partial-ownership watersheds occur along the eastern and southern boundary of the ESRF and are not tributaries to the Millicoma, along with the Hakki Ridge parcel, form the MRW Partials - Other Watershed Protection Zone (Figure 7.1).

### 7.1.4 Stream Protection Class

Four administrative *Stream Protection Classes* were specified for development of the ESRF Research Proposal (OSU College of Forestry 2021): *Fish-bearing streams* (FB), *wood-delivery non-fish-bearing streams* (WNFB), *perennial non-fish-bearing streams* (PNFB), and *other non-fish-bearing streams* (XNFB).

***Fish-bearing streams (FB):*** ESRF's FB protection class follows the Oregon FPA regulatory definition of fish-bearing streams: "[streams] inhabited at any time of the year by anadromous or game fish species or fish that are listed as threatened or endangered species under the federal or state Endangered Species Act" (OAR 629-600-0100[46]). This definition encompasses the upstream limit of resident cutthroat trout (*Oncorhynchus clarkii clarkii*) in Oregon Coast Range stream networks. Notably, the presence of cutthroat trout typically extends further into headwater streams than any other fish species, including non-game fish such as sculpin. Based on eDNA (Penaluna et al. 2021) and electrofishing (Latterell et al. 2003) studies of habitat limits for resident cutthroat trout, fish-bearing streams on the ESRF are defined to be any stream with a downstream gradient of 20% or less and a mean annual streamflow of greater than 0.005cms.

***Wood-delivery non-fish-bearing (WNFB):*** WNFB streams are any non-fish-bearing stream (perennial or non-perennial) that are modeled to deliver greater than a threshold quantity of large wood to fish-bearing streams by debris flow processes. Based on a wood recruitment model described by Carlson and Miller (2023) non-fish-bearing streams were ranked according to their respective modeled annual wood recruitment contributions to FB streams. The top-



**Figure 7.1.** Watershed Protection Zones on the ESRF as of October 2023. Watershed Protection Zones provide the framework for specifying protections that apply to each Stream Protection Class.

ranked streams that account for 25% of total non-fish wood recruitment to FB streams are classified as WNFB.

**Perennial non-fish-bearing (PNFB):** PNFB is an administrative stream protection class, and is a subclass of all perennial streams. Perennial streams, in general, have flowing water throughout the year. As a technical standard we define perennial streams to be streams with a greater than 80% probability of non-zero streamflow during the driest three months of the year (August, September, and October). Based on an analysis of the flow duration of streams on the Siuslaw National Forest (Clarke et al. 2008), we specify streams with a contributing watershed area greater than 6.2 hectares (approximately 15 acres) to be perennial streams. Using this 6.2-hectare perenniality threshold there are a total of 483 miles of perennial stream on the ESRF; of these, 238 miles are classified as FB streams, 65 miles are classified as WNFB streams, and 180 miles are classified PNFB streams. Although all FB streams

on the ESRF are perennial streams, PNFB streams, as an administrative stream protection class, are presumed to be absent of fish (see FB classification above), and are not otherwise classified as WNFB streams.

**Other non-fish-bearing (XNFB):** XNFB are streams not otherwise classified as FB, PNFB, or WNFB. XNFB streams may be *intermittent* (consistent flow during the wet season) or *ephemeral* (flow only during or immediately following significant precipitation). XNFB streams are typically located in the distal regions (i.e. headwaters) of the stream network, but may include small tributaries throughout the stream network. In many instances XNFB streams may not have a defined stream channel and therefore do not meet the regulatory definition of a stream (e.g., OAR 629-600-0100[“channel”]). Thus, only a subset of XNFB streams are identified in the current (June 30, 2023) ODF regulatory stream layer.

**Table 7.1.** Length (miles) of delineated stream on the ESRF by watershed protection zone (see Figure 7.1 above) and stream protection class: FB: *Fish-bearing streams*. WNFB: *Wood-delivery non-fish-bearing*. PNFB: *Perennial non-fish-bearing*. XNFB: *Other non-fish-bearing*.

Stream Protection Class	Watershed Protection Zone						ESRF Total
	Big Cr / Alder Cr	CRW	MRW Partial: Millicoma	MRW Partial: Other	Triad: Millicoma	Triad: Other	
FB	3.7	88.3	8.0	12.8	50.9	73.8	237.5
PNFB	3.8	67.3	6.9	22.6	32.2	48.2	181.0
WNFB	2.5	46.3	2.4	3.4	7.0	15.4	77.0
XNFB	45.2	662.9	63.3	161.4	246.3	433.1	1612.2
Zone Total	55.1	864.8	80.6	200.1	336.4	570.5	2107.7

## 7.2 Riparian Conservation Strategy

The ESRF riparian conservation strategy is comprised of seven distinct but related components:

1. Land use allocation
2. Modeling and monitoring of wood recruitment processes
3. Protective measures and operational constraints within Riparian Conservation Areas
4. Protection strategies for steep slopes and headwater streams
5. Restoration treatments in Riparian Conservation Areas (RCAs)
6. Minimizing hydrologic connectivity with roads
7. Partnerships with other groups and institutions, including Tribal Nations, watershed councils, NGOs, and state and federal agencies

These seven conservation strategy elements are each detailed below.

### 7.2.1 Land Use Allocation and Arrangement

Land use allocations are a primary component of the ESRF aquatic and riparian conservation strategy. Riparian Conservation Areas (RCAs) are technically an allocated land use, but are discussed as a separate conservation strategy in Section 7.2.3 below. The non-RCA land allocations cover the balance of the ESRF landscape, and include allocations with primary objectives that range from species conservation to commodity timber production. RCAs and the aquatic ecosystems within them are embedded in this matrix of terrestrial land allocations, and are interconnected with the conditions and ecosystem processes that occur there. Thus, upslope (i.e. non-riparian) land allocations play a major role in the functioning of riparian and aquatic ecosystems.

There are a multitude of potential upslope management actions represented in the terrestrial land allocations employed on the ESRF, all of which in some way will inevitably affect downslope riparian and aquatic ecosystems. Discussion of these upslope management regimes is framed in terms of six primary land allocations: *CRW Reserves*, *MRW Reserves*, *CRW Thin*, *Intensive*, *Extensive/VRH*, and *Flex50*.

## CRW Reserves

At the landscape scale, the 33,440 acre CRW forms a cornerstone of the ESRF conservation strategy by establishing a contiguous area managed for the conservation of native ecosystems and ecological processes that is supported by restored and undisturbed terrestrial, riparian, and aquatic ecosystems. Within the CRW site-disturbing research and management activity will be limited to projects intended to benefit the long-term conservation of native biota (e.g., restoration thinning to enhance forest complexity, stream restoration projects, road decommissioning, etc.).

## CRW Thin

During the first two decades of implementation of this FMP (i.e. years 2024 to 2043) restoration thinning is planned for approximately 5,600 acres of Douglas-fir plantations in the CRW that are not also part of the CRW RCA. Maintaining the function of ecosystem processes linking upslope conditions with downslope riparian and aquatic ecosystems for the benefit of coho salmon will be a primary consideration in determining appropriate silvicultural guidelines and harvesting systems in these areas.

## MRW Reserves

In the MRW, RCAs themselves are embedded in a matrix of other land use allocations that includes reserves, intensive, extensive, and non-Triad hybrid allocations, such as the “Flex50” allocation. In areas where RCAs abut upslope protected allocations, effective stream protections extend beyond the RCA boundary to the upslope edge of the protective allocation; thus, in much of the MRW, reserves provide additional stream protections beyond those provided by RCAs alone. XNFB streams have no designated RCA; nevertheless, many XNFB streams are situated within a protective allocation, including reserves and RCAs on protected stream classes. Forest-wide, 58% of XNFB stream miles are within a protected allocation (Table 7.3).

## Extensive

Extensive allocations provide the opportunity to target areas of retention on steep slopes or XNFB streams with debris flow potential that are not otherwise protected. Retention areas may also be used to supplement existing RCAs. There are 275 miles of XNFB streams within extensive allocations.

Sensitive streams will be protected using aggregate and single tree retention to provide shade, sources of large wood, and colluvial channel stability.

## Flex50

The Flex50 allocation is intended to provide operational flexibility and, as implemented, will likely be a blend of the intensive and extensive/VRH silvicultural systems. Intensive treatments in the Flex50 category will be managed using a 60-year rotation. As with extensive allocations, retention silvicultural systems will be used to protect steep slopes and XNFB streams.

## 7.2.2 Conservation and Modeling of Wood Recruitment Process

The aquatic and riparian research strategy for the ESRF recognizes the importance of large wood recruitment processes given the value of large wood (defined as dead wood within the bankfull stream channel that is >1m in length and >10 cm diameter) as a key habitat element in aquatic and riparian ecosystems, as a mediator of ecological and morphological processes, and as an indicator of the integrity of ecological function. Typically, most large wood recruited to streams comes from channel-adjacent sources through tree mortality, bank erosion, and localized landslides (Figure 7.2). However, episodic debris flows that travel through steep and constrained non-fish-bearing channels can deposit substantial quantities of accumulated large wood and sediments into fish-bearing streams. These deposits of large wood and sediments can create patches of high complexity habitat that may persist for decades (May and Gresswell 2003; May 2002; Bigelow et al. 2007; Reeves et al. 2003). Based on the work cited above, and because of the steep topography, wet climate, strongly constrained and dissected morphology, and weak (Tyee) sandstone/siltstone lithology, debris flows are expected to be a primary source of large wood and sediments such as spawning gravels for fish-bearing streams on the ESRF. Wood recruitment models will be employed that incorporate debris flow processes into wood recruitment estimates, such as that described by Carlson and Miller (2023), to evaluate potential wood recruitment protected under alternative management strategies.





**Figure 7.2.** Large wood is a key habitat element in aquatic and riparian systems.

### 7.2.3 Delineation of Riparian Conservation Areas (RCAs)

Riparian Conservation Areas (RCAs) vary in width according to stream protection class and watershed protection zone (Table 7.2). The maximum RCA width (200 feet, horizontal measure) shown in Table 7.6 is based on the estimated average site-potential-tree-height (SPTH) for the ESRF of 240 feet (vertical distance, based on LiDAR-derived tree heights). Following the Forest Ecosystem Management and Assessment Team report (FEMAT 1993), the influence of a tree on aquatic ecosystems is a function of its height measured in terms of slope distance across the forest floor. Assuming an average riparian slope gradient for the ESRF of 34 degrees, 240 feet SPTH (slope distance) is converted to 200 feet (horizontal distance) for representation in orthographic projections (e.g., maps, GIS). Accordingly,

RCA widths are measured as horizontal distance from the bankfull edge of the stream or the distal edge of the channel migration zone (where a channel migration zone is evident), perpendicular to the stream channel away from the stream and into the adjacent forest. Horizontal-measure RCA widths (Table 7.6) will be converted to slope distance based on site-specific conditions during field layout of RCA boundaries.

RCA widths shown in Table 7.6 are commitments documented in the ESRF Research Proposal (OSU College of Forestry 2021) and in the ESRF HCP. Buffers on FB streams in the “Triad: Other” watershed protection zone have a nominal width of 120 feet. However, a buffer width of 100 feet (minimum) may be applied to FB streams in this protection category, provided the areal difference between the 100-foot applied buffer and the 120-foot nominal buffer is used for, or added to, riparian protections elsewhere in

**Table 7.2.** ESRF stream miles sorted by ESRF *stream protection class* and ESRF *allocation class*. All FB, PNFB, and WNFB streams have RCAs of specified widths. Although RCAs are not specified for XNFB streams are not protected by an RCA, 932.4 miles of XNFB streams are situated within a protective allocation (i.e. MRW reserves, CRW, or RCAs on protected streams).

ESRF Stream Protection Class	ESRF Stream Miles by ESRF Allocation Class					
	Intensive	Extensive/ VRH	Flex50	CRW Thin	Reserves/ RCA	Class Total
FB	0	0	0	0	237.5	237.5
PNFB	0	0	0	0	181	181
WNFB	0	0	0	0	77	77
XNFB	175.3	275.2	109.9	119.4	932.4	1,612.20
All Stream Classes	175.3	275.2	109.9	119.4	1,427.90	2,107.70

**Table 7.3.** ESRF stream miles sorted by ESRF stream protection class and ESRF allocation class, expressed as *percent of stream miles by ESRF stream protection class*. 100% of all FB, PNFB, and WNFB stream miles are within RCAs, as specified in Table 7.2. Approximately 58% of all XNFB stream miles are situated within protective allocations and approximately 11% of XNFB streams are situated within intensive management allocations.

ESRF Stream Protection Class	ESRF Stream Miles by ESRF Allocation Class (% of class total)					
	Intensive	Extensive/ VRH	Flex50	CRW Thin	Reserves/ RCA	Class Total
FB	0.0%	0.0%	0.0%	0.0%	100.0%	100.0%
PNFB	0.0%	0.0%	0.0%	0.0%	100.0%	100.0%
WNFB	0.0%	0.0%	0.0%	0.0%	100.0%	100.0%
XNFB	10.9%	17.1%	6.8%	7.4%	57.8%	100.0%
All Stream Classes	8.3%	13.1%	5.2%	5.7%	67.7%	100.0%

**Table 7.4.** Oregon FPA stream miles sorted by *FPA stream type* and *ESRF allocation class*. All FPA Type F streams are situated within RCAs with widths specified according to Table 7.2.

OFPA Stream Type	OFPA Stream Miles (September 2023) by ESRF Allocation Class					
	Intensive	Extensive/ VRH	Flex50	CRW Thin	Reserves/ RCA	Type Total
Type F	0	0	0	0	181.4	181.4
Type Np	0.2	0.3	0.1	0	61.8	62.4
Type Ns	66.6	107.7	41	52.8	679.8	947.9
All Stream Types	66.8	108	41.1	52.8	923	1,191.70

**Table 7.5.** Oregon FPA stream miles sorted by FPA stream type and ESRF allocation class, *expressed as percent of streams miles by FPA stream type*.

OFPA Stream Type	OFPA Stream Miles (September 2023) by ESRF Allocation Class (% of class total)					
	Intensive	Extensive/ VRH	Flex50	CRW Thin	Reserves/ RCA	Type Total
Type F	0.0%	0.0%	3.4%	0.0%	100.0%	100.0%
Type Np	0.3%	0.5%	3.4%	0.0%	99.0%	100.0%
Type Ns	7.0%	11.4%	3.4%	5.6%	71.7%	100.0%
All Stream Types	5.6%	9.1%	3.4%	4.4%	77.5%	100.0%



**Table 7.6.** RCA Width (each side of stream) by *Watershed Protection Zone* and *Stream Protection Class*. (FB: fish-bearing streams. WNFB: Wood-delivery non-fish-bearing. PNFB: Perennial non-fish-bearing. XNFB: Other non-fish-bearing.)

Stream Protection Class	Watershed Protection Zone*					
	Big Cr / Alder Cr	CRW	MRW Partial: Millicoma	MRW Partial: Other	Triad: Millicoma	Triad: Other
FB	200	200	200	120	200	120/100**
PNFB	200	200	50	50	50	50
WNFB	200	200	120	50	120	50
XNFB	0	0	0	0	0	0

\*RCA widths on each side of stream, horizontal distance from edge of bankfull stream (feet)

\*\* There will be a 100' minimum buffer width on FB streams permitted in "Triad: Other" watershed protection zone, provided the difference in area between a 100-foot buffer and a 120-foot buffer on such streams is applied elsewhere in the subject watershed according to research design and/or as a means of optimizing aquatic and riparian protections within the subject watershed

the subject watershed as specified by research design and/or as a means of optimizing aquatic and riparian protections within that watershed.

Allowable activities in the RCAs will follow Oregon FPA rules. Riparian restoration experiments (see restoration experiments sections below) will include securing a research exemption from ODF per FPA rules (see Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.1.2).

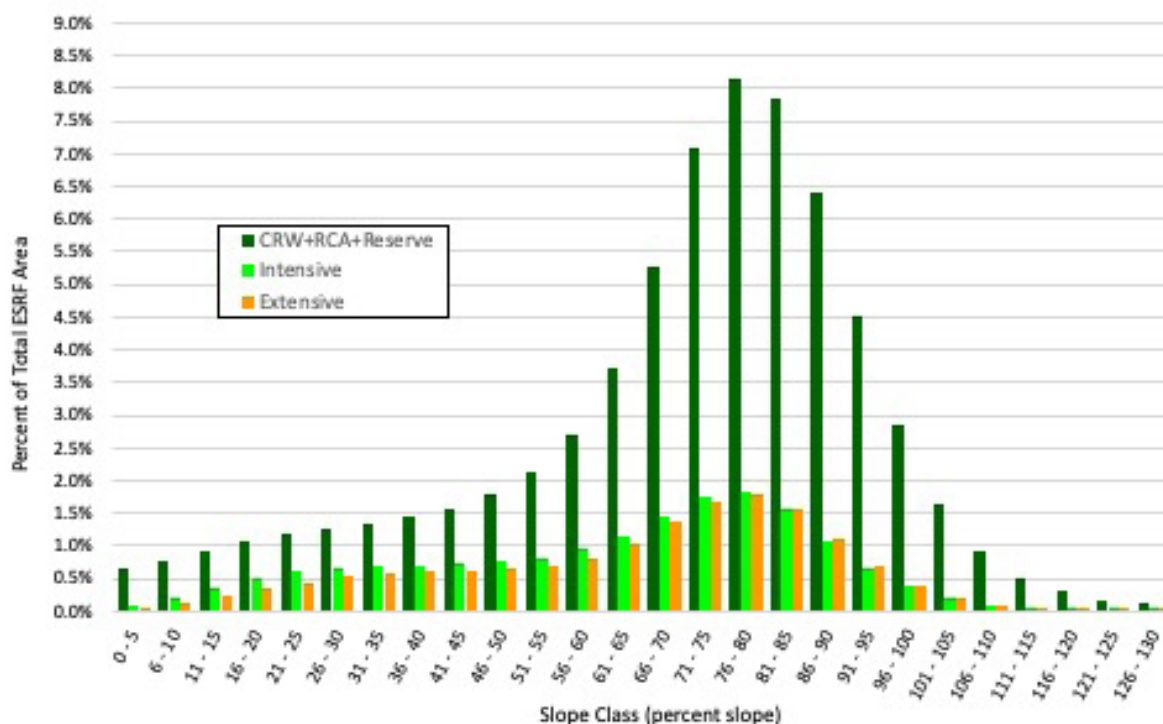
## 7.2.4 Other Seasonal and Intermittent Streams

Harvest will occur along XNFB streams as allowed by the Oregon FPA, which may include a Plan for Alternate Practice Stewardship Agreement as approved by ODF (see Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.1.2). Equipment Limitation Zones (ELZs) will be used as described in Section 6.7.2. As noted above, for analytical purposes streams are identified on the ESRF at a much higher resolution than standard regulatory practices, creating an extensive network of convergent flow paths at the distal end of the stream network classified as XNFB streams. XNFB streams are typically intermittent or ephemeral streams, and may not meet the current (2023) regulatory definition of a stream. The XNFB stream class is expected to encompass Type N streams in the Oregon

FPA with which ESRF research will comply. This may include a Stewardship Agreement (approved by ODF pursuant to Oregon FPA rules) to address application of provisions of an ESRF Habitat Conservation Plan and Incidental Take Permit to activities on the forest. Because of the large reserve area on the ESRF (CRW and MRW reserves) and protections afforded in extensive allocations, XNFB streams (Class I) receive substantial protections beyond the information reflected in Table 7.3 due to how RCA buffers are defined.

In the CRW, riparian areas along XNFB streams in stands over 65 years (as of 2020) will remain unmanaged and fully protected as the adjacent upslope stands are in reserve. In CRW stands under 65 years of age (as of 2020) some riparian areas along XNFB streams may be subject to a one-time restoration thinning if they are adjacent to a plantation stand that is assigned a thinning as part of the CRW restoration experiment, but these areas will undergo no further active management beyond this one-time thinning. There will be no timber harvest in MRW reserves, so XNFB streams in these areas will be fully protected. Extensive management prescriptions, which specify between 20% and 80% of the original stand as dispersed or aggregate retention, provide the opportunity for specific protections beyond those required by Oregon FPA rules. In many cases such retention will be used to protect steep slopes and XNFB stream channels. An estimated 55% of XNFB streams





**Figure 7.3.** Slope class by land allocation. Slope values are derived from 2021 LiDAR, and are based on October 2022 reallocation.

in the ESRF will be fully protected within the CRW or MRW reserves, or within RCAs protecting other (larger) streams.

### 7.2.5 Protection for Steep Slopes and Headwater Streams

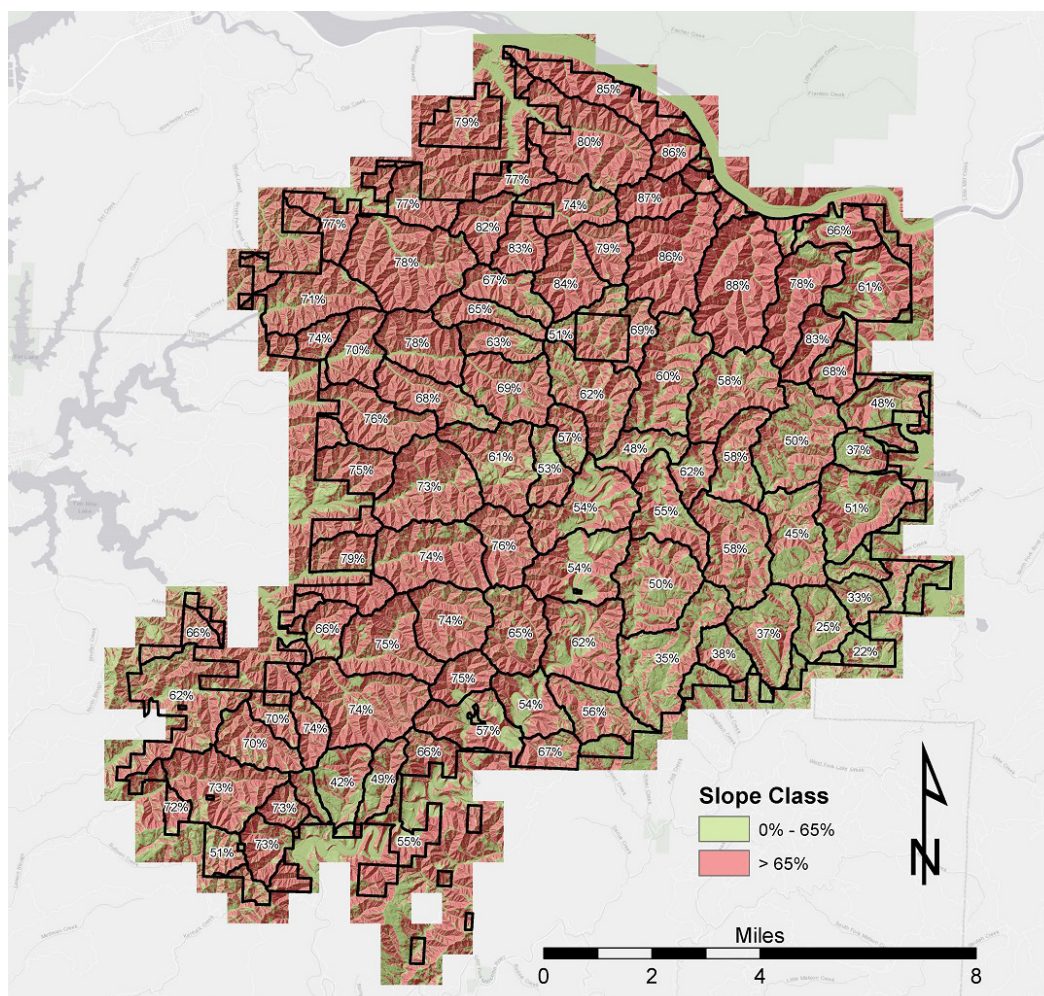
Steep slopes dominate the landscape of the ESRF. An estimated 53,200 acres of the ESRF's 82,520 acres have slopes greater than 65 percent. Approximately 72% of slopes greater than 65% gradient on the ESRF are within fully protected land allocations (CRW, RCA, or MRW reserves), with the balance of steep slopes within extensive harvest allocations (14%) and intensive harvest allocations (14%; Figures 7.3, 7.4).

As integrators of local and watershed-scale processes, streams are ideal systems to research how steep slopes and headwater channels, directly and indirectly, affect ecological processes in downstream aquatic ecosystems. In mountainous terrain such as the ESRF, headwater streams reflect a mix of hillslope and channel processes because of their proximity to sediment source areas (Benda et al.

2005). The ESRF provides excellent opportunities to better understand the integration of steep slopes and the streams confined by them, and how this relationship changes with time and space. Studies on the ESRF will seek to increase knowledge of short and long-term effects of headwater stream tree retention (such as will occur in extensive harvests and reserves) and headwater stream tree removal in intensive harvest. Research on silvicultural practices, including those on steep slopes, will comply with the Oregon FPA. This may include a Stewardship Agreement (approved by ODF pursuant to Oregon FPA rules) to address application of provisions of an ESRF Habitat Conservation Plan, research exemptions in small, localized areas associated with targeted experiments, and Incidental Take Permit to activities on the forest. See Appendix O for further information on context and ESRF research related to steep slopes.

### 7.2.6 Colluvial Hollows and Stream Protection

Since about 1990, the term *headwall* has been used in Oregon forest practice guidance to describe obviously



**Figure 7.4.** Percent of ESRF subwatershed area with slopes greater than 65%.

concave-shaped slopes in headwater zones that can concentrate sediment and water to increase landslide susceptibility (e.g., ODF 2019). These ecologically and managerially important bowl-shaped areas where hillslopes transition into headwater streams are also referred to as *unchanneled headwater basins*, *zero-order basins*, or *bedrock hollows*. Another commonly-used term – *colluvial hollow* – describes both the nature of accumulated sediment and shape of the landform, and is used in this FMP to refer to these convergent hillslope features. Colluvial hollow areas are of particular interest in the management and conservation of the aquatic and riparian landscapes because of their high potential to deliver sediment and wood to the stream network.

The ESRF riparian protection strategy is integrated with shallow translational landslide probabilities in non-channel areas and is conceptually based on identifying and prioritizing for protection those slopes and stream channels most likely to initiate and sustain a debris flow that delivers large wood to fish-bearing streams. A LiDAR-derived landslide inventory was generated in 2022 to identify areas with known past landslide scars and deposits. The landslide inventory contains metadata associated with landslide mechanisms, including deep-seated features often predisposed to intermittent movements and creep (typically earthflows, complex movements, bedrock landslides) and shallow-seated features often predisposed to more rapid and highly mobile failure (typically shallow landslides in soil and/or weathered rock, debris fans). To assist in

making decisions about landslide potential, the ESRF may consult with geotechnical or geology experts for planning for harvest or stream/riparian restoration activities. This additional consultation will be sought if (1) there are on-the-ground observations of distress/movement prior to management activities of any kind, and/or (2) there are signs of activity from other data sources (e.g. repeat LiDAR, imagery, InSAR, etc.). See Chapter 12: *Disturbance, Forest Health and Resilience*, Section 12.1.3 *Mass Wasting* and Figure 12.2 for more details.

As with most landslide inventories, there is an unavoidable under-mapping of shallow landslide features owing to (1) resolution limitations of bare earth terrain, and (2) a relatively short-lived signature of a scar on the landscape. Other mapped features, such as debris fans may serve as a proxy for upstream shallow landslide activity. As the activity, timing, and age of mapped landslides in such inventories are largely unknown, site interpretation from trained geotechnical professionals will provide critical information as to landslide activity, including exposed mineral soils, recent cracks, terraces and/or signs of distress, bowed and/or tilting trees, seeps, and other geomorphological signs of instability.

As described in Section 7.1 above, for planning and analytical purposes the stream network has been extended into colluvial hollow areas at the head of the network to better recognize the integral nature of streams and their associated terrestrial counterparts, and the effects that these transitional processes have on downstream aquatic ecosystems. The prevalence of headwater streams with channel gradients greater than 50% shows a similar distribution pattern to steep slopes relative to reserve, extensive, and intensive treatments. Thus, at the scale of the entire ESRF, reserve treatments (CRW, MRW reserve, and RCAs) provide an appreciable level of protection to steep slopes and headwater streams.

In general, the ESRF management approach in steep colluvial hollow areas is to ensure a high level of protection at landscape scales by placing large areas in reserve. In intensive allocations it is assumed that areas without harvest will be limited to reserves and RCAs. In extensive allocations, it is expected that retention will be used to create – and investigate – protections for steep slopes and debris-flow-prone channels not otherwise protected within the RCA. Creating core areas of protection while also maintaining the ability to conduct research and harvest in sites outside of a reserve is critical to the research

goals of the ESRF as it provides a space for site-specific experimentation to test alternatives, assumptions, and process-level understanding of forest management while assuring areas of landscape-scale protection. In contrast to the emphasis on landscape-scale protections described here, the proposed PFA assumes that probabilistically determined site-specific protections can offer appropriate levels of protection by placing less area in reserve.

Landslides occur naturally in the Oregon Coast Range, and are commonly induced by heavy rainfall associated with strong storms in late fall and winter, which infiltrates and increases ground-water pressures. These elevated pressures can, in turn, induce landslide movement. In 2009, the USGS and cooperators initiated research on the Elliott to investigate hydrologic factors that control landslide initiation. The USGS team installed tensiometers, piezometers and other instruments in a young stand on a steep hillside above Knife Creek in the upper WF Millicoma River. Buried in three soil pits just below Knife Ridge, the USGS instruments are used to monitor and detect changes in:

- Rainfall
- Ground water pressure (tensiometers)
- Ground water and atmospheric pressure (piezometers)
- Soil water content
- Soil temperature

Measurements are taken at 15-minute intervals. Data are transmitted hourly and displayed on graphs that are updated hourly, available online at: <https://www.usgs.gov/programs/landslide-hazards/science/knife-ridge-elliott-state-forest-oregon-landslide-monitoring>

Publications associated with this research include Smith et al. (2013), Mirus et al. (2018) and Orland et al. (2020). The Knife Ridge instrument array and data provide excellent opportunities for additional research and collaborations, including potential development of a larger network of similar installations across the ESRF to better understand landslide hydrology and processes.

## 7.3 Roads and Aquatic Systems

Roads provide critical access points for research, management, recreation, and fire protection. They also represent a significant human impact on the larger forest system in terms

of chronic long-term disturbance, fragmentation, altered hydrology, increased sediment yield, and access for invasive species. Oregon FPA rules revised under the Private Forest Accord (PFA 2022) require a forest road inventory and assessment and associated improvements. The ESRF HCP stipulates that during the first 12 years of management, the existing ESRF road network is to be inventoried, including an assessment to determine the degree of hydrologic connections of current and legacy roads and identification of priorities areas for mitigation due to impacts on aquatic systems. As detailed in Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.6 *Roads*, the ESRF will utilize findings and recommendations from Biosystems et al. (2003), as well as assessments and action plans developed by the Coos Watershed Association and Coos Basin Coho Partnership (e.g., CoosWA 2015) as a baseline for the updated forest roads assessment and as a guide to highest priority areas for inventory and subsequent improvements.

The ESRF will work with local watershed councils, state agencies, and Tribal partners to identify critical, time-sensitive road restoration projects and collaborate on continued restoration work and funding opportunities. Mitigation and restoration work will be conducted within a research context of the forest (e.g. assessing sediment fluxes and turbidity during storm events before and after road modification) so as to support the establishment and functionality of long-term research studies and monitoring. The ESRF road system will be regularly assessed for surface erosion and potential sediment delivery in order to mitigate impacts to aquatic systems in accordance with Oregon Forest Practices Rules. Development of new roads in, near, and across streams will be limited to minimize sediment transfer to fish-bearing stream channels. See Section 6.6 for further information.

## 7.4 ESRF Restoration Experiments in Aquatic and Riparian Systems

The following section outlines initial research and restoration activities in ESRF aquatic and riparian systems. As with all components of the research platform, the research described here relies on adequate funding and also does not preclude the incorporation of other nested studies or experimental adjustments under the adaptive

experimental design approach. Monitoring aquatic and riparian biota, habitat and ecosystem processes (see Chapter 10: *Monitoring*) will yield important information for observational studies, but explicit experimental manipulations provide opportunities to ask more direct and mechanistic questions about ecosystem function.

Provided that adequate funding is available, two initial areas of focus for research experimentation will be established at the ESRF: (1) riparian restoration treatments, and (2) in-stream habitat enhancements. The overarching design as well as key details about design and implementation of these two experiments, are laid out in Sections 7.4.1 and 7.4.2 below. Riparian restoration and stream enhancement projects will occur directly in stream channels and adjacent floodplains. Equipment such as helicopters, excavators, dump trucks, front-end loaders, full-suspension yarders, and similar equipment may be used to construct projects. These will be areas of focus during the first 10 years of work at the ESRF. As noted above, Oregon FPA guidance for obtaining research exemptions for work in riparian zones will be followed.

### 7.4.1 Restoration Treatments in Riparian Conservation Areas (RCAs)

Riparian forests throughout the PNW and coastal Oregon have been changed and simplified by forest management activities over the past century (Nierenberg and Hibbs 2000, Pabst and Spies 1999). Until at least the 1970s timber harvests often encompassed riparian areas up to the edges of streams. Channel margins were then typically planted with commercial conifers (usually Douglas-fir), resulting in dense, relatively uniform conifer stands and a corresponding decrease in riparian hardwoods. Where conifers did not regenerate well, or were not planted, logged riparian zones regenerated in dense and largely uniform alder stands with understories of salmonberry thickets and few conifers. Given the strong connections between riparian forests and headwater ecosystems, changes to the riparian forest translate to both short and long-term changes in the stream.

The goal of this research is to gain knowledge that will lead to improvements in aquatic, riparian, and terrestrial habitat for focal species (salmonids, salamanders, and potentially birds/bats, however the latter taxa are outside the scope of our assessments) by increasing downed wood in the stream and on the forest floor along the stream, by diversifying tree communities (and therefore litter composition), by creating opportunities for recruitment of new trees, and by setting



the experimental patch on a trajectory toward greater forest structural complexity. Exploring whether thinning or other manipulations of previously altered riparian vegetation within RCA buffers can set forest stands on a trajectory to restore or enhance recovery of riparian forest communities is a key area of focus for the riparian and aquatic research effort at the ESRF. To that end, a riparian thinning experiment will be an early area of planned research on the ESRF within current plantation stands less than 65 years old as of 2020. Researchers from ESRF will consult with Tribal partners in developing additional restoration priorities in stream and riparian ecosystems that stand alone or can be incorporated into existing efforts. For example, western red cedar (*Thuja plicata*) has been noted by Tribal and Indigenous communities as culturally important trees, and therefore cedar planting will be an explicit part of the riparian restoration experiments.

The riparian restoration experiment will have three phases, beginning with small, localized pilot studies to assess the initial effects (positive or negative) of a proposed restoration option. This first phase will take place in sites upstream of anadromy (Figure 7.6). Responses to manipulation will be assessed relative to a stream with an unmanipulated riparian forest. It is important to note that in this context, leaving previously managed riparian stands to develop without modification (i.e., no action) is itself a management decision that warrants assessment. If overall results from the pilot study indicate a positive response in habitat and persistence or enhanced abundance of stream salmonids, a second phase of this experiment will be to establish and build out the experimental restoration of riparian forest to other areas of the ESRF that have simplified riparian forests.

The third phase of this study will use results from the first two phases to explore either (1) further application of the treatments from phases one and two (if successful) across other parts of the forest that meet decision tree criteria for restoration treatments (Figure 7.5), or (2) to modify treatments based on results from phases one and two. Because the treatments in phase 3 will be dependent upon the results from the pilot study (phase one) and the larger experiment detailed below (phase two), it is not possible to indicate explicitly the nature of the treatments in that effort at this time. Results of the first two study phases will be assessed using the adaptive research framework (Chapter 11: *Adaptive Research Strategy and Implementation*) and reviewed with both the Science Advisory Committee and Implementation and Adaptive Management Committee before a third phase of the study is planned. At the current

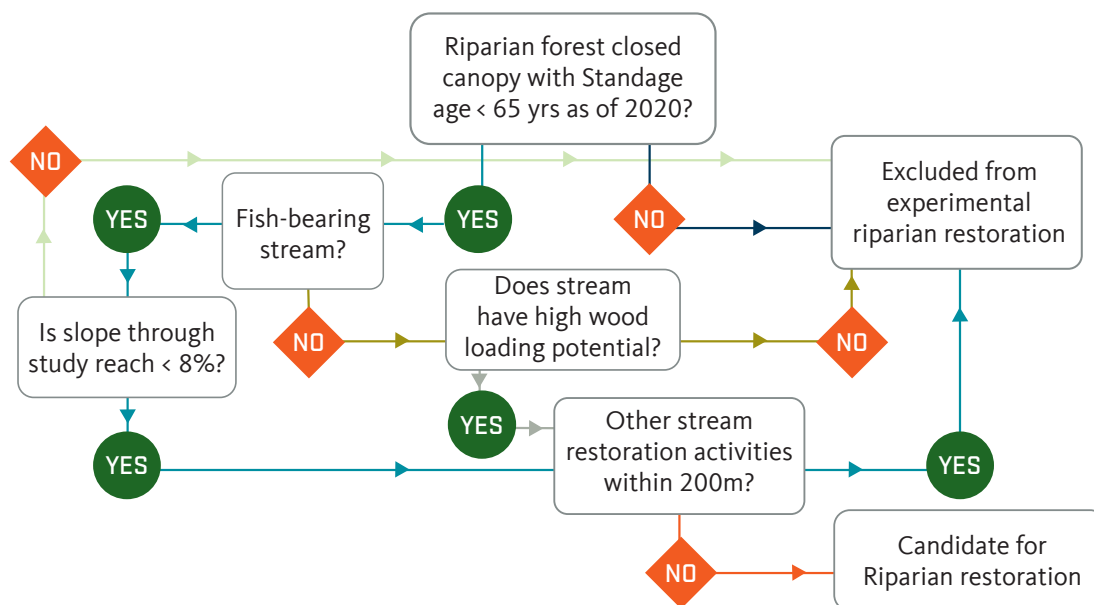
stage, some of the key side-bars can be articulated along with criteria for potential inclusion of a given site in future work (Figure 7.5) to identify which areas may be candidates for later research experiments.

The research proposed below is a novel approach for managing and restoring riparian ecosystems on the ESRF that allows for potential management in the entire designated riparian area rather than being restricted to the outer portion, which is the current norm. This approach will be tested initially (phase one) on a limited number of sites above anadromy, but which contain populations of resident cutthroat trout. The project will modify forests in a manner that will increase patchiness of the system and promote structural complexity in the forest canopy, in the forest understory, and in the streams themselves. As noted above, the goal for this work is to improve habitat for fish, salamanders, and a range of aquatic and riparian species.

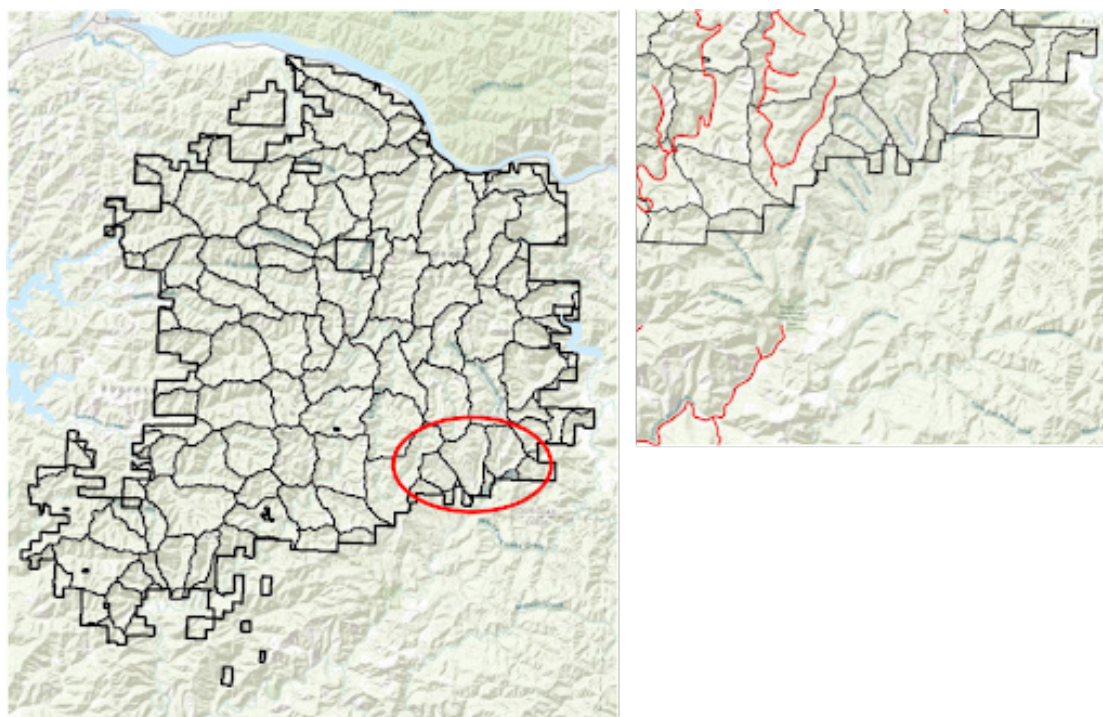
## Study Design - Phases One and Two

The following guidelines are proposed for the first phase of the experimental riparian forest thinning study. These are in alignment with the conservation measures and commitments in the ESRF HCP. Because of the uniqueness of the proposed research, it is prudent to thoroughly assess the effectiveness and potential consequences of the approach in a limited area before proceeding with a full-fledged restoration effort. For phase two of the study, this same framework will be used but the experimental thinning will also be evaluated against other potential riparian treatments. The details of the experimental treatments may shift based on what is learned from phase one to better meet the overall study goals.

- Riparian restoration treatments will only occur in stands aged less than 65 years as of 2020.
- The initial focus will be primarily on small and medium fish-bearing streams above anadromy (cutthroat trout streams). Phase two work will likely include both fish (FB) and non-fish streams more broadly across the ESRF in a study evaluating experimental thinning (stands < 65 years of age as of 2020). In the phase one and phase two studies, work will be conducted along select 200m sections of RCAs. Thinning in the RCA will be done with the goal of creating greater complexity in the riparian forest (rather than simply uniform thinning), setting the system on a trajectory toward greater complexity and/or promoting or enhancing habitat in the stream.



**Figure 7.5.** Decision tree for identifying areas where riparian restoration may occur. Specific locations for the pilot study and for the larger experiment will be drawn from areas that meet these criteria and will also take into account logistical, social and ecological considerations, such as accessibility, recreational use, and presence of threatened or endangered species.



**Figure 7.6.** (A) Potential area for proposed pilot study for riparian thinning restorations. (B) upstream limits of anadromy (red lines) in this potential area.

**Table 7.7.** Proposed phase two study design for evaluating riparian thinning restorations relative to other riparian treatments/protectations across the ESRF. Phase two would be implemented only if pilot study indicates persistence of salmonids in experimental sites and would require coordination with upland harvest activities.

Allocations	Treatment Type	No. of Reaches	Reach Length	Estimated Acres
Fish Bearing Streams	Current practice riparian management in Intensive management or regeneration thinning areas	3	656' (200m)	9.1
	Experimental thinning in RCA in Intensive management or regeneration thinning areas	3	656' (200m)	9.1
	Experimental thinning in MRW Extensive management areas	3	656' (200m)	9.1
	Experimental thinning in sites with no upland management (MRW or CRW)	3	656' (200m)	9.1
	Unmanipulated riparian zone in reserve watershed (MRW or CRW)	3	656' (200m)	9.1
Non-Fish Bearing Streams	Experimental thinning in MRW Extensive treatments	3	656' (200m)	9.1
	Experimental thinning in sites with no upland management (MRW or CRW)	3	656' (200m)	9.1
	Unmanipulated riparian zone in reserve watershed (MRW or CRW)	3	656' (200m)	9.1

- The decision criteria for selecting potential sites for experimental restoration treatments are outlined in Figure 7.5. Preliminary analysis of the ESRF stream network indicates that sites in the southeast portion of the forest may be optimal locations for the pilot study (Figure 7.6), however, exact locations have not yet been identified. Final selection will take into account logistical, social and ecological considerations, such as accessibility, recreational use, and presence of threatened or endangered species.
- A before-after control-impact (BACI) study design will be employed in the pilot study and in phase two with the presence of both treatment reaches and paired reference reaches. Ideally, reference reaches will be upstream of treatment reaches – with a minimum of 100m buffer between reference and treatment sites, however, if there is not enough space upstream of proposed treatment areas, a nearby stream with comparable habitat and fish communities will be selected as the reference.
- Riparian restoration thinning in the pilot study will be applied along 200m reaches on non-anadromous fish streams.
- If the pilot study indicates increased habitat quality and persistence of stream salmonids, the larger phase two study will apply experimental thinning treatments that will go forward (if funding permits). In the phase two study, experimental restoration thinning will be assessed relative to three different “reference” conditions on fish streams each with three replicates (total of 9 reaches): (1) ESRF current practice no-touch buffers under intensive upland treatment, (2) ESRF current practice no-touch buffers under extensive upland treatment, and (3) unmanipulated riparian zones in reserve units with no upland harvest but with similar forest age.
- In addition to assessing experimental riparian restoration thinning in fish-streams, experimental thinning may also be implemented in non-fish bearing streams. Due to logistical limitations, only three treatments would be assessed each with 3 replicates for total of 9 additional reaches): (1) thinning (likely in the extensive in MRW watersheds), (2) current regulatory practices at the time of the treatment for non-fish streams (managed sites in MRW or CRW), and (3) in MRW Reserve or CRW stands with no management.
- Single-entry riparian thinning experiments in RCAs adjacent to CRW restoration treatments are planned to be completed within the first 20 years following establishment of the ESRF in coordination with the single-entry restoration thinnings in current plantations in the CRW. Riparian treatments in RCAs outside of reserves have the potential for multiple-entry treatments, supporting the use of a range of silvicultural treatments and experimentation to reduce short-term impacts.

Assuming the larger thinning effort can move forward (pending results from the pilot study), an estimated total of 90 acres of RCAs on the ESRF would be affected by the larger experiment, which is 1.4% of the total area of RCA in the MRW, and 0.6% of RCA area across the ESRF.

Assessments for this study are proposed to last for at least 5 years, with a minimum of 2 years of pre-restoration assessment and then a minimum of 3-years post-restoration assessment. Workshops to discuss the study will be conducted (1) prior to the initial restoration to finalize actions, (2) yearly to discuss findings and any potential issues that arise, and (3) when the assessment is completed to make necessary adjustments for future restoration. Adjustments made to restoration efforts will follow the framework outlined in Chapter 11: *Adaptive Research Strategy and Implementation*.

## Riparian Restoration Study Implementation

As noted above, the study will begin with a small-scale pilot project (phase one), and it will expand to larger-scale implementation (phase two) only if habitat improves and salmonids persist. The experimental restoration thinning study will be conducted to meet the objectives below.

- Reduce stand densities to promote increased residual tree growth rates (Roberts and Harrington 2008, Dodson et al. 2012, Newton and Cole 2015), larger crowns, and more rapid development of large limbs (Maguire et al. 1991, Roberts and Harrington 2008, Dodson et al. 2012) that may be utilized as nesting habitat for marbled murrelets or benefit other native species.
  - Prioritize the retention of shade tolerant conifers, which are underrepresented relative to reference conditions for riparian forests in the Coast Range (e.g., Wimberly and Spies 2001), hardwoods when in conifer-dominated patches due to their disproportionate importance of in supporting wildlife diversity in conifer-dominated landscapes (Hagar 2007), and large trees with wildlife habitat features that require multiple decades to develop including, but not limited to (Puettmann et al. 2016): (1) larger tree diameters and heights, (2) complex crown and branching structures such as broken tops, epicormic branches, platform structures, and large-diameter limbs, and (3) bark containing deep furrows or crevices.
- Vary residual densities within the thinned matrix to promote the development of increased tree size variability (Roberts and Harrington 2008, Dodson et al. 2012, Kuehne et al. 2015), promote diverse understory vegetative communities (Ares et al. 2009, Ares et al. 2010), and provide regeneration opportunities for a range of tree species (Cole and Newton 2009, Dodson et al. 2014).
  - The range of residual densities within thinned areas may vary to meet the needs of ongoing research activities. For example, harvest units may incorporate areas of low residual densities to promote increased herb and shrub diversity (Ares et al. 2009, Ares et al. 2010), accelerate the development of large-diameter residual trees (Newton and Cole 2015), and provide opportunities for regeneration of shade intolerant conifers such as Douglas-fir (Cole and Newton 2009, Dodson et al. 2014, Lam and Maguire 2011).
- Incorporate unharvested leave islands (“skips”) within thinned areas to provide refugia for disturbance-sensitive species (Halpern et al. 2012) and promote continued sources of deadwood recruitment (Puettmann et al. 2016). The size of skips may vary from one acre to several acres, and the percentages of treated areas designated as skips to meet the needs of ongoing research activities. Skips may also serve as an unmodified reference condition area for experimental studies comparing restoration activities with no-touch treatments.
- Incorporate gaps within thinned areas to promote increased primary (Warren et al. 2016) and fish (Wilzbach et al. 2005) productivity in streams, increase residual tree growth rates around gap edges (Roberts and Harrington 2008, Dodson et al. 2012, Gray et al. 2012) and to promote the regeneration of diverse vegetative communities (Fahey and Puettmann 2008, Davis and Puettmann 2009), including patches of early seral habitat (Fahey and Puettmann 2008, Puettmann et al. 2016) within RCAs.
  - The size of gaps should vary as needed to promote the successful regeneration of both shade tolerant and shade intolerant tree species within RCAs and to meet the needs of ongoing research activities. For example, treatments may incorporate gaps greater than 0.5 acres to promote regeneration of shade intolerant species such as Douglas-fir and red alder (Gray and Spies 1996, Sarr et al. 2011, de Montigny and Smith 2017).
  - Percentages of treated areas designated as gaps may vary to meet the needs of ongoing research activities.
- Utilize planting, natural regeneration, or both within gaps and thinned areas to promote the regeneration of diverse vegetative communities (Puettmann and Tappeiner 2014).
  - Promote increased conifer diversity in hardwood-dominated areas.



- Promote increased establishment of shade tolerant conifers and hardwoods within conifer-dominated areas.
- Promote diverse shrub and forb communities that enhance the ecological functioning of riparian forests.
- Plant cedar (with fencing for the first 5 years if needed) to increase the density of this key species across the riparian system.
- Utilize site preparation and vegetation management activities to promote the successful regeneration of diverse vegetative communities.
- Prescribed fire, mechanical treatments, and manual treatments may be utilized to prepare newly harvested areas for regeneration of desired vegetative species.
- Prescribed fire, mechanical treatments, and manual treatments may be utilized to manage competing vegetation as needed to promote the successful establishment of desired vegetative communities as defined by the needs of ongoing research activities.

Multiple variables will be evaluated in each of the riparian restoration treatments before and after thinning in reference and treatment sites (Table 7.8).

### Study Design - Phase 3

The third phase of the riparian thinning work would occur only after the first two phases have been completed and the results from those studies have been evaluated. Phase three will progress only if the results from the two earlier efforts indicated no significant declines in salmonid abundances in association with the experimental treatments. For the third phase, the same constraints on available sites that are laid out in the decision tree above (Figure 7.5) will apply. Specifics on treatments in the third phase cannot be laid out at this time because the ESRF is working under an adaptive management framework and so decisions about future management will necessarily depend upon the outcome of earlier work, but the work will continue to work toward the overarching goal of enhancing habitat for fish and other biota in streams and riparian corridors.

### 7.4.2 In-stream Habitat Enhancements

Wood additions are a well-established restoration tool in streams that create patches of habitat that can benefit fish and enhance biogeochemical processing in streams. The goal of this experiment is to explore whether and to what

**Table 7.8.** Monitoring framework for Riparian Restoration Experiment

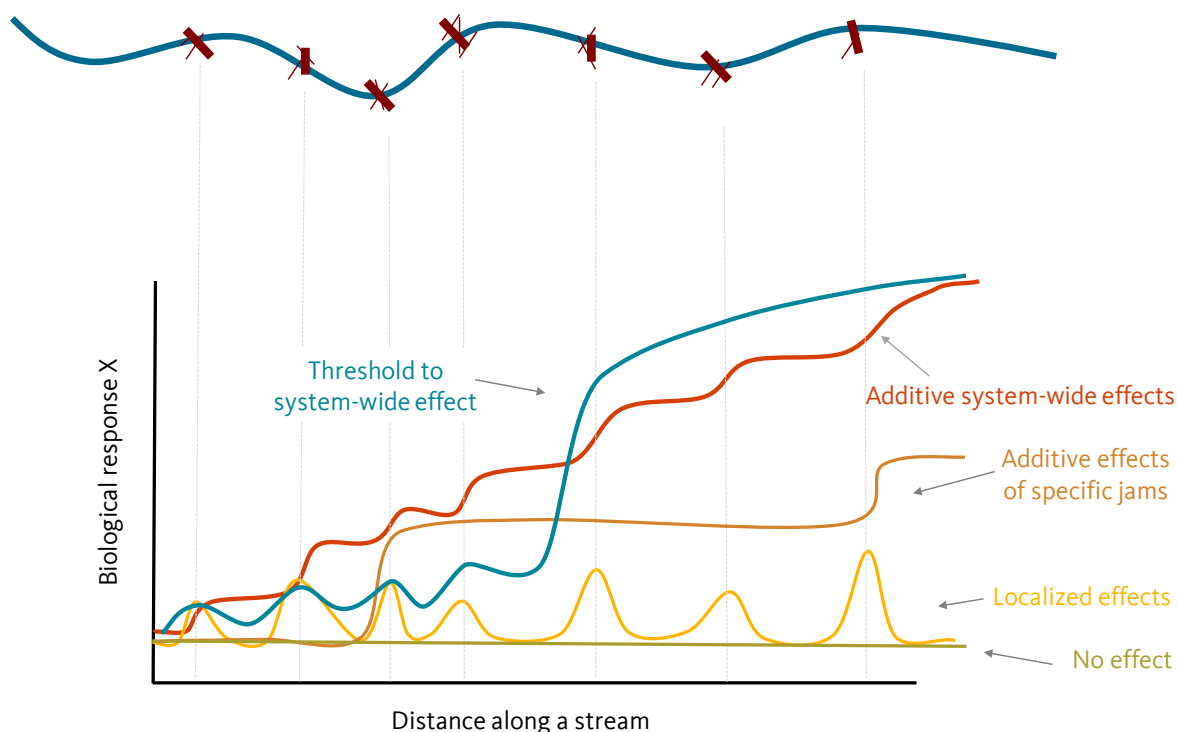
Stream/Riparian Metric	Sampling Frequency
Large wood assessment (number, size, volume, wood jams)	1 time per year
Habitat units (size and number)	1 time per year
Substrate sizes (including % fines)	1 time per year
Riparian tree community (species and size distributions)	1 time per year
Riparian herbaceous plant community (% cover)	1 time per year
Channel configuration (bankfull width, depth, sinuosity, etc.)	1 time per year
Water temperature	Continuously monitored
Canopy cover over the stream	1 time per year
Light flux to the stream	Continuously monitored through summer
Dissolved oxygen	Continuously monitored through summer
Turbidity	Continuously monitored
Stream nutrient concentrations	Min of 3x per year
Benthic biofilms (chl a and/or AFDM)	Min of 1x per year
Amphibians (species and quantity)	Min of 1x per year
Fish (species and quantity - fish stream only)	Min of 1x per year
Beaver activity (signs and impacts if present)	Min of 1x per year

degree increasing availability of favorable resource patches (wood jams in this case) affect target species (salmonids) or ecosystem processes (nutrient uptake) and ultimately generate results that contribute to larger restoration efforts across the region.

While it is understood that adding wood jams to a stream can benefit aquatic biota, questions remain about how much value is added with each additional resource patch (wood jam). To address this question wood will be added at varying densities across the ESRF to explore the nature of responses. There are a number of potential scenarios associated with increasing resource availability that range from positive effects of just a few specific patches, aggregate positive effects of each additional patch, or a threshold response in which there is minimal effect with the addition of just a few patches but notable effects once enough patches are added. These alternative trajectories are illustrated in Figure 7.7 below.

Potentially larger effects of individual jams are expected that aid in reconnecting stream floodplains. And “no

effect” is maintained as one of the alternative hypotheses here not only as a null model, but also to reflect issues of bedrock streambeds. The response of aquatic biota and ecosystem processes to wood additions will likely depend upon underlying streambed condition. In main stem sections of the stream network, in contrast to an excess of sediment, there is a lack of stable alluvium which leads to limited hyporheic habitat (with implications for stream temperature), reduced spawning gravel, limited habitat for juvenile lamprey and overall disconnection of the stream bed from historic floodplains (Figure 7.8). Overall, the simplification of streams and riparian forests regenerating from historic management has caused dramatic changes in these systems compared to natural disturbance regimes. And, for some aspects of the system there has been a transition to an alternate steady state. For example, the channels that have been scoured to bedrock do not hold sediment, even if upstream sediment delivery processes are restored. As with many alternate steady-state scenarios, passive restoration is not practical, and a great deal of additional effort needs to be exerted to return the system to



**Figure 7.7.** Conceptual framework for assessing individual versus aggregate effects of wood addition restorations in streams.

conditions and processes that historically dominated these systems. To that end, considerable research has been done.

### **In-stream Restoration Study Design and Implementation**

Individual wood jam additions will follow established practices used by local watershed groups, however the amount of area treated and the number of wood jams added will vary from one to at least 12. The restorations will be implemented over multiple years and we will partner with local watershed groups in implementing the wood additions.

As with the riparian alternatives a before-after-control-impact (BACI) study design will be used in which data is collected

from reference and treatment sites before and after wood additions. Data collection will focus on stream salmonids and stream habitat. If funds allow, nutrient releases will also be conducted to quantify nutrient uptake. Fish assessments will be conducted using electrofishing or snorkel surveys, depending upon stream site conditions and permits.

Past land use practices of stream cleaning and splash damming removed most large wood, resulting in downcutting, loss of stream gravel and exposure of the bedrock stream substrate in most reaches. In addition to loss of spawning gravels, hyporheic function (subsurface streamflow through gravel) has been lost. This can result in warmer stream temperatures from reflective heating when



**Figure 7.8.** Wide view of bedrock substrate, WF Millicoma River. Loss of large wood, gravel and sediment has resulted in a lower water table, loss of hyporheic flow and reduced connectivity to off-channel habitat for salmonids. Wood additions aim to reverse these losses by attenuating flow velocities, and increasing sediment retention and floodplain connectivity.



sunlight is reflected off the bedrock substrate back into stream water (Johnson 2004) and also from sunlight heat retained in the thermal mass of the bedrock. Restoring the supply of large wood to the channel to retain stream gravels, reconnect the floodplain and attenuate flow velocities is expected to improve the long-term viability of coho and other salmonids.

The objective of both wood addition and riparian restoration activities is to contribute to the persistence and improvement of aquatic biodiversity on the ESRF and areas downstream. This includes directly and indirectly restoring ecological attributes and processes that benefit multiple life histories of the three independent populations of the Oregon Coast coho ESU in the permit area (Tenmile, Lower Umpqua, and Coos) as well as in downstream reaches outside the permit area.

## 7.5 Additional Stream Restoration and Stream Assessment Activities

While the experimental treatments will focus on riparian forests and stream wood loading, there are other areas of stream degradation that have been identified in the ESRF. For example, in 2015, the Coos Watershed Association (CoosWA) completed its Coos Model Watershed Program Supplemental Action Plan for the Millicoma Forks Coho Restoration Partnership (SAP; CoosWA 2015). The SAP encompassed the East Fork Millicoma River basin, mostly owned by Weyerhaeuser Timber Company and the WF Millicoma River basin, mostly contained within the Elliott State Forest. The SAP refined previous Model Watershed Program restoration strategies using 10 years



**Figure 7.9.** Large wood placement project in Elk Creek, completed by Coos Watershed Association.



of high-quality data obtained via the ODFW protocol Aquatic Habitat Inventories (AHI), and U.S. Forest Service Geomorphic Road Analysis and Inventory Protocol (GRAIP).

The SAP used a structured process to identify and prioritize restoration projects focused on three goals: (1) remove fish passage barriers and impediments to improve connectivity among stream habitats; (2) decrease catastrophic and chronic sediment inputs to streams from forest roads; (3) and restore instream habitat complexity in order to develop the high-quality habitat necessary to recover coho salmon. Riparian restoration and stream wood addition experiment projects align well with goal three. As noted in Section 7.3 above and in Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.6.3, a roads survey informed by previous work will be conducted and road, culvert, passage, and sediment issues that require mitigation will be prioritized and addressed. Any activity to address roads or sedimentation will be planned and applied from an experimental perspective. For issues around sedimentation, at a minimum, pre- and post-treatment data on turbidity will be collected using turbidity data loggers. For passage issues, stream fish upstream of the passage impediment will be assessed before and for at least three years after treatment using electrofishing, snorkel surveys, or eDNA.

Beavers are important ecosystem engineers in streams and their reduced numbers on the ESRF could affect multiple aspects of the riparian and aquatic ecosystems. Structures created by beavers alter flow paths, promote carbon retention and increase water residence time on the landscape. Beaver activity in the ESRF is currently relatively limited, but the system has areas that may be viable for additional beaver colonization and dam building. While active beaver reintroductions are not anticipated among the initial project efforts at the ESRF, any beaver activity that is observed will be noted as a component of stream monitoring and research activities. With additional opportunities, there may be additional beaver habitat, research, and restoration projects in collaboration with partners including ODFW, ODF, Coos Watershed Association, Partnership for Umpqua Rivers and the Tenmile Lakes Basin Partnership.

Whether placing large in-stream structures, exploring innovative methods, replacing or removing culverts, or conducting more limited stream structural changes, in-stream restoration efforts provide ideal opportunities for research – not only on effects of specific projects, but more broadly on linkages between habitat, aquatic ecosystem processes, and aquatic biota in streams. The goal will be to approach all in-stream and riparian restoration from an experimental standpoint with at least one year (ideally more) of data prior to project implementation and one year (ideally more) of data after implementation. Realistically, in coordinating with partners, not every restoration action can be part of a study with this level of data collection. However, whenever possible stream habitat and stream ecosystem processes will be assessed and monitored before and after (using ESRF monitoring sites as reference sites for later BACI analysis; see Chapter 11: *Adaptive Research Strategy and Implementation*).



# Chapter 8

## Climate Change, Adaptive Silviculture, and Forest Carbon

Climate change is already increasing temperatures, lengthening the summer dry season and changing precipitation patterns in the Pacific Northwest, trends that are expected to intensify in coming decades. As a result, forests in the region are likely to experience increased drought stress, more frequent insect outbreaks, increased risk of large wildfires, more frequent severe winter storms, reduced summer streamflows, and higher water temperatures (Dalton et al. 2013, Mote et al. 2014, May et al. 2018). Predictions are that future warming and changes in precipitation will considerably alter the spatial distribution of suitable climate for many important tree species and vegetation types in Oregon by the end of the 21st century (Dalton et al. 2017; 2021). A better and more detailed understanding of how to manage Oregon's incredibly productive Coast Range forests for climate change mitigation and adaptation is among our most critical science information needs.

## 8.1 ESRF Carbon and Climate Change Research

Over the time horizon envisioned for the ESRF research management program, climate change and its effects on regional forest ecosystems are expected to become increasingly important. (See Chapter 1: *Introduction and Background*, Section 1.4.6 and Halofsky et al. [in press] for information on climate change vulnerability and projections in the Coast Range.) The ESRF is designed with climate adaptation of forests and carbon sequestration as key areas of study under the integrated research platform and harvest treatments. The ESRF will conserve, enhance, and sustain ecosystem processes, including carbon storage, with increased rotation ages in intensively managed stands, retention of older trees and complex forest structures in extensively managed stands, and the network of reserves and Riparian Conservation Areas designated under the research design. Above and belowground carbon will be monitored through space and time (See Chapter 10: *Monitoring*, Section 10.1.1.2) across Triad treatments and reserves, contributing to development of a database of information related to forest carbon processes, stocks, and fluxes. These data will be used to help inform the ESRF adaptive management strategy to inform future treatments (i.e., intensive, extensive, restoration), parameterize and test biogeochemical process models that will serve the Elliott and other forests, and contribute to ongoing research.

See Appendix 2 of the ESRF Research Proposal (OSU College of Forestry 2021) and Appendix P of this FMP for a preliminary list of carbon and climate change research questions that would be encompassed by the ESRF research design. Research operations and knowledge generated by the ESRF hold opportunities for contributing to Oregon's Climate Action goals, including recommendations for further analysis to inform decision makers and continue to guide effective climate action (Oregon Global Warming Commission 2023).

## 8.2 Carbon Markets

Carbon markets and carbon offset sales are an emerging practice and are often referred to as nature-based climate solutions. Current markets for carbon offset sales are relatively limited and despite their promise, have recently been criticized due to challenges related to demonstrating

key project principles such as *additionality* (i.e., whether carbon financing shifts climate impacts relative to a baseline) and *durability* (i.e., the risk of forest carbon loss over short time frames). Moreover, methodologies for quantifying carbon benefits from carbon market and offset projects are in constant development, and require further integration of economics, carbon cycle science (e.g. measurements of forest carbon stocks and fluxes) and product life cycle assessment (e.g. carbon held in harvested wood products).

The science behind nature-based approaches is under rapid development and is therefore a great opportunity for a carbon rich, well-monitored research forest like the ESRF to not only advance Oregon's carbon objectives but to be a global leader in forest ecosystem carbon research. For example, the ESRF is uniquely positioned to improve scientific understanding of how to optimally manage forest carbon while simultaneously improving productivity to meet demand for harvested wood products. At the same time, ESRF offers multiple opportunities to advance scientific understanding of carbon cycling and sequestration in productive coastal forest ecosystems.

The ESRF has the scale and long-term outlook for addressing research and demonstration opportunities including entering and evaluating new carbon markets, evaluating social license and actual outcomes of selling carbon, contrasting storing carbon within the forest or in durable wood products derived from the forest, and long-term monitoring of carbon storage and fluxes, (above and belowground) as a function of management practices. Much like life cycle analysis, there is a need to explore the fate of carbon sold in a forest as it moves through the market and is emitted elsewhere. Carbon offsets may potentially be explored on the ESRF if it is determined that this is in alignment with research objectives and the mission of the forest, does not conflict with other research, can be accomplished in a way that maximizes scientific and educational outcomes, and is approved by the ESRFA Board of Directors.

## 8.3 Climate-Smart Forestry Strategies and Approaches

Climate-Smart Forestry (CSF) is an emerging branch of sustainable forest management aimed at enhancing the potential of forests to adapt to and mitigate climate change, and is envisioned as a key area of research on the ESRF. Modifying forest management practices is effective for mitigating climate change while producing commodities (Ameray et al. 2021). Climate-smart forestry practices



can increase both the rate of carbon removal from the atmosphere and carbon storage on the landscape and the built environment. Climate-smart forestry aims to sustain ecosystem integrity and functions, and continuous delivery of ecosystem goods and services, while minimizing impacts of climate change on forests.

*Adaptive* capacity to changes in climate and disturbances (e.g., fire, extreme weather events, pests, diseases) can be enhanced by promoting genetic, compositional, structural and functional diversity at both stand and landscape scales. This includes natural regeneration and planting of tree species and genetic variants suitable for future conditions. Practices that support adaptation seek to maintain or improve tree vigor and growth under current and projected climate conditions and increase resistance and resilience.

*Mitigation* of climate change by forests includes above and belowground carbon sequestration by trees and forest ecosystems (especially soils), carbon storage in forest-derived products (e.g. structural timber), substitution of wood for construction materials with larger carbon footprints, avoidance of deforestation, and reduced emissions from operations. Research and management on the ESRF will address both the role of forests in mitigating climate change and the ability of forest ecosystems to adapt to changing conditions. Climate change adaptation research and management on the forest will include the incorporation of management approaches that consider impacts of climate change, as well as research and monitoring of reserves where natural disturbances and other impacts from global change will occur without active management.

8.3.1 Climate Change Adaptation Strategies and the ESRF Approach

Climate adaptation approaches can be viewed as a continuum of adaptation actions ranging from broad concepts to practical implementation. At the broadest scale, the concepts of *resistance*, *resilience*, and *transition* are fundamental options for managers to consider when responding to climate change (Millar et al. 2007; See Appendix Q).

The ESRF will draw upon new and tested approaches, practices that are regionally appropriate, and partnerships to assess adaptation strategies and incorporate adaptive silviculture into treatments in an experimental forest context. When tailored to local conditions, climate change adaptation strategies and tools will allow the ESRF to contribute fundamental new knowledge regarding how forests can be actively managed for resistance, resilience or transition to new, more sustainable states as climate change unfolds. Several planning tools and opportunities for collaboration have been identified for the ESRF. Tactics have been developed by the U.S. Forest Service, USDA Climate Hubs, Adaptation Partners, and Adaptive Silviculture for Climate Change Network to align climate change strategies, approaches, and tactics for forests. ESRF managers will review and adopt the planning tactics that are most useful for broadening these adaptation strategies across a broad range of forest landowner objectives.

Many existing tools provide a framework of adaptation actions relevant to ESRF research management goals (Table 8.1). These tools are designed to facilitate interaction with researchers

**Table 8.1.** Existing tools outlining potential management actions for forest management climate change adaptations and methodologies.

Agency/Entity	Tools
Adaptive Silviculture for Climate Change Network	Northern Institute of Applied Climate Science (NIACS) Adaptation Workbook (General Technical Report NRS-87)
Adaptation Partners	Climate Change Adaptation Library for the Western United States
USDA Forest Service	Climate Change Resource Center Compendium of Adaptation Approaches
Climate Change Response Framework (led by NIACS)	NIACS Adaptation Workbook (General Technical Report NRS-87)
USFS Pacific Northwest and Pacific Southwest Research Stations	Experimental Network for Assisted Migration and Establishment Silviculture



and resource managers to provide scientific information on climate change effects and adaptation in the western United States.

### **8.3.1.1 Adaptive Silviculture for Climate Change Network**

As part of the process outlined above, the ESRF will continue to explore the potential opportunity to join the multi-region *Adaptive Silviculture for Climate Change* (ASCC) project (Nagel et al. 2017). Using the Adaptation Workbook described above, ASCC has created a peer-reviewed treatment design process to facilitate development of site-specific climate change adaptation treatments across a network of project sites in different forest ecosystem types. The ASCC project couples the structured decision-making tools from an Adaptation Workbook with a rigorous scientific design (Nagel et al. 2017). Using this process, ten project sites and three affiliate sites have been established across North America within the ASCC effort to research long-term forest ecosystem responses to a range of silvicultural actions focused on climate change adaptation.

Each ASCC experiment is focused on understanding and evaluating management options designed to enable forests to better respond to a changing climate. Treatments are developed according to local conditions and tailored to meet site-specific management objectives, while at the same time aligned under the common ASCC framework for answering questions about how different forest types will respond to future climate. This two-tiered design provides a means for evaluating adaptive management strategies across distinct forest types, allowing researchers to ask broad questions about climate change adaptation across all study sites while also addressing on-the-ground management goals specific to individual sites. Each ASCC site utilizes three adaptation options (i.e., resistance, resilience, and transition), as well as a control or “no action” treatment which serves as a baseline for how forests without active management respond to the same climatic factors the treatment areas experience. ESRF researchers and operations teams will use the foundation provided by this forest management plan, current analyses, and discussions with ASCC and other partners to determine whether research following ASCC design could be nested within the ESRF research platform. In alignment with the work of the ASCC network, this may include research on climate change adaptation in addition to exploring silvicultural practices for optimally managing forest carbon.

### **8.3.1.2 Climate Change Adaptation Library and Compendium of Adaptation Approaches**

Based on climate change vulnerability assessments and science-management partnerships, a series of adaptation strategies and tactics were developed for a digital library organized according to U.S. Forest Service (USFS) region. The ESRF may reference the resources for Region 6 to assist in further development of site-specific management actions. The USFS Climate Change Resource Center provides a similar tool for identifying adaptation approaches based on climate change impacts within the Pacific Northwest region. The adaptation approaches highlighted by such tools represent a broad spectrum of possible adaptation actions and examples of tactics that can be used to assist in designing site-specific management actions. Not all strategies will be applicable or relevant to the ESRF. The ESRF will seek to develop research collaborations with partners such as the Pacific Northwest Research Station and USDA Northwest Climate Hub to leverage these tools in operational planning.

### **8.3.1.3 The Experimental Network for Assisted Migration and Establishment Silviculture**

Climate change, drought, and high-severity wildfire are killing trees across large areas of the western United States, including in wetter forests. In some of these areas, trees may regenerate naturally while other areas may transition into non-forest as conditions change. Active forest regeneration by replanting is a management goal in many previously forested areas and there is a large backlog of lands with this need. The 2021 Infrastructure Investment and Jobs Act directs the USDA Forest Service to plant 1.2 billion trees in the next decade. Under Oregon law, industrial timberland owners are legally required to replant harvested areas to trees and ensure that they are “free to grow” within 24 months. Applied science knowledge is critically needed to support public and private investments in reforestation and help maximize the survival of replanted trees that will constitute a large percentage of our future forests.

Rapid changes in climate could complicate replanting efforts by outpacing rates of natural plant adaptation and migration. Existing science provides a foundation, but more information is needed about which seedlings (i.e., which species and populations within species) to plant and how to plant them to survive changing and increasingly harsh conditions after planting. Researching these questions can provide knowledge and tools to greatly increase rates of

reforestation success and improve long-term resilience of forests to changing conditions. Intensive and extensive treatments under the Triad design on the ESRF will offer excellent opportunities to partner on this key facet of research to inform ecological, climate-smart silviculture.

One such opportunity is the USFS PNW and PSW Research Stations' *Experimental Network for Assisted Migration and Establishment Silviculture* (ENAMES) project. This experimental network will focus on assessing the effect of assisted population migration and silvicultural practices on the short- and long-term success of reforestation activities. Researchers will examine the movement of seed sources or populations of a particular species from their existing location to new, currently cooler locations within their habitat range. The project team will investigate how to align seed sources with the future climate of planting sites, without moving so far that trees suffer cold damage in the near term, and evaluate post-disturbance stand establishment practices to determine which will increase short-term seedling survival. Examples of these practices include planting larger seedlings than typical, reducing competition from other vegetation, and reducing planting density so that more resources are available to fewer trees.

Actions being undertaken for the ENAMES project include:

- Establishing a new network of 20 experimental sites across California, Oregon, and Washington through collaboration between researchers and land managers. Many sites will be installed by spring 2024 but sites will continue to be installed in future years.
- Testing the effect of assisted population migration in partnership with forest managers across all ownerships. Assisted migration treatments at each site will include seed sources representing four inherent climate scenarios:
  - **Recent-past:** Seed from currently recommended local seed zones for a study site (generally based on climate from the 1961-1990 – baseline condition)
  - **Current:** Seed from environments that match the current climate at the study site (reflecting an approximate 1°C increase from baseline)
  - **Mid-century:** Seed from environments that are approximately 2°C warmer than the baseline condition reflecting climate projections from about mid-century
  - **End of century:** Seed from environments that are approximately 4°C warmer than the baseline condition

reflecting the worst-case scenario of climate projection from the end of the century

- Testing different silvicultural establishment practices designed to increase reforestation success and long-term forest resilience. Silvicultural treatments are determined through a collaborative process with partners, and then crossed with each assisted migration treatment to represent a gradient of adaptation strategies.

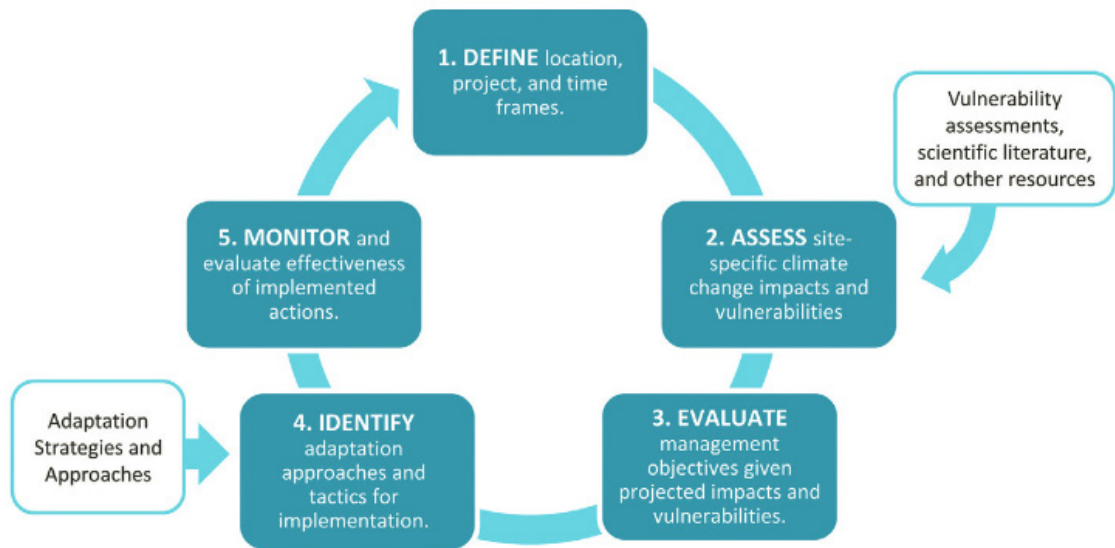
Becoming a partner with the USFS PNW Research Station on their ENAMES may align with potential research and climate-adapted silviculture on the ESRF, including under the example of strategies that promote genetic, compositional, structural, and functional diversity at both stand and landscape scales (Section 8.4). A climate-smart forestry practice that supports this approach is the use of seeds, germplasm, and other genetic material from across a greater geographic range.

The ENAMES has similarities and potential synergies with the Adaptive Silviculture for Climate Change Project described in Section 8.3.1. A key distinction is that the ASCC design is primarily focused on actions in an existing forest to modify structure and/or composition for adaptation or managing for forest carbon, whereas the ENAMES is focused on adaptation actions during the reforestation phase after disturbance (e.g., harvest, fire, wind). The ESRF Research Director (PI) will identify opportunities that may exist to partner with ENAMES or other projects based on continuity with research goals and details of the climate-smart forestry developed for the forest.

#### 8.3.1.4 Northern Institute of Applied Climate Science Adaptation Workbook

Numerous goals and objectives for the Conservation Research Watersheds (CRW), Riparian Conservation Areas (RCAs), and stand-level treatments in the Management Research Watersheds (MRW) already align with strategies described in these resources and General Technical Report NRS-87 (Swanston et al. 2016), an Adaptation Workbook developed primarily for the U.S. Midwest and Northeast that has recently been applied in California (Swanston et al. 2020).

The Climate Change Response Framework is a cross-boundary effort led by the Northern Institute of Applied Climate Science (NIACS) to support incorporation of climate change considerations into natural resource management through collaboration between scientists, managers, and landowners. The Adaptation Workbook



**Figure 8.1.** Adaptation process used to incorporate climate change as a management consideration and help forest ecosystems adapt to the anticipated effects of climate change. The process is supported with site-level science and vulnerability information, along with “menus” of focused adaptation tactics and actions (Source: Swanston et al. 2016). See Appendix Q for more details.

(Swanston et al. 2016) developed by this group provides a structured, adaptive process for integrating climate change considerations into planning, decision-making and implementation of management by translating broad concepts into actionable approaches (Schmitt et al. 2021).

Using processes outlined by the NIACS as guidance (Swanston et al. 2016, 2020; Schmitt et al. 2021), the ESRF will convene a group of 10-15 researchers, managers, and partners to (1) further prioritize and refine a set of adaptation approaches and tactics appropriate for the ESRF based on modeling and analysis in the forest management plan, and (2) develop climate adaptive silvicultural prescriptions and operational considerations specific to intensive, extensive, and restoration treatments in MRW Reserves and RCAs.

Workshop participants will include (but may not be limited to) ESRF research and operations personnel, state and federal agencies, tribal natural resource managers and representatives of Tribal Nations, forestry practitioners, local watershed associations, climate partnerships, and researchers from OSU and other institutions. The group

will also consist of participants from different scientific and professional disciplines (e.g., ecology, climate science, hydrology, silviculture, wildlife science) and Indigenous Knowledge holders in order to capture a range of perspectives. Through presentations and discussions of current science, data, and vulnerability assessments specific to the Oregon Coast Range, field visits on the ESRF, and working sessions, this group will expand on the climate-smart forestry approaches embedded in the ESRF research platform and forest management plan as part of the adaptive management strategy (Figure 8.1).

The ESRF research management team will identify workshop participants and begin initial meetings based on the guidelines above by January 2025, with development of a research-based approach to climate-smart forestry practices on the ESRF by January 2026. The Adaptation Workbook will be used as a decision support tool to focus the group’s work on defining climate considerations specific to the southern Oregon Coast Range and generating actionable tactics for integration of these considerations into broader planning and decision making for the forest within a research context (Schmitt et al. 2021). Specific actions that incorporate climate adaptation



practices at the stand and harvest level will be detailed in biennial operations plans and harvest prescriptions.

## 8.4 Climate Resilience and Forest Carbon Research Needs

The ESRF research platform and nested studies offer a unique opportunity to help fill these critical information gaps.

### 8.4.1. Forest Carbon Research and Process-Based Models

Case et al. (2021) outline three broad areas of information needs for understanding how climate change is expected to affect forest types and forest carbon storage across the PNW. These categories of research needs are listed below, with specific examples of each:

1. Belowground Carbon
  - Research how climate change affects soil processes, especially under low moisture conditions
  - Identify how soil microbial interactions will be affected by climate change
  - Improve how soil microbial interactions are simulated within earth system models/process-based models
  - Improve models and understanding of drivers of deep soil carbon of cycling under climate change conditions
2. Ecotone Carbon
  - Better monitoring of vegetation changes and microclimate within ecotones
  - Improved assessments of tree seedling establishment and survival
  - Vulnerability assessments of tree establishment and mortality in ecotones
  - Quantify current carbon storage and monitor changes, analyze for trends
3. Process-based models
  - Include insect interactions and outbreaks
  - Improve fire modeling
  - Integrate statistical and process-based models
  - Incorporate more sophisticated belowground microbial interactions

- Include tree demography and regeneration dynamics
- Incorporate risks of carbon loss from natural disturbances, including their projected shifts under climate change

Adequate quantification and verification of the carbon consequences of varying forest management scenarios under future climate conditions requires the use of process-based models. Current models used for carbon accounting rely heavily on historical relationships between stand age, growth, and climate, but as climate changes these relationships begin to break down (Crookston et al. 2010). Forest carbon accounting methods often used by the USFS and others are based on growth and yield models which reduce annual growth in response to drought but cannot estimate drought-driven forest mortality, carbon losses, or legacy effects. Further, disturbance events can alter both forest carbon stocks and fluxes, and the trajectory of forest recovery will determine carbon cycling dynamics for years to decades following the event. To estimate forest response to climate conditions outside the observational record it is crucial to represent the mechanisms that control ecosystem carbon cycling.

Researchers at University of Oregon and OSU are parameterizing LANDIS II and iLand for the ESRF; see Chapter 4: *Research Platform and Experimental Design*, Section 4.4. In the near future, the Community Terrestrial Systems Model (CTSM), a process-based model designed for weather prediction, ecological modeling and hydrological prediction, and earth system and climate modeling will also be utilized. CTSM is open-source and designed to involve users in development and validation. CTSM is actively supported by the National Center for Atmospheric Research and will be used in drought monitoring by the National Integrated Drought Information System and North American Land Data Assimilation System. CTSM will be used for drought prediction at sub-seasonal to decadal scales, so infrastructure already exists for extension to operational carbon monitoring.

CTSM users can tailor it for their specific application, for example, by turning on modules that simulate harvest, fire, or nutrient cycling, and configuring for point, watershed, or regional domains. CTSM represents the dynamic flow of carbon among live and dead aboveground biomass pools, and soil carbon and belowground carbon pools. Carbon flows are driven by process-based representations of photosynthesis, heterotrophic and autotrophic respiration, C:N allocation ratios, and decomposition. Carbon and

water cycling are linked through plant hydraulic functioning and water availability constraints on photosynthesis. Soil hydrology determines plant available water and soil moisture constraints on decomposition rates. Wood harvest can be prescribed spatially based on area of the grid cell or amount of biomass. Live stem carbon removed during harvest is extracted and proportion of slash can be prescribed.

CTSM will be calibrated to represent dominant ESRF tree species using decades of OSU Coast Range research (e.g., Hudiburg et al. 2009; Law et al. 2018; Law et al. 2021) to define plant traits and set model parameter values. Similar to Buotte et al. (2019) plant functional types will be defined in CTSM to represent individual species. These simulations will then be tested against the carbon monitoring network established on ESRF and CTCLUSI Tribal lands. CTSM model simulations of harvest yields and carbon stocks will be compared to Forest Vegetation Simulator (FVS) and COMET tools currently used by USDA. This will help identify when historically based growth curves begin to diverge from process-based model projections to identify when added model complexity is required. Modeling tools will be used to assess effects of different harvest prescriptions on carbon stocks and harvest yields under multiple future climate scenarios to determine the sensitivity of different approaches to changing conditions. A range of future disturbance regimes will also be implemented to assess resilience under different harvest prescriptions.

Carbon cycle researchers anticipate future research opportunities at the interface of process-based modeling and novel remote sensing tools such as imaging spectroscopy, lidar, and solar-induced fluorescence. Process-based vegetation models such as the Soil Canopy Observation of Photosynthesis and Energy fluxes (SCOPE; Yang et al. 2021) and the Climate Modeling Alliance (CliMA) land model (Wang et al. 2023) are being developed by the scientific community to use remote sensing data streams for vegetation model parameterization and validation. As such models are developed and refined, they can help estimate carbon stocks, and fluxes of carbon, water, and energy in forests. These tools may open the possibility of extrapolating from intensive carbon monitoring plots to estimate carbon pools and fluxes at larger spatial scales captured by remote sensing. The ESRF offers opportunities to test and improve these models for coastal range PNW forests through ‘ground-truthing’ observations from remote sensing, and evaluating parameters and simulations from process-based models.

## 8.4.2 Climate-Smart Forestry Research and Practices

Climate-smart forestry practices can increase both the rate of carbon removal from the atmosphere and carbon storage on the landscape (Bowditch et al. 2020.) The ESRF plans to implement and refine (via adaptive management; see Chapter 11: *Adaptive Research Strategy and Implementation*) many of the strategies and practices under a climate-smart forestry approach, including under the following categories (in no particular order). Many ESRF objectives and management guidelines, as well as current best management practices in forestry, apply to these categories. Many of these actions are also likely to be beneficial in the context of adaptation, either in their current form or with modifications to address potential climate change impacts as part of the approach. Examples of strategies, approaches, and tactics under these categories are drawn from the Adaptation Workbook (Swanston et al. 2016) and ASCC resources, including the following approaches with particular relevance to the ESRF.

### 1. Reforestation promoting genetic, compositional, structural, and functional diversity at both stand and landscape scales

A range of silvicultural approaches will be used across intensive, extensive, and restoration treatments to promote diversity at these scales. For intensive treatments, the types of species planted and genetic source of seeds may vary depending on context on the landscape.

A climate-smart forestry practice that supports this approach is the use of seeds, germplasm, and other genetic material from across a greater geographic range (Strategy: *maintain and enhance genetic diversity*). Under this approach, the ESRF may choose to use mapping programs to match seeds collected from a known origin to planting sites based on climatic information, or plant seedlings germinated from seeds collected from various locations throughout a species’ native range. Researchers could source planting stock from seeds collected from local trees that exhibit drought tolerance, pest resistance, or other desirable qualities; or retain some survivors of a die-back event to promote structural complexity and natural regeneration of well-adapted phenotypes. In extensive treatments, silvicultural treatments will aim to promote multi-aged stand structures with varied tree sizes and multi-layered canopies. The ESRF will design regeneration activities to introduce variability in

vegetative species composition and density at the stand level when consistent with research activities.

The ESRF will explore the potential to collaborate with USFS researchers through the Experimental Network for Assisted Migration and Establishment Silviculture project to develop management recommendations related to short- and long-term success of reforestation under climate change. That project is described above in Section 8.3.1.

## **2. Extending rotation times compared to business-as-usual**

On the ESRF, the 60-year minimum rotation for regeneration harvests in intensive treatments and 100-year rotation minimum for extensive treatments support this approach. Lengthening harvest rotation periods has been shown to increase carbon stocks, and this practice will be a foundation of ESRF management. In the PNW, typical rotations are around 35-45 years but productivity peaks at 80-125 years (Hudiburg et al. 2009). Increasing rotations to 80 years could increase carbon stocks by 24% on average across Oregon by 2100 (Law et al. 2018). Harmon et al. (2009) also found that carbon stores increased with longer rotations in Coast Range type forests.

This approach connects with extensive silviculture methods to promote uneven-aged stands with higher ecosystem carbon capacity than even-aged stands (Kern et al. 2021, Williams and Powers 2021; Susaeta et al. 2021). Moreover, partial cuts may have lower impacts on soil organic carbon depending on the harvest residues and large standing and down dead wood left on site, soil characteristics, and climate conditions (Jandl et al. 2007). Old growth forests, which the ESRF will actively manage to promote (particularly in the CRW and MRW Reserves), store the most carbon (Gray et al. 2015; Williams and Powers 2019).

## **3. Maintaining and improving forest soil quality and below-ground carbon sequestration**

Research on forest carbon sequestration, carbon fluxes, and soils are part of the foundational research platform and monitoring system on the ESRF. Researchers will have the ability to explore topics that include understanding relationships between silvicultural treatments, harvest operations, and soil and carbon processes, as well as conservation measures to mitigate impacts.

A related climate-smart forestry practice is reducing impacts to soils and nutrient cycling (Strategy: *sustain fundamental*

*ecological functions*). Researchers may choose to study a range of tactics under this approach, including altering the timing of forest operations to reduce potential impacts on water, soils, and residual trees, especially in areas that rely on particular conditions for operations that may be affected by a changing climate (e.g., dry conditions). Research on timing and impacts of harvest operations is described in the ESRF Research Proposal (OSU College of Forestry 2021), and monitoring on the forest will include measurements related to water quality, soils, carbon processes, and forest structure. Researchers and managers may also modify forest operations techniques and equipment to minimize soil compaction, rutting, or other impacts on water, soils, and residual trees. Guidance in extensive and riparian restoration treatments to retain coarse woody debris to maintain moisture, soil quality, and nutrient cycling also applies to this climate-smart forestry practice.

## **4. Increasing carbon storage via stand management**

Objectives and management guidelines for extensive silviculture (particularly in higher retention treatments) and in reserves will support structural complexity and growth of older forest at the stand and landscape scale, with monitoring of carbon storage using LiDAR and permanent network of forest inventory and carbon plots.

## **5. Ecological restoration of forest plantations**

Restoration treatments in plantations less than 65 years of age (as of 2020) in reserves and RCAs will seek to shift these stands to a trajectory informed by natural disturbance processes (increasing resistance and resilience to disturbance), structural complexity, and support for ecological processes.

A climate-smart forestry approach to reduce competition for moisture, nutrients, and light (Strategy: *sustain fundamental ecological functions*) fits within this objective. Tactics in support of this approach include thinning forest stands to remove crowded, damaged, or stressed trees in order to reduce competition for light, nutrients, and water; and potentially using prescribed fire.

## **6. Managing forests for resistance to climate change effects**

Research that focuses on restoring or supporting ecosystem processes and functions will contribute to management for resistance to climate change. Restoration treatments in



current plantations in the CRW and RCAs, as well as efforts in aquatic systems such as reconnecting floodplains will contribute to this goal for the ESRF.

A climate-smart forestry approach to maintain or restore hydrology (Strategy: *sustain fundamental ecological functions*) fits under this objective. Tactics include upgrading culvert size and cleaning culverts regularly to accommodate changes in peak flow and thus reduce damage to infrastructure and the environment during heavy rain events. Managers may also decommission, relocate, or temporarily close roads to reduce erosion and sedimentation and to restore permeability and soil hydrology, actions that will be informed by a comprehensive roads assessment and monitoring on the ESRF.

An example of another climate-smart forestry approach is maintaining or restoring riparian areas (Strategy: *sustain fundamental ecological functions*). Tactics under this approach include restoring or promoting a diversity of tree and plant species to increase stream shading, provide a source of woody debris, stabilize the soil, and provide habitat and connectivity for wildlife. Managers may also work to reconnect floodplains to rivers and restore natural floodplain conditions and associated native habitats in order to restore fluvial processes.

## 7. Managing for increased resilience

The ESRF plan for research management, including application of the Triad, will create greater structural and species diversity at stand, subwatershed, and landscape-levels as stands are managed from even to uneven age structures using treatments that are applicable to current conditions and unique features in a stand.

A climate-smart forestry approach for increased resilience is to maintain or improve the ability of forests to resist pests and pathogens (Strategy: *reduce the impact of biological stressors*). Tactics include thinning to reduce the density of a pest's host species in order to discourage infestation, based on the knowledge that species are especially susceptible to pests and pathogens at particular stocking levels; creating a diverse mix of forest or community types, age classes, and stand structures to reduce the availability of host species for pests and pathogens; and using impact models and monitoring data to anticipate the arrival of pests and pathogens and prioritize management actions.

## 8. Building partnerships and identifying areas for collaboration

The ESRF will seek opportunities to build partnerships and formal collaborations with regional and national partners on climate-smart forestry research and practices. Such partners would include the Northwest Climate Hub, U.S. Forest Service, US Geological Survey Northwest Climate Adaptation Science Center, Tribes, local watershed associations, and other experimental sites (e.g., Adaptive Silviculture for Climate Change project, HJ Andrews Experimental Forest, Olympic Experimental State Forest) to develop site-specific climate change adaptation treatments and align research-management needs.



At the time of completion of this ESRF Forest Management Plan, the ESRF HCP had not been finalized. The ESRF HCP provides the regulatory sideboards for the FMP. Once completed, any adjustments in the HCP will need to be incorporated into this FMP document so that the text is aligned. Within this document, the ESRF HCP is referred to as the ESRF HCP, but it should be noted that it is referring to the draft form of the ESRF HCP.

## Chapter 9

### Species Conservation

The ESRF encompasses habitat suitable for most native species found in Coast Range forests. Oregon DSL and ODF (2011) developed a list of 209 species (58 mammals, 103 birds, 15 amphibians, 8 reptiles, and 25 fish) currently known or likely to exist on or adjacent to the ESRF. An updated list, incorporating species status information from USFWS (2022), ODFW (2021) and the Oregon Biodiversity Information Center (2019) is shown in Appendix T. The Coast Range Ecoregion mixed conifer forest also supports diverse floral communities. An overarching goal and numerous specific objectives for the ESRF are focused on maintaining and improving conditions for the forest's native species and their aquatic and terrestrial habitats.

Biosystems et al. (2003) found that few wildlife studies or surveys specific to the Elliott had been conducted, aside from those focused on endangered species. Since that time, an increasing amount of wildlife surveying and monitoring has been conducted by ODF, ODFW, watershed councils, and others, including for the three species covered under the ESRF HCP. Biodiversity surveys were initiated in 2022 to address knowledge gaps and establish baseline information regarding species occurrence, populations, and habitat usage on the forest. The ESRF will serve as a laboratory for biodiversity research from site to landscape-scale. The preliminary data provided by the 2022 biodiversity pilot study (Appendix V), continued field work in 2023, and future biodiversity surveys, will contribute to a dynamic public database of species on the ESRF that is maintained and updated as new information becomes available.

Conservation of biodiversity on the ESRF is anchored by the 34,139-acre Conservation Reserve Watersheds (CRW), buttressed by smaller reserve areas and Riparian Conservation Areas (RCAs) contained within the Management Research Watersheds (MRW) and enhanced by efforts to promote connectivity across actively managed watersheds. Restoration treatments planned for existing plantations, implementation of the Triad design, and conservation of reserves across the ESRF are expected to, over time, broadly increase the diversity and quality of habitats available in both upland terrestrial and riparian systems. Research and actions are also being aimed more specifically at benefiting the northern spotted owl, marbled murrelet and Oregon Coast coho salmon under the ESRF Habitat Conservation Plan (ESRF HCP).

This chapter summarizes species conservation on the ESRF, including: (1) high level conservation strategies connected to the ESRF research design and goals, (2) more targeted strategies for the three species covered under the ESRF HCP and, (3) other species of interest or concern.

## 9.1 Strategies for Multispecies Conservation

For practical reasons, actions to conserve biodiversity often focus on individual species, triggered when the species is recognized as facing significant risk to its continued existence. The ESRF HCP and the three species it covers is an example of this “species-specific” approach to biodiversity conservation. The ESRF HCP focuses tightly

on covered species, their specific habitat needs and threats to individuals and populations, and creates a regulatory obligation to manage specifically to protect and improve the status of these species.

Multispecies conservation strategies can encompass species covered under the ESRF HCP but also provide broader coverage for numerous other species that inhabit the ESRF but are not recognized and regulated as threatened or endangered. While they are not accompanied by the same regulatory obligations as the ESRF HCP, landscape level, multispecies conservation strategies help assure that biodiversity will be maintained over the longer term across a broad range of habitat characteristics and species needs.

This section outlines a set of multispecies conservation strategies that will be pursued on the ESRF.

**Strategy 1: Maintain Protected Areas.** Perhaps the most obvious and common approach to multispecies conservation is to place large tracts of contiguous habitat under protection. This approach recognizes the critical importance of not only protecting species but also the ecosystems on which they rely. The CRW and nearby Devil’s Staircase Wilderness Area represent 65,246 acres of forest in protected reserve. Large areas of older forest provide many benefits, including protection of both upland and lowland reaches of integrated riparian systems, maintenance of genetic diversity by allowing intermixing and dispersal across larger areas and populations, and buffering the temporary loss of habitat area after natural and human disturbances. Large reserves are also often the only means of maintaining viable populations of wide-ranging species such as large predators.

The ESRF Conservation Research Watersheds and system of MRW reserves create a protected network through conservation of existing older forests, restoration of plantations to support more complex structures and diverse species mixes over time, integration of terrestrial and aquatic ecosystems, limits on management activities, and decommissioning of roads.

**Strategy 2: Maintain and Increase Connectivity.** Landscape connectivity is defined as the extent to which movements of genes, propagules (e.g., pollen, seeds), individuals and populations of living organisms are facilitated by the structure and composition of the landscape. *Structural connectivity* refers to physical characteristics of a landscape that facilitate movement, including topography, hydrology, vegetative cover, and patterns of human land use.

*Functional connectivity* refers to how well genes, propagules, individuals, or populations are able to move through the landscape. Functional connectivity results from the ways that an organism, via its habitat preferences and dispersal ability, interacts with structural characteristics of the landscape (Rudnick et al. 2012).

Connectivity is lost through landscape *fragmentation*, the breaking up of larger contiguous areas of forest cover or habitat into smaller, more isolated patches. Loss of connectivity can reduce the size and quality of available habitat and impede the ability of animal and plant species to disperse to new habitats. Such changes can lead to decreased carrying capacity, population declines, loss of genetic variation and eventual species extinction. Thus, species and biodiversity conservation often focus on protecting and enhancing connectivity to offset the impacts of habitat fragmentation and loss, and to increase the resilience of reserve networks (Rudnick et al. 2012). Creation and maintenance of interconnecting forest habitat *corridors* and *stepping stones* are common strategies for enhancing connectivity with larger protected areas.

Within the ESRF, the CRW represents a major increase in Oregon Coast Range protected area connectivity by linking to adjacent designated wilderness on the federal Siuslaw National Forest. Within the CRW, connectivity will be enhanced via the selective decommissioning of forest roads, and by treatments to promote integration of plantation stands with adjacent older forests. Within MRW subwatersheds, reducing fragmentation is an important criterion for allocating stand level treatments. Subwatersheds that have intensive treatments will have an equal amount of land area placed in reserve status, helping to maintain stepping stone patches of forested habitat and a measure of connectivity to larger blocks of reserve. Connectivity is an important criterion used in the spatial design of treatment allocations (i.e., location of intensive, extensive, and reserve stands) within a subwatershed and between subwatersheds, in order to support landscape connectivity.

Addressing landscape and habitat connectivity is an important issue facing state, federal and private landowners. In July 2023, ODFW published results and tools from the Oregon Connectivity Assessment and Mapping Project (OCAMP; ODFW 2023), identifying three types of *Priority Wildlife Connectivity Area* (PWCA) across the state. The ESRF encompasses substantial amounts of PWCA, highlighting the potential for collaboration with ODFW and adjacent land ownerships to maintain and enhance connectivity within

and across ESRF boundaries. See Section 9.3 below for more details. The ESRF Research Director (PI), Executive Director, and foresters will coordinate with ODFW and local partners on contributions of the ESRF to maintaining and improving connectivity in the context of the broader landscape through the management and research taking place on the forest. As described in Chapter 10: *Monitoring*, the ESRF will collect and maintain forest inventory data (including aerial and ground-based LiDAR) and biodiversity data through surveys across the forest. The ESRF will use spatial analysis tools to track conditions across the forest, and to test the hypotheses of increasing connectivity and the impacts on species conservation.

**Strategy 3: Focal Species.** Another common strategy for multispecies conservation is to use a monitored “focal” species as a surrogate to assess or improve the status of other unmeasured species that are associated with the same type of habitat. The assumption is that monitoring and management aimed at a particular focal species will provide useful information and confer protection on co-occurring species (Noon et al. 2008). Variations of the focal species concept include the designation and tracking of:

- *Indicator species*, an organism so intimately associated with particular environmental conditions that its presence indicates the existence of those conditions.
- *Umbrella species*, a species that needs such large areas of habitat that managing for its viability encompasses many other species with similar habitat but smaller area needs.
- *Keystone species*, species which significantly affect one or more key ecological processes or elements to an extent that greatly exceeds what would be predicted from their abundance or biomass (e.g., beavers, wolves).

As a reference, the multispecies conservation strategy on the Olympic Experimental State Forest (OESF) has an explicit intent of non-species-specific management. Specific habitat types (caves and balds) are protected, but habitat for most native species is envisioned as an outcome of landscape-level management. For example, conservation measures for riparian areas and northern spotted owl and marbled murrelet habitat are expected to create interconnected patches of late-successional, mid-aged, and young forests that support a range of species (Washington DNR 2016).

Strategies outlined for the ESRF under its HCP should provide similar benefits. Increasing structural diversity within streams and adjacent terrestrial riparian forests to improve habitat for coho salmon is expected to also benefit



a range of other species (e.g., amphibians, invertebrates, birds) that rely on such habitats. Similarly, maintaining older forests and actively managing to accelerate development of old forest characteristics on behalf of the northern spotted owl and marbled murrelet could be expected to benefit the status of other species associated with this type of forest. In addition to the three species covered under the ESRF HCP, ESRF managers will work with ODFW and other partners to identify other potential focal species, and how best to incorporate information regarding these species into management.

A focal species approach can provide benefits and potentially sufficient information regarding broader biodiversity and ecological conditions, while saving time and resources that monitoring and management of multiple species individually would require. However, the aspects of biodiversity for which the focal species are acting as surrogates should be clearly defined because not all biodiversity changes can be detected or mitigated with this approach. The most reliable way to improve or detect

changes in the status of a species of significant interest or concern is through surveys, monitoring and restoration actions targeted specifically on that species.

**Strategy 4: Biodiversity Monitoring.** A network of permanent biodiversity plots will be established across subwatersheds in the MRW and CRW (See Chapter 10: *Monitoring*, Section 10.1.5 *Biodiversity*) to monitor long-term trends in species diversity and habitat structure. This monitoring system will align, when possible, with forest inventory plots, aquatic and riparian monitoring, and microclimate measurements to provide detailed information about a range of species on the forest. Plot design and sampling protocols for biodiversity will target multiple taxa, including mammals, birds, arthropods, bees, soil fungi, amphibians, vegetation, and microbial communities, canopy microbiome, and amphibians. Long-term data from biodiversity monitoring will help track changes in habitat and species trends, inform adaptive management on the forest to continually improve management and conservation strategies, and create a foundation for additional targeted research.



**Figure 9.1.** Bobcat on the ESRF photographed by a wildlife camera installed as part of biodiversity monitoring program (8.22.22).

Given the paucity of presence and population surveying that exists for many species on the ESRF, the robust biodiversity monitoring program being initiated is expected to rapidly increase knowledge in this area. This will facilitate more informed and targeted actions to protect and enhance biodiversity on the forest.

## 9.2 Species Covered Under the ESRF Habitat Conservation Plan

Management of the ESRF will be consistent with and promote the objectives of the ESRF Habitat Conservation Plan prepared under the federal Endangered Species Act (ESA) of 1973. The ESA provides a regulatory framework to conserve, protect and recover endangered and threatened species and the ecosystems upon which they depend. When a species is listed as *endangered* under the ESA, it means that species is in danger of extinction throughout all or a significant portion of its range. Being listed as *threatened* means the species is likely to become endangered within the foreseeable future.

The ESRF Habitat Conservation Plan (ESRF HCP) provides more detailed information on the conservation approach for the three listed species: northern spotted owl, marbled murrelet, and Oregon coast coho. The ESRF HCP should be referenced when planning management or conservation activities on the ESRF. The sections below provide targeted information relevant to implementation of the FMP.

### 9.2.1 Northern Spotted Owl

In 1990, the U.S. Fish and Wildlife Service (USFWS) designated the northern spotted owl as threatened throughout its range, which includes the ESRF, by degradation and loss of suitable habitat from timber harvesting and other disturbances. In 2020, the USFWS found that reclassification of the northern spotted owl from a threatened species to an endangered species was warranted, and a proposed rule to reclassify the species is expected as agency priorities allow. Two of the most comprehensive reviews of the scientific literature on the northern spotted owl are the 2018 Forest Service Science Synthesis Report (Lesmeister et al. 2018) and the supporting materials submitted for the 2020 USFWS 12-Month Finding (USFWS 2020). The most recent northern spotted owl recovery plan (USFWS 2011) focuses on largely on five topics:

- Conservation of spotted owl sites and high value spotted owl habitat;
- Ecological forestry and active forest restoration to meet the challenges of climate change and altered ecological processes;
- The threat posed by Barred Owls and management options to address it;
- The potential need for State and private lands to contribute to spotted owl recovery in certain areas; and
- Completion of a habitat modeling framework as an informational tool to better enable future land management decisions.

On state lands such as the ESRF, USFWS works with managers to develop ESRF HCPs and Safe Harbor Agreements for the northern spotted owl to allow for timber harvest and other activities consistent with requirements of the ESA.

Northern spotted owls are nocturnal hunters. Owl locations are closely correlated with availability of prey such as northern flying squirrels. The owls are territorial and, as adults, often occur as mated pairs that share a core territorial nesting area and overlapping foraging territories which they may maintain for many years. For management purposes, northern spotted owl territories are defined as “activity centers” centered on nest sites or daytime roost locations. While nesting pairs are of particular importance for maintaining populations, resident single owls, transient owls, and dispersing juveniles are all important for population maintenance (Courtney et al. 2004; Lesmeister et al. 2018) through their ability to colonize or recolonize unoccupied habitat.

### Habitat Requirements

Critical habitat for the northern spotted owl identified by USFWS in Oregon as of 2021, includes 38,764 acres (approximately 42%) on the ESRF. The USFWS recognizes three types of forest habitat that support fundamental behaviors for the northern spotted owl: *nesting and roosting habitat*, *foraging habitat* and *dispersal habitat*. See ESRF HCP Section 2.3 for a detailed description of northern spotted owl habitat requirements.

### Status on the ESRF

Based on survey results conducted in 1990, 1992-1996, 2003, and 2010-2016 (Kingfisher Ecological, Inc. 2016), the



population and density of northern spotted owls across the ESRF have declined significantly over time, reflecting similar rangewide population declines (Lesmeister et al. 2018). As of 2016, 19 northern spotted owl pair sites, 1 unconfirmed pair site, and 2 resident single sites centered on the Elliott had been consistently occupied over several years and had at least 1 detection between 2011 and 2016 (within 5 years of the last full survey conducted in 2016). In addition, 5 northern spotted owl pair sites centered on lands adjacent to the Elliott State Forest (i.e., within 1.5 miles) had been consistently occupied over several years and had at least 1 detection between 2011 and 2016. The most recent and historic activity centers are shown in Figure 9.2.

Historically, northern spotted owl declines have been linked with habitat loss and degradation. Current northern spotted owl population declines throughout its range are attributed primarily to widespread expansion of the Barred Owl (*Strix varia*), an invasive species. Barred owls were first detected in Washington in 1965, Oregon in 1974, and California in 1981 then increased rapidly. Barred owls have now displaced northern spotted owls throughout much of their historic range including the ESRF. See Conservation Measure 6 and barred owl description in the ESRF HCP and FMP Section 8.3.1 for more information.

### Forest Management and Habitat Enhancement for Northern Spotted Owl

Northern spotted owls in the central Oregon Coast Range appear to prefer a mixture of older forests with younger forest and non-forested areas (Glenn et al. 2004; USFWS 2012). An analysis of habitat edge types showed that northern spotted owls also select the edge (or ecotone) between hardwood and conifer stands, suggesting that this edge habitat may promote a healthy prey base or enhance access to prey (Anthony et al. 2000). The configuration of treatments under the Triad design (particularly in extensive treatments and reserve restoration treatments) at the subwatershed scale will create habitat that would be anticipated to support spotted owls based on this data. Restoration treatments in the CRW and MRW Reserves will create research opportunities to study techniques and ecosystem responses while transitioning current plantations to older, more complex forests that support a range of species, including nesting, roosting, foraging, and dispersal needs for northern spotted owl (Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.4.1). See ESRF HCP Section 8.2.5 and the ESRF HCP Conservation Strategies below.

### ESRF HCP Conditions on Covered Activities Related to Northern Spotted Owl

The conservation strategy for northern spotted owl includes conditions that define specific take avoidance and minimization measures for the northern spotted owl to be applied as part of forest management activities covered under the ESRF HCP (e.g., thinning and regeneration harvests as described in the research design, associated experiments to study alternative approaches to accelerating old forest structure and habitat for northern spotted owls and marbled murrelets, tree climbing and canopy work for research purposes). Additional details on these five conditions are provided in the ESRF HCP.

Research that would require handling of individual northern spotted owls or other potentially harmful activities are not covered activities under the ESRF HCP because the specific methods, intensity, frequency, and duration of such activities have not yet been defined at the level needed to identify effects and issue take permits. ESA compliance for research that requires handling of northern spotted owls or marbled murrelets will be conducted under an approved scientific collectors permit; take associated with those activities will be tracked to the collectors permit and not the ESRF HCP.

**Condition 1: Seasonal restrictions around northern spotted owl nest sites.** To minimize adverse effects on nesting northern spotted owl, seasonal restrictions on disturbance distances will apply to the 22 northern spotted owl activity centers described in the ESRF HCP and to any additional actively nesting northern spotted owls that may become established within the permit area. Activities will be restricted during the critical nesting season (March 1–July 7) for active single and pair sites, and within USFWS-recommended seasonal disturbance distances given in ESRF HCP Table 5-4, unless it is determined using USFWS-approved survey protocols that no nesting is occurring, or has failed, or until July 15, whichever is sooner. Exceptions to these restrictions will only occur when (1) applying the restrictions would compromise the safety of staff, contractors, or the public; or (2) applying a more limited restriction is clearly justified based on site conditions. Exceptions to the restrictions are expected to be rare and will be applied only after a site-specific review by a northern spotted owl expert and documentation of recommendations. Any exceptions will be summarized in the annual report.





**Condition 2: Retention of northern spotted owl nesting core areas.**

A 100-acre nesting core area of the best contiguous habitat will be maintained around the nest tree (or designated activity center if nest site unknown) for the 22 northern spotted owl activity centers described in Condition 1 above. There will be 100 percent retention in the nesting core area. This nesting core area does not need to be circular in shape, but habitat will be contiguous and the distance between the nest tree and the edge of the nesting core will be no less than 300 feet. The location of the nest tree will be determined by northern spotted owl experts. Designation of the nesting core area will be done prior to any harvest activities occurring in the surrounding approximately 502-acre core use area.

**Condition 3: Retention of northern spotted owl core use areas.**

Core use areas of at least 502 acres of the highest-quality contiguous habitat will be established around active northern spotted owl nest sites. The 502 acres does not need to be in a circle but will be contiguous, and the edge of the core use area will be no less than 300 feet from the nest location. Within the core use areas, at least 50 percent (more than 251 acres) of the highest-quality contiguous habitat will be retained as nesting, roosting, and foraging habitat at all times. For core use areas that extend beyond the permit area the ESRF will be responsible for retaining nesting, roosting, and foraging habitat on at least 50 percent of the total area inside the core use area (which is also inside the permit area).

Core use habitat will not need to be kept in the same location through time, as long as minimum quality and quantity are retained. The location of designated core use areas may be reallocated within each 502-acre core use area. Any core use areas that currently do not meet the minimum standard of at least 251 acres of nesting, roosting, and foraging habitat will not be thinned or harvested until that minimum is met. Once met, the percentage of nesting, roosting, and foraging habitat will not drop below the 50 percent threshold. Retention and long-term application of ecological forestry practices within extensive treatment areas may contribute to the maintenance of 50 percent nesting, roosting, and foraging habitat in core use areas. This standard will be applied to at least 22 northern spotted owl core use areas at any one time. Initially, this condition will apply to northern spotted owl activity centers shown in Figure 9.2. If new owl nest locations are discovered in the future, the ESRF, in coordination with USFWS, could choose to remove protections from another (inactive) core use area and apply protections to the core use area of the newly discovered (active) nest site.

**Condition 4: Retention of habitat in northern spotted owl home ranges.**

The ESRF will retain at least 40 percent of the home range (a 1.5-mile-radius circle centered on the activity center) as nesting, roosting, and foraging habitat around the active nest core areas described in Condition 2. For a 1.5-mile-radius circle, 40 percent equates to 1,809 acres. For areas within the home range but outside of the core use area, the “highest-quality contiguous habitat” requirement will not apply to the broader home range area, although any habitat grown and used as replacement habitat must meet the requirements of nesting, roosting, and foraging habitat. A home range will be recognized for each northern spotted owl nest location that also has a nesting core area and core use area. Similar to the requirements in core use areas, if the 1.5-mile buffer around a nest site, which defines the home range, includes areas outside of the permit area, the ESRF is only responsible for retaining at least 40 percent of the total area that is inside the permit area.

**Condition 5: Maintenance of northern spotted owl dispersal landscape.**

This condition establishes the commitment to retain at least 40 percent of the MRW as dispersal habitat. Although suitable nesting, roosting, or foraging habitat is probably the best dispersal habitat, owls will use younger forest for dispersal. Dispersal habitat can occur between larger blocks of nesting, foraging, and roosting habitat or within blocks of nesting, roosting, and foraging habitat. The standard is met when forests—at a landscape level—are composed of at least 50 percent of trees with 11 inches diameter at breast height or greater, and with roughly a minimum 40 percent canopy cover. Setting the commitment in this condition at 40 percent dispersal habitat is with this standard. The majority of the CRW and MRW reserves are expected to continue to develop into nesting, roosting, and foraging habitat over the permit term. These areas will also continue to support dispersing northern spotted owls. It is anticipated that the dispersal habitat commitment will be achieved through the covered activities and conservation measures, and that this commitment is primarily to monitor and report that dispersal habitat within the MRW is being maintained at 40 percent or greater.

**9.2.2 Marbled Murrelet**

USFWS listed the marbled murrelet as federally threatened in October 1992. Historical loss of marbled murrelet nesting habitat is generally attributed to timber harvest and land conversion, although forest fires have also caused losses. Timber harvest loss has been greatest on lower elevation sites and throughout the Oregon Coast Range. A Recovery Plan was published in 1997, and critical habitat was

designated in 2016 (including lands within the ESRF). In 2021, the marbled murrelet was uplisted from *threatened* to *endangered* under the Oregon Endangered Species Act.

## Habitat Requirements

The marbled murrelet is a seabird that spends most of its life in nearshore marine waters but nests inland in mature and older forests up to 50 miles inland. Inland nesting habitat is the focus of habitat management for this species in the ESRF. See ESRF HCP Section 2.4 for a detailed description of marbled murrelet habitat requirements.

## Status on the ESRF

The ESRF is thought to have a relatively large population of nesting marbled murrelets, and the area is considered important to the distribution of the marbled murrelet on the Oregon Coast. Beginning in 1992 or prior, ODF began conducting murrelet occupancy surveys on the Elliott. While the surveys were primarily linked to harvest and management activities, and were thus not fully comprehensive, they resulted in 120 survey sites with “significant observations”, a level of activity that indicates nesting activity taking place on the forest. Additional surveys conducted by OSU researcher S. Kim Nelson in the mid 1990s to early 2000s were added to a database of historically occupied stands on the ESRF.

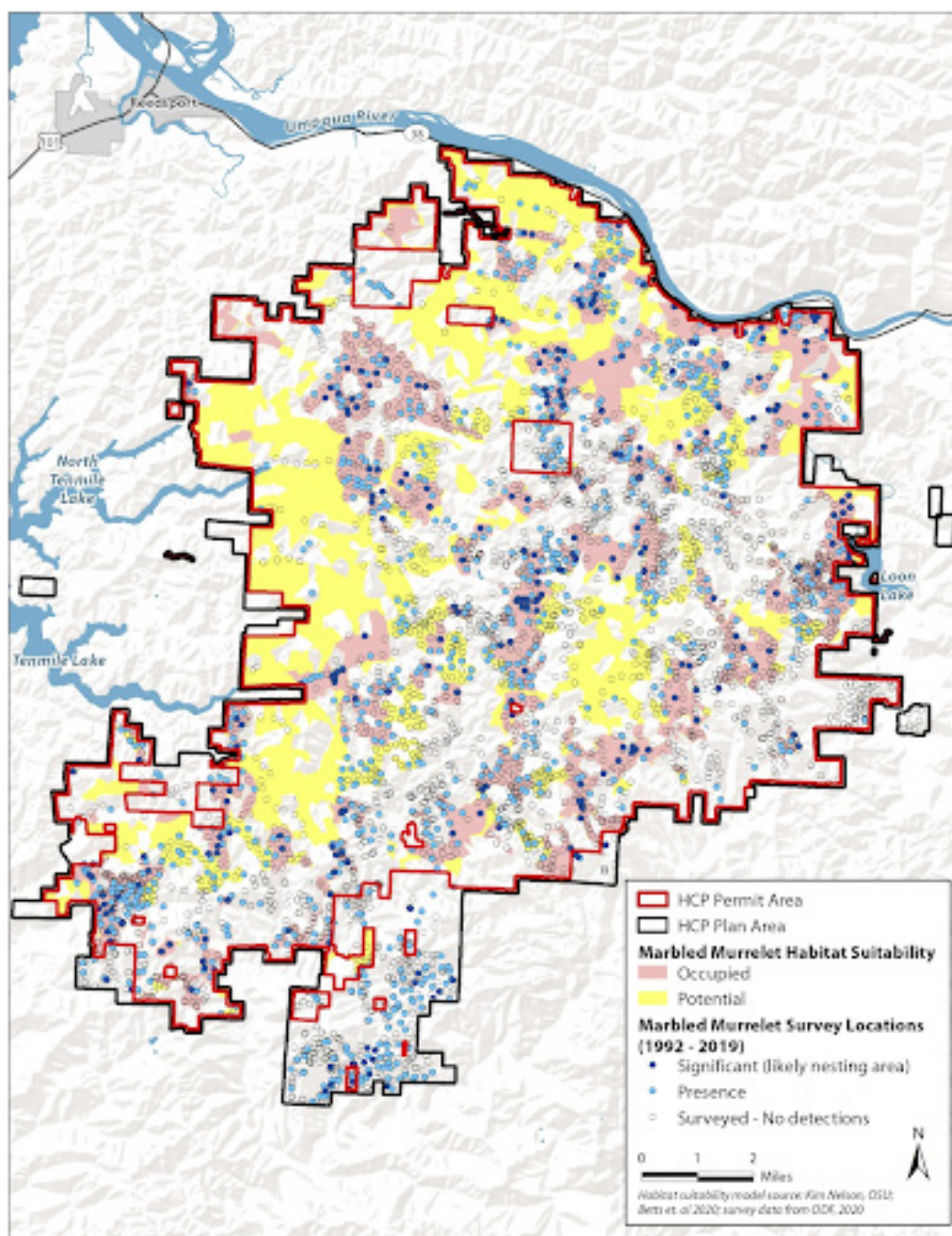
Of the 6,965 sites that have been surveyed on the Elliott since 1992, the majority were surveyed as a step in pre-harvest planning and only 17% have detected murrelet presence. Combining both the ODF and Nelson surveys, 15,151 acres of the Elliott were designated as ‘occupied’ habitat. Murrelets are known to have a high degree of site fidelity and historically occupied stands would be expected to remain occupied into the future unless the stand is drastically altered to the point where it no longer contains suitable nesting habitat. With recent LiDAR imagery (2021), approximately 2,600 acres were identified to have been harvested between 2009 and 2020. In consultation with the U.S. Fish and Wildlife Service, these acres were removed from the ‘occupied’ data layer in the ESRF HCP Section 2.4.

Acknowledging that large areas of the forest have remained *unsurveyed*, in 2020, a *species distribution model* (SDM) was developed using Landsat and 2014 LiDAR data in combination with the ODF and Nelson known occupied sites to create a better estimate of total potential murrelet habitat on the ESRF. See Betts et al. (2021) for details on model development and validation. In October of 2022,

OSU researchers began updating the SDM with 2021 LiDAR data and adjusted the model inputs to reflect conditions within occupied polygons that have not been impacted by recent management. With the new imagery, an additional 4,300 acres were identified to be potential habitat for murrelets. In January 2023, a Consolidated Layer GIS map that incorporates these new SDM results was generated to identify interior forest habitat with the highest habitat suitability value for murrelets (Figure 9.3). This Consolidated Layer map includes both *historically occupied* stands that have retained their forest structure and *potential habitat* identified by the model. Stringers and small patches/stands of older trees identified by the model were not included in the Consolidated Layer as they were made up entirely of edge habitat. The majority of the stringers are located within Riparian Conservation Areas (RCAs).

All models carry some uncertainty and are best considered collectively with survey and site-level forest inventory data to determine habitat suitability. Per the ESRF HCP, modeled potential marbled murrelet habitat needs to be surveyed with the current USFWS accepted survey protocol prior to any harvest activity taking place. If the stand is found to be occupied within the modeled potential habitat, the acreage will be added to the land base categorized as occupied habitat. In accordance with the ESRF HCP, acreage within the Volume Replacement Allocations (Section 3.3.4 ESRF HCP) would become eligible for harvest at a rate of 1.5 times the modeled potential acres found to be occupied. Within the occupied habitat, only 1,400 total acres of extensive harvest at 80% retention of relative density (Appendix L) is permitted (see Section 9.2.3 below for details). If the stand is found to be vacant or unoccupied, extensive harvest is permitted, with a 150-foot buffer left on any land adjoining the formerly potential habitat with designated occupied habitat (see ESRF HCP for further details). The overall cap for harvest in stands greater than 65 years old (as of 2020) is 3,200 acres. If younger stands in the Volume Replacement Allocation substitute for acres in the Consolidated Layer that are found to be unoccupied by murrelets, acres of older forest in the Flexible Allocations that are found to be unoccupied can be harvested Extensively, but only up to the 3,200 acre cap.

The fragmentation of murrelet habitat from timber harvest and fire has widely been hypothesized to be a limiting factor in the recovery of murrelet populations, but supporting evidence has been limited and sometimes contradicting. A recent occupancy modeling study by Valente et al. (2023) found negative impacts of fragmentation at the



**Figure 9.3.** Marbled murrelet *occupied* and *potential* habitat that make up the Consolidated murrelet data layer. Historically occupied stands were determined based on marbled murrelet occupancy surveys conducted by S.K. Nelson and ODF. (Source: ESRF HCP.)



broad landscape scale, but increases in occupancy with fragmentation at the local scale. From a silviculture perspective, local edge habitat may create opportunities for the growth of the large crown structure required for nesting platforms, but opening up the canopy may also create loss of habitat or failure in nesting through changes in microclimate and predator density along harvest boundaries that negatively impact the reproductive success of nesting murrelets (e.g., van Rooyen et al. 2011; Malt and Lank 2007; Malt and Lank 2009). Current literature indicates that there may be a time limitation to the negative impacts of edge effect, with adjacencies to a hard edge (0-20 year old adjacent stand) having the greatest impact and soft edge (20-40 year old adjacent stand) having a moderated effect (Malt and Lank 2007; Malt and Lank 2009). To date, there is no data on the impacts of variable retention or partial harvests that might be more similar to the extensive treatments planned for the ESRF. The ESRF provides a unique opportunity to research the regional effects of habitat fragmentation, partial harvests, edge effect, and the mitigation of negative effects through the addition of varying types of buffers at both the local and landscape scale (See Section 9.2.3 below). The results of these types of studies could directly inform management and efforts to recover the species in Oregon, and also rangewide.

As a part of the species monitoring efforts described in the ESRF HCP, researchers will be analyzing habitat suitability using a *Habitat Suitability Index* (HSI) across the forest for marbled murrelets as a part of the biennial planning process. The HSI was developed in consultation with the U.S. Fish and Wildlife Service and builds off the 2022 Betts and Yang model of murrelet habitat on the ESRF as well as accounts for assumed habitat degradation along edge boundaries. A full description of the HSI can be found in Appendix S. HSI weighted acres will be used to track the improvement of marbled murrelet habitat across the ESRF over the 80-year permit term. Detailed use of the HSI is described in Condition 9, ESRF HCP Chapter 5. As research on the ESRF improves existing knowledge of suitable habitat and the impacts of habitat fragmentation and edge effect, researchers will work with the USFWS to refine the habitat suitability model and associated habitat tracking (see Chapter 11: *Adaptive Research Strategy and Implementation* for adaptive pathways).

### **ESRF HCP Conditions on Covered Activities related to marbled murrelet**

The marbled murrelet conservation strategy includes conditions that define specific take avoidance and

minimization measures for the marbled murrelet to be applied as part of covered forest management activities under the ESRF HCP (e.g., thinning and regeneration harvests as described in the research design, associated experiments to study alternative approaches to accelerating old forest structure and habitat for northern spotted owls and marbled murrelets, tree climbing and canopy work for research purposes). Additional details on these four conditions are summarized below, with additional details are provided in ESRF HCP Chapter 5.

Research that would require handling of individual marbled murrelets or other potentially harmful activities are not covered activities under the ESRF HCP because the specific methods, intensity, frequency, and duration of such activities have not yet been defined at the level needed to identify effects and issue take permits. ESA compliance for research that requires handling of marbled murrelets will be conducted under an approved scientific collectors permit; take associated with those activities will be tracked to the collectors permit and not the ESRF HCP.

**Condition 6: Seasonal restrictions in marbled murrelet occupied habitat.** To avoid disturbance to nesting marbled murrelet adults and chicks, the ESRF will apply seasonal restrictions for covered activities. Seasonal restrictions will apply in designated occupied habitat, or other areas that have been determined to be occupied using surveys described in Condition 7, during the murrelet nesting season (April 1 to September 15). Seasonal restrictions prohibit certain covered activities from occurring within a set distance of occupied habitat, using distances approved as adequate by the USFWS. Recommended distances identified by USFWS can be found in Table 5-5 of the ESRF HCP. Some activities can have daily restrictions as well, which avoid disturbance during certain times of day later in the nesting season.

The ESRF may deviate from these restrictions only in situations where either (1) applying these restrictions would compromise the safety of ESRF staff, contractors, or members of the public; or (2) applying a more limited restriction is clearly justified based on site conditions (e.g., topographic features on the landscape shield the occupied site from the activities in question) and there would be little to no likelihood of incidental take. Deviations from these restrictions are expected to be rare and will be applied only after a site-specific review by the wildlife biologist, documentation of recommendations, and approval by the ESRF HCP Administrator. The wildlife biologist will consider site-specific, topographic features and the location of the

likely nesting habitat when considering any deviations from these restrictions. Any deviations will be documented as part of annual reporting requirements.

**Condition 7: Survey requirements for designated occupied and modeled potential marbled murrelet habitat.**

In order to minimize effects, and regardless of stand age, all designated occupied and modeled potential marbled murrelet stands that are identified by the ESRF HCP, that are subject to proposed harvest treatments, will be examined for presence of marbled murrelet nest sites prior to treatments utilizing the following three-step process. Harvest treatments will not occur in habitat determined to be occupied through this process.

1. **Desktop Review**—All harvest treatments in designated occupied or modeled potential marbled murrelet habitat will be reviewed using the most current air photos and LiDAR imagery to determine which have contiguous patches of trees older than 65 years (estimated current age at time of review) that are 5 acres or larger. Contiguous potential habitat is that which contains no gaps in suitable forest cover wider than 328 feet (Evans Mack et al. 2003). Stands that do not have contiguous patches of trees older than 65 years can be harvested as an intensive or extensive treatment. Those that do have contiguous patches of trees older than 65 years will undergo a field assessment.
2. **Field Assessment**—Harvest treatments in designated occupied or modeled potential marbled murrelet habitat that have contiguous stands of residual trees 5 acres or larger that are likely older than 65 years will undergo a field assessment by a marbled murrelet biologist to determine the likelihood that those stands support nesting marbled murrelets. Aspects of stand size, stand age, and habitat structure will be considered in the field assessment. Those stands that are determined to have characteristics that could support nesting marbled murrelets will be included in a marbled murrelet survey effort (Evans Mack et al. 2003).
3. **Marbled Murrelet Nesting Survey**—Those stands that are determined in the desktop review to have contiguous habitat and in the field assessment to have characteristics that could support nesting marbled murrelets will be surveyed for murrelets. Surveys will follow occupancy survey methods approved by the USFWS at that time (currently Evans Mack et al. 2003). Surveys may also be modified to meet the needs of ongoing marbled murrelet research projects, upon approval from the USFWS. At a minimum, all

survey protocols will include survey information sufficient to make occupancy determinations and to make comparisons across the permit area and across survey years (e.g., surveying during “favorable” and “unfavorable” ocean condition years). A determination of presence/absence will follow the methods described by Evans Mack et al. (2003), or methods otherwise mutually agreed to between the ESRF and the USFWS. This may include acoustic detection at some point during the permit term, as defined by future protocols.

Ultimately, presence/absence is what will influence decisions around how a stand is managed. In areas planned for intensive treatments where nesting marbled murrelets are discovered, the contiguous habitat where the murrelets were found will be designated as a reserve (or expanded RCA) or limited to extensive treatments, and the intensive treatment will be reallocated to another part of the subwatershed not occupied by murrelets. In areas allocated to extensive treatments where nesting marbled murrelets are discovered, stand management will be done consistent with Condition 8. If modeled potential habitat in areas planned for intensive or extensive treatments are found to be occupied, and therefore ineligible for harvest similar to designated occupied habitat, an acreage equivalent of 1.5 times the original acreage of volume replacement allocation would become available for treatment. These volume replacement treatments would be restricted in northern spotted owl activity centers (see ESRF HCP Section 5.5.4), designated occupied and modeled potential marbled murrelet habitat, and within 150-foot buffers where marbled murrelet habitat occurs adjacent to proposed treatments (see ESRF HCP Section 5.5.7), RCAs (see ESRF HCP Section 5.4.2), and in any remaining areas of old growth (pre-1868 trees and stands).

**Condition 8: Limits on harvest in designated occupied and modeled potential marbled murrelet habitat.**

Intensive harvest treatments in designated occupied and modeled potential marbled murrelet habitat are prohibited unless they are in areas determined as not occupied through the process set forth in Condition 7. Extensive harvest treatments will not exceed 1,400 acres within designated occupied and modeled potential marbled murrelet habitat found to be occupied pursuant to Condition 7. In addition, locations that were previously determined to be occupied will continue to be considered occupied, regardless of survey results, if there have been no changes to habitat condition since the last marbled murrelet detections were made (e.g., pre-ESRF HCP harvest or stand management

activities, changes in habitat quality due to natural events such as storms, fire, or disease). This condition only applies to designated occupied and modeled potential habitat as defined in Figure 9.3. Any areas outside of designated occupied or modeled potential habitat, as shown in Figure 9.3, are not subject to the 1,400-acre cap, and can be managed according to their treatment allocation. This includes stands that may develop into habitat within extensive allocations if such habitat is not designated by the ESRF for use in meeting biological objectives. Such areas may be harvested consistent with Conditions 6 and 7. Changes in determinations of occupancy within designated occupied or modeled potential habitat will be coordinated with USFWS.

Of the 1,400 acres of extensive treatments allowed in designated occupied and modeled potential marbled murrelet habitat (as defined in Figure 9.3) over the permit term, no more than 500 acres of treatments will be allowed in the first 10 years of the permit term. In those areas, the entire stand will count toward the initial 500-acre cap and stand density will be retained at 80 percent or greater of pre-harvest density.

Consistent with adaptive management, further harvesting (beyond the initial 500 acres) will be contingent on the outcome of the experiments (testing for both statistical and biologically meaningful effects). If experiments find that (1) murrelets do not return to, or colonize, the areas that received the extensive treatments, or (2) the harvests are determined by an external science review committee that includes the USFWS to be substantially impacting nesting success by altering environmental or biological indicators linked to nest success (i.e., microclimate, predator abundance), the ESRF will not proceed with harvest in the remaining 900 acres. Initial treatments will be monitored through surveys, biophysical measurements, and ARUs for a minimum of 5 years, but likely longer to observe long-term changes in the ecosystem. Results from this monitoring will be used to inform the external science review committee in their decision whether or not to proceed to the remaining 900 acres. Treatments in the remaining 900 acres, if they occur, will be informed by the findings of research on the initial 500 acres and undertaken subject to review and concurrence by USFWS. In all of these locations there would be 80 percent or greater retention of pre-harvest density, unless results from the initial experiment supports a lesser retention standard that is agreed upon by the USFWS and

the implementation and adaptive management committee (See ESRF HCP Section 7.2.4). Further, any known nest trees or trees within 300 feet of known nest trees will be included in those retained.

**Condition 9: Maintaining aggregate amount of marbled murrelet occupied habitat over time.** There will be no temporal loss of the aggregate number of acres of designated occupied habitat or HSI-weighted acres as a result of harvest treatments in the permit area. The ESRFA will demonstrate that at least as many acres of designated occupied habitat proposed for extensive harvest will have been replaced by designated occupied or modeled potential habitat in the CRW or MRW reserves that is first determined to be occupied during the permit term. This condition only applies to designated occupied habitat as defined in the ESRF HCP (Figure 2-11). Any areas outside of designated occupied habitat, as shown in the ESRF HCP Figure 2-11, are not subject to this requirement and can be managed as described in the ESRF HCP Chapter 3.

Newly occupied areas that could be used to offset loss of designated occupied habitat would be locations in the CRW or MRW reserves where surveys have been conducted in the past and no occupancy was documented. In order for newly occupied habitat to count as replacement habitat, it must already be allocated as a reserve (within the CRW or MRW reserve) or—if located outside of reserves—reallocated as a reserve.

Potential marbled murrelet habitat will be preserved across the permit area by maintaining an area-weighted mean marbled murrelet HSI value as described in the ESRF HCP Objective 2.3. Although the likely future scenario will involve increasing levels of suitable marbled murrelet habitat over time, this condition will ensure, at a minimum, that the HSI-weighted acres of habitat suitable for marbled murrelet occupancy will not fall below the 2022 forest conditions at any point during the permit term.

Acres of occupied habitat and HSI-weighted acres will be accounted for annually and summarized in annual reports along with 6-year Summary Report and 12-year Comprehensive Reviews, including the newly discovered locations in the CRW or MRW reserves, in order to demonstrate compliance with this condition.



### 9.2.3 Marbled Murrelet Experimental Design

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The marbled murrelet (hereafter murrelet) is a seabird that nests in late-successional and old-growth coastal forests, and is classified as threatened federally and endangered in Oregon, Washington, and California. Current estimates indicate that there may be up to ~37,800 acres of potential murrelet breeding habitat in the ESRF (Oregon DSL 2022), approximately ~3.5% of the higher value murrelet total breeding habitat modeled for the state of Oregon (Valente et al. 2023). Recent modeling with 2021 LiDAR imagery indicates that the amount of murrelet habitat may be close to 40,000 acres, nearly half the total ESRF land base (Betts and Yang 2022). Within that context, one of the stated goals in the ESRF Research Proposal (OSU College of Forestry 2021) is to understand the potential impacts of silvicultural treatments on the distribution and demography of murrelets in stands greater than 65 years old (as of 2020). Conducting a scientific experiment on the effects of silviculture on distributions and demography of murrelets will be important for sound decisions related to management and conservation planning.

While timber harvesting is not currently permitted within known occupied murrelet habitat on state and federal lands, it is allowed in forest that is considered unsuitable murrelet habitat yet adjacent to occupied stands. It is also allowed in stands with appropriate structure and composition for murrelet habitat, but that remain unoccupied. It will be critical to understand how murrelets respond to selection harvest over the short and long terms, because it is possible that policies protecting murrelet habitat could change, for example in the context of HCPs on state and private lands. Indeed, within 30 years, hundreds of thousands of acres on federal lands will have aged to become >80-100 years old. Examining the effects of timber harvest on murrelet activity in older stands is therefore essential for understanding the future impact of harvest activities on this large land base.

Within the ESRF, 4,042 acres of murrelet habitat are in extensive silviculture treatments, within which this experiment will be nested. Condition 8 of the ESRF HCP sets a total limit of 1,400 acres of designated occupied marbled murrelet habitat that can be managed under extensive allocations. This includes a limit of 500 acres of management in the first 10 years of the permit term for this murrelet experiment. If results of the research outlined under this experiment show no discernible negative effects to the species (subject to agreement with the USFWS), the remaining 900 acres of designated occupied murrelet habitat in extensive treatment areas could be managed.

#### 9.2.3.1 MAMU Experiment Research Priorities

The Triad design on the ESRF provides a unique opportunity to investigate the potential impacts of silvicultural harvest treatments on murrelet habitat. Intensive and extensive treatments can alter the accessibility of remnant habitat patches (Valente et al. 2023), and both approaches could affect murrelet productivity by altering the biophysical properties of those patches (Marzluff et al. 2004, van Rooyen et al. 2011, Cahall et al. 2013). Although no intensive treatments will occur in murrelet occupied habitat, the ESRF HCP allows for extensive harvesting within a total limit of 1,400 acres of occupied murrelet habitat as part of the research program. Acting as a conservative test of the impacts of the extensive removal of  $\leq 20\%$  of the relative density (i.e., 80% retention), any measured changes in the biophysical properties of the stand would be expected to increase with increased timber removal. While this is not currently a common prescription for timber harvest, testing for a response at a high retention balances the need to test for impacts with the need to conserve murrelet habitat. Importantly, no studies to date have evaluated how such an approach would impact murrelet distribution and productivity.

The gold standard in animal population studies is the collection of long-term demographic data. This can comprise data on population trends of a focal species, detailed information on productivity (e.g., nest success, recruitment) and survival, or all of these components. Unfortunately, demographic data are exceptionally difficult to collect for murrelets due to challenges with finding nests. Murrelets typically breed in stands of old trees, nesting on limbs that can be located hundreds of feet above the ground (Nelson 2020). Finding nests efficiently thus requires radio-tagging birds in the marine environment and tracking them to nest sites or hiring experienced biologists to conduct systematic tree climbing to search for nests, both of which

are extremely costly and time-consuming. As a result, researchers have identified fewer than 600 murrelet nests globally. As evidence of this challenge, the Oregon Marbled Murrelet Project (OMMP), a recent study conducted by Oregon State University, located a total of 37 nests in Oregon over the course of 5 years of field work and were able to attribute a definitive fate based on video evidence to just over 50% of those nests (OMMP, unpublished data). Additionally, direct monitoring of nest productivity is complicated by low power to detect moderate treatment effects (Appendix R) and because nesting propensity can be extremely low in years with poor ocean conditions (Betts et al. 2020).

Due to the challenges in finding murrelet nests and attributing fate, data collected by the OMMP will be built upon to evaluate a suite of indicators for habitat suitability and nesting success that may overcome some of the hurdles of using only nest success as a measure of the impacts of the treatment. While analysis of the OMMP data is ongoing, further data collection to verify nest success indicators or proxies will be required to justify this approach at the ESRF. The intent is to first evaluate whether indicators or proxies for nest success are statistically valid (albeit imperfect) substitutes for the gold standard of direct measurement of nest success. Similar to the use of the NOAA Ocean Ecosystem Indicators which serve as a proxy for prey availability for murrelets (Betts et al., 2020), it is likely that a Principal Component Analysis (PCA) will be used to combine multiple environmental and biological variables to determine a valid proxy for nest success that can be used in combination with measured nest success. Time will be required to complete this analysis and have the results verified in a peer-reviewed publication or by the external science review committee that includes the USFWS to advise on murrelet monitoring planning conversations, prior to the initiation of the marbled murrelet Silviculture Experiment. This may extend the monitoring period before the experimental treatments can commence. Once completed, (1) a targeted nest searching component will be performed, the extent of which will be funding-dependent, (2) murrelet presence and occupancy will be monitored, and (3) a hierarchical approach will be employed to monitor key indicators of murrelet nesting habitat and productivity (e.g., bioacoustics, nest predator density, microclimate).

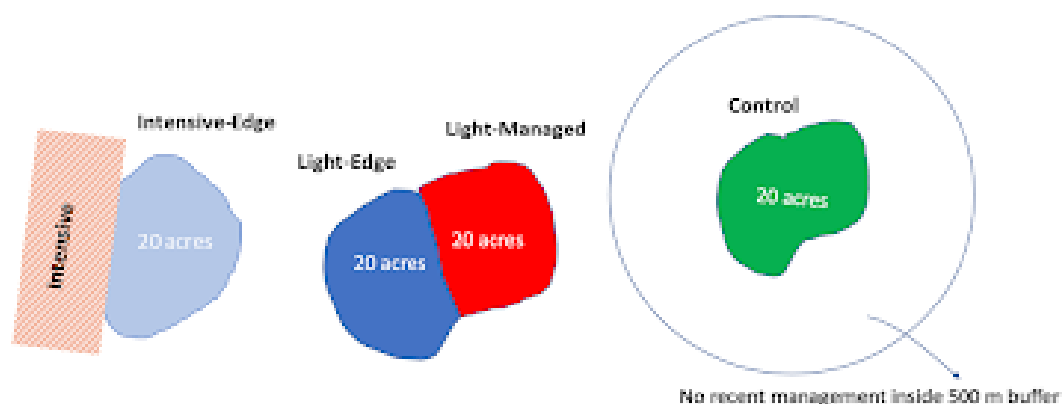
It is hypothesized that the extensive treatment – where  $\leq 20\%$  relative density (Appendix L) is removed and constitutes  $\sim 20\%$  volume harvest – will decrease murrelet reproductive

success over the short-term ( $< 15$  years); reproductive success will be measured as declines in stand-level attributes (i.e., composition, structure) associated with nest success from previous work (with  $N=37$  nests), changes in microclimate, and an increase in nest predators. These elements are based on previous work showing: (1) increases in the abundance of some species of corvids within areas of more open canopy along forest edge habitat (Chalfoun et al. 2002; Raphael et al. 2002), (2) increases in nest predation rates due to a higher prevalence of corvids (Luginbuhl et al. 2001, Marzluff et al. 2004, Cahall et al. 2013), and (3) declines in epiphytes needed for murrelet nesting related to reduced moisture on edges or in open areas (van Rooyen et al. 2011). It is predicted that these potential effects of ‘extensive’ harvest on murrelets will be compounded by canopy removal in adjacent unoccupied stands, which creates “hard” habitat edges, defined as artificially created boundaries between mature and open canopy forest. It is hypothesized that over the longer term ( $> 15$  years; the time it typically takes for the canopy to close; Cahall et al. 2013) murrelet habitat will recover or improve in light selection harvesting treatments. In addition to testing light selection harvest impacts on murrelet habitat, the edge effects of both light treatments and intensive treatments (unoccupied habitat) adjacent to occupied murrelet habitat will also be tested.

### 9.2.3.2. Study Area and Experimental Design

Given the power analysis (Appendix R), the optimal design is one that has the greatest number of replicates (number of sites within treatments) rather than one with the greatest number of samples (i.e., survey stations). Additionally, treatments must be sufficiently large so that they occur at a spatial scale that is relevant to murrelets. Given these constraints, experimental units of 20 acres (8.09 ha) in size, subjected to one of the following four treatments are proposed (Figure 9.4):

1. Stand-level 80% tree retention (hereafter “Light-Managed”),
2. An unmanipulated murrelet occupied area immediately adjacent to the managed treatment (hereafter “Light-Edge”),
3. An unmanipulated murrelet occupied area immediately adjacent to an intensive treatment that is not murrelet habitat (hereafter “Intensive-Edge”), and
4. An unmanipulated area embedded within a 500 m no-management buffer (hereafter “Control”)



**Figure 9.4.** Four treatments proposed in the Marbled Murrelet Silviculture Experiment. The *Light-Managed* treatment is designed to test the degree to which stand-level (localized) variable retention (80%) harvesting will affect murrelet demography. The *Light-Edge* treatment and *Intensive-Edge* treatment will be used to determine whether harvest activities in the managed stand influence demography in adjacent stands that are unmanipulated. Note that the Intensive harvest treatment is not occupied murrelet habitat. Finally, an unmanipulated area (*Control*) will be embedded within a 500 meter unmanaged buffer (no management within a period of 20 years [post canopy closure]) and serve as the control in this study.

In total, 25 replicates will be implemented per treatment for a total of 100 replicates, with 500 acres receiving the light-managed treatment (20 acres \* 25 replicates = 500 acres) and corresponding to the extensive harvest of the Triad design. Given the potential for negative effects on murrelet nesting habitat, this study design will be implemented in two phases. The initial work will be restricted to  $n=15$  replicates per treatment ( $n=60$  replicates in total). If results are inconclusive (effect size is apparently small and variance is high), the study would then expand into the additional replicates.

Experimental treatment locations will be selected using a nested randomized block design wherein stratified randomization will be used to determine *Light-Edge/Light-Managed* and *Intensive-Edge* treatment versus *Control* stands, and a separate randomization process will be used to select which partial stand receives the Edge versus Light-Managed treatment. This is a blocked design because *Control* areas should be within 2-3 km of the *Light-Edge/Light-Managed* and *Intensive-Edge* treatment stands to account for statistical noise contributed by landscape-level variation (e.g., nest predator abundance, distance to coast).

The overall design will be *Before-After-Control-Impact* (BACI), so all response variables of interest will be monitored in all treatment and control sites both before and after the treatment applications. This approach provides the greatest

statistical power to detect treatment effects. For response variables used as indicators of murrelet habitat (see response variables below), all stands should be monitored for 3-5 years prior to treatment implementation. The length of pretreatment period will depend on the presence of at least one “good” ocean year that supports murrelet nesting activity (Betts et al. 2020). Climate forecasting will be utilized to attempt to select the best ocean condition years for the monitoring in order to reduce the impacts that “poor” ocean years have in reducing occupancy (Betts et al. 2020). However, as with any forecasting approach, the true ocean conditions will not be known until after the breeding season takes place and will be factored into the analysis. After pretreatment monitoring has concluded, treatments will be implemented, and monitoring should continue for 5-10 years after treatments to all study stands. Such a period is necessary because harvest effects are most likely to occur during the period of understory reinitiation when berry-producing shrubs and herbs are hypothesized to draw generalist nest predators into treated areas and increase murrelet nest failure.

### 9.2.3.3 Response Variables

#### *Indicators of murrelet and nest predator presence*

- **Audio-visual occupancy surveys** – The Pacific Seabird Group’s (PSG) audio-visual survey protocol (Evans Mack



et al. 2003, or the current accepted survey protocol at the time of the study if it changes) will be used to monitor murrelet use of experimental sites pre- and post-treatment. The protocol involves early morning breeding season surveys during which trained observers record all murrelet encounters and their associated behaviors. Behaviors that indicate sites have importance for breeding include murrelets flying below the canopy, circling above the canopy, or calling from nesting platforms (Evans Mack et al. 2003). Our sampling design will follow all recommendations within this well-established protocol with respect to densities of sampling points and frequency of surveys.

- **Bioacoustic monitoring** – Automated recording units (ARUs) have become popular for monitoring avian communities in recent decades (Shonfield and Bayne 2017). As part of the OMMP, a doctoral student has been testing the feasibility of using ARUs to (1) identify occupied murrelet sites, and (2) estimate proximity to nesting locations. Initial results have indicated ARUs may be an effective murrelet monitoring tool (M. Weldy, personal communication), so the plan is to utilize ARUs to supplement audio-visual surveys at experimental sites. The timing, frequency, and density of ARU placement will be dependent on results from the published dissertation, but he is working closely with our group to help support our research questions.
- **Nesting activity and nest success** - The goal of this additional component will be to monitor at least one nest in each treatment and control stand in each year of the study (both pre- and post-treatment). To identify nests, a team of field technicians would conduct more thorough dawn surveys at stands where occupancy has been detected using audio-visual occupancy surveys and bioacoustic monitoring. These more intensive surveys will involve a team of individuals surveying for below canopy murrelets that are entering the stand and moving towards nest trees. Over multiple days, the team follows murrelets under canopy to narrow down the individual tree that the murrelet uses for nesting. Once the tree has been identified, an experienced tree climber would climb a nest-adjacent tree to place a custom-designed video camera that runs continuously and records all activity at the nest, including its fate (fledge or fail). Logistic exposure models (Shaffer 2004) will then be used to estimate the daily probability of nest survival as a function of the three treatment types. The extent of this nest searching effort will be funding-dependent and may play a supportive role to additional indicators of murrelet demography.

- **Predator surveys** – Standard point count surveys will be used to monitor sites for densities of avian predators that could prey on active murrelet nests. Corvids including the Steller's jay (*Cyanocitta stelleri*), Canada jay (*Perisoreus canadensis*), and common raven (*Corvus corax*) have been implicated as a substantial source of murrelet nest failure (Nelson and Hamer 1995, Hébert & Golightly 2007) while raptors such as the red-tailed hawk (*Buteo jamaicensis*) have been documented preying on murrelet nestlings (OMMP unpublished data). Thus, point count surveys will be used to monitor the densities of these species, and these counts will be conducted in the same locations and with the same time and frequencies as the PSG protocol surveys. These point counts will last 10 minutes, during which observers will record all birds seen and heard. Additionally, there is concern that the expanding populations of barred owls (*Strix varia*) in the Pacific Northwest could have negative impacts on murrelets, so three nighttime surveys will also be conducted for barred owls at each location using established protocols (Wiens et al. 2011). Densities for all predator species will be estimated using N-mixture models that allow explicit modeling of covariates (e.g., wind, noise, cloud cover) that may affect detectability (Royle 2004).

#### **Local-scale indicators of murrelet habitat**

At present, knowledge about what local environmental factors drive nest site use and nest success in murrelets is limited, despite its importance for recovering populations. Several covariates are listed below that will be monitored because they are strongly linked with murrelet nest locations. Additionally, it is worth noting that as part of the OMMP data collection and analysis an OSU graduate student is utilizing information from previously discovered murrelet nests to identify environmental factors that affect murrelet nesting propensity and nest success in Oregon coastal forests. Their research will use LiDAR surveys to examine structural characteristics of nest trees, and it is anticipated that this will yield useful information regarding additional local covariates to measure.

- **Nesting platforms** - Murrelets nest on large-diameter, horizontal limbs in older trees that can support their egg and chick (Nelson 2020). Each year experimental stands will be surveyed and the number of potential nesting platforms recorded to test how treatments influence availability of nesting structure.
- **Moss microclimate** - Murrelets typically create a small depression in moss and other materials within a nesting platform in which to lay their egg (Nelson 2020).

Moss cover and depth will be measured, coupled with automated temperature and humidity gauges at several heights of potential murrelet nest platforms to monitor local environmental variables that can affect moss development throughout each breeding season (after van Rooyen et al. 2011). This environmental data will be collected in tandem with measurements of moss cover and moss depth at a subset of sites.

- **Understory fruits** - Corvids are dietary generalists and, in addition to preying on murrelet nests, they will also forage on fruits of understory shrubs such as *Rubus* spp. Such shrubs often become established within canopy gaps created by harvest treatments. Thus, in addition to monitoring predator densities, stands will be surveyed and the density of fruiting shrub plants will be recorded during the breeding season.

#### **Landscape-scale indicators of murrelet habitat**

- **Habitat suitability** – Dr. Zhiqiang Yang with the U.S. Forest Service in collaboration with Dr. Matt Betts (FES) have developed a marbled murrelet species distribution model (SDM) for the species' entire breeding area within the conterminous United States (Yang, personal communication). This model has proved especially useful at distinguishing occupied and unoccupied murrelet habitat based on PSG protocol surveys, and it can be updated annually with Landsat imagery. This SDM will be used to estimate mean annual occupancy probability within each experimental stand and within 1 km buffers around each stand to assess how treatments are affecting broad-scale habitat suitability.
- **Habitat disturbance** – Pairing the Yang/Betts SDM with canopy cover data from the regional Gradient Nearest Neighbor map products (Ohman and Gregory 2002, Ohman et al. 2014, <https://lemmadowndownload.forestry.oregonstate.edu/>) has enabled identification of scale-dependent effects of habitat loss and fragmentation on murrelet distribution patterns (Valente et al. 2023). Using this established approach, monitoring of landscape-level disturbance patterns (within scales ranging from 100 m to 2 km) will continue to assess how experimental treatments affect distribution and structure of murrelet habitat.

### **9.2.4 Oregon Coast Coho**

The Endangered Species Act (ESA) provides for the listing not only of full species but also named subspecies and distinct population segments of vertebrates. This is particularly

critical for wide-ranging species that have wide variation in life-histories, genetic diversity, and other traits that allow them to adapt to local conditions. In the case of Pacific salmon (*Oncorhynchus* spp.), aggregates of populations that are: (1) substantially reproductively isolated from conspecific populations, and (2) represent an important component in the evolutionary legacy of the species (Waples 1991) are the listed entities and referred to as *Evolutionarily Significant Units* (ESUs). The National Marine Fisheries Service (NMFS) has identified over 50 ESUs of Pacific salmon and from California and the Pacific Northwest.

Two ESUs of coho salmon, the Oregon Coast ESU and the Southern Oregon/Northern California ESU, are currently listed under the ESA in coastal Oregon. The depressed status of the ESUs is attributed primarily to habitat degradation, harvest, and hatchery fish production. Adverse effects of natural environmental variability from drought, floods, and poor ocean conditions have been exacerbated by degradation of habitat by human activities. In its most recent status review the NMFS found that risks from hatcheries and fisheries had been greatly remedied, but continued threats from habitat degradation and climate change remain factors that affect the ESU's long-term status and that the Oregon Coast coho salmon ESU should remain listed as *threatened* under the ESA (NMFS 2016a).

Populations within each ESU are classified as *independent* - populations that historically would have had a high likelihood of persisting in isolation from neighboring populations for 100 years (Lawson et al. 2007) and *dependent* - populations that historically relied upon periodic immigration from other populations to maintain their abundance and would not have had a high likelihood of persisting in isolation for 100 years (Lawson et al. 2007). The Oregon Coast ESU has 18 independent populations (Lawson et al. 2007) and the ESRF is unique in that it is the nexus of three of these populations. The persistence and productivity of the ESU is tied to the persistence and productivity of the independent populations (Wainwright et al. 2008). Additional information on the freshwater life history of the Oregon Coast coho salmon can be found in the Oregon Coast Coho Recovery Plan (NMFS 2016b).

#### **Status on the ESRF**

The Oregon Coast coho salmon ESU is further subdivided into *strata*, and finally independent *populations*. The ESRF includes portions of three coho strata:

- The *Lakes Stratum* consists of three independent coho populations. The ESRF encompasses part of the Tenmile

population, about 17 stream miles in Big Creek, Benson Roberts, and Johnson Creek management basins. The Tenmile Lake systems provide a unique winter rearing habitat and are one of the most productive complexes on the Oregon Coast. The ESRF encompasses approximately 19% of the range of the Tenmile independent population.

- The *Umpqua Stratum* extends into the Cascade Range and consists of four independent coho populations. The ESRF encompasses part of the Lower Umpqua population, about 22 stream miles in the Mill Creek, Charlotte Luder, Dan Johanneson, and Schofield Creek management basins, about 4% of the Lower Umpqua independent population.
- The *Mid-South Coast Stratum* consists of four independent coho populations. The ESRF encompasses part of the Coos population, about 56 stream miles in the Palause Larson, Henrys Bend, Marlow Glenn, Millicoma Elk, and Trout Deer management basins, about 11% of the Coos independent population.

The ESRF sits at the top of the watersheds of the three independent populations (Figure 9.5), and management activities within the ESRF will affect not only local conditions but also downstream habitats through an influence on the export of water, wood, nutrients, and sediment. The ESRF can therefore play a critical role in the conservation and recovery of the three independent populations found within its boundaries despite containing a relatively small percentage of respective critical habitat for any population (Table 9.1).

**Table 9.1.** Miles of stream and percent of critical habitat of the three independent populations of the Oregon Coast Coho Evolutionarily Significant Unit found on the ESRF.

Independent Population	Amount of Critical Habitat (miles)	Amount on the ESRF (miles)	% of miles on the ESRF
Lower Umpqua	618	22	4
Tenmile Lakes	90	17	19
Coos	489	56	11

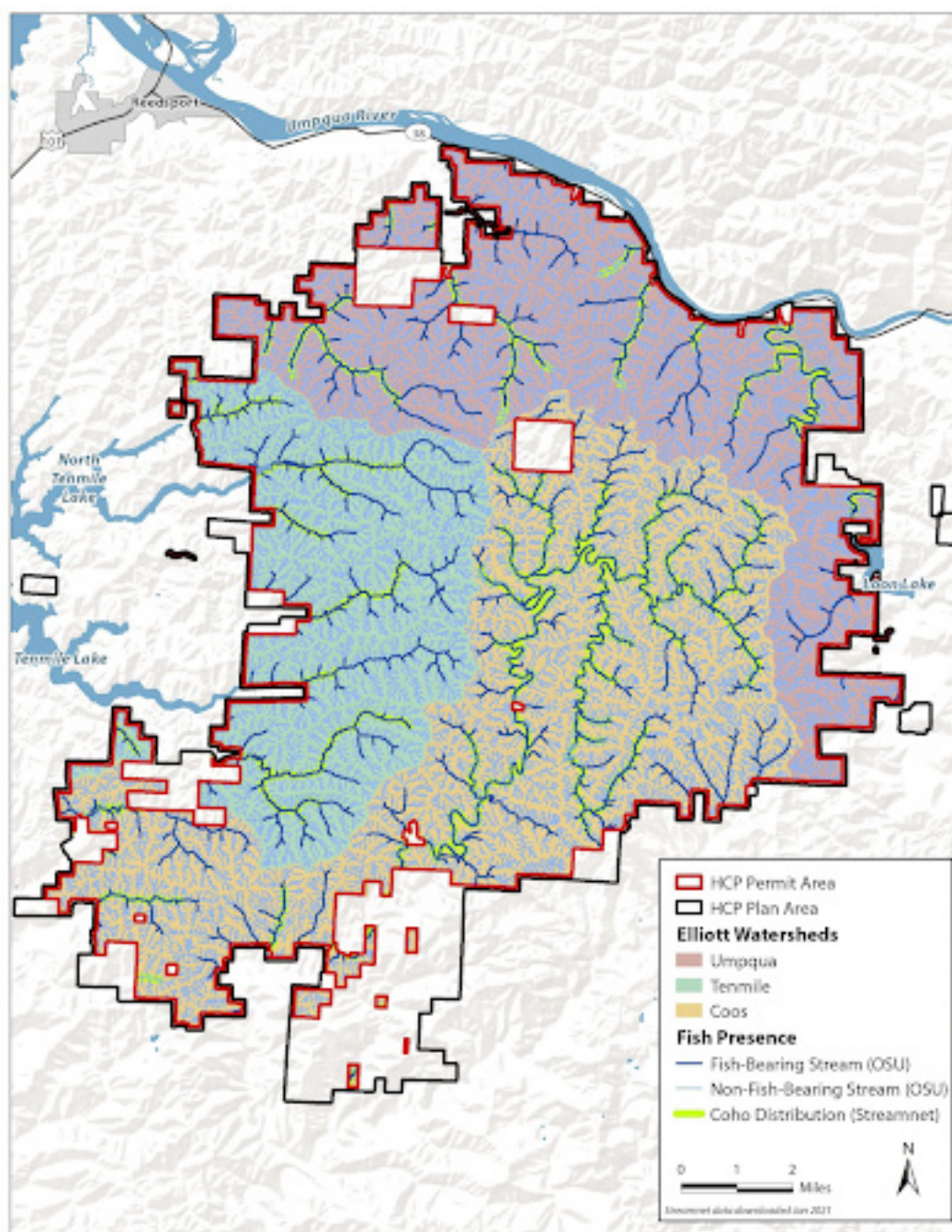
The three independent populations associated with the ESRF have ranged from 1% to 21% of total ESU spawner abundance by population. Combined, the three populations have ranged from 14% to 44% of total ESU spawner abundance. Coho densities in management basins that are part of the Tenmile population are high relative to other coastal Oregon streams. Densities in management basins that are part of the Coos and Lower Umpqua populations are similar to other coastal populations. Analysis of limiting factors indicates that stream reaches in the ESRF primarily rate moderate for coho spawning, egg incubation, and summer rearing. Areas of high intrinsic value for coho are limited, occurring primarily along the borders of the forest.

Availability of abundant, high quality overwinter habitat was the most limiting. Models suggest that for ESRF streams to support large numbers of coho, a portion of juveniles must redistribute to downstream mainstem rivers and upper estuary habitats for overwinter rearing. Kavanagh et al. (2005) concluded that barriers do not appear to be a major issue to coho in the Elliott State Forest. However, they note that data on migration barriers is limited. An assessment of roads and infrastructure, as well as continued monitoring on the ESRF (see Chapter 10: *Monitoring*) will identify barriers to fish passage and areas that require action to mitigate impacts.

The ESRF will contribute to recovery of Oregon Coast coho directly and indirectly. Overall, the ESRF has limited potential to increase numbers of coho salmon because steep streams and narrow valleys dominate it. However, some areas have habitat conditions where coho salmon numbers are relatively strong. Contributions of these local populations may be important for the associated independent populations (Lower Umpqua, Tenmile, and Coos).

A focus of the ESRF HCP is to protect existing productive habitats for coho on the ESRF and to improve areas where habitat is degraded. This is done through active restoration (e.g., wood additions) as well as passive means (e.g., restoration of riparian vegetation), all of which will be evaluated as part of the research effort. These actions will contribute directly to the conservation and recovery of coho on the ESRF. However, the most significant contribution of the ESRF to recovery of Oregon Coast coho may be in the production and export of wood, sediment, high-quality water, nutrients, and food to the lower watersheds outside the forest, where habitat quality has been compromised and the potential for productive habitats and increases in fish numbers is greatest. ESA compliance for research that requires handling of coho will be conducted under an





**Figure 9.5.** Distribution of the three independent populations of Oregon Coast Coho distribution on the ESRF (Source: ESRF HCP.)

approved scientific collectors permit; take associated with those activities will be tracked to the collectors permit and not the ESRF HCP.

Under ESRF HCP Conservation Measure 4: *Research on Coho Salmon and Their Habitat*, this conservation measure is aimed at research towards a better scientific understanding of the effects and biological response of natural and human-made disturbances in forest landscapes on water quality and quantity. Researchers will test the effectiveness of buffer combinations relative to tradeoffs with other economic and ecological attributes, such as habitat, accessibility, and fiber yield in riparian systems.

## 9.2.5 ESRF HCP Conservation Strategy and Measures

The ESRF HCP conservation strategy for the covered species is articulated in a set of *biological goals* and measurable *objectives* as required by the ESRF HCP Handbook (USFWS and NMFS 2016). The strategy is anchored in implementation of the ESRF research design – a combination of the Triad treatments, restoration treatments of plantations in reserves, RCAs, and designation of the CRW.

Biological goals broadly describe the desired future conditions for each species in succinct statements. Each goal steps down to one or more objectives (conservation targets) that define how to achieve these desired conditions. Objectives are measurable and quantitative when possible; they clearly state a desired result that collectively will achieve the biological goals and that can be monitored over time.

The biological goals and objectives were developed within the context of research activities described in Chapters 3 and 5, most of which reflect ESRF research goals of exploring management strategies to ensure the conservation of aquatic and terrestrial ecosystems as an integrated system. The goals and objectives, as well as detailed rationales and supporting documentation, are provided in the ESRF HCP.

*Conservation measures* are categories of activities that will be used on the ESRF to mitigate effects on covered species that cannot be fully avoided or that are not already offset by the research design.

## 9.2.6 Addition or Deletion of Species Covered by the ESRF HCP

Over the 80-year term of the ESRF HCP and expected lifespan of the Triad and other experiments, the status of one or more of the covered species or other species that live within ESRF borders may change. In the event that any of the three covered species are delisted or, conversely, that another species residing on the ESRF is listed as threatened or endangered under the ESA, the ESRF HCP may need to be modified. Changes to the ESRF HCP or incidental take permits that do not qualify for an administrative change may be accomplished through an ESRF HCP *amendment* requested by ESRF governance. Once an amendment is requested, the USFWS and NMFS (Services) will decide the level of review needed to satisfy ESA, NEPA, and other regulatory requirements. ESRF HCP amendments require written approval by the Services.

An ESRF HCP amendment is defined as a change in the ESRF HCP that may affect the effects analysis or conservation strategy. Amendments to the ESRF HCP may require an amendment to the ITP through generally the same formal review process as the original ESRF HCP and ITP. To obtain USFWS and NMFS approval, the ESRF must submit the proposed amendment in a report that includes a description of the need for the amendment, an assessment of its impacts, and any alternatives by which the objectives of the proposal might be achieved.

Examples of changes that would require an amendment include, but are not limited to:

- Addition of new species, either listed or unlisted or designation of critical habitat.
- Increased level or different form of take for covered species.
- Changes to funding that affect the ability of the permittee to implement the ESRF HCP.
- Changes to covered activities not previously addressed.
- Changes to covered lands.
- Significant changes to the conservation strategy, including changes to the Conservation Actions and Conditions.
- Extending the ITP term
- Any other changes in Plan implementation not described as corrective measures.

See ESRF HCP Section 7.6.2 for further details on amending the HCP.

## 9.3 Oregon Conservation Strategy and the ESRF

The 2016 Oregon Conservation Strategy (OCS), coordinated by the Oregon Department of Fish and Wildlife (ODFW), is an overarching state strategy for conserving fish and wildlife. It brings together the best available scientific information and presents a menu of recommended voluntary actions and tools for all Oregonians to define their own conservation role. The OCS aims to sustain healthy fish and wildlife populations by maintaining and restoring functioning habitats, preventing declines of at-risk species, and reversing declines in these resources where possible.

The Elliott State Forest and Tenmile Lakes region immediately to the west are OCS *Conservation Opportunity Areas* (COA) which are areas of the state prioritized to increase the likelihood of long-term success of conservation efforts, maximize effectiveness over larger landscapes, and promote cooperation across ownerships. The Tenmile Lakes COA is influenced by ESRF hydrology. Priority Actions for the Elliott COA include:

- Maintaining/enhancing in-channel watershed function, connection to riparian habitat, flow and hydrology;
- Maintaining/restoring riparian habitat and ecological function; and
- Ensuring sufficient habitat complexity for wildlife

Designation of the western region of the ESRF as CRW, reserve areas and RCAs in the MRW, maintaining and enhancing connectivity as a criterion in selecting Triad watersheds, and restoration treatments in plantation stands across the forest are all consistent with OCS goals for the Elliott and Tenmile Lakes COAs. Under the OCS, the Elliott is also listed as an *important nature-based recreational area* for the Coast Range Ecoregion. The Umpqua River adjacent to the northern border of the ESRF is listed as an *important river*.

*Key conservation issues* under the OCS include climate change, land use change (including conversion of forestland to other uses), water quality and quantity, and barriers to animal movement. Research and management of the ESRF will encompass these conservation issues and will contribute to the development of relevant scientific knowledge that can help inform management practices and policies in the Coast Range and beyond. ESRF researchers and managers will work with Tribes, the ODFW, USFS, BLM and other state and federal agencies, watershed

associations, and other relevant organizations to identify opportunities for collaboration on research, knowledge-sharing and education that promote conservation of fish and wildlife under the OCS.

The ESRF encompasses areas of several OCS *strategy habitats*, primarily late successional mixed conifer forests and flowing water and riparian habitat, but also areas of oak woodlands, grasslands, and wetlands. The CRW and MRW reserves will provide most late successional mixed conifer forest on the ESRF, with additional habitat provided by extensive reserves and areas within the RCAs. Specialized *local habitats* associated with the ESRF are off-channel habitats and forest openings.

OCS *strategy species* for the Elliott, and their bases for association are:

- California Myotis (Modeled Habitat, Bioacoustic recording in 2022 [Appendix V])
- Chinook Salmon (Documented)
- Clouded Salamander (Observed)
- Coastal Cutthroat Trout (Documented)
- Coastal Tailed Frog (Modeled Habitat)
- Coho Salmon (Documented)
- Fringed Myotis (Modeled Habitat, Bioacoustic recording in 2022 [Appendix V])
- Hoary Bat (Modeled Habitat, Bioacoustic recording in 2022 [Appendix V])
- Long-legged Myotis (Modeled Habitat, Bioacoustic recording in 2022 [Appendix V])
- Marbled Murrelet (Observed)
- Northern Red-legged Frog (Observed)
- Northern Spotted Owl (Observed)
- Olive-sided Flycatcher (Observed)
- Purple Martin (Observed)
- Red Tree Vole (Modeled Habitat)
- Silver-haired Bat (Modeled Habitat, Bioacoustic recording in 2022 [Appendix V])
- Southern Torrent Salamander (Observed)
- Townsend's Big-eared Bat (Modeled Habitat, Bioacoustic recording in 2022 [Appendix V])
- Northwestern Pond Turtle (Modeled Habitat)
- Western Toad (Modeled Habitat)



Biodiversity monitoring underway throughout the forest (Appendix V) will improve detection probability for these species. ESRF forest managers will coordinate with ODFW in acquiring, tracking and sharing species occurrence information to facilitate conservation efforts, including development of management guidance as new species are detected on the forest.

As part of the OCS 2026 update, the recently completed *Oregon Connectivity Assessment and Mapping Project* (OCAMP) mapped statewide wildlife habitat connectivity at high resolution for 54 diverse species representing a variety of taxa, movement types, dispersal capabilities, and sensitivity to anthropogenic threats. These species' connectivity models were compiled to highlight *Priority Wildlife Connectivity Areas* (PWCAs), an interconnected network representing the parts of the landscape with the highest overall value for facilitating wildlife movement.

Three types of PWCAs make up the network: *Regions*, *Connectors*, and *Steppingstones*, each identified for a slightly different purpose and playing a distinctive role in wildlife connectivity. *Regions* were delineated from the combined top 1% of connectivity priorities across all 54 OCAMP surrogate species. Regions are large, contiguous areas and represent the highest-value habitat for facilitating species movement throughout the state. *Connectors* follow optimal pathways between Regions and represent the best available habitat for facilitating movement from Region to Region. *Steppingstones* are isolated hexagons within urban growth boundaries.

The network of PWCAs and associated connectivity models are non-regulatory, science-based tools to aid in maintaining functional habitat connectivity; help direct efforts for restoration and conservation of fish and wildlife habitat, and inform future research, monitoring and long-term land management plans. PWCAs complement landscape-scale conservation maps, including the OCS Elliott State Forest and Tenmile Lakes COAs. The ESRF encompasses substantial areas of region and connector PWCA (ODFW 2023). The OCAMP mapping tool can be used to highlight areas prioritized for connectivity within and across ESRF borders in relation to existing stand conditions and subwatershed allocations, helping managers identify and refine decision point areas that can feed into extensive designs and the biennial planning process (Figure 9.6).

A key focus of management and restoration on the ESRF will be the protection of existing areas of late successional mixed conifer forest and the promotion of these conditions for the future. The OCS describes three *limiting factors* for

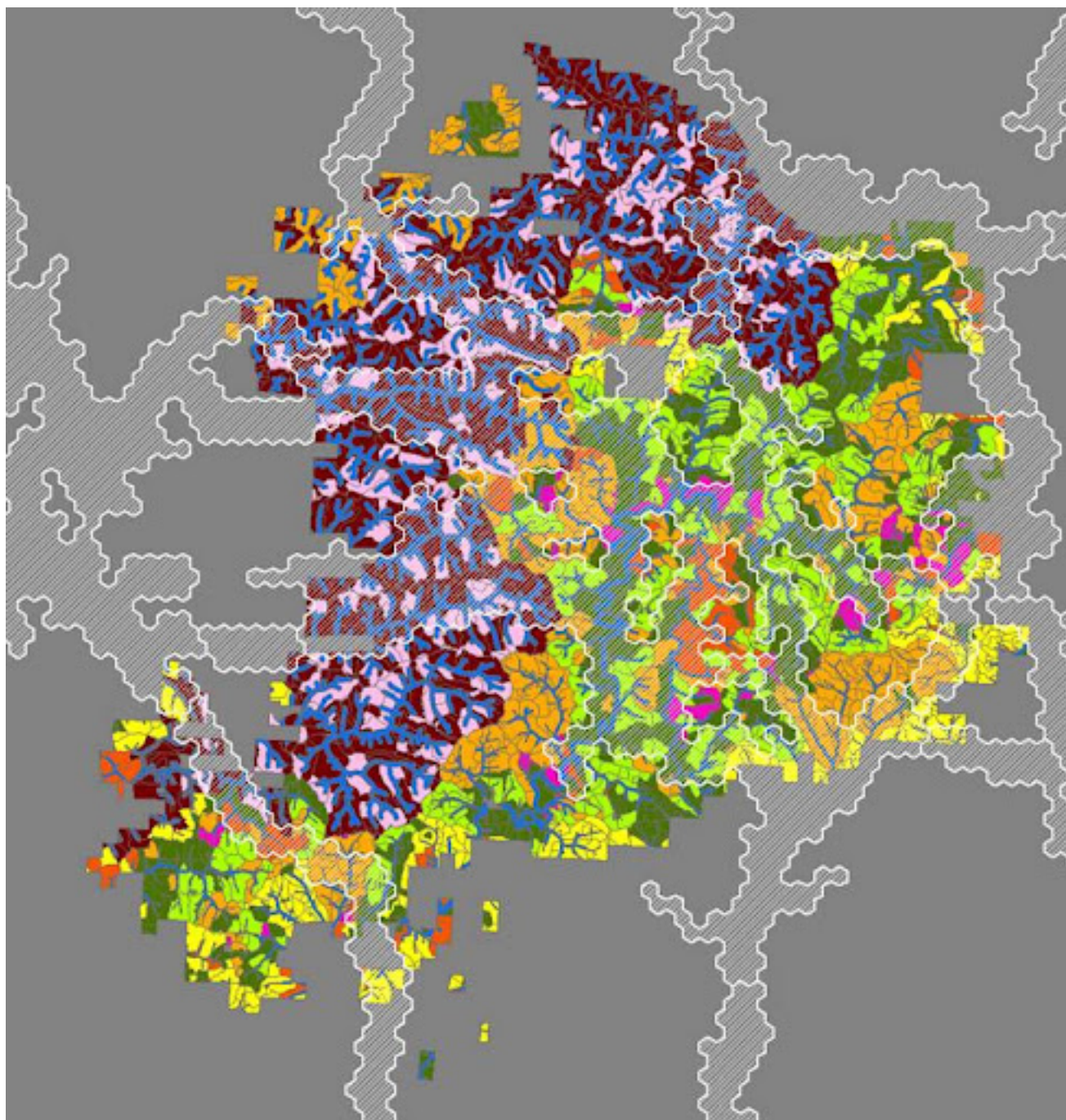
late successional mixed conifer forests, and recommended approaches for mitigation. The overall vision and many specific management actions planned for the ESRF align well with these OCS recommendations:

### **Limiting Factor 1 – Loss of Structural Habitat Elements**

Where historical stands were perpetuated for 200 to more than 1,000 years, commercial forestlands are now commonly harvested every 60 years or less, which limits the maintenance and future recruitment of large-diameter trees. In addition, the number of large-diameter snags and logs has been reduced over time through wildfire and timber harvest. Recommendations for mitigation include *“develop programs, incentives, and market-based approaches to encourage longer rotations and strategically located large-diameter tree tracts. Where feasible, maintain structural elements, such as large-diameter tall trees, snags, and logs. Create snags from green trees or high-cut stumps where maintaining snags is not feasible or where snag management goals are not being met.”* Actions planned for reserves, extensive treatments and RCAs are designed to increase the amount and diversity of forest structural elements on the ESRF, especially in riparian areas, current plantations in the CRW that receive restoration treatments, and in younger stands that will be managed using extensive treatments. Reserve, extensive, and RCA areas will provide late successional habitat. Early seral conditions associated with intensive harvests and a range of successional stages across extensive stands (including complex early seral) will provide habitat for a range of species that rely on these forest conditions. Rotations planned for intensive treatments will be at least 60 years, significantly longer than the industry average of 35-45 years, and all intensive treatments will be balanced with an equal acreage placed in reserve status.

### **Limiting Factor 2 – Impacts of Vegetation Spraying in Early Seral Stage Forest Stands**

Within the past two decades, biologists have become increasingly concerned with intensive vegetation management in early seral forest stands and associated impacts on wildlife, from birds to big game. Recommendations for mitigation include *“continue efforts to understand the impacts of vegetation management in early seral stage forest stands by advocating for scientific research on the issue. Provide outreach and technical assistance to help landowners understand the potential for impacts and alternate management techniques.”* Plans for intensively managed



**Figure 9.6.** ESRF Triad subwatershed allocations with overlay of mapped OCS Priority Wildlife Connectivity Area (PWCA) Region and Connector areas (hatched areas within white borders) (ODFW 2023.)

stands include research on methods to reduce or eliminate the use of herbicides during regeneration of forest stands on intensively managed timberlands, toward the eventual goal of fostering widespread adoption of successful alternative methods on industrial timberlands in Oregon.

### Limiting Factor 3 – Loss of Late Successional Stand Size and Connectivity

Late successional forest stands have been greatly reduced in size and connectivity, particularly at lower elevations. This can impact species that are highly adapted to late successional conditions and/or species that have limited ability to move over long distances to find new suitable areas. It also allows edge species to compete with ones adapted to extensive interior forest habitat. Recommendations for mitigation include *“maintain existing plans to protect and develop habitat that has been identified as important to species of conservation concern. Use active management to accelerate development of late successional structural characteristics in key areas to expand existing late successional patches into larger areas; these will provide greater blocks of habitat for species with large area requirements or those that require interior forest habitat and are vulnerable to ‘edge effects’.* Continue to carefully plan forest practices to maintain connectivity, particularly when species vulnerable to fragmentation are present. Seek opportunities to coordinate management of public and private lands (e.g., All-Lands Approach) whenever possible to address conservation needs...recognize that a diversity of forest types and ages should be considered to support wildlife habitat connectivity and ecosystem services at a landscape scale.”

Plans for the CRW and reserve blocks within the MRW on the ESRF align well with the OCS Strategy Habitat recommendations for late successional mixed conifer forests. At 34,139 acres, the CRW will increase connectivity with adjacent protected areas to create one of the largest contiguous tracts of protected older forest in the Oregon Coast Range. One-time restoration treatments on plantations-in-reserve stands are designed to accelerate development of late successional structural characteristics. Stand-level treatment allocations within subwatersheds on the ESRF explicitly consider maximizing connectivity within the constraints of the overall research design, and location of treatments (intensive, extensive reserve) minimize fragmentation where possible. Riparian Conservation Areas (RCAs) provide connectivity across the MRW, CRW, and partial watersheds.

## 9.4 Species of Interest or Concern

This section describes additional species that occur or potentially occur on the ESRF and are (a) listed as threatened or endangered under the federal ESA, (b) may be candidates for listing in the future, or (c) are otherwise of interest to stakeholders and wildlife specialists. A full list of species that are currently or formerly listed as threatened or endangered (state and federal levels) can be found in Appendix T.

### 9.4.1 Coastal Marten (*Martes caurina humboldtensis*)

The coastal marten (also known as Humboldt marten) is a rare, medium-sized carnivore that is endemic to northwestern California and western Oregon. A subspecies of the Pacific marten, they are a member of the Family Mustelidae, which also includes the weasels, wolverine, fisher, badgers, skunks and otters. Populations declined from heavy trapping pressure in the late 19th and early 20th centuries and loss and fragmentation of mature forests. In October of 2020 the coastal marten was officially listed as threatened under the Federal ESA. The coastal marten is closely associated with late-successional, mixed conifer forests with multi-layer stands, and is currently known to exist in four isolated populations (two in California and two in Oregon including one just to the west of ESRF boundaries). The Oregon Conservation Strategy recommended conservation actions for the marten are to (1) minimize forest fragmentation around core sites, (2) restore habitat to increase and reconnect suitable habitat patches in the vicinity of known populations and, (3) restore functional landscape connectivity to enable recolonization.

In a study that included a Humboldt marten population just to the west of the ESRF, Moriarty et al. (2019) evaluated the extent to which marten and northern spotted owl current use overlapped to determine if spotted owls were a viable umbrella species for martens. They found that sites used by both species had overlapping vegetation characteristics, but areas used by spotted owls represented only a portion of broader vegetation conditions used by Humboldt martens. In contrast to areas used by owls, Humboldt martens in the South and Central Coast regions of Oregon used areas with dense and diverse shrub communities. Shrub cover may be a surrogate for the structural complexity typically provided by downed



logs, both of which provide protective cover and foraging opportunities for the small-bodied, carnivorous marten.

Currently, northern spotted owl management focuses on treatments to create or maintain “nesting-roosting” stands- conifer stands with a multi-layered, multispecies canopy dominated by large (>30”) conifer overstory trees, a shade-tolerant understory, substantial decadence, large accumulations of logs and other woody debris, and a canopy that is open enough to allow northern spotted owl flight patterns. Humboldt martens may use these stands, but Moriarty et al. (2019) findings suggest that Humboldt martens exist in areas with a higher conifer size class diversity where expansive dense shrub cover, predominantly tall and contiguous salal and evergreen huckleberry, are also available. In these areas, ground-level prey may be unavailable to foraging spotted owls.

Moriarty et al. (2019) demonstrated that despite perceived similarity in structural elements associated with both species, Humboldt martens in Oregon used a much broader range of vegetation types than spotted owls. They propose that harvest practices that partially alter the overstory while encouraging dense shrub growth, particularly salal and evergreen huckleberry, and retain or increase large downed woody material would provide benefits to coastal Humboldt marten populations. Based on this research, extensive treatments, restoration treatments, and areas in reserve may provide suitable habitat for coastal marten populations currently or in the future. But they caution that their Central Coast study area has coastal fog, significant rainfall and sandy soils conducive to tall, dense, shrubs which may not grow well elsewhere.

In the 1950s, Loon Lake was a known location for the coastal marten, but they have since not been detected on the Elliott. Although not specifically surveying for coastal marten, no marten were detected on any of the 56 biodiversity survey sites with baited camera traps in 2022 biodiversity surveys (Appendix V). In 2023, OSU researchers increased the number of baited camera traps to 235 and did not detect any coastal marten (Margaret Hallerud, *pers. comm.*). The ODFW also completed surveys targeting coastal marten on portions of the ESRF in 2019 - 2020. None were detected over 710 trap nights at 23 sites.

It is suspected that Highway 101 may act as a barrier for eastward movement of the population that is currently documented in the Oregon Dunes National Recreation Area (Moriarty; personal communications). The permanent network of biodiversity plots on the ESRF includes wildlife

cameras set up to detect small to medium carnivores, including coastal marten if they are moving within 140-150m of these baited traps. Topography (drainages) and wind will determine scent detectability, and wildlife cameras should be placed to maximize detection by species in the area. New research is aimed at determining the number of plots needed to distinguish between lack of presence and lack of detection (Moriarty and Levi; personal communication). A recent power analysis of surveys for marten and fisher found that at least one-quarter of the landscape would need to be monitored at the same location over time (Tucker et al. 2021).

Competition for prey and risk of predation may limit habitat suitability for the coastal marten on the ESRF. During the 2022 biodiversity surveys of the ESRF, barred owls were detected at 100% of the 56 sites, which may impact the availability of prey for both the northern spotted owl and coastal marten. Additionally, bobcats were detected with higher frequency on the ESRF than other areas in the central Oregon Coast Range (M. Hallerud, unpublished data). As the primary predator of coastal martens (Martin et al. 2022), increased bobcat density in intensively logged forests is one of the leading hypotheses for coastal marten absence in these forests (Eriksson et al. 2019; Appendix V).

Schrott and Shinn (2020) developed a landscape-scale habitat connectivity model for the coastal marten across its historical range to better understand distribution of its habitat, likely degree of isolation of existing populations, and the potential for the marten to recolonize areas of suitable but unoccupied habitat. They identified “habitat cores”, relatively large patches (>1500ha; about 3700 acres) that are likely to contain sufficient high-quality habitat to support long-term occupancy by coastal martens, and thus represent important areas for conserving the species. One such habitat core, about 2990ha (7390 acres) in size, lies within the northern boundary of the ESRF adjacent to the Umpqua River. Two other areas of habitat, about 1103ha (2726 acres) and 906ha (2239 acres) that did not meet the >1500ha criterion were also identified within the forest boundaries (Figure 9.7).

The ESRF will seek opportunities to partner with researchers, state and federal agencies, and other specialists on the potential for additional monitoring for coastal marten, including methods such as conservation detection dogs and eDNA. Research and monitoring will track suitable habitat on the ESRF for coastal marten and other species over time and seek to understand whether coastal marten

populations are present on the forest. If coastal martens are found to be present, (1) this monitoring effort will increase to understand population levels and space-use of the marten on the ESRF, and (2) the ESRF will work with ODFW, USFWS, and other state and federal agencies to develop an appropriate conservation and management plan.

### 9.4.2 American Beaver (*Castor canadensis*)

The semi-aquatic American beaver is a large rodent averaging a weight of 40 pounds and approximately 3 feet in length. Once among the most widely distributed North American mammals, beavers were trapped nearly to extinction in the 1800s but are now restored to many Oregon waters due to improved management and greater awareness of their ecological benefits. Beavers are recognized as a keystone species and an “ecosystem engineer” for their outsize effects on landscape-level aquatic habitat heterogeneity and species richness. Their dams affect channel flow, geomorphology, and ecology by increasing lateral connectivity, pools, sediment and nutrient storage, and the extent of backwater and wetland habitats. Beaver dams may also accentuate hyporheic flow, helping to reduce downstream water temperatures. Beavers can strongly influence salmon populations in the side channels of large alluvial rivers by building dams that create pond complexes. Smolt production increases significantly in systems where beavers are present (Pollock et al. 2004). According to ODFW, beavers provide the following benefits:

- Pond creation – Beaver dams protect fish from winter flows and increase water storage, resulting in more stable water supplies and higher flows for longer periods. Ponds and other areas of slow-moving water provide important habitat for aquatic species, including summer rearing and overwintering habitat coho (Castro et al. 2017).
- Availability of large woody debris – Beaver dams provide large woody debris that juvenile fish can use to evade predators. They also provide winter pool habitat critical for species such as cutthroat trout and coho.
- Storage of leaf litter – Beaver ponds store leaf litter and support aquatic insect production. This acts as an important food source for fish, amphibians, bats, and birds.
- Nesting and rearing areas for waterfowl – Beaver dams and ponds support the creation of nesting and brooding habitat for waterfowl. Increased vegetation growth as a result also provides increased forage and cover for wildlife.
- Wildlife habitat – Beaver ponds provide habitat for wildlife species including mink, river otter, muskrats,

turtles, frogs, and salamanders.

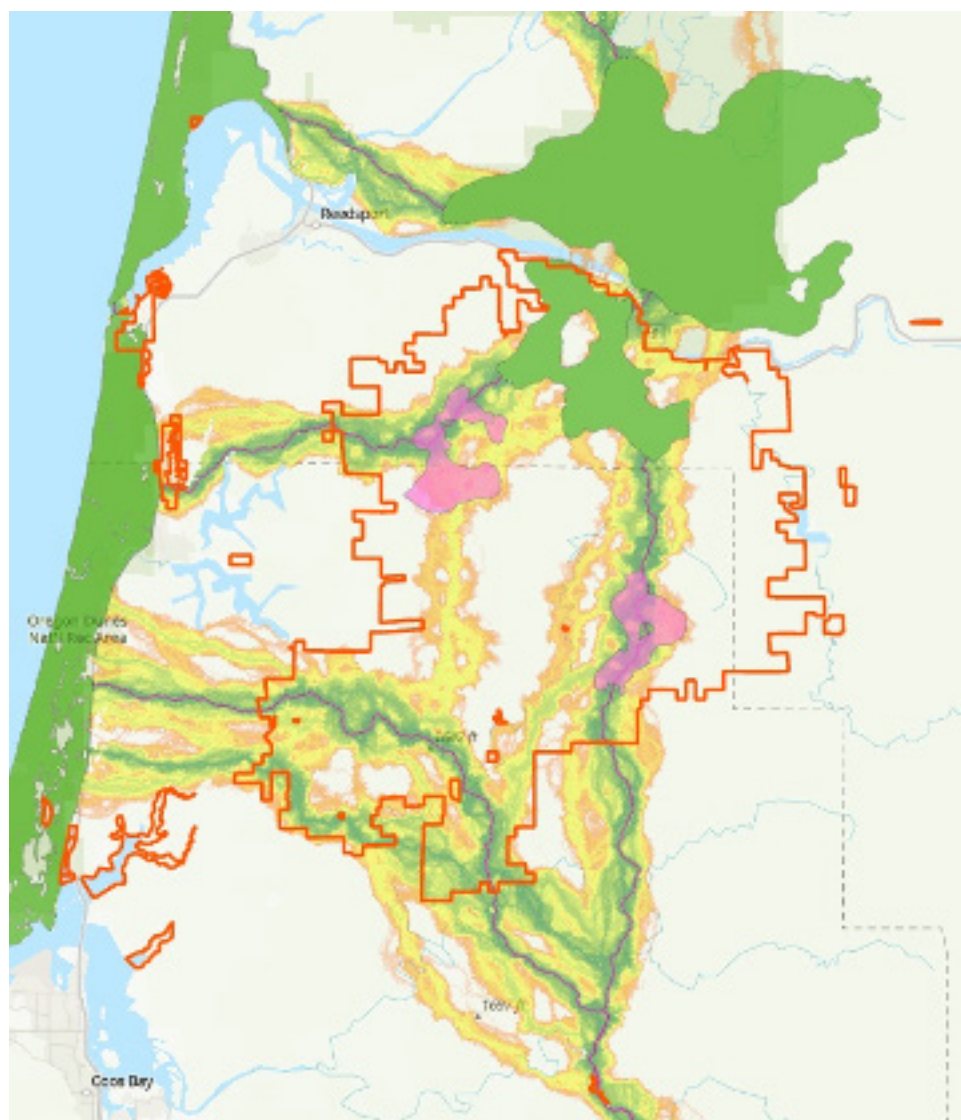
- Food source for wildlife species – Rising water levels behind beaver dams may cause trees to die that attract insects and become a food source for species such as woodpeckers. Dead and dying snags become wildlife habitat for cavity-nesting birds.

Much recent stream restoration has focused on active replacement of large wood in stream channels to create habitat for salmon and other aquatic biota. Promoting new or existing populations of beavers could create the same types of habitat more cost effectively in order to improve floodplain connectivity, stream complexity, and slow-moving aquatic habitat (ESRF HCP). Increasing the number of beaver dams in key areas would create high-quality rearing habitat that promotes stream complexity and increases smolt capacity.

The Oregon Conservation Strategy (OCS) identifies beavers as key to maintaining and restoring floodplain functions and recommends that managers support and encourage beaver dam-building activity. Biosystems et al. (2003) found that ponds and wetlands are not common on the ESRF but where they do occur, they are a part of stream channels and often a result of beaver activity. Beavers generally colonize low-gradient streams that flow through unconfined valleys with a preference toward the lower-gradient areas. Many rivers and streams in the ESRF are in narrow valleys, bordered by steep side slopes with gradients on the side slopes that commonly exceed 65 percent, limiting potential beaver dam habitat. However, substantial beaver activity has been observed in certain areas of the forest such as Dean Creek (Ruwaldt 2011a). Potential beaver dam habitat in the permit area was identified using the following criteria from Suzuki and McComb (1998) and Petro (pers. comm.) and is shown in ESRF HCP Figure 5-3.

- Active Channel width – between 3 and 6 meters
- Valley Floor Width – >25 meters
- Channel Gradient – <3%

Under the ESRF HCP “creation or recreation of beaver dam habitat” is identified as a potential action for Conservation Measure 1, Targeted Restoration and Stream Enhancement, following guidance provided in *The Beaver Restoration Guidebook: Working with Beaver to Restore Streams, Wetlands, and Floodplains* (Castro et al. 2015). After further assessment, the ESRF research management program may determine whether to design a beaver restoration project (e.g., installation of a beaver dam analog, beaver habitat



**Figure 9.7.** Map showing areas within ESRF boundaries greater than 1500ha (green) and less than 1500ha (pink) with habitat modeled as likely to be of sufficient quality to support coastal (Humboldt) marten. Map courtesy of Joel Shinn, USFWS and part of research summarized in Schrott and Shinn (2020).



enhancement), dependent on funding and available resources. If such a project were proposed it would follow relevant scientific literature, to develop achievable goals, strategies, and objectives that are in line with the ESRF research design and biological goals and objectives under the ESRF HCP. Efforts to characterize, create, or enhance beaver dam habitat will be coordinated with regional partners, ODFW, USFWS, and NMFS to ensure beaver management actions fit into the larger context of salmonid recovery and statewide beaver management principles. Tenmile Lakes Basin Partnership (TLBP) has coordinated Beaver Dam Analog (BDA) projects within ESRF borders in Big Creek, Johnson Creek and Plum Gulch (Mater 2023). As a research forest administered by a public agency, beaver trapping restrictions will follow ODFW policy. If a future research design requires a partial or full ban of trapping on the ESRF, researchers will work through the proper channels of a formal application process with ODFW and impacted stakeholders to communicate research objectives and identify an appropriate scale and duration for a trapping ban.

### 9.4.3 Barred Owl (*Strix varia*)

The barred owl is a native raptor that has invaded the Pacific Northwest (PNW) during recent decades and become a point of conservation concern because of its negative impact on the threatened northern spotted owl (*S. occidentalis caurina*). Despite being closely related and ecologically similar to the northern spotted owl, the barred owl is a superior competitor for older-forest resources and has a much broader diet that includes many aquatic and terrestrial prey species that are uncommon or absent from northern spotted owl diets (Wiens et al. 2014).

Invading barred owl populations have grown rapidly and achieved particularly high densities, especially in older forests of Washington and western Oregon, which has exacerbated northern spotted owl population declines historically attributed to habitat loss. In response, a recent landscape-scale experiment (conducted under the Oregon Department of Forestry Safe Harbor Agreement for Northern Spotted Owl for Barred Owl Removal) demonstrated that northern spotted owl populations stabilized in areas with lethal removal of barred owls, yet spotted owl populations continued to decline sharply in areas without barred owl removal (Wiens et al. 2021). Thus, lethal removal serves as an effective management tool to mitigate the negative impact of barred owl on northern spotted owl.

Despite promising results from barred owl control measures, little is known regarding the consequences of, and the

mechanisms behind, the barred owl invasion in PNW forests. For example, it is unknown to what extent the extreme generalist diet of barred owls – which includes small mammals, birds, amphibians, crustaceans, and even insects – is serving as a novel stressor on its prey populations. Ongoing research suggests that barred owl diets have shifted from being dominated by small mammals to other groups within the last decade (Wiens et al., unpublished data), a pattern consistent with the hypothesis that the barred owl invasion is exerting strong, top-down changes to lower trophic levels and impacting food-web dynamics (Holm et al. 2016).

Knowledge of how juvenile barred owls disperse is also very limited, including information about the rate at which new individual barred owls move into areas from which barred owls are removed. Nevertheless, data on juvenile dispersal and settlement patterns is essential for evaluating the cost and long-term viability of barred owl management strategies. Although the broader ecosystem impacts of barred owl invasion and the dispersal dynamics of young barred owls have been identified as critical research priorities by the California Barred Owl Science Team (2018), new field studies on these topics are needed to understand ecosystem-scale consequences of barred owl invasion and evaluate factors that influence the success of planned barred owl management strategies. Given infrastructure and planned programs at the ESRF, it is an ideal location for undertaking research to evaluate the consequences of barred owls on forest biodiversity and provide information needed for adaptive management of barred owl control programs.

Several research priorities have been identified on the ESRF to advance science and management of barred owls in the PNW. These priorities require experimental barred owl removal to establish causation and provide strong inference, and that landscapes monitored in the periphery of ESRF may serve as reference areas to strengthen inference about the effectiveness of removals in benefiting northern spotted owl and overall forest biodiversity.

1. Assessing the trophic effects of barred owls on prey populations, with a focus on small mammals and amphibians, and evaluating prey population recovery after experimental removal of barred owls.
2. Evaluating the effectiveness of barred owl removals on northern spotted owl demographic rates.
3. Measuring the effect of barred owls on sympatric upper trophic predators, with a focus on species whose

prey populations have the greatest potential for being negatively impacted by barred owls.

4. Quantifying first-year movements and space use of juvenile barred owls in a landscape mosaic representing treated (barred owl removal) areas and control (non-removal) sites.

Under ESRF HCP Conservation Measure 6, the ESRF will collaborate with USFWS and other federal and state management agencies to design and implement appropriate barred owl management on the ESRF in support of federal management strategies for northern spotted owl recovery. Research initiatives will be integrated into monitoring and data collection related to northern spotted owl and biodiversity. Timing and extent of ESRF research management on barred owls as part of the experimental design, including the research initiative associated with this mitigation measure will be designed and budgeted by January 2025 and begin no later than the appropriate field season of 2026.

#### 9.4.4 Red Tree Vole (*Arborimus longicaudus*)

The red tree vole is a highly specialized arboreal rodent that lives in the tree canopy of coniferous forests in western Oregon and northwestern California. The North Oregon Coast Range (NOCR) Distinct Population Segment (DPS) is a candidate for federal ESA listing, and the red tree vole is also listed as a state sensitive species. Tree voles are mostly associated with structurally complex old coniferous forest ( $\geq 80$  years old) but are often found in young forests ( $< 80$  years old) especially in unthinned young forests adjacent to old forest. Throughout much of their range tree voles primarily forage and nest in Douglas-fir and occasionally in grand fir. Along the Oregon Coast they also nest in Sitka spruce and western hemlock (Lesmister and Swingle 2017). The ESRF is outside of the current range maps for red tree vole provided by U.S. Fish & Wildlife Service, although the species may occur outside of these range maps.

Management goals and protection for the red tree vole are generally thought to be compatible with those for the threatened northern spotted owl and other late-successional forest species. Complex older forests found in reserves and RCAs, as well as the matrix of forest at various successional stages and complexity across intensive and extensive treatments support the range of habitat identified for red tree voles. As a component of the ESRF biodiversity monitoring plan, canopy access through climate towers and

tree climbing will allow for monitoring of arboreal mammals (including red tree voles) and other species through surveys, wildlife cameras, and acoustic recording devices.

#### 9.4.5 Fisher (*Pekania pennanti*)

The fisher is an agile cat-size member of the weasel family found in late-successional, low- to mid-elevation mixed-conifer-hardwood forests and riparian corridors with moderate to dense canopy cover and diverse structural stages and plant communities. Fishers once occurred throughout the coniferous and mixed forests of Oregon's Coast Range and Cascades. There is currently a native population in the Siskiyou Mountains, and another population in the southern Cascades, consisting of descendants of individuals reintroduced by ODFW from British Columbia and Minnesota in the 1960s and 1980s. The Sierra Nevada population of the fisher was listed as endangered in 2020, and the fisher is a state sensitive species in Oregon. The USFWS initiated a status review for Northern California and Southern Oregon (NCSO) population on 26 September 2023.

Fishers primarily prey upon small mammals, but also consume birds, insects, seeds/mast, and reptiles. Fishers have extensive home ranges, low reproductive rates, and specialized habitat requirements for den sites consisting of cavities in live or dead standing trees. Fishers are active year-round, but more so in summer. They can move considerable distances relatively quickly and have the reputation of being fleet and agile. Limiting factors for fisher include low dispersal, lack of rest den sites, high mortality from predation, and habitat loss/fragmentation from wildfire. Other conservation actions for fisher potentially applicable on the ESRF may include treatment buffers and seasonal restrictions, recruiting and retaining den and rest site structures, and management of bobcat, mountain lion, and coyote populations. The network of habitat provided by the CRW, MRW reserves, RCAs, and extensive treatments are anticipated to provide complex forest structure suitable for fisher habitat. In the 2022 biodiversity surveys of 56 sites on the ESRF, no Pacific fisher were detected on the ESRF (Appendix V).

#### 9.4.6 Birds

Intense management focus on the marbled murrelet and northern spotted owl cannot overshadow the many other bird species present on the ESRF. The forest encompasses an array of mostly forest and riparian habitats for birds, but also

patches of oak woodland, wetland and grassland. Over 100 bird species have been observed or are thought to be present on the ESRF (Appendix T) including species of concern such as the harlequin duck and purple martin. In recent ESRF biodiversity monitoring (Appendix V) birds were detected more often than expected, particularly ground-foraging birds including thrushes, grouse, quails, Steller's jays, and spotted towhees. Songbirds including Bewick's wren, evening grosbeak, MacGillivray's warbler, golden crowned sparrow, song sparrow, and Wilson's warbler were each detected once. Corvid species, like the common raven and Stellar's jay, are of particular interest in consideration of increasing predation for marbled murrelet nests.

The network provided by the CRW, MRW reserves, RCAs, and extensive treatments are anticipated to continue to provide and enhance the diversity of bird habitats across the ESRF. Increased monitoring already underway will strengthen understanding of bird species occurrence and abundance. The network of automated recording unit (ARU) monitoring occurring throughout the forest will greatly increase the detailed measure of avian biodiversity on the forest. ESRF forest managers and staff will coordinate with ODFW, other agencies, watershed councils and NGOs to build and share data and science knowledge regarding bird populations on the forest, to focus efforts aimed at maintaining these species.

### 9.4.7 Amphibians and Reptiles

With abundant precipitation and a mild climate, Oregon Coast Range forests are home to a rich diversity of native amphibians. In headwater streams above the upper extent of fish distribution, amphibians are often the dominant vertebrate predators. Amphibians are sensitive to management activities and are thus viewed as indicators of riparian and wetland ecosystem health. Worldwide, amphibians are more threatened and are declining more rapidly than either birds or mammals (Stuart et al. 2004).

There is limited information on the occurrence and population status of amphibians on the ESRF. According to Biosystems et al. (2003) 13 aquatic and riparian-dependent species of amphibians are known to occur on the forest. Oregon DSL and ODF (2011) list these same 13 species, along with the western toad and non-native bullfrog for a total of 15 amphibian species as "likely to be present" on the forest. Based on recent ESRF biodiversity monitoring and input from ODFW, 9 additional species were added to this list (Figure 9.2).

Five stream-dwelling amphibian species will be covered under the ESRF HCP being prepared under the Private Forest Accord for Western Oregon, three of which occur on the ESRF: the Southern torrent salamander (*Rhyacotriton variegatus*), Coastal giant salamander (*Dicamptodon tenebrosus*), and Coastal tailed frog (*Ascaphus truei*). In western Oregon forests, these species are stream-obligates during early development (eggs and larvae). Upon metamorphosis, they can occur in or along streams and use riparian and upland forests for foraging, dispersal, overwintering and aestivation. However, in some cases, mature life forms of giant salamanders remain in streams for their entire lives ("neoteny") (PFA 2022).

While no conservation actions targeted specifically toward amphibians are currently planned on the ESRF, protections provided by designation of the CRW, reserves within the Triad treatments, and protections and restoration treatments within the RCAs are expected to also confer benefits for amphibians over the longer term. Conservation of amphibians on the ESRF will occur through ongoing adaptive management based on knowledge gained from biodiversity inventorying and monitoring and may shift as knowledge is gained through these efforts. Monitoring efforts will include a focus on the foothill yellow-legged frog (*Rana boylei*) which is a declining species considered to function as a "sentinel" for assessing ecological health of stream ecosystems. While yellow-legged frogs were not detected in the 2023 ESRF biodiversity monitoring efforts (see Appendix W) and have not otherwise been detected by ODFW (*pers. comm.*) on the forest, the Elliott is within their range and has potential habitat and an observation was made by ODF in 1993 (Biosystems et al. 2003). Monitoring for stream-dwelling and terrestrial amphibians is described in Chapter 10: *Monitoring*.

Reptiles also occur on the ESRF. Six reptile species were identified during 2023 monitoring (Table 9.2). Western pond turtles are listed as a federal species of concern, an ODFW sensitive-critical species and an Oregon Conservation Strategy species. While the ESRF appears to encompass fairly limited western pond turtle habitat (Henderson 2019), Biosystems et al. (2003), citing ODFW survey data (Allbritten 2002) reported that the turtles were found on the Elliott, having been "sighted in [a] number of ponds and lakes, including Gould and Loon Lakes, and may be present in some slow water areas of streams" (p. 8-19). Pond turtles require quiet water with rocky or mud bottoms and floating logs or other platforms for resting and basking at the water's surface. Pond turtles nest on land where there is appropriate



substrate and a sunny location within a mile of water. Juvenile pond turtles are especially vulnerable to mortality from aquatic and nest predation and destruction of nesting areas. Population declines are due to habitat loss, degradation of nesting areas by invasive plants, competition from non-native turtles and disease. Predators include raccoons and invasive bullfrogs and fish.

**Table 9.2.** List of amphibians and reptiles (adapted from Biosystems et al. 2003). Species status is updated from the Oregon Biodiversity Information Center 2019 ‘Rare, Threatened and Endangered Species of Oregon’ report. The 2023 ESRF Amphibian and Reptile report can be found in Appendix W.

Species	Preferred habitats; comments	Status, ORBIC List
Coastal tailed frog, <i>Ascaphus truei</i>	Partially Aquatic. Larvae usually found in cold, rocky streams. Adults prefer areas along aquatic margins and cool, moist forests near streams. Tadpoles, especially during first year, do not tolerate warm water. Observed on the Elliott 2023 <sup>1</sup> .	Oregon Sensitive, ORBIC 4
Northern Red-legged frog, <i>Rana aurora</i>	Adults are terrestrial and use areas adjacent to streams. Eggs laid in marshes, bogs, swamps, ponds, lakes, and slow-moving streams. Observed on the Elliott 2023 <sup>1</sup> .	Oregon Sensitive, ORBIC 4
Foothill yellow-legged frog, <i>Rana boylei</i>	Adults found in vicinity of permanent streams. Most common in and near streams with rocky, gravelly, or sandy bottoms. Eggs are attached to rocks or gravel in pools and stream margins. Observed on the Elliott by ODF <sup>2</sup> .	Sensitive-Critical, ORBIC 2
Pacific treefrog, <i>Pseudacris regilla</i>	Very common in the Oregon Coast Range. Requires slow, open water for breeding. Observed on the Elliott 2023 <sup>1</sup> .	Not listed
Southern torrent salamander, <i>Rhyacotriton variegates</i>	Adults live close to cold streams, splash zones and seeps. Are uncommon. Larvae may be abundant in gravel with water percolating through it. Observed on the Elliott 2023 <sup>1</sup> .	Not listed
Pacific giant salamander, <i>Dicamptodon tenebrosus</i>	Adults can metamorphose into terrestrial or aquatic morphs. Range through cool, moist forest areas in vicinity of cold streams and lakes. Larvae are stream-adapted and common. Salmonids feed heavily on salamander larvae and adult salamanders feed on small fish. Observed on the Elliott 2023 <sup>1</sup> .	Not listed
Long-toed salamander, <i>Ambystoma macrodactylum</i>	Aquatic and terrestrial. Requires quiet water for breeding and feeding. Adults use downed logs or rock for cover and resting. Observed on the Elliott <sup>2</sup> .	Not listed
Dunn’s salamander, <i>Plethodon dunni</i>	Adults usually associated with streams or seeps in splash zone or under rocks, or occasionally woody debris. Eggs deposited in rocks near stream margin. Observed on the Elliott 2023 <sup>1</sup> .	Not listed
Western red-backed salamander, <i>Plethodon vehiculum</i>	Terrestrial. Adults range throughout forest areas, often found in rocky areas and under logs and other wood. Observed on the Elliott 2023 <sup>1</sup> .	Not listed
Northwestern salamander, <i>Ambystoma gracile</i>	During dry months, adults seek refuge in rotting logs and moist crevices. Larvae are adapted to ponds and slow-moving streams. Observed on the Elliott 2023 <sup>1</sup> .	Not listed
Clouded salamander, <i>Aneides ferreus</i>	Adults often associated with large, decayed logs and stumps, particularly Douglas-fir. Also arboreal, canopy dwelling; potentially two different life histories. Old burns and clearcuts may have large populations. Eggs laid in cavities in large logs or stumps or openings deep in rocks. Observed on the Elliott 2023 <sup>1</sup> .	Sensitive, ORBIC 4
Ensatina salamander, <i>Ensatina eschscholtzii</i>	Adults often found in or under large wood, especially conifer logs, on forest floor. Eggs are usually laid in cavities of logs and stumps. Observed on the Elliott 2023 <sup>1</sup> .	Not listed

Rough-skinned newt, <i>Taricha granulosa</i>	Aquatic young, adults terrestrial and range throughout forested areas. Eggs deposited along vegetated fringes of lakes, beaver ponds, slow-moving streams. Very common. Observed on the Elliott 2023 <sup>1</sup> .	Not listed
Western toad, <i>Bufo boreas</i>	Presence on ESRF uncertain. [Listed as “likely to be present” by ODF 2011.]	Not listed
Bullfrog, <i>Rana catesbeiana</i>	Presence on ESRF uncertain. Invasive and expanding its range in Oregon.	Not listed
Western skink, <i>Plestiodon skiltonianus</i>	Under rocks or wood in dry, open forests or openings in more heavily forested areas. Often found near water but also in dry habitats far from water. Observed on the Elliott 2023 <sup>1</sup> .	Not listed
Western fence lizard, <i>Sceloporus occidentalis</i>	Wide range of habitats, including conifer forests that are not too dense or humid. Requires vertical structure, such as rock piles or logs. Observed on the Elliott 2023 <sup>1</sup> .	Not listed
Southern alligator lizard, <i>Elgaria multicarinata</i>	Variety of habitats-grassland, chaparral, oak woodlands, edges of open conifer forests, also riparian zones, moist canyon bottoms. Requires thickets, brush heaps, downed logs, or rock piles for cover. Observed on the Elliott 2023 <sup>1</sup> .	Not listed
Northern alligator lizard, <i>Elgaria coerulea</i>	Humid areas, such as edges of meadows in coniferous forests, also found in riparian zones. Observed on the Elliott 2023 <sup>1</sup> .	Not listed
Northwestern garter snake, <i>Thamnophis ordinoides</i>	Prefers damp areas in western Oregon with dense vegetation and open sunny areas. Often uses large woody debris for cover. Observed on the Elliott 2023 <sup>1</sup> .	Not listed
Red-spotted garter snake, <i>Thamnophis sirtalis concinnus</i>	Usually found in moist areas such as marshes and lake or stream margins, but may occur some distance from water. Observed on the Elliott 2023 <sup>1</sup> .	Not listed
Ring-necked snake, <i>Diadophis punctatus</i>	Requires moist micro-habitats- downed logs, rocks, stumps. Found in a variety of vegetation; most often pine-oak woodlands and moist canyon bottoms. Feed on small lizards, snakes, salamanders; also slugs, worms, frogs, insects. Observed near Loon Lake <sup>3</sup> .	Not listed
Northern rubber boa, <i>Charina bottae</i>	Variety of habitats including oak and pine woodlands, grassy areas, brushy chaparral and moist sandy areas along rocky streams. Eats small rodents, mostly mice and shrews. Observed south of Loon Lake <sup>3</sup> .	Not listed
Northwestern pond turtle, <i>Actinemys marmorata</i>	Lives up to 40 years. Requires quiet water with sunny logs for basking, and safe corridors between aquatic and terrestrial habitat: sparsely-vegetated ground nearby for digging nests and moist, shrubby or forested areas for aestivation and over-wintering. Observed on the Elliott <sup>2</sup> .	Sensitive-Critical, ORBIC 2

<sup>1</sup>Observed during 2023 biodiversity surveys. <sup>2</sup>Biosystems et al. (2003). <sup>3</sup>ODFW.

## 9.4.8 Bats

Despite deforestation being listed as the top threat to bat diversity globally, forest bats can be particularly challenging to study due to the dispersal of roosting locations throughout a forest ecosystem. The Triad research design for the ESRF will allow researchers to test the current hypothesis posed in literature that creating “spatial-temporal heterogeneity in forest age and structure at landscape scales and retain mature forest trees with cavities are likely to benefit bats” (Frick et al. 2019). Like amphibians, no conservation actions targeted specifically toward bats are currently planned on the ESRF, but protections provided by designation of the CRW, reserves within the Triad treatments, and protections and restoration treatments within the RCAs are expected to also confer benefits for bats over the longer term. During the 2022 biodiversity

pilot study, OSU researchers were able to detect up to 14 species of bat using ultrasonic recorders for bat bioacoustic data collection (Table 9.3; Appendix V). The results are preliminary and still being confirmed through further analysis, but they indicate that there are multiple sensitive species within the ESRF. ESRF forest managers and staff will coordinate with ODFW, other agencies, watershed councils and NGOs to build and share data and science knowledge regarding bat populations on the forest, to focus efforts aimed at maintaining these species.

**Table 9.3.** Preliminary list of bat species identified in 2022 ESRF Biodiversity Study (Appendix V) through bat bioacoustics. Results of this study are still being reviewed and this table may change with additional analysis.

Species	Preferred habitats; comments	Status, ORBIC List
Big brown bat, <i>Eptesicus fuscus</i>	Common in deciduous forest areas; forages above canopy and along forest edges and clearings	Not listed
California myotis, <i>Myotis californicus</i>	Forested habitat at lower elevations; roosts in rock crevasses, under bark, in snags	Sensitive species included in the Oregon Conservation Strategy Species for the coast range
Canyon bat, <i>Parastrellus hesperus</i>	Uncommon in conifer forests, preferring desert mountain ranges, scrub flats and woodlands; may be associated with lowland riparian areas; roost under rock outcrops	Not listed
Fringed myotis, <i>Myotis thysanodes</i>	Coastal conifer and riparian forests; roosts in caves, trees, snags, rocks	Sensitive species included in the Oregon Conservation Strategy Species for the coast range
Hoary bat, <i>Lasiurus cinereus</i>	Prefer diverse forest habitat with mixture of forest, edge and small clearings; roosts in trees; migrates south during winter	Sensitive species included in the Oregon Conservation Strategy Species for the coast range
Little brown myotis, <i>Myotis lucifugus</i>	Lives in forest habitat near water; hibernates overwinter in caves	Not listed
Long-eared myotis, <i>Myotis evotis</i>	Conifer forests; forages in openings of dense forests; roosts in caves, hollow trees, loose bark on trees	Not listed
Long-legged myotis, <i>Myotis volans</i>	Associated with mountain coniferous forests and riparian habitats; hibernates in winter months	Sensitive species included in the Oregon Conservation Strategy Species for the coast range
Mexican free-tailed bat, <i>Tadarida brasiliensis</i>	Commonly found in urban or riparian areas; the ESRF would be at the northernmost edge of their range	Not listed or included as Oregon species by ODFW
Pallid bat, <i>Antrozous pallidus</i>	Found in arid deserts, grasslands, and high-elevation coniferous forests; roost in rocky outcroppings	Sensitive species included in the Oregon Conservation Strategy Species for other areas of Oregon, but not the coast range
Silver-haired bat, <i>Lasionycteris noctivagans</i>	Older forests; forages over riparian areas and roads; roots in trees	Sensitive species included in the Oregon Conservation Strategy Species for the coast range
Townsend's big-eared bat, <i>Corynorhinus townsendii</i>	Conifer forests, riparian areas; sensitive to human disturbance; roost in caves	Sensitive species included in the Oregon Conservation Strategy Species for the coast range
Western small-footed myotis, <i>Myotis ciliolabrum</i>	Listed as living in dry climates, east of the Cascade range; roosts in caves and rocky outcrops	Not listed
Yuma myotis, <i>Myotis yumanensis</i>	Very closely associated with riparian areas; migrate in autumn	Not listed



### 9.4.9 Rare or Endangered Plants

Very little is known about occurrences of rare or endangered plant species on the ESRF. As of 2011, no comprehensive assessments or basic systematic surveys for rare plants had been conducted in the forest (Oregon DSL and ODF 2011). Biosystems et al. (2003) reported that ODF staff queried the 2001 Oregon Natural Heritage Program database for plant species in Coos and Douglas Counties that met at least one of these criteria: (1) listed as threatened or endangered by federal statute; (2) listed as threatened or endangered by state statute; (3) identified as a candidate for the state threatened and endangered list by the Oregon Department of Agriculture; or (4) identified under policy by ODF as a special concern plant. Three species were identified that live in habitats found on the Elliott:

- Bensonia (*Bensoniella oregona*), a state-listed candidate species that occurs in wet meadows and moist streamside sites in pre-cretaceous meta-sedimentary rock at elevations above 2,500 feet.
- Tall bugbane (*Cimicifuga elata*), a state-listed candidate species that occurs in Douglas-fir forests with maple and sword fern.
- Howell's montia (*Montia howellii*), a state-listed candidate species that occurs in moist lowland areas, vernal wet sites, often on compacted soils at less than 1,300 feet.

While these species potentially occur on the ESRF, there are no known occurrences of these species on the forest.

Port-Orford-cedar (*Chamaecyparis lawsoniana*, POC) is the largest member of the Cypress family and native only to southwestern Oregon and northern California conifer forests. Distribution is often localized, but POC occurs in many different environments from sea level to over 6000'. POC usually grows along streams and in areas with year-round seepage but may occupy a broader range of sites in the northernmost parts of its range, to the north and east of Coos Bay. It often grows within the active stream channel, where, as large, old trees, POC provides shade and long-lasting stream structure and a stabilizing fibrous root system. (Hansen et al. 2000.)

POC is declining throughout its range, threatened by Port-Orford-cedar root disease (*Phytophthora lateralis*) a non-native, aggressive, fungus-like water mold that lives and grows in the roots and lower stems of its host trees. As a result of the root disease, POC was once considered for candidate status under the state and federal ESAs but was never listed. Naturally established stands of Port-Orford-cedar occur in some scattered tracts of Oregon state forest lands to the south but have not been documented on the ESRF. However, two small stands (about 6 acres total) of Port-Orford-cedar were planted on the Elliott around 2002-2003 (ODF 2016).



# Chapter 10

## Monitoring

The size of the ESRF and commitment to the long-term nature of the OSU research forest vision provides a framework that allows experiments to be devised and executed at unprecedented spatial and temporal scales. Experiments at these scales make it possible to realistically address questions that remain unresolved and even controversial regarding forest management, conservation, and restoration of forested watersheds. This work will be approached from a whole ecosystem and whole network perspective.

Monitoring conducted as part of the experimental design on the ESRF will be an evolving, comprehensive, multi-faceted endeavor and fundamental to achieving many of the goals envisioned for the forest. In view of the multi-decadal monitoring timeline envisioned for the Triad experiment and other studies nested within it, a deliberate approach is being taken in setting up monitoring programs. Monitoring will be conducted to assess change across different biological, physical and

sociological parameters using protocols structured to meet a diverse array of science and management information needs. This chapter describes how this monitoring framework will be developed and implemented initially across the ESRF.

Practitioners recognize different types and purposes of monitoring, which sometimes overlap. One common type is *implementation monitoring* (also referred to as compliance monitoring) which assesses whether a management action has been executed as designed. *Effectiveness monitoring* focuses on the degree to which the objectives of management actions have been met. Effectiveness monitoring as required by the ESRF HCP will be nested within the proposed overall monitoring protocol. Much ongoing monitoring on the ESRF will assess background stability and change in the forest by tracking a set of key response variables across well-distributed locations and extended time frames to support the Triad experiment and nested research. This type of monitoring has been termed *ecological effects monitoring* (Hutto and Belotte 2013). Robust monitoring on the ESRF will require an initial period of *baseline monitoring* to understand existing conditions and establish reference points against which changes can be measured.

Monitoring of research outcomes is the primary means by which new information is generated and used in the integrative adaptive management approach allowing assessment of the success of species conservation, ecosystem services delivery, and other goals and objectives called for in ESRF guidance documents and enabling legislation. Research and monitoring databases will be the depository of all current and archived research projects and long-term monitoring data.

Monitoring will be initiated on the ESRF to establish pre-treatment baselines prior to initiation of silvicultural activities. This is a critical step as long-term research findings and management effects will be assessed relative to baseline conditions and through time. While categories of monitoring are described separately in this chapter, research, management, and monitoring of the forest are fully integrated so that no one area of inquiry is separable from the rest. This is particularly true with instrumentation and collection of data on conditions across stand-level, subwatershed, and landscape scales. Adaptive research implementation, management and monitoring are integrated processes, and monitoring will inform and change management actions to continually improve outcomes for research, management, and species conservation. The ESRF monitoring program and priorities may evolve to continually

align with research programming and utilize (or test) emerging techniques and technologies.

All ESRF baseline monitoring data will be publicly available through real-time data portals and archived data.

## 10.1 ESRF Research Program Monitoring

The following section provides a framework for long-term monitoring on the ESRF as a backbone of the research program. Additional monitoring and research projects may be incorporated into the monitoring program over time (as discussed below in Section 10.3).

### 10.1.1 Forest Inventory and Carbon Monitoring

Precise, long-term monitoring of forest inventory and ecosystem carbon on a research forest is more complex and thus has much higher data requirements than on lands managed for timber or those managed for conservation objectives. Fortunately, these data requirements can be met by new technologies that support continuous, in situ monitoring of forest carbon in real time (Torresan et al. 2021).

The ESRF forest inventory will initially overlap traditional inventory methods (ground sampling) and emerging technologies such as high-density aerial LiDAR and high-resolution multispectral imagery aerial flights. A network of approximately 200 permanent forest inventory and carbon monitoring plots will be established across the ESRF (covering intensive, extensive, RCA, and reserve areas). Measurements taken on this system of permanent forest inventory plots will track forest (above and below ground) growth and structure as well as contributing to the ESRF goal of establishing and validating a rigorous yet cost effective carbon monitoring framework that can serve as a model for monitoring of carbon-dense forest ecosystems elsewhere in the PNW region.

#### 10.1.1.1 Forest Inventory Permanent Plots Forest Inventory Permanent Plots

A network of approximately 200 nested, permanent inventory plots will be established and re-measured on a five year rotating basis. Permanent plot measurements will be conducted in coordination with aerial and ground-



based LiDAR inventories to characterize long-term forest vegetation dynamics across the ESRF. Permanent inventory plots will be established in pairs, stratified across MRW reserves, intensive management areas, extensive management areas, the CRW reserve, and riparian conservation areas. Each permanent inventory plot pair will include two sets of nested subplots to characterize different structural elements, with each set of nested subplots centered on points located 197 ft (60 m) apart. A subset of these permanent inventory plots will be located such that one set of the nested plots within the permanent inventory plot pair will overlap with a biodiversity monitoring plot (described below). However, due to differences in goals, anticipated numbers, and location criteria between them, not all permanent forest inventory plots will be associated with a biodiversity monitoring plot.

Each of the two sets of nested plots in a permanent inventory plot pair will include the following measurements:

- DBH, crown class, species, and condition data will be collected for all live and dead standing stems  $\geq 29.5$ -in (75 cm) DBH in circular, 0.5-ac (0.2-ha) macroplots following Pacific Northwest Permanent Sample Plot program protocols (PNW-PSP).
- DBH, crown, class, species, and condition data will be collected for all live and dead standing stems  $\geq 3.9$ -in (10 cm) DBH in circular, 0.125-ac (0.05-ha) subplots following PNW-PSP protocols.
- Woody stems  $\geq 4.5$ -ft (1.37 m) tall and  $< 3.9$ -in (10 cm) dbh will be recorded by species, dbh and height class in a pair of circular, 0.01-ac (0.004-ha) microplots located 10 m on opposite sides of each nested subplot center point.
- Live tree stems  $< 4.5$ -ft (1.37 m) tall will be tallied by species and cover will be estimated for all shrub species, fern species, forb species, and graminoids in a pair of circular, 0.002-ac (0.0008-ha) understory plots located 10 m on opposite sides of each nested subplot center point.
- Estimates of litter, duff, and downed woody debris biomass will be generated using line-intercept sampling procedures as described in Harmon and Sexton (1976). Litter, duff, and down woody debris line intercept sampling will be conducted along a 100 m transect that intersects the two nested subplot centers in each permanent sample plot pair. Briefly, this will include:
  - Measurements of litter depth and duff depth at points located every 10 m along the 100 m transect.
  - A tally of all downed woody debris  $< 0.25$ -in (0.635 cm) diameter and all downed woody debris from 0.25-in up

to and including 0.99-in (2.51 cm) diameter along a 1 m transect beginning at four total points, located 10 m on each side of the two nested subplot center points at each permanent sample plot pair.

- A tally of all downed woody debris from 1.0 in (2.54 cm) diameter up to and including 2.99 in (7.59 cm) diameter along two, 10 m lengths along each 100 m woody debris sampling transect, as measured from the nearest nested subplot center point.
- The species (if determinable), decay class, and diameter at the point of transect intersection of all down woody debris  $\geq 3$  in (7.62 cm) diameter along the entire, 100 m length of each downed woody debris sampling transect.

### LiDAR

Given the research focus of the ESRF, the forest inventory will be executed using two sets of complementary data: one with high density ( $> 30$  points / m<sup>2</sup>), which would be acquired using fixed wing manned systems, and one with very high density ( $> 500$  points / m<sup>2</sup>), which will be acquired using unmanned aerial systems (UAS). The fixed wing acquisition of aerial LiDAR will be carried out every 10 years, and will cover the entire ESRF. The complete coverage of the ESRF in one year will ensure the description of the entire forest in one phenological season. The decadal LiDAR data will be complemented by annual flights using UASs, which would cover  $\frac{1}{5}$  of the entire forest; therefore a quinquennial description of the entire forest is ensured. The flights will be executed by graduate students from the OSU College of Forestry coordinated by ESRF staff, while data processing and forest inventory will be executed by the OSU Forest Geomatics lab, the Management, Algorithm, and Remote Sensing (MARS) research group.

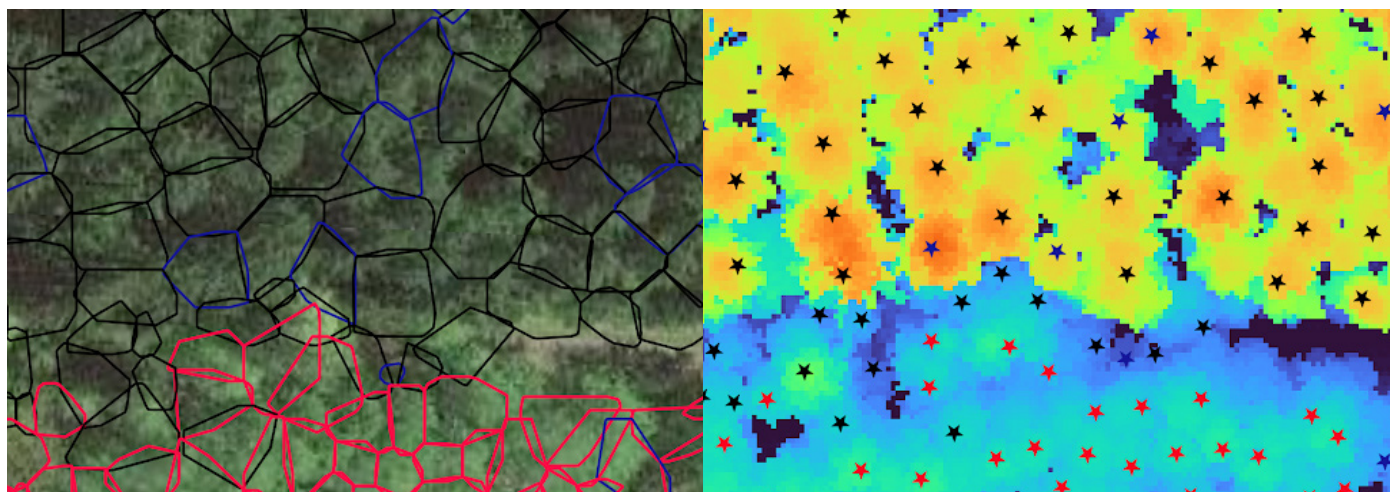
In 2022, MARS mapped the species groups, location and height of each dominant and codominant tree on the entire forest. Approximately 9.4 million individual trees were identified by using an enhanced Hyyppä et al. (2001) algorithm from the fused 2021 high-density LiDAR acquisition ( $> 30$  pts/m<sup>2</sup>) with the high-resolution multispectral data captured during the same vegetation season.

The individual trees will be identified using two algorithms, one based on the geometry of the crowns (Strimbu and Strimbu 2015) and one based on a deep learning algorithm which are expected to provide  $> 95\%$  accurate results for dominant and codominant trees. The execution of the inventory using two fundamentally different algorithms



**Figure 10.1.** Return to home of a UAS LiDAR flight on upper Lost Creek (top). Resulted point clouds at the perspective view of an upper side of the ridge (bottom left) and zoom in around the road (bottom right).





**Figure 10.2.** Tree crowns overlaid on orthophoto (left) and treetops overlaid over the canopy height model (right). The color represents the species: Douglas-fir (black), Western hemlock (blue), and hardwoods (red).

helps in estimating the accuracy of the estimated trees as well as serving for verification of the procedures themselves. Identification of trees allows estimation of crown dimension, particularly height to crown base, which translates in accurate and precise identification of diameters along the stem.

From individual tree dimensions, the distribution of volume along the stem will be estimated by enhancing taper equations developed by Poudel et al. (2018) with LiDAR attributes, similar to Hao et al. (2019) and allometric tools identified in the USDA Entity publication (Eve et al. 2014). Tree species will be identified by fusing multispectral images with several elevation percentile surfaces created from the point clouds using a convolutional neural network, similar to Fricker et al. (2019) and Natesan et al. (2020). LiDAR data and analysis of dominant and codominant trees will be cataloged in the ESRF database.

An average of 40 permanent sample plots will be terrestrial scanned every year using a handheld unit (e.g., Geoslam or FJ Dynamics), if possible in areas scheduled to be flown by UAS. The high density terrestrial scans (i.e., approximately 1000 points / m<sup>2</sup>) will allow not only estimation of dimensions but also of various attributes important for wildlife, such as branching architecture and diameter of the large branches at the insertion point. The combination of UAS terrestrial LiDAR, which will take place between the decadal aerial LiDAR flights that will cover the entire forest in one season, are focused on stands with planned intensive, extensive, or restoration treatments.

### **Downed wood**

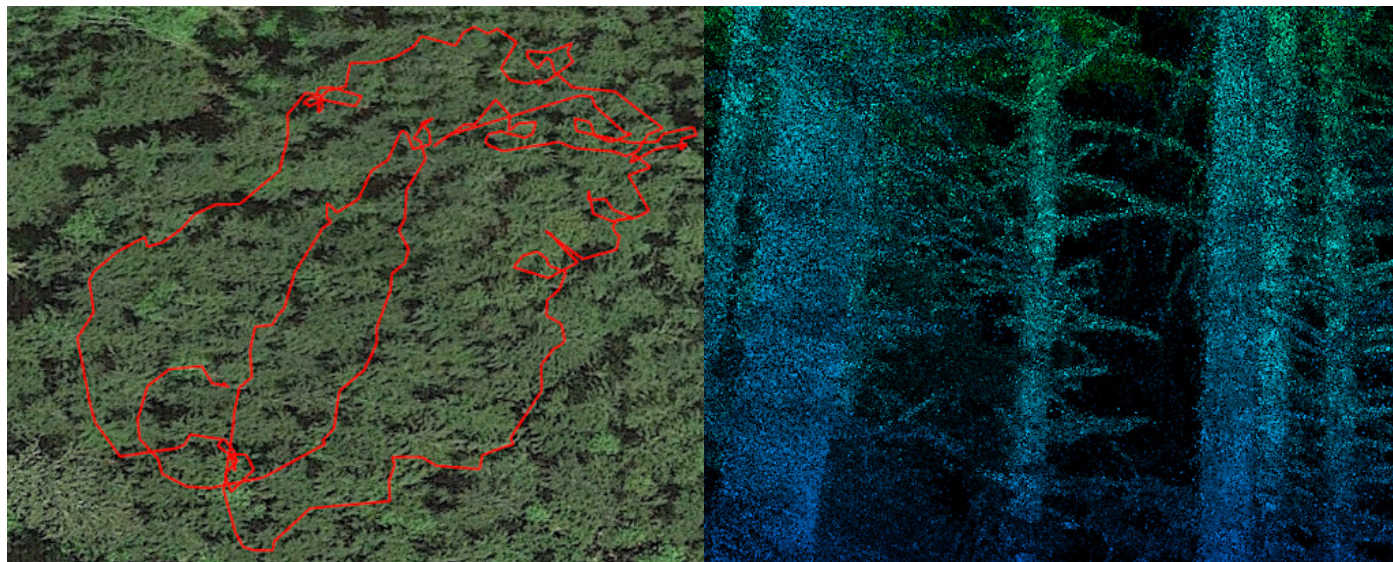
Monitoring of fine to coarse woody detritus will occur within the permanent plot networks and in areas of the ESRF where researchers are seeking to quantify the role of and variations in dead trees and other downed woody material among and between treatments. To capture the full range of size in detritus, downed wood will be quantified along transects >100m using a variation of the line intercept sampling method outlined in Harmon and Sexton (1996) that includes a decay class system. To account for mobility of woody detritus over longer monitoring periods, researchers will be tagging decaying material along transects. Transects may not be sufficient to monitor the impacts of snags on woody debris, but adaptations on existing protocols may be implemented to capture the impacts of fragmentation of snags over time.

### **Regeneration surveys**

There are two primary objectives of regeneration surveys: (1) estimate current stocking and (2) estimate rates of mortality. Other objectives may include observations related to browse, vegetative competition, or seedling vigor and performance. Three methods may be used to accomplish one or both of these primary objectives.

Estimating current stocking can be accomplished through use of temporary, fixed radius plots distributed randomly or systematically throughout the planting area. In either case,





**Figure 10.3.** Terrestrial laser scan of one biodiversity plot from the southern slope of Dean Mountain. Left: Scanning path overlaid on the orthophoto. Right: Perspective view of the point cloud.

the plots should cover the entire area to capture variations in site and microsite conditions. Plot size should be at least 1/50th acre (16.7' radius) to ensure a sufficient plot-level sample size. Sampling may also include detection of naturally regenerated seedlings.

Permanent plots can be used for estimates of both stocking and mortality. Permanent plots are distributed across the site and set up similarly to temporary plots, but use a monumented and GPS-located plot center to facilitate revisiting the same plot over multiple years. Individual trees on the plot may be marked with pin-flags to aid in future location of the seedlings. Sampling immediately following planting establishes baseline stocking and subsequent sampling shows any change (mortality) in stocking.

A transect using a numbered stake placed at each tree along the transect may be used to estimate mortality. Transects must be located throughout the unit to ensure coverage of the entire planting area. Baseline information on species, size and vigor may be recorded at the time of transect establishment. Subsequent site visits would show change in number of live trees to allow calculation of percent mortality. Transects may not be sufficient to establish accurate stocking estimates, but allow close tracking of individual seedlings.

Regeneration surveys should occur during leaf-off periods (e.g., November-December) for increased ease in locating

seedlings. Surveys should occur following the first, second and (if necessary) fourth growing seasons.

### 10.1.1.2 Forest Carbon

#### *Carbon monitoring using the permanent plot network*

Carbon will be monitored on the permanent forest inventory plots using appropriate methods for Entity-scale inventory (e.g., Table 6-1 in Hoover et al. 2014) such as soil carbon pools and soil respiration rates, stem carbon using dendrometers, photosynthesis and respiration rates of tree canopies, litterfall, down wood, mortality and other canopy level processes using towers and tree climbers to access the canopies, fine-scale ground based LiDAR systems and UASs.

#### *Approaches to carbon inventorying and monitoring*

Carbon measurements and long-term monitoring on the ESRF will include analyzing changes in forest carbon before and after novel harvest methods, monitoring outcomes of adaptive silviculture for climate change strategies, studying disturbance dynamics, and using both novel and existing methods for forest inventory. Monitoring infrastructure includes soil sampling and analytic equipment (including a C/N analyzer, trace gas analyzers, and drying ovens) to measure carbon concentration and decomposition rates in live and dead wood, forest floor, and soil.

Carbon stored in trees, soils, and streams will be monitored using two approaches. The first traces change in carbon pools and fluxes through time using climate-sensitive process-based models such as Community Land Model (CLM), iLand and LANDIS II. Monitoring will also be done by direct measurements including hand held and automated gas-exchange instruments, LiDAR, soil carbon analysis, litterfall, mortality, and dendrometer bands. Integrating monitoring with forest management activities will capture changes in the amount of carbon sequestered and reductions in GHG emissions. Details on some of these tools and approaches are provided below.

Carbon stored in the tree and shrub woody biomass will be computed for each tree by summing the product of volume and wood density according to location on the stem, as identified from LiDAR. Amount of non-stem within canopy carbon will be estimated using the models as discussed below. Predicting carbon by using summation of carbon in individual trees based on height, crown size and allometric equations, ensures significantly better accuracy and precision compared to conventional inventory methods (Hao et al. 2019). Carbon stocks in non-woody vegetation will be derived using allometric equations relating percent cover estimates to biomass, and carbon stocks in deadwood pools will be estimated using decay-class specific allometric equations as described by Harmon and Sexton (1996). Carbon stocks in litter and duff will be generated using equations relating litter and duff depth to biomass (Van Wagner 1968) and locally to regionally-derived percent carbon per unit biomass estimates.

A dendrometer network will be established to monitor fine-scale changes in tree growth and tree water status, using low-cost automated point dendrometers such as those available from the electronic manufacturer TOMST. The network will provide fundamental new information on spatial variation in forest water use and growth based on real-time, high-frequency (sub-hourly) logging of stem diameter changes. These changes occur in response to daily weather variations and on longer time scales to seasonal progression of climate and to events like droughts and heat waves. Information on stem area increment/growth can be linked to other measures of carbon accumulation such as from LiDAR and forest models. This information can also be used to help scientists assess vulnerability of the ESRF to climate change and whether estimates for GHG benefits require adjustment.

## **Canopy**

The forest canopy is the primary location for carbon fixation and therefore a foundational component in understanding carbon flows as well as a carbon pool itself. Repeated LiDAR scanning captures changes in canopy structure and the imagery accompanying LiDAR scans (and also other data sources, such as state-level surveys) supports monitoring of canopy health. An emerging area of research is the classification of high resolution LiDAR and imagery to identify trees' leaves, branches, and main stems, enabling tracking of arboreal photosynthetic capacity and trees' allocations to these components of their aboveground biomass. LiDAR data also enables monitoring of shrub and other vegetation layers below tree canopies, by inference of deep shade from lack of LiDAR returns near the ground, aerial observations of understory vegetation through gaps in the main canopy, and ground observation from handheld and terrestrial LiDAR.

## **Monitoring soil carbon and carbon dynamics**

Soil represents the largest carbon storage body on the terrestrial component of Earth. Forest soils generally have a well developed O horizon (surface organic horizon) that is rich in carbon (soil carbon concentration greater than 12% organic carbon) over mineral soil horizons (0 – 12% organic carbon) with the greatest total mass of soil carbon stored in the mineral soil (DeLuca et al. 2019). Soils present on the ESRF are predominantly formed in residuum and colluvium of Tye formation soft marine sedimentary rock. These loosely consolidated sediments are amenable to rapid soil development to depth and result in fairly rapid accumulation of soil carbon (Lindburg et al. 2013). The O horizon of forest soils is directly influenced by harvesting activity; however, subsurface mineral soil carbon is fairly resilient to this type of disturbance (James et al. 2020; Holub and Hatten 2019). The analysis of soil carbon pools on the Elliott requires a combination of deep profile sampling and annual sampling of surface cores (0 – 30 cm) for soil carbon analyses. Pre-treatment and post-treatment sampling will be conducted in a series of replicated plots across intensive, extensive and reserve treatments in different subwatersheds of the Triad design, with initial focus in the early implementation watersheds (see Chapter 4: *Research Platform and Experimental Design*).

The soil sampling protocol will be conducted in a manner that parallels that of the forest inventory and analysis layout to ensure conformity with that larger effort. Similar

to the National Ecological Observatory Network (NEON) sampling protocol, a single megapit will be dug in each subwatershed to assess soil morphology and deep soil carbon concentrations. Megapits will be dug from 0 – 200 cm deep. Samples will be taken at 0 – 10, 10 – 20, 20 – 30, 30 – 60, 60 – 100, 100 – 150, 150 – 200), air dried and analyzed for particle size distribution, soil bulk density (5 x 5 bulk density core), and soil total carbon and nitrogen using a dry combustion analyzer. A network of samples will be taken in a 1 ha circular plot near the center of each treatment unit.

Sampling area consists of a cluster of four 7.32 m radius subplots arranged in a triangular pattern around a central subplot (O’Niell et al. 2016). Subplot centers are located 36.6 m apart with the centers of subplots 2, 3, and 4 oriented at 120° angles around the plot center. Each subplot is surrounded by a 17.95 m radius annular plot that is used for destructive sampling, including collection of soil samples. O horizon samples will be collected with a 20 cm dia sampling ring and separated into individual horizons (Oi, Oe, Oa), the depth and mass determined for each and then dried and ground for carbon and nitrogen analysis by using a dry combustion analyzer. Mineral soil samples will be collected to a depth of 30 cm and analyzed for total carbon and nitrogen as above and soil microbial biomass carbon by fumigation-extraction and analysis of extractable soluble C.

One sample from each plot will be extracted for bulk soil DNA and stored at -20C for additional analyses including total bacterial and fungal counts by measuring 16s (bacterial) and 18s (fungal) rRNA fragment abundance. Samples stored at -20C may also be used for DNA analysis using primers specific to ectomycorrhiza (Pulido-Chavez et al. 2021) and specific enzymes (Gao and DeLuca 2020). Initial plans for monitoring soil trace gas flux will use installation of gas sampling collars near each of the subplot centers. Gas samples will be collected during each quarter and analyzed for CO<sub>2</sub> and CH<sub>4</sub> flux using a Li-Cor 7810 carbon gas analyzer. Methods and technology may change over time as part of adaptive research approaches on the forest.

### ***Dissolved organic carbon***

In addition to quantifying inorganic components, dissolved organic carbon (DOC) concentrations in stream water will also be quantified. An additional water collection sample will be collected at each sampling location for DOC analysis. If funding allows, the DOC in these samples will also be evaluated for organic matter character to help elucidate origin and “quality” of the carbon. Collecting DOC concentrations in consort with inorganic chemistry samples

will allow estimation of fluxes of DOC out of the system. Because DOC concentrations can change with discharge during high flow events (and at different times of year), an additional objective is to capture at least three storm events (one in fall, one in winter, and one in spring) at at least one sampling site with high resolution data on stream discharge.

### ***Ecosystem modeling of carbon pools and GHG emissions through time***

Adequate quantification and verification of the carbon consequences of varying forest management scenarios under future climate conditions requires the use of process-based models. Current models used for carbon accounting rely heavily on historical relationships between stand age, growth and climate, but as climate changes these relationships begin to break down (Crookston et al. 2010). Forest carbon accounting methods often used by the USFS and others are based on growth and yield models which reduce annual growth in response to drought but cannot estimate drought-driven forest mortality, carbon losses or legacy effects. Further, disturbance events can alter both forest carbon stocks and fluxes, and the trajectory of forest recovery will determine carbon cycling dynamics for years to decades following the event. To estimate forest response to climate conditions outside the observational record it is crucial to represent the mechanisms that control ecosystem carbon cycling.

For application on the ESRF, researchers are parameterizing LANDIS II, iLand, and in the future the Community Terrestrial Systems Model (CTSM), a process-based model designed for applications ranging from weather prediction, ecological modeling and hydrological prediction to earth system and climate modeling. CTSM is open source, designed to involve users in development and validation. CTSM is actively supported by the National Center for Atmospheric Research. CTSM infrastructure already exists for extension to operational carbon monitoring. CTSM users can tailor it for their specific application, e.g. by turning on modules that simulate harvest, fire, or nutrient cycling, and configuring for point, watershed, or regional domains.

CTSM represents the dynamic flow of carbon among live and dead above ground biomass pools, and soil carbon and below ground carbon pools. Soil hydrology determines plant available water and soil moisture constraints on decomposition rates. Wood harvest can be prescribed spatially based on area of the grid cell or amount of biomass. Live stem carbon removed during harvest is extracted and proportion of slash can be prescribed. CTSM will be calibrated



to represent dominant ESRF tree species using decades of OSU Coast Range research (e.g., Hudiburg et al. 2009; Law et al. 2018; Law et al. 2021) to define plant traits and set model parameter values. Similar to Buotte et al. (2019) plant functional types will be defined in CTSM to represent individual species. The simulations will then be tested against the carbon monitoring network established on ESRF.

The fine-scale LiDAR data will enable the carbon pool and change through time in the shrub, down wood and tree regeneration layer to be quantified across a range of forest conditions including environmentally sensitive riparian areas and adjacent streams. Climate and other potentially explanatory variables will be monitored allowing for refinement and validation of the process models being tested. Logs and snags, an important long-term pool of carbon, will be identified and mapped. Once established, this monitoring framework can be utilized to assess other co-benefits and services, e.g. quantifying effects of forest practices on water quality and quantity under a changing climate. The monitoring framework will serve as a platform for investigating broader science questions as well as operationalizing near-term predictions of reductions in GHGs.

### 10.1.2 Aquatic and Riparian Systems

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*Gordie Reeves, Oregon State University College of Forestry*

Assessment and monitoring of aquatic and riparian resources is relevant to long-term understanding of the system and explicit evaluation of forest management, riparian management, and in-stream restoration activities planned over short and long time-scales at the ESRF. Specific research, management and restoration concepts are discussed in more detail in the Research Proposal (OSU College of Forestry 2021) and in Chapter 7: *Aquatic and Riparian Systems*. The following section focuses on in-stream and streamside habitat assessment and monitoring.

#### 10.1.2.1 Riparian Vegetation

The purpose of this assessment and monitoring will be (1) to identify potential areas for riparian restoration, (2) to determine effects of these restoration actions, (3) to facilitate in-stream restoration, in particular in local watershed councils, and (4) to determine ecological and structural development of riparian forests in fish-bearing and non-fish-bearing streams.

LiDAR data will be used to determine the density, height, growth, mortality, species, and diameter of streamside trees in specific areas of proposed forest or riparian research or management. Aerial LiDAR will be flown every 10 years across the entire forest, including riparian systems. Repeated UAS LiDAR flights during winter and summer (associated with forest inventory assessments) will be used to determine fine-scale hardwood versus conifer cover in riparian zones, down wood recruitment, movement, and decomposition. Analysis of riparian zones across the entire ESRF network is a long-term goal of the monitoring program. Initial efforts will focus on early implementation areas of the Triad experiment, on areas identified as core monitoring areas for the ESRF HCP, and on any areas subject to management in the next 5 years (e.g. restoration management actions in the CRW sites). Assessments of the riparian forest stand density and tree height from LiDAR will be included in stream habitat survey data (see habitat surveys below).

Riparian forests will also be assessed on the ground. One of the key focal areas of interest in work on riparian forests in the ESRF is wood loading potential to streams – especially large logs. Some of the proposed management and research will have explicit goals of increasing the rate at which riparian trees grow to these larger sizes. In addition to carbon inventory and biodiversity assessment plots that fall within the riparian forest, a minimum of five riparian forest plots will be established along any sites that are planned for potential riparian forest restoration experiments (exact sites and locations will depend upon location of other projects and on results from pilot studies planned for sections of forest streams without anadromy in southeastern section of ESRF). Plot assessments will include: Species and dbh of all trees >10 cm dbh, count of trees <10 cm dbh, understory herbaceous cover (as percent cover in a series of 1m<sup>2</sup> areas within the larger plot, quantification of standing dead, dominant canopy species, canopy cover (using densiometer), downed wood number, diameter, length, and decay class.

In addition to plots in proposed treatment areas, an additional set of at least five plots will be established in areas without any proposed treatment to serve as reference sites (located upstream of proposed restoration areas or in a nearby catchment with comparable forest community and structure). Further, within each plot, trees will be selected to monitor growth rates of the bole, either through repeat measurements or through uses of dendrometers. In three additional sub-catchments in the MRW and three additional sub-catchments in the CRW subject to early management activities, five riparian plots will be established along the



sub-catchment mainstem within 300m of its downstream confluence (one sub-catchment in each region will be an unmanaged site). Exact locations will depend upon where management activities are planned. Forest plots will be assessed for (ideally) at least three years before management activities are initiated.

### 10.1.2.2 Coho Salmon

The Oregon Coast coho salmon (*Oncorhynchus kisutch*) evolutionarily significant unit (ESU) is one of 19 ESUs and distinct population segments of salmon and steelhead in the Pacific Northwest listed as threatened or endangered under the ESA. A federal recovery plan for the Oregon Coast coho salmon ESU was finalized in December 2016 (81 FR 90780). The primary threat identified in the recovery plan is deteriorating freshwater habitat conditions and a concern that existing voluntary and regulatory mechanisms are inadequate to protect and recover Oregon Coast coho salmon (NMFS 2016). The Oregon Coho Plan (2007) describes the population status and conservation plan for 56 coho salmon populations in multiple Oregon Coast watersheds, including the following three watersheds that partially originate from the ESRF: (1) Lower Umpqua, (2) Tenmile, and (3) Coos.

Fish will be sampled from each of the three independent coho populations found on the ESRF once every three years following the methodology of Hankin and Reeves (1988). Trends in population numbers and habitat quantity will be summarized in the 6-year Summary Report (ESRF HCP Section 7.3.2) and a more comprehensive assessment will be completed during the 12-year Comprehensive Review (ESRF HCP Section 7.3.3).

During the 12-year Comprehensive Review more in-depth analysis of long-term trends will be conducted, particularly as the permit term progresses and more years of monitoring are completed. The intention is to track trends in covered species habitat quality and quantity over time and relate the trends back to management activities and conservation measures in the permit area. The 12-year Comprehensive Review will allow compilation of four monitoring cycles for each of the three independent populations. The 3-year cycle coincides with the life history of coho in western Oregon and coho salmon in the Oregon Coast range. This design allows monitoring in each independent population through time, with a focus on one location, reducing potential variability introduced by multiple cohorts. While it is a different cohort each year, a cohort is strongly influenced by

the cohort 3 years earlier, including the habitat conditions that were in place when that cohort was in the watershed. Over time the association between returning cohorts and habitat quality can be tracked.

### 10.1.2.3 Stream Amphibians

Amphibians in streams and riparian zones include entirely aquatic organisms or life stages and others with seasonal or facultative (but important) associations with stream and riparian zones. All salamanders detected during fish surveys will be noted (and processed for length and weight if handled). These will most likely include coastal giant salamanders (*Dicamptodon tenebrosus*), but may also include southern torrent salamander, (*Rhyacotriton variegatus*). Similarly, any northern red-legged frogs (*Rana aurora*) or foothill yellow-legged frogs (*Rana boylei*) that are seen in stream habitat or fish surveys will be documented as they are critical species for conservation. The historic ranges for these two species have shrunk. The red-legged frog was detected on the ESRF during 2023 biodiversity surveys. There have been no reports of the foothill yellow-legged frog being present on the forest since 1993. Thus, the abundance of these species in the ESRF stream network remains unclear. Their presence will be noted in any surveys (habitat or fish). They will not be quantified in monitoring efforts, but their populations may be more closely assessed in the context of specific research projects.

In addition to in-stream quantification of amphibians associated with stream habitat (see Section 10.1.2.4) and fish surveys (see Section 10.1.2.2), surveys for amphibian diversity in small (fishless) headwater streams will be conducted using eDNA methods pending adequate funding and personnel resources. Surveys would be conducted on a five-year rotation across streams which will be on schedule with the terrestrial amphibian transects. Established eDNA primers will be used to determine presence (and potentially relative abundance depending on eDNA analysis method used). Primers may not currently be available for all amphibians. Findings from the eDNA and stream habitat assessments will be used to identify reaches where more focused studies could be conducted to understand ecology and life histories of amphibians in the ESRF.

Terrestrial amphibians in riparian forests, will be assessed in association with terrestrial biodiversity monitoring (see Section 10.1.5 below) and therefore they will not be evaluated separately in aquatic-riparian monitoring efforts.

### 10.1.2.4 Stream Habitat

Monitoring data on instream habitat variables will be collected annually in sections of both the fish-bearing and non-fish-bearing portion of the stream network. The collection methods will be conducted to allow comparison with Oregon Department of Fish and Wildlife Aquatic Inventories Project data, both in the ESRF and in watersheds outside the ESRF. This protocol is a continuous survey of habitat units along the entire length of the sampled stream. Assessments will initially focus on the fish-bearing portion of the network and will then move into select non-fish streams. Following the initial survey, a process will be established to consistently re-survey streams (e.g. in a 5-year rotation throughout the network; 20% of the fish-bearing network assessed each year with repeat surveys starting in year 5 and continuing on a 5-year cycle thereafter). The specific regular sampling regime for fish and non-fish streams will be finalized after the first network survey, when more is known about the amount of time and personnel needed to complete the surveys.

Under the ESRF HCP, the same watershed will be monitored throughout the life of the ITP. Frequency and distribution of monitoring will be such that the ESRF will be able to report on trends in instream habitat quality over a 12-year period, with four monitoring years for each independent coho population. As noted in the ESRF HCP, the following variables will be tracked over time to represent the long-term trends in streams:

- Wood (size classes to be determined); total count
- Pools; number and size
- Fine sediments at pool tail crests; at systematically determined intervals
- The extent of multiple channels; number of channels and total length
- Beaver activity; number of sites and estimated area affected
- Vegetative conditions in selected areas along the stream corridor (e.g. stand density and tree height, but specific metrics for assessment are still being explored)

As noted above, riparian data linked to the stream habitat surveys will in large part be gathered using remote sensing technologies (e.g., LiDAR) and other automated monitoring capabilities. Automation provides more consistent application of methodologies and therefore more repeatable sampling. Methods and technologies will evolve over time, and new methodology may be incorporated into the monitoring program based on current science and through

the adaptive research implementation strategy (see Chapter 11: *Adaptive Research Strategy and Implementation*).

As noted in the ESRF HCP, an in-depth landscape analysis of the ESRF will be completed in the first 12 years of the permit term to characterize baseline conditions. This will include baseline data collection on instream aquatic habitat parameters, listed above. Changes in habitat quality are not expected to be linear due to the stochastic nature of natural events in instream habitat (e.g., landslides). There will be an ongoing assessment of instream habitat quality, and changes that occur will be compared to baseline conditions. When natural events occur that change instream habitat quality, a new baseline may need to be established to inform the monitoring program going forward from that point in time.

Stream habitat monitoring activities that are completed each year will be summarized in an annual report, and monitoring results will be summarized in the 6-year Summary Report and in the 12-year Comprehensive Review. Monitoring changes in riparian and aquatic conditions will provide information for tracking status and trends based on implementation of the covered activities and natural disturbance. Any changes to monitoring and/or enhancement will be documented and rationale for the change will be provided in the 6-year Summary Reports or 12-year Comprehensive Review.

In addition to the core data from the habitat surveys, the following additional components of stream habitat will be noted (when possible/available):

- Potential areas of overwintering habitat (refuge from high flows)
  - As noted in the ESRF HCP, the capacity and quality of streams for winter juvenile rearing has been rated as low in all three watersheds, and the availability of abundant, high quality overwinter habitat is considered to be among the most limiting habitat conditions in the ESRF.
- Coldwater refuge habitats
  - Elevated stream temperatures are a concern for native salmonid fish. The presence of refuge habitat has been identified as a key habitat feature in allowing salmonids to persist in streams that are otherwise inhospitable in regard to temperature.
  - Aspects of stream restoration activities will have the potential to enhance coolwater refuge if areas can be created that increase the size of hyporheic zones

and/or promote streamwater exchange with the hyporheic zone.

- Potential passage barriers or areas of lower passage probability
  - Kavanagh et al. (2005) concluded barriers do not appear to be a major issue for coho in the Elliott State Forest. However, they note that data on migration barriers is limited and recommended additional surveys.
- Shade
  - Quantified using a densiometer at regular intervals in the network habitat surveys
  - In specific areas light exposure will be quantified (as photosynthetically active radiation [PAR] or as lux, which would then be converted to PAR using an established PAR-lux relationship).

### 10.1.2.5 Water Quantity

Forests influence water yield through the interception of precipitation and transpiration by trees. Therefore, changes in the forest have the potential to change streamwater export on short and long time scales. The potential for forest management to increase short-term yield and to decrease long-term yield are critically important processes to understand entering a future with changing climate regimes. Further, the ESRF is in a region where fog can be an important source of water, but this input has not been quantified to date in these systems and the interaction of fog collection with forest structure remains a poorly understood but potentially critical factor in Coast Range forest ecosystems.

In order to understand nutrient and elemental dynamics in these systems, clear quantification of inputs and outputs of water are necessary. This will begin with accurate quantification of stream water fluxes. Water output will be estimated using flumes or gaging stations (that estimate discharge based on stage height and an established stage to discharge rating curve). If funding allows, we will establish an initial set of 16 flume/gage sites in small/medium watersheds. These will be placed/established in tributaries within twelve of the Triad early implementation watersheds. Flumes or gages will be placed in MRW sub-catchments subject to different stand management scenarios including thinning, clearcut and reserve treatments. Four additional flumes or gage sites would also be placed/established in

a minimum of three CRW subwatersheds that serve as unmodified reference systems. Potential flume and gage locations will be identified in 2024.

In addition to establishing high quality discharge estimates in management sub-basins to quantify flow from the sub-catchments, the intention is to establish gaging sites on at least 3 of the larger rivers within the system within each of the three independent populations. When there is a bridge site downstream that will be used as the gaging point. The initial plan is to establish sites on (1) the mainstem of the WF Millicoma River, (2) Big Creek and/or Benson Creek – depending upon access and potential for quality gage sites, and (3) Deans Creek. Establishing gaging stations at downstream mainstem sites will enable evaluation of export from the larger systems, however, if it is not possible to establish sites on larger rivers, export will still be estimated, based on a watershed area to discharge relationship linking the downstream sites to one of the sub-basins within the tributary.

The ESRF may partner with Coos Watershed Association (CoosWA) in establishing and running larger gage stations if it is determined that this would be feasible and mutually beneficial. The CoosWA is a well-established organization in the region which has operated and maintained a gauging station on the WF Millicoma River since 2002. Their CoosWA website hosts downloadable annual summaries and also access to real time data updated every 15 minutes. In working with CoosWA, the ESRF would be able to plug directly into an established program to provide publicly available and searchable real-time and long-term data on stream flow in the system. The exact nature of partnerships with CoosWA, Tenmile Lakes Basin Partnership (TLBP), and Partnership for the Umpqua Rivers (PUR) will be determined through further work with the watershed councils, the ESRF Research Director, ESRFA Executive Director, and research technicians.

Water fluxes are critical to understanding responses to restoration and upland management, however, they are only one half of the water budget. Creating a full water budget requires establishing weather stations throughout the ESRF to collect data on the amount and chemical composition of water entering the system. In addition to rain and (occasional) snow, the ESRF has a striking gradient in fog, which could be important to water budgets, particularly in summer. Data collected as part of climate and microclimate monitoring (see Section 10.1.4 below) will address these data needs.



### 10.1.2.6 Water Quality

Temperature, sediment loads, and dissolved solutes in stream water (collectively “water quality”) in the ESRF is a concern for fish and other aquatic biota, particularly in the Coos and Lower Umpqua independent coho salmon populations.

Regular monitoring of water quality metrics will be established in the following locations on the ESRF:

1. In the same sub-basins in which ESRF HCP associated fish monitoring surveys occur – one system within each of the Coho independent populations,
2. In tributaries of the 16 “early implementation” subwatersheds of the MRW for the Triad experiment,
3. In tributaries of the four unmanipulated reference watersheds for the Triad experiment in the CRW,
4. Downstream WF Millicoma monitoring site (described below)

In addition to water quality monitoring associated with fish survey sites, and the upland forest manipulations (and their controls), a water quality monitoring station will be placed at the downstream mainstem discharge (gage or estimates) sites. These will be monitored to provide an overall integrated assessment of whether activities on the forest are leading to changes in nutrient, sediment or thermal export to downstream areas. It is recognized that monitoring at this one site would not capture impacts or export across the full ESRF, however, given limited resources, the focus is on the larger Triad treatments in the WF Millicoma basin. Monitoring at the downstream sites will reflect an integrated measure of activities, the effects of particular actions in many cases will be captured through monitoring at upstream sub-catchments or in association with experiments or restorations.

Water quality metrics will be monitored over a shorter time frame explicitly associated with stream and riparian experiments and restoration efforts. Monitoring for these projects will ideally occur annually for at least three years prior to project implementation, with adjustments possible based on timelines and funding. Post-treatment monitoring will be conducted annually for at least three years after completion of a given stream or riparian experiment and will ideally continue for longer time periods if funds allow. The following projects – outlined in Chapter 7: *Aquatic and Riparian Systems* as priority research for the aquatic and riparian ecology program at ESRF – will receive initial site-specific monitoring efforts (exact locations to be determined based on site conditions and coordination with other projects):

- Experimental riparian forest restoration thinning to increase current and future stand complexity restorations (with associated stream wood inputs)
- Experimental wood additions at varying densities to assess individual versus aggregate effect of habitat patches

### Temperature

Temperature is a fundamental controlling factor in ecology. In aquatic habitats where most of the animals are ectothermic, temperature can have a particularly strong influence on which species are present and how well they persist. Elevated temperatures have been a particular concern in areas subject to current and historic forest management, and temperature responses are an important factor in evaluating different upland and riparian management and restoration strategies as well as in-stream restoration efforts. While many studies focus only on summer maximum temperatures, the annual thermal regime of a system is important for biota as it can control survival, growth, and emergence through the winter and spring as well.

Water temperature trends will be tracked over time at a minimum within each of the sub-basin networks in which populations will be monitored for each of the three independent coho populations (three sub-basins see fish monitoring section). Temperature loggers will be deployed at intervals of 1000m or less along the mainstem of each sub-basin, and a minimum of 12 additional loggers will be deployed in a subset of perennial non-fish streams within each network. Loggers will record temperatures at a minimum of every hour. This sampling interval allows the capture of daily trends while also ensuring that loggers will have the capacity to record data over long-term deployments in the field. Loggers will be collected and downloaded at least two times per year. Loggers will be replaced when battery life falls below 70% (most loggers use lithium batteries that have a non-linear decline in battery life, and therefore a >6-month deployment could lead to issues).

In addition, temperature data loggers will be deployed across tributaries of the 16 early implementation sub-watersheds and four additional control watersheds. As with the salmon monitoring sub-basins, the loggers will be deployed at intervals of 1000m or less throughout mainstems with additional monitoring in smaller perennial tributaries. Further, higher resolution stream monitoring (every 500m or less) will be conducted along additional key areas of interest for thermal dynamics. These reaches will

be identified based on network-scale thermal imaging work and/or mid-summer temperature assessments of the larger system conducted in these areas within the first five years.

Temperature loggers will also be placed at the focal downstream monitoring site on the mainstem WF Millicoma River and at intervals of 2000m or less upstream to its confluence with Fish Creek, and (2) at the focal downstream monitoring sites. As resources allow, additional temperature logger networks will be established to quantify year-round temperature trends elsewhere in the ESRF encompassing catchments that include the three independent Coho salmon populations.

Water temperature monitoring will also be integrated into aquatic and terrestrial research projects to provide information on how management influences temperature, which can be continually incorporated into adaptive management decisions on the ESRF. Stream temperature monitoring associated with management and restoration will occur upstream, within, and below all experimental in-stream and riparian management and restoration areas. The specific number and configuration of loggers will vary depending upon the site and nature of the management/restoration action. All other in-stream restoration efforts (e.g. wood additions or passage mitigation) conducted within the ESRF but outside an explicit experimental framework for directed ESRF research will include a minimum of three temperature data loggers (upstream, within, and downstream of restoration) deployed as long as possible prior to restoration and continuing at least three years after the project is complete.

### ***Sediment and Turbidity***

Sediment can refer to small or large inorganic particles in a stream. While there is interest in the abundance of some larger size ranges (such as those best-suited for coho salmon spawning), in regard to water quality, the focus in this section is on fine sediment (< 2mm diameter) in this section, which can impact the habitat and production of coho salmon and other aquatic biota by reducing spawning habitats, smothering reeds, decreasing pool depth, and decreasing available substrate used by fry. Suspended sediment loads can increase as a result of natural processes (mass wasting events), but have also been found to increase as a result of forest management, agricultural operations, and road building. Given the potential negative effects of high suspended sediment loads and given the potential for management to increase suspended sediment, this

is a water quality metric of particular interest in ESRF monitoring efforts.

Stream turbidity is often closely correlated with the amount of fine sediment suspended in the water column, and turbidity is much easier to quantify as it can be easily recorded in real-time on data loggers. As noted in ESRF HCP Section 6.3.1, paired turbidity monitors will be installed upstream and downstream of a representative sample of new roads that cross a fish-bearing stream to monitor changes in instream turbidity following the construction of new and maintenance of existing haul roads. Monitors will be placed in locations that allow for reporting on trends in turbidity over a 12-year period. These monitors will predominantly occur lower in the watershed, in perennial fish-bearing streams, to detect potential changes to stream turbidity in locations where covered species occur. These data will be used in conjunction with the road monitoring data to determine if changes in fine sediment inputs associated with road activities are occurring.

Further, additional turbidity monitoring may occur on locations that are determined to be “problem” areas during the road network baseline evaluation that will occur in the first 5 years of the ESRF. Monitoring will attempt to determine the degree to which those locations contribute sediment in order to prioritize when and how to address those road segments. Further, monitoring will occur both before and after those road segments are addressed to determine whether there is a measurable difference in sediment delivery to the stream. This data will inform how future road segments that contribute sediment to aquatic environments will be addressed. See Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.6 for further details on road management and reporting. If funding allows, monitoring will be conducted to link turbidity and particularly turbidity “events” associated with storms and/or debris flow with behavioral responses in fish and aquatic macroinvertebrates.

Turbidity will be monitored using data loggers at the downstream end of each of the three ESRF HCP fish survey sub-basins for the three independent coho populations. Turbidity will also be logged at 12 tributaries associated with the Triad early implementation projects. These loggers will ideally be co-located with discharge measurement stations (flumes or gage/stage monitoring locations). Turbidity loggers will also be deployed at the downstream discharge locations. Upstream and downstream turbidity monitoring will also be conducted at all riparian restoration sites (ideally beginning 3 years before treatment and

extending at least three years after treatment in both restoration reaches and an unmanipulated reference site). Data loggers will record turbidity every hour.

Although there is a relationship between turbidity and suspended sediment loads, turbidity is not a direct measure of the suspended sediment and the relationship between these two metrics can change across systems. Therefore, over the first ten years of the ESRF, the riparian and aquatic program will build a relationship between turbidity and suspended sediment load that can be applied to the long-term turbidity data across the ESRF.

### ***Dissolved oxygen***

Oxygen levels are key for focal stream biota. Stream fish and many aquatic macroinvertebrates have high oxygen demands and so oxygen concentrations in stream water are important. However, it is relatively rare for oxygen to fall below critical levels in small headwaters. Ecologists monitor dissolved oxygen in streams more commonly because this information allows for estimation of stream primary production, a key ecosystem metric in these systems.

As with turbidity, dissolved oxygen (DO) will be monitored using data loggers at the downstream end of each of the three ESRF HCP fish survey sub-basins for the three independent coho populations. DO will also be logged at 12 tributaries associated with the Triad early implementation projects. These loggers will ideally be co-located with turbidity loggers at discharge measurement stations (flumes or gage/stage monitoring locations). A DO logger will be deployed at the downstream sampling location on the mainstem WF Millicoma River. DO will also be monitored at a minimum of one location within 100m downstream of experimental stream and riparian restoration work. Data loggers will record DO every hour.

### ***Water chemistry***

There are numerous elements dissolved in streamwater, and quantifying these solutes can be a powerful tool to understand ecosystem ecology and earth surface geologic processes. With regular long-term quantification of stream solute concentrations, the ESRF is well-positioned to advance fundamental research in these fields. Dissolved solutes also provide a useful suite of metrics in evaluating ecosystem responses to management, restoration, and long-term changes that may not manifest elsewhere. Further, there is particular interest in dissolved nutrients such as nitrogen

and phosphorus, which can be critical limiting nutrients to primary production. Enhancing primary production can be viewed as a positive outcome in some cases, but too much nutrient availability can lead to an algal bloom.

Monitoring water chemistry (chemical constituents in the water) is an important part of the ESRF monitoring effort not only to understand nutrient availability within ESRF streams, but also because the solutes dissolved in the water are exported from the system to downstream habitats and communities. Beyond nutrients, there are numerous other elements and compounds dissolved in stream water, and knowing the concentration of all dissolved elements in a stream is important in understanding a number of key watershed processes. However, quantifying all anions and cations in all locations is impractical. Therefore, most stream chemistry monitoring will focus on the inorganic and biologically reactive forms of nitrogen and phosphorus, nitrate, ammonium and phosphate ( $\text{NO}_3^-$ ,  $\text{NH}_4^+$  and  $\text{PO}_4^{3-}$ , respectively).

The full suite of water chemistry will be assessed in four watersheds. In ten additional watersheds explicitly associated with the Triad early implementation experiments and in the downstream WF Millicoma sampling site,  $\text{NO}_3^-$ ,  $\text{NH}_4^+$  and  $\text{PO}_4^{3-}$  will be measured. Because water chemistry can change with season and with stream discharge, a system of regular water sample collection throughout the year at each of these fifteen sites will be established. The timing of water sample collections at each site will vary depending upon season and storm events (likely fewer in summer during baseflow and more in winter when flows are higher and more variable). The specific sampling regime will depend in part on personnel availability and funding for chemical analysis.

It is important to note that concentration alone does not provide a full picture of chemical export. Concentration must be coupled with discharge estimates in order to determine the total export (flux) of a given element from the system. Therefore, stream water will be collected from areas where stream discharge is well quantified (flumes or gage/stage stations) when possible.

Concentrations of  $\text{NO}_3^-$ ,  $\text{NH}_4^+$  and  $\text{PO}_4^{3-}$  will also be quantified in stream water collected during the summer baseflow period in each of the three focal systems for coho salmon monitoring. Samples will be collected near dissolved oxygen data logger locations and will ideally (if time allows) also include a discharge estimate at the sampling location.



In addition to the inorganic elements and compounds dissolved in streams, there are also organic compounds dissolved in stream water, groundwater, and soil water (the latter two of which often enter the stream during storm events). These organic compounds are collectively referred to as dissolved organic carbon (DOC). For monitoring purposes at the ESRF flume/gaging sites, we will measure overall DOC concentrations during each of the water chemistry collection events. However, DOC is a broad term and the characteristics of DOC can vary a great deal. Quantifying structural complexity or potential lability of DOC is beyond the scope of the monitoring program but may be explored in specific projects.

### 10.1.2.7 Stream Wood Loading

Wood is a critical structural element in stream ecosystems. Wood has been lost from ESRF streams and streams across North America due to active wood removal and the loss of streamside trees that can contribute new wood to the system. While stream wood standing stocks will be an important part of the habitat assessments, those assessments do not explicitly account for future wood loading nor do they encompass the full network. If time and funding allow, annual wood standing stock assessments will be conducted along three to four 2 mile or longer stream reaches across the ESRF. However, individual ground-based surveys can take significant time. Therefore, the focus of wood recruitment assessments at the ESRF will be based on the model ElliottSFWood, developed by Dr. Dan Miller of Earth Systems Institute. The model estimates the relative proportions of total wood recruitment attributable to stream-adjacent, landslide, and debris torrent processes (Carlson and Miller 2023), which can then be integrated with the large wood source-distance relationships described by McDade et al. (1990) within a geographic information system (GIS) environment to estimate protected wood recruitment (Carlson and Miller 2023). Model output estimates potential wood recruitment, which is the quantity of large wood that could be recruited to a specified aquatic ecosystem, given reference forest conditions (Carlson and Miller 2023). Wood loading and sorting will be monitored on the ESRF as part of the LiDAR inventory outlined above for riparian assessments.

On-the-ground wood assessments will also be a part of riparian restoration experiments. Wood will be quantified in treatment and reference reaches annually for (ideally) three years before riparian restoration and three years after restoration at treatment and reference sites. Additional long-term monitoring of wood in treatment and reference sites will be conducted (ideally) every five years for at least 30 years.

### 10.1.2.8 Herbicides

Currently available evidence suggests that silvicultural herbicide applications implemented according to contemporary BMPs are unlikely to result in chronic exposure of aquatic biota, or to degrade surface waters (Souder and Strimbu 2021). When trace concentrations of forest herbicides have been observed they typically occur either as a pulse at the time of application or in the first few storm events following application (Tatum et al. 2017). Therefore, detection of any pulses that may occur requires temporally intensive sampling of surface water targeting these time periods. Contemporary studies in Oregon found that when trace concentrations have been observed they remained well below levels of concern for human health or aquatic biota (Tatum et al. 2017; Caldwell and Courter 2020).

Herbicide use and oversight on the ESRF will be conducted in compliance with FPA regulations. Examples of uses are described in Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.1.4 *Supporting Management Activities*. Herbicides selected for use will be labeled for forestry application rates and methods will follow EPA rules contained in the product label. Ongoing monitoring of herbicide concentrations in the ESRF can determine if and when active ingredients or their surfactants are detectable in surface waters. Therefore, dependent on funding and resources, monitoring for herbicides will be conducted in ESRF streams adjacent to where herbicides are applied to identify water column concentrations and duration to better understand potential effects on coho salmon and other aquatic organisms, using appropriate collection and analytical techniques.

Two methods are typically used to obtain samples to analyze for herbicides in water: *grab samples*, which are discrete surface water samples taken from the water column at a specific timepoint, and *passive samplers*, which are integrative samplers placed in the stream for a certain duration. Collection of event-based grab samples using auto-samplers has been the standard method to detect silvicultural herbicides in streams because it allows for the quantification of the actual chemical concentration in the water column. In contrast, to date most passive sampler deployments relevant to silvicultural herbicide application have presented data in units of time-integrated concentrations per disc and these results were not directly comparable to a traditional concentration (e.g., µg/L), the standard for human health and aquatic biota limits. By spiking passive samplers with chemical compounds of

interest (performance reference compound; PRC) prior to deployment, concentrations of exposure in the stream can be determined. Typically at least 3 passive sampler discs are included in a single container deployed in one location. Flow rate, discharge, and environmental conditions should also be accounted for to determine concentrations from passive samplers spiked with PRC.

Grab sampling is widely used in water monitoring as the procedures are established, its limitations are well understood, and water quality regulations are based on grab sampling values. Grab sampling can be labor-intensive but allows for integrated assessment of site conditions when analyzed data is paired with field observations and measurements.

As an alternative to traditional grab sampling, passive samplers are beginning to be applied in forestry. Coble et al. (2022) conclude that while PSDs have great potential as a method to incorporate into forestry herbicide monitoring, they are still an emerging technology. On the ESRF, grab sampling methods will be targeted with appropriate timing and frequency as outlined above (i.e., at time of application, and during the first few storm events following application) in gaged locations prioritized in consultation with ESRF staff, forest managers, and aquatic biologists. A forestry herbicide monitoring protocol may be developed and provided in the first ESRF biennial operations plan. ESRF managers and researchers will also keep abreast of developments regarding use of passive sampler-based methods and may test such methods on the forest as funding and support allow.

### 10.1.3 Landslides

Landslides are prevalent throughout the landscape of the ESRF and are a dominant agent for transporting carbon, sediment, and wood from hillslopes to streams. A spectrum of landslide mechanisms and sizes are observed in the ESRF, ranging from shallow soil landslides that intermittently yield large quantities of wood and sediment during rain and/or snow events to deep-seated landslides that exhibit intermittent activity and create topographic heterogeneity. Besides seismic forcing, the activity of this wide range of landslide features is largely driven by infiltration and consequent seepage of rainfall and snowmelt. Shallow landslides are the most frequent failure mechanism, and are primarily driven by extreme events, occurring in large numbers during and after intense precipitation and/or snowmelt. Deep-seated landslides tend to creep from continuous, long-term infiltration and exhibit a more diffuse

response to intense storm events. To understand these hydrological controls on slope movement, climate and hydrological monitoring stations (as available) will be placed in CRW and MRW sub-catchments on steep slopes, moderate slopes, and active deep-seated landslides to capture groundwater response to winter groundwater recharge and intense precipitation events. We intend to leverage existing instrumentation and open-access data from the USGS Landslide Hazard Program at Knife Ridge. Similarly, we can supplement archived data from the nearby Millicoma Meander site in potential collaboration with the USGS.

Baseline monitoring will include creation of a landslide inventory on at least an annual basis derived through high-resolution satellite imagery. LiDAR change detection, both planned aerial and ad-hoc terrestrial collections as outlined in Section 10.1.1 above, will also be leveraged to constrain geomorphic changes in landslide terrain. For shallow landslides often associated with debris flows, post-event reconnaissance will occur as resources allow through collection of terrestrial/UAS LiDAR for both landslide source and runout path following the event and in the subsequent years. Tasked high-resolution imagery (~0.5m) will be collected on a yearly basis to enable higher-temporal resolution change associated with evacuated shallow and deep-seated landslide activity. Continued monitoring of soil moisture, rainfall, interception, and pore pressures will enable understanding of a baseline set of hydrological controls on both shallow and deep-seated landslide activity. For select, active, deep-seated landslides, global navigation satellite system (GNSS) rovers, extensometers, and in situ instruments that enable tracking of surface movements over time will be placed as available to understand feedbacks between hydrological controls and movement. For deep-seated landslides impinging streams, terrestrial LiDAR will be collected to understand ground movements of the landslide mass, as well as feedbacks between landslide advance, scour, and sediment yield. Aerial LiDAR will be used to evaluate broad-scale, lower-resolution landslide events through differencing and provide a first-order estimate of sediment yield at large spatial scales.

Of particular interest is landslide response following a variety of management activities, ranging from conservation reserves to ecological forestry to intensive regeneration harvests. Stream monitoring, including stage, flow rates, turbidity, and sediment composition will occur as described in Section 10.1.2 above in addition to any ad hoc monitoring and data collection. Comparative studies in these management conditions will provide insights on how

**Table 10.1.** Data Sets for Monitoring Landslides on the ESRF

Dataset	Purpose	Coverage/Scale	Frequency
Landslide Inventory	Tracking landslide rates and activity	Entire forest	Biannual
Aerial bare earth LiDAR	Mapping/inventorying/change analysis	Entire forest	Decadal
Satellite Imagery (~0.5m)	Mapping/inventorying/change analysis	Entire forest	Biannual
UAS LiDAR/Terrestrial LiDAR	Change analysis	Ad hoc/ watershed/ subwatershed	Ad hoc
Weather Station/Soil Moisture	Hydrological Preconditioning/Timing landslide triggering	Dispersed through forest (~3-5 km spacing)	Near Continuous
GPS Units	Deep-seated landslide movements	Ad hoc	Near Continuous
Stream Metrics	Sediment loading events and location Large wood loading events and location	Stream-riparian network in ESRF	Biannual (in conjunction with Landslide Inventory)

to integrate management of landslide benefits (e.g., sediment and wood for fish, channel formation) and impacts (e.g., damaged infrastructure, public safety) with a range of forest practices and desired ecological outcomes. A hierarchy of data collection is presented in Table 10.1.

#### 10.1.4 Climate and Microclimate

Climate and microclimate are key factors influencing regeneration and ecological processes in forests. Canopy microclimates exhibit different characteristics than the forest above or below canopy, with the upper canopy often being brighter, hotter, windier, and drier than other areas of the forest. Because the upper canopy also contains a significant amount of the leaf area in a forest and absorbs most of the solar radiation, this zone often accounts for most of the carbon and water exchange in a forest. Below ground forest processes have a very different relationship with climate since soil effectively dampens many of the daily and seasonal temperature changes, but can also store precipitation for long periods. Incoming moisture also varies at the top and bottom of a forest canopy as canopy and litter interception and evaporation significantly reduces the amount of precipitation that reaches the soil and roots.

Data are needed to understand both connections with large-scale climate processes and variation within forests in response to global change. These climate data will be used

to tailor the process-based models (e.g., LANDIS II, iLand, CTSM) to improve model output.

Climate monitoring on the ESRF will include climate and soil stations for measuring a range of metrics with collection of real-time data above and below canopy. A network of 20 climate stations will be established across the ESRF to collect long-term measurements of temperature, precipitation, relative humidity, soil moisture, and radiation. Slope transects within subwatersheds will use additional microclimate monitoring tools (i.e., ibuttons, Hobo, Meter) for understory sampling in subwatersheds. Measurements will be taken at high and low elevations within subwatersheds. Towers in the climate station network will provide access above and within canopy, allowing for assessment and monitoring of canopy processes that affect carbon forest capture and sequestration (see Forest Inventory and Carbon section above) and ecological communities (see Canopy Macro and Microbiome section below).

At the 20 climate stations, temperature profiles and incoming 4-way solar radiation above and below the canopy, precipitation above and below the canopy, leaf wetness, soil moisture and temperature from just below the litter layer to 1m, wind speed and direction, and RH profiles will be measured. The interval for each variable will depend on the expected rate of change. In addition, temperature and moisture in down wood and litter will be monitored.



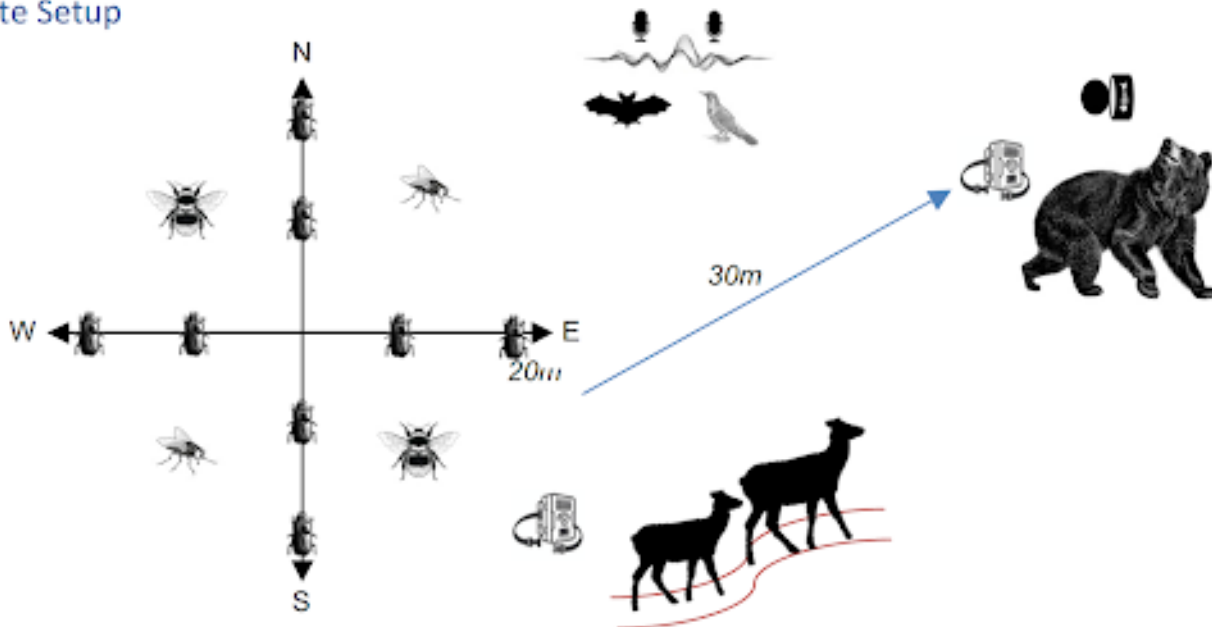
### 10.1.5 Biodiversity

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*Marie Tosa, Oregon State University College of Agricultural Sciences*  
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Biodiversity will be monitored to determine response to land management and climate with implications for conservation policies and forest management practices. A network of permanent biodiversity plots will be established across subwatersheds in the MRW and CRW using a stratified random sampling approach (Betts et al. 2021), and based on a biodiversity monitoring report prepared for the ESRF (Tosa et al. 2022, Appendix U). Findings from this study and a 2022 biodiversity pilot study on the Elliott (Appendix V) inform the design of the ESRF biodiversity

monitoring system. The preliminary data provided by the 2022 biodiversity pilot study, continued field work in 2023, and future biodiversity surveys, will contribute to a dynamic database of species on the ESRF. Measuring and monitoring biodiversity on the ESRF will include the establishment of vegetation plots, wildlife camera traps, and species and community-level monitoring (e.g., arthropods, bees, amphibians, birds, bats). The forest will also be instrumented for measuring and monitoring marbled murrelet, northern spotted owl, and Oregon coast coho through biodiversity surveys and bioacoustic technology. Multiple taxonomic groups (i.e., plants, fungi, invertebrates, songbirds, amphibians, and mammals) will be surveyed using some traditional techniques and “next-generation natural history” (Tosa et al. 2021), including acoustic recorders, camera traps, and genetic techniques such as shotgun sequencing and DNA metabarcoding to estimate species presence.

#### Site Setup



**Figure 10.4.** Illustration of biodiversity sampling design, Hallerud et al. 2023. The center of each sampling (A) site will contain (B) two game cameras, and (C) a malaise trap (pictured in the distance) to collect flying insects, and a bat songmeter. (C) Pitfall traps will sample ground-dwelling arthropods, (D) Soil cores will be collected at the center and 10-meters away along the cardinal directions. (E) Blue vane traps will be placed 20-meters from the center. Three 3-meter radius plant survey plots will be located 20-meter from the center. Avian point counts will sample birds in a 50-meter radius around the center.

### 10.1.5.1 Birds

At each sampling site (Figure 10.4), we will use advanced bioacoustical techniques combined with sound recordings from Wildlife Acoustics Songmeters to detect individual birds (Appel et al. 2023). Sampling will take place throughout the breeding season (May through July). In order to calculate detection-corrected abundance estimates (in n-mixture models; Royle 2004), recordings will occur for 4 hours each morning (5:00 - 10:00 hrs) and then segmented into three primary sampling periods. This enables us to test for, and control potential confounds caused by imperfect detection (Kéry et al. 2005, Royle 2004).

### 10.1.5.2 Trees and Shrubs

Tree and shrub data will be collected at three plots arranged around the center of the sampling site. All tree and shrub data will be collected during June and July – the approximate timing of peak leaf area. Plant survey plots are 3 m radius circles spaced equidistant and 20 m from the sampling site center and will include species, density, and basal area (trees only). Canopy cover and downed wood by decay class will be measured following the line transect methods of Van Wagner (1968).

### 10.1.5.3 Mammals

A baited camera-trap will be set at each biodiversity plot to detect small carnivores and other medium-sized mammals. Baited cameras will be placed a minimum of 30 meters from the outermost insect traps and should also be placed at a high point where scent will travel. An unbaited trail camera will be placed on the heaviest game trail near the site center.

Bats will be sampled with an acoustic detector located in the vicinity of the sampling site center (Figure 10.4 above). An ultrasonic microphone will be used to record bat calls between sunset and sunrise for five hours per night for the same duration as the bird sampling (May-July; Kelly et al. 2016). Wildlife acoustics analysis software will then be used to identify bats to species. Similar to in the bird analysis, we will estimate occupancy of bat species using standard occupancy techniques (MacKenzie et al. 2002).

### 10.1.5.4 Arthropods, Soil Fungi, and Bees

Genetic-based biodiversity monitoring protocols will be used for sampling arthropods, soil fungi, and bees. The development of large biodiversity and genetic repositories such as the Barcode of Life Database now allow for rapid biodiversity surveys using genomics. Such methods are

particularly useful for invertebrates, whose identification requires advanced family- or order-specific taxonomic expertise. A principal advantage of taxonomic identification using DNA barcode repositories is that accessioned specimens are permanently tied to genetic data for consistent and verifiable taxonomic assignment. Surveying invertebrates is key for any biodiversity monitoring effort because they represent, by far, the majority of eukaryotic species, and play key roles in many ecosystem processes and services including plant pollination.

Soils constitute one of the largest reservoirs of terrestrial biodiversity on earth (Anthony et al. 2023). Soil microbial diversity is assessed using molecular techniques that usually rely on extracting DNA from soil organisms, followed by an amplification through polymerase chain reaction (PCR) to get copies of a particular DNA sequence of interest (Thies 2015). As a group, soil fauna play an important role in the decomposition of litter and predation of lower order flora and fauna (Huhta 2007), and yet remain a poorly studied group of organisms in forest soils. Sampling methods for soil fauna on the ESRF will utilize current and emerging technology, including eDNA.

Fungi play a key role in Pacific Northwest forests through their ectomycorrhizal association with trees and, in the case of below-ground hypogeous fungi such as truffles, as critical nutritional resources for small mammals including Douglas squirrels (*Tamiasciurus douglasii*), flying squirrels (*Glaucomys sabrinus*), and red-backed voles (*Myodes californicus* and *M. gapperi*), the latter of which nearly exclusively consumes hypogeous fungi in our region (Ure and Maser 1982, Hayes et al. 1986). These small mammals are in turn a basal food web resource that feeds everything from weasels (*Mustela* spp.), to bobcats (*Lynx rufus*), to spotted-owls (*Strix occidentalis*). Genetic-based biodiversity monitoring is even more useful for surveying fungal species composition because fungal fruiting bodies are only intermittently observable (if at all), and many species are challenging to distinguish morphologically.

Sampling methods will follow a recent landscape scale genomics-based biodiversity survey at 96 sites across a forest structure gradient in the Cascade Mountains of Oregon (Tosa et al. 2022). Each site will be sampled twice, using malaise traps and pitfall traps to sample aerial and ground-dwelling invertebrates respectively (see Figure 10.1 above for spatial sampling layout). Bottles for malaise traps will be filled with 400 ml of fresh 100% ethanol. Each trap will be deployed for seven days and sample each location in

July and August. For ground-dwelling arthropods, each pitfall trap will consist of two 16 oz plastic cups (10.0 cm diameter opening, 6.0 cm diameter bottom, 12.0 cm height) and 150 ml of 50:50 mixture of propylene glycol and DI water. Plywood covers placed over the pitfall traps are intended to reduce vertebrate bycatch to the degree possible.

Blue vane traps will be used to collect bees at each sample site. Blue vane traps, consisting of a collecting basin filled with ethanol and two ultraviolet semitransparent polypropylene blue-colored vanes have been shown to be very effective at sampling bees in both open and forest habitats (Hall 2018). Blue vane traps will be deployed for seven continuous days between July and August. Upon collecting the samples, fresh 100% ethanol will be used to sufficiently cover the samples for DNA preservation. Five soil cores (15cm length x 1.3cm radius) will be taken at the site center and 10m away along each cardinal direction. Samples will be placed in a cooler while in the field and in a -20 C freezer until processed. In the laboratory, FNA will be extracted from malaise, pitfall trap samples, blue vane traps, and soil cores (see Levi Lab DNA metabarcoding protocols).

### 10.1.5.5 Terrestrial Amphibians

Annual amphibian surveys will occur across a subset of intensive, extensive, RCA, and reserve areas on the ESRF. As described in Garcia et al. (2020) an occupancy analytical approach using detection and non-detection data from repeat surveys will be utilized on 7 sub-plots (9m x 9m) within each surveyed stand. Crews will assign a random starting point as the center of one sub-plot. Once the first sub-plot is identified, 6 additional sub-plots will be established in a random direction with 40 m between them. Crews will search sub-plots for salamanders in 3 sequential 10-minute intervals to estimate individual detection probabilities for each species. Crews will record habitat information at the point of detection for all salamanders, including size, decay class, and pyrogenic carbon class of any associated downed wood. At each sub-plot within all sites, crews will record soil moisture at multiple depths using handheld volumetric soil probes under and adjacent to downed wood structures, sub-plot canopy cover using densimeters, temperature and relative humidity, substrate type, and sampling time and date. Further, sub-plots will be evenly distributed along a linear transect that will, in part, be located within riparian forests. At each subplot, two perpendicular 9m transects will be established, and the planar intersect technique will be used to characterize the size and frequency of downed wood in the plot. Depth

of the duff/litter layer will be measured at 5 points along each transect. Within the survey design, transects will bisect streams where possible to survey for both terrestrial and stream-dependent amphibians. Transects will be aligned with the network of permanent biodiversity plots to leverage monitoring infrastructure and other data collection points.

Plot-level variables will be grouped into three categories: salamander data (diversity, occupancy, and abundance), habitat (downed wood abundance, size, decay class, duff depth, and canopy cover) and microclimate (soil moisture, ambient temperature and relative humidity). Salamander species-specific occupancy and abundance will be estimated using a modification of the MacKenzie model (Mackenzie et al. 2002) and the Royle-Nichols model (Royle and Nichols 2003). These plots will overlap with the biodiversity plots described above and additional plots may be added after preliminary assessment of variability and probability of detection. Section 10.1.2.3 provides details specific to stream amphibians.

### 10.1.5.6 Canopy Macro and Microbiome

Canopy surveys will sample microbiome diversity with the goal of characterizing the foliar endophyte community of old-growth Douglas-fir and trees across a range of successional stages and species on the forest. A 2022 pilot study will contribute to development of a sampling strategy to monitor the diversity of the foliar microbiome community prior to management in areas with treatment allocations, as well as across the CRW and MRW reserves.

The pilot study will focus on old-growth Douglas-fir trees which are representative of the environment and stand conditions across the forest. For each tree, measurements of the length from the tree-top to the lowest contiguous (vertical distance < 2m) branch will be recorded. This distance will be considered the canopy depth. Canopy depth will be divided into five equal length vertical zones. Within each vertical zone, 1-year-old needles will be sampled from four aspects (N, E, S, and W). At each aspect, one sample will be taken for microbiome analysis and one sample for swiss needle cast (SNC) examination (Appendix X). Samples will be stored temporarily at 5oC. DNA will be extracted and samples sent to the Center for Quantitative Life Science at Oregon State University. Standard approaches (reference) will be used to evaluate the diversity and composition of microbial communities, including evaluation of fungi, bacteria, and oomycetes.



Canopy access through climate towers and tree climbing will allow for monitoring of arboreal mammals, birds, amphibians (e.g., clouded salamanders, Aneides), and insects through surveys, wildlife cameras, and acoustic recording devices.

### 10.1.6 Forest Management and Economics

#### 10.1.6.1 Local Economies and Socio-Economic Factors

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Management activities on the ESRF have the potential to aid local and regional communities and economies in a variety of ways. Nearby communities with the potential to realize market and non-market economic benefits include Coos Bay, Reedsport and Lakeside. Monitoring under this topic will be focused on understanding economic impacts of the ESRF through direct employment, contracting, workforce development, local purchases of goods and services, and the harvesting and processing of timber. It will also be important to understand the degree to which funds spent through ESRF management ripple through local economies via the multiplier effect. This occurs when increases in local expenditures are then re-spent by recipients of the initial expenditures, over several cycles, which multiplies the effects of initial increases. Multiplier effects may be significant, although recipients pay taxes, place funds into savings and buy imported goods, so the impact of each successive cycle is reduced.

A focus of timber production and harvesting research on the ESRF will be on wood products and supply chains. This will provide opportunities to bar code or block chain track each individual tree as it enters and works its way through the supply chain.

Monitoring and documentation of socio-economic factors will be conducted on an annual basis by ESRF staff in categories that may include the following:

##### OSU employment and activities

- Number of OSU employees working on the ESRF that are based within Coos/Douglas Counties
- Number of overnight stays within Coos/Douglas Counties by OSU researchers and non-local employees working on the ESRF

##### Contracting

- Business location and location of workforce for contracted services including road construction/maintenance, planting, harvesting, forest restoration work.

- Contracts for improvements to the Shutter Creek correctional facility for use by ESRF staff

##### Workforce development

- Participation in internship or skills training programs on the ESRF
- Community partnerships developed and maintained with local workforce development agencies (e.g., Southwestern Oregon Community College, Southwestern Oregon Workforce Investment Board, high schools or alternative school programs)
- Partnerships developed with Tribal Nations to support youth programs in alignment with ESRF mission
- Community partnerships developed and maintained with local non-profit environmental organizations (e.g., Watershed Councils)

##### Harvesting of timber

- Scribner MBF or merchantable m<sup>3</sup> harvested, depending on contract and scaling method, by tree species and grade
- Destination (mill or other facility) location of all harvested fiber
- Value added, including premiums for certified and/or “Climate Smart” forest products

To understand any changes in community condition resulting from ESRF activities and values associated with the forest, a baseline community asset map will be created and updated at regular intervals.

#### 10.6.1.2 Recreation Economic Contribution and Value

The benefits of nature-based recreation include economic outcomes that may be locally and regionally significant. Economists distinguish between recreation economic *contribution* and economic *value* (Watson et al. 2007). Recreation economic *contribution* measures the gross change in economic activity associated with recreation in an existing regional economy. In plainer terms, recreation economic contribution is the amount of money that outdoor recreationists add to a local economy. This measure includes direct spending on lodging, food, fuel, equipment, guide services, etc. and indirect effects via wages and secondary spending supported. To estimate recreation economic contribution, federal land agencies typically aggregate district-level visitor use data with estimates of per capita, per day spending garnered from onsite or phone surveys, e.g., the USFS National Visitor Use Monitoring (NVUM)

Program. Segmenting visitors by trip type (e.g., local-day and local-overnight, and non-local day and non-local overnight trips) allows for better estimates of local economic contribution than segmenting by activity only (White and Stynes 2008).

Recreation economic *value* is a monetary measure of the benefits received by an individual or group directly engaged in an outdoor recreation activity, calculated as the amount they are willing to pay for the activity, minus their costs to engage in it. In plainer terms, recreation economic value is an empirical, quantitative estimate of what the recreation experience is “worth” to a person. These direct use values can be used to evaluate change in access or change in quality that might alter types of activities and enjoyment. The Benefit Transfer Toolkit (Rosenberger et al. 2017) can be used to derive average per person, per day recreation economic values for a range of outdoor recreation activity sets from studies conducted 1958-2016 in numerous locales. These values can be used in combination with local visitation data to derive empirically grounded estimates of recreation economic values for particular recreation areas.

Recreation on the ESRF is assumed to be generally dispersed and relatively light, although detailed, quantitative information on this topic is scant. Recreation visitation and use may be monitored, using methods described in Section 10.1.7 below and depending on available resources, to support estimates of economic contribution and value on the ESRF. The ESRF recreation and education planning process (see Chapter 3: *Managing a Research Forest for Multiple Values*, Section 3.2) will address these issues in more detail.

### 10.6.1.3 Harvest Operations and Silvicultural Outcomes

In addition to socio-economic impacts, monitoring of merchantable wood fiber harvested provides feedback on the accuracy of growth and yield predictions and thus informs harvest level planning, development of harvest schedules, setting of operating and research budgets based on anticipated timber sale values, and improvements to the growth and yield models making the predictions. Tree-level tracking through the supply chain allows detailed comparison of logs bucked from trees to predicted logs and grades, allowing yield estimates to be improved both scaling tickets and by structuring harvest contracts to include access to the data recorded by harvester or processor heads (e.g. Vähä-Konka et al. 2020, Sanz et al. 2021). Monitoring of log truck traffic provides additional information on road use, load size, and seasonal variation in bark retention by species

(Murphy and Pilkerton 2011), all of which affect operational efficiency and road maintenance costs.

Collection of other data logged by harvest equipment or additional record keeping during harvest operations additionally supports forest operations research into improvement and calibration of harvest productivity models and, thus, refinement of timber sale valuations along with predictions of the revenue and operational consequences of selecting among different choices of silvicultural prescriptions. Of particular interest to the ESRF is to use this monitoring data to quantify differences between intensive and extensive silviculture and provide decision support when considering adjustments to these silvicultural systems.

### 10.1.7 Human-Ecosystem Relationships and Recreation

Nature-based recreation activities and experiences contribute to quality of life by providing an array of physical and psychological health benefits and can also be a significant component of local and regional economies. Especially in settings that receive substantial visitation and use, balancing visitor access, experience quality and environmental protection can present challenges for recreation managers. In other cases, managers may have reason to identify and provide desired, sustainable outdoor recreation activities in support of regional economies and quality of life. Effectively addressing these challenges and goals requires (1) an inventory of the types of outdoor settings where recreation experiences take place, (2) knowledge about visitor use levels, patterns, and impacts; (3) understanding of visitor characteristics, motivations and experience quality and, (4) monitoring of changes in these parameters over time.

By definition, nature-based recreation requires natural settings. The natural, social and managerial attributes of these settings (i.e., the physical setting itself, amount of visitation and human impact, level of development and infrastructure) affect the kinds of recreation opportunities and experiences they support. Thus, monitoring of recreation on the ESRF could begin by inventorying the array of recreation settings available across the forest. The Recreation Opportunity Spectrum (ROS) is a well-established tool for classifying and inventorying different types of recreation opportunities, typically via maps generated manually and through digitization by analysts with in-depth knowledge of the region of interest. The ROS allows accurate stratification of outdoor recreation

environments by dividing a spectrum of recreation opportunities into broad classes. On the ESRF these classes may include rural natural, semi-primitive, and primitive (wilderness). Each mapped ROS class is defined by a particular package of setting attributes, activities, experiences, and benefits. Some managers use seasonal ROS maps where opportunities vary significantly by season. With changes in technology—especially increased availability of remotely sensed data and greater use of GIS—recent studies have focused on better utilization of spatial data to generate ROS maps, e.g., USDA Forest Service 2019. This is especially true for biophysical setting attributes, although progress has also been made in bringing social recreation data into GIS environments.

A variety of methods are utilized to monitor outdoor recreationists and their effects, depending on the kind of information being sought. A common and highly management-relevant type of information concerns levels of visitor use and how use level varies temporally and spatially. Monitoring of visitor use level is often accomplished via methods such as:

- Vehicle counts at trailheads or attraction site parking lots
- Traffic counters
- Infrared sensors at trailheads to count the number visitors per day
- Tracking the number of use permits (e.g. hunting, camping) issued per unit of time

Wildland recreation often entails some level of environmental impact, which can be significant depending on the type of equipment used, including loss of plant cover, soil compaction and erosion, reduced water quality, disturbance of wildlife, and motor noise. On a per capita basis non-motorized activities tend to have less overall impact than motorized but even foot travel results in some effects, especially in sensitive or pristine areas. Assessment and monitoring of these types of environmental effects (the field of recreation ecology; Hammitt et al. 2015) involves variables such as:

- Percent of loss of vegetation cover
- Amount of damage to trees (e.g. limbs removed, carving)
- Amount of litter present
- Amount of human waste present
- Presence/number of fire rings
- Amount (e.g., total length) of unofficial or “social” trails

- Presence/depth of rutting in trails, variation in trail width
- Presence, number, length of unofficial 4x4 or OHV routes

To effectively provide for and maintain high quality experiences, recreation managers also assess and monitor sociological variables such as visitor behaviors, values, perceptions, experience quality, satisfaction, demographics, attachment to particular places, and visitor conflict and displacement. Methods for acquiring these types of information include:

- Visitor surveys or interviews completed at recreation sites
- Visitor surveys provided to visitors onsite, which they complete later and mail in
- Mail surveys of random samples of residents in a predetermined region
- Phone interviews of random samples of residents in a predetermined region
- Observing visitor behavior in recreation settings
- Public meetings and listening sessions

An emerging and rapidly expanding area of research and sourcing wildland recreation use data involves data from smartphones and other devices with imaging and GPS capabilities, combined with social media. Examples of such information sources include:

- Geotagged images shared on websites such as Flickr
- Trip reports shared on hiking, fishing, birdwatching or other forums focused on particular activities
- Volunteer GPS data from tracking apps

These sources can provide novel types of information such as how far visitors travel, and what kinds of landscape features are favored. A major source of bias is that access to and willingness to use the devices from which the data originates affects the subset of the population being sampled and what they post. Even within a local area, factors including gender, age, education level and wealth affect rates of internet usage and smartphone ownership. (Pickering et al. 2018.)

Recreation within the ESRF tends to be quite dispersed and use levels are generally light. This may limit the relevance and applicability of some of these monitoring methods. However, substantial recreation impacts have been noted in certain localized areas, and visitor use on the ESRF may increase over time as Oregon's population continues

to grow. Establishing a more robust knowledge base for recreation on the ESRF may initially involve administration of mailed surveys in adjacent communities to assess recreation uses, preferences and opportunities, coupled with local outreach and engagement, and impact analysis and monitoring at existing sites where recreation use appears to be concentrated, such as campsites along the WF Millicoma River. These issues will be addressed in much more detail in the ESRF Recreation Plan described in Chapter 3: *Managing a Research Forest for Multiple Values*, Section 3.2.

## 10.2 Habitat Conservation Plan (ESRF HCP) Compliance and Effectiveness Monitoring

The ESRF monitoring program includes measurements and tracking to ensure compliance with the ESRF HCP, to assess the status of covered species habitat, and to evaluate the effects of management actions such that the conservation strategy described in ESRF HCP Chapter 5: *Conservation Strategy*, including the biological goals and objectives, is achieved. The monitoring program will provide the information necessary to assess ESRF HCP compliance and project effects, verify progress toward achieving the biological goals and objectives, and provide the scientific data necessary to evaluate the success of the ESRF HCP's conservation program, using routine monitoring and modeling of ecosystem function that supports covered species. The ESRF will conduct compliance monitoring to ensure adherence to ESRF HCP implementation and management standards, and effectiveness monitoring to determine if conservation measures are having the intended effect of improving conditions for covered species. Effectiveness monitoring will track long-term trends in ecosystem processes, covered species' responses to habitat management, and habitat quality over time.

Completed monitoring activities will be reported in annual reports. Monitoring results and trends will be summarized in the 6-year Summary Report (ESRF HCP Section 7.3.2) and a more comprehensive assessment will be completed during the 12-year Comprehensive Review (ESRF HCP Section 7.3.3).

### 10.2.1 Compliance Monitoring

- Location, extent, and timing of loss of covered species habitats to ensure the proposed maximum extent of

take is not exceeded and that increases in the quantity and quality of habitat are appropriately balanced with loss of habitat from covered activities. For northern spotted owls, habitat losses and gains will also be tracked by habitat type (i.e., by nesting, roosting, and foraging habitat types as described in ESRF HCP Section 2.3.

- Data will be tracked through forest inventory (LiDAR and ground sampling), biennial operations plans, annual reports, and spatial database.
- Monitoring of compliance with retention standards will be completed during sale closeout or completion of research harvest activities. Demonstration of compliance with these standards will be summarized in the annual report.
- Types, acres, and location of silvicultural activities conducted in the permit area, including regeneration harvests, thinnings, and restoration treatments.
  - Data will be tracked through forest planning documentation (biennial operations plans), harvest prescriptions, contracts, annual reports, forest inventory, and spatial database.
  - Details regarding removal of any trees that predate the 1868 fire, including number, location, species, dimensions, age, forest stand conditions and context, and reason for removal.
  - Data will be tracked through harvest prescriptions, post-harvest notes, and annual reporting.
- Miles and locations of roads built and vacated, including those in reserves and riparian conservation areas (RCAs).
  - Data will be tracked through biennial operations plans, annual reports, and ESRF roads database.
- Number and location of culverts upgraded or removed.
  - Data will be tracked through biennial operations plans, annual reports, and ESRF roads database.
- Acres of upland restoration activities completed.
  - Data will be tracked through biennial operations plans, annual reports, forest inventory, and restoration research project documentation.
- Miles of stream and acres of riparian habitat thinned.
  - Data will be tracked through biennial operations plans, annual reports, forest inventory, and restoration research project documentation.
- Location of harvest and width of RCAs implemented in treatment areas.



- Data will be tracked through biennial operations plans, annual reports, forest inventory, and spatial database.
- Aquatic restoration projects completed.
  - Data will be tracked through biennial operations plans, annual reports, and restoration research project documentation.
- Reporting of conservation measures and monitoring activities (e.g., what monitoring activities were implemented and resulting reports produced).
- Any waivers to the proposed actions and conservation measures, as well as documentation of any required pre-approvals by the Services.

### 10.2.2 Effectiveness Monitoring

As described in ESRF HCP Section 6.2.2, effectiveness monitoring assesses the biological success of the ESRF HCP by evaluating whether the effects of implementing the conservation strategy are consistent with the assumptions and predictions made during strategy development. Effectiveness monitoring typically measures the effects of management actions on covered species, status and trends in resources, and status and trends of stressors to the covered species (Atkinson et al. 2004). Conditions will be monitored before and after management over a multi-decadal time horizon to analyze short- and long-term impacts of management and conservation strategies. Understanding the effects of management actions is a critical component of the monitoring and adaptive management program. The purpose of this monitoring is to ascertain the success of management in achieving desired outcomes, to provide information and mechanisms for altering management if necessary, and to evaluate the ESRF HCP conservation strategy.

#### 10.2.2.1 Aquatic and Riparian Monitoring

See Aquatic and Riparian Systems monitoring section above and the ESRF HCP for details on effectiveness monitoring for turbidity, water temperature, and instream habitat monitoring. A rotating panel design will be used where one stream in each of the independent populations (determined in consultation with NMFS) will be sampled once every 3 years. See ESRF HCP Section 6.3 for further details on Aquatic and Riparian Monitoring.

#### 10.2.2.2 Terrestrial Monitoring

The terrestrial monitoring program will consist of both habitat monitoring and species response monitoring. Monitoring methods will be based on the current state of the science and U.S. Fish and Wildlife Service accepted protocols. Over time, field-based protocols will be paired with automated monitoring and once automated monitoring becomes scientifically accepted as a way to monitor habitat condition, species presence, and species use, it will be the primary tool. Remote sensing (manned aerial, UAS, and ground-based LiDAR) will be used to track habitat quality for species covered under the ESRF HCP.

The terrestrial monitoring program will cover one-third of the ESRF in any given year. Survey efforts will be designed based on efficiency, access, and information needs for research and planning activities covered under the ESRF HCP.

- One-third of northern spotted owl nesting territories (i.e., home range, which includes habitat within a 1.5-mile radius of a circle centered on the activity center). All sites will be visited every 3 years. See ESRF HCP Section 6.5.1 for further details.
- One-third of marbled murrelet occupied and potential habitat will be monitored every year, and all habitat will be monitored at least once every 3 years. Location of marbled murrelet monitoring will also be tailored to areas where timber management is expected. See ESRF HCP Section 6.5.2 for further details.

Habitat monitoring will track habitat loss versus gain over time by acreage using LiDAR and forest inventory ground sampling (see Forest Inventory section above). Metrics of stand age, average tree height, number of large trees (.30 inches in diameter at breast height) per acre, and percent canopy closure will be used to determine habitat suitability for species covered under the ESRF HCP. UAS LiDAR and ground-based LiDAR sampling conducted under the forest inventory will provide further details on habitat structure and quality. See ESRF HCP Section 6.4 for further details on terrestrial monitoring.

### 10.3 Monitoring for Additional Research and Experimental Projects

Information described in Section 10.1 above is the backbone of the ESRF research monitoring program. It is not intended to cover all experimentation, research, and associated monitoring that will occur on the forest. As described in Chapter 4: *Research Platform and Experimental Design*, additional research will be nested under the broad ESRF research platform according to the process described for integrating new research projects with existing research. External funds will be required for researchers to support their projects. Decisions about new research will be made in consultation with the Scientific Advisory Committee (Chapter 5: *Research Planning and Implementation*) and incorporated into the ESRF database system. Researchers who engage in these projects will be able to leverage the ESRF monitoring program described here for data and analysis, and monitoring data from their own research projects will be accessible through the ESRF database after publication.

### 10.4 Monitoring Partnerships

Partnerships with local watershed councils and associations, Tribal Nations and Indigenous Peoples, educational institutions, state and federal agencies, and other organizations will contribute to successful implementation of the ESRF monitoring program and effective communication of information. Chapter 3: *Managing a Research Forest for Multiple Values* provides further details on developing partnerships as an important element of the ESRF program. The ESRF Research Director, ESRFA Executive Director, and research operations staff will seek opportunities to partner on monitoring efforts that are in alignment with shared objectives and resources of the parties involved.

### 10.5 Monitoring Communication, Outreach, and Information Management

The new generation of sensors and monitoring tools to be deployed on the ESRF can make data available in near real time to scientists and forest managers. Onsite monitoring coupled with remotely sensed data can boost forest monitoring by increasing the spatial and temporal scales of monitoring, fostering a clearer understanding of forest processes and potential threats. These new monitoring tools and programs will generate large amounts of data and the potential for transforming how forests are managed.

Data sources will be diverse, including onsite sensors, forest machinery sensors, drone and aircraft mounted LiDAR, satellites, data from nested research projects, citizen scientists, legacy information, and social media. This diversity will represent the complexity of the ESRF in ecological, economic and social dimensions. Considering all of these data sources and the inevitability of ongoing technological advances, such data can be expected to grow exponentially over time (Torresan et al. 2021). Some immediate data management challenges may stem from the heterogeneity of data sources, e.g. long-term, intensive tree-level monitoring to nested shorter-term science and remotely sensed data. Every effort will be made to standardize monitoring data, but some diversity in data structures from different collecting entities is inevitable.

In alignment with the mission and values of the ESRF, data will be maintained and made available to researchers, managers, and the public as outlined in Section 5.3. The Findable, Accessible, Interoperable, and Reusable (FAIR) data principles (Wilkinson et al. 2016) are one approach to increasing data usability and accessibility. However, use of the FAIR principles may potentially neglect the rights of Indigenous Peoples and Tribal Nations regarding cultural, spiritual, and ecological information. Therefore, the ESRF will also strive to apply the Collective (benefit), Authority (to control), Responsibility and Ethics (CARE) Principles for Indigenous Data Governance to support ethical data stewardship (Jennings et al. 2023).





# Chapter 11

## Adaptive Research Strategy and Implementation

Undertaking the design and implementation of a research program with the magnitude and complexity of that planned for the ESRF is daunting. Additionally, as discussed in the Executive Summary, it is also understood that this is a dynamic plan that will evolve over time as researchers and managers begin to implement the research and form meaningful relationships with Tribal Partners to engage in co-stewardship. Accordingly, a combination of a phased research implementation plan coupled with adaptive management protocols informed by modeling, ecosystem monitoring, Indigenous Knowledge, and



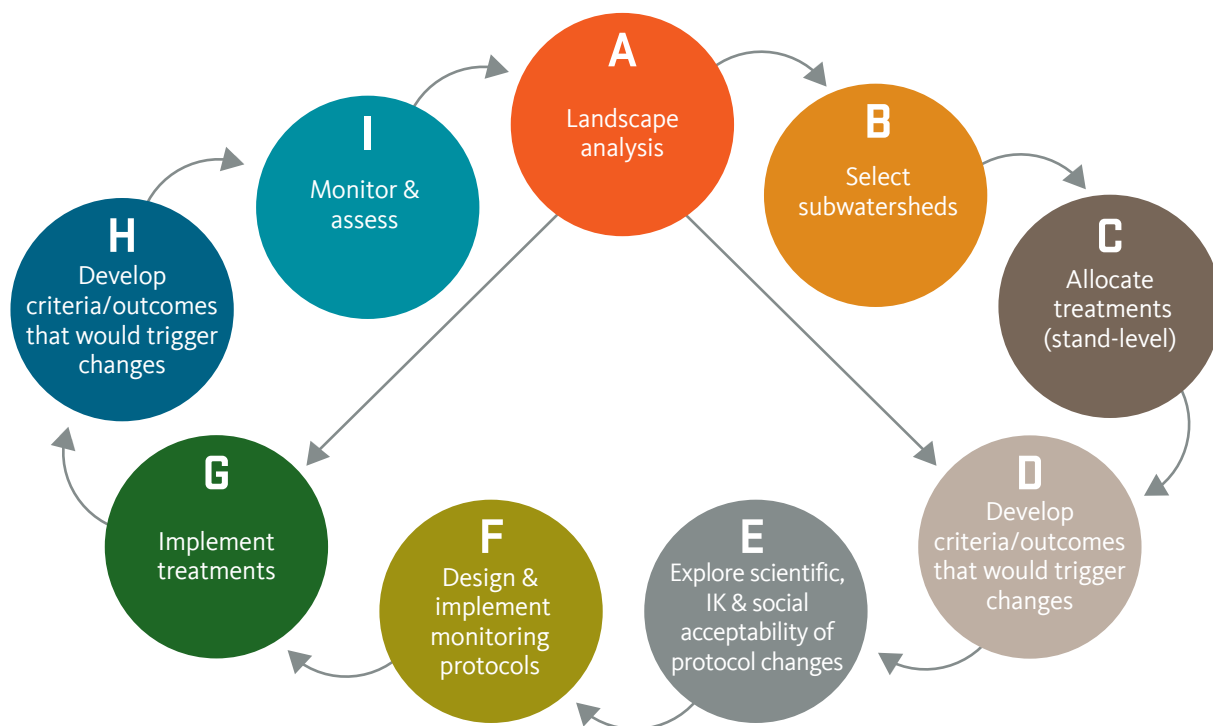
stakeholder input has been explicitly chosen to ensure the viability of the research through time. This chapter describes how adaptive approaches will be woven into the fabric of the ESRF research program.

Adaptive implementation of research on the ESRF will utilize concepts from adaptive forest management, with a fundamental difference. The key distinction is that components such as terrestrial and aquatic monitoring, data analysis, financial analysis, modeling and deployment of emerging findings will be used to refine the research approach as an essential component of the scientific method. Because forest management on the Elliott is primarily an outcome of implementing the Triad research design, the adaptive approach for the ESRF is best described as an *adaptive experimental design*, which can be contrasted with a static experimental design.

A static design applies the same procedures throughout the experiment. In contrast, an adaptive design may, based on interim analysis of information and a defined process, adjust parameters if the experimental design is not meeting

key experimental targets or if there are major changes over the life of the experiment. For example, if the ESRF is not achieving regeneration targets following extensive or intensive harvests due to climate change, it will be necessary to adjust research protocols such as desirable species to ensure regeneration is occurring and thus research sustainability. Adaptive designs have the potential to allow detection of changes in outcomes that may otherwise have been missed or detect the best-performing treatments more quickly than a static design (Green and Offer-Westort 2018). Clearly, an adaptive research design is essential with a multi decadal if not century long experiment such as is envisioned on the ESRF.

Implementation of the ESRF research program over the long-term will require the flexibility to make essential adjustments and refinements of research and monitoring methods within the scope of vision outlined by the ESRF Research Proposal and the ESRF HCP. A structured process will be set in motion when certain conditions or triggers are met as explained in more detail in the research proposal and summarized below (Figure 11.1).



**Figure 11.1.** Adaptive Experimental Design as an Iterative Process



## 11.1 Phased Implementation of the Triad Research Design

Initially, a subset of 16 subwatersheds were selected from the Management Research Watersheds (MRWs) to conduct trial treatments under the Triad experimental design. The ESRF will integrate data, modeling, Indigenous Knowledge, and stakeholder input to adapt and refine the research plan over time based on current scientific understanding. Steps in this adaptive approach to increasing depth of activity over time are outlined below.

- A. Conduct an in-depth landscape analysis of the ESRF, including creation and continued updates to a LiDAR-based forest stand inventory, refined age class distribution data, and parameterization of landscape models (LANDIS II and iLand) for the ESRF to lay the groundwork for implementation of the research design, monitoring protocols, and future landscape analyses. As the research program is applied, data collection will continue under the monitoring plan, and new information and perspectives will be incorporated into ESRF planning. This includes changes in data, models, analytical tools, and the incorporation of multiple ways of knowing.
- B. Select 16 subwatersheds (4 replicates of the 4 treatment categories, *Reserve with Intensive*, *Triad-I*, *Triad-E*, *Extensive*) and 4 subwatersheds in the CRW to serve as controls for early implementations. These subwatersheds will be the focus of monitoring (pre-treatment and post-treatment) for at least 5 years prior to harvest under the Triad design in the MRW. The 4 CRW control subwatersheds and 16 MRW subwatersheds identified for early implementation (see Chapter 4: *Research Platform and Experimental Design*, Section 4.3.3) will be instrumented with key monitoring equipment and baseline data collected for at least 5 years. At the end of 5 years, management will begin in the early-implementation subwatersheds according to harvest planning and stand eligibility for harvest based on treatment type. The timing, location, and stand-level prescriptions for research management activities in these subwatersheds will be further detailed in biennial operations plans.
- C. Allocate treatments to each stand within the subwatershed in proportion to the initial experimental design. Stand-level treatment allocations developed during the FMP phase are based on current knowledge of forest stand conditions, silvicultural considerations, operational feasibility, NSO and MAMU habitat outlined in the ESRF HCP, stakeholder concerns, colluvial hollows and steep slopes, and fragmentation and connectivity. Further adjustments may occur based on these criteria, consultation with Tribal partners, feedback from the Scientific Advisory Committee, updated data analysis, on-the-ground assessment, and approval of biennial operations plans.
- D. Develop a list of criteria or outcomes that would trigger changes in experimental protocols. A framework for assessing the level of review needed for adaptive adjustment in the ESRF research design is presented in Table 11.1. An initial list of criteria or outcomes is outlined in Table 11.2. Additional criteria or outcomes may be included as the research design is implemented, based on scientific and operational knowledge gained by the ESRF team, input from the Science Advisory Committee, consultation with Tribal partners, external peer feedback, and public discussion. While developing these triggers it should be kept in mind that research integrity is the key criterion and while there will be an initial list, further candidates may be incorporated, or current triggers removed through time.
- E. Explore which protocol changes are experimentally and socially acceptable if triggers are met. This process should be open and transparent, based on knowledge gained by the ESRF, collaboration with Tribal partners, input from the Scientific Advisory Committee, external peer feedback, and public discussion.
- F. Design and implement monitoring protocols that include previously established triggers in initial subwatersheds and several untreated watersheds. Monitoring protocols and triggers are detailed in Chapter 10: *Monitoring* and sections below. Monitoring protocols and thresholds may be adjusted over time based on data analysis and scientific and Indigenous knowledge through the overall process outlined in this chapter once treatments have been implemented over enough time to begin interpreting information.
- G. Initiate monitoring within the first 16 subwatersheds and controls. Pre-treatment and post-treatment monitoring data will be collected as treatments are conducted in stands within the first 16 subwatersheds according to harvest scenarios for eligible stands based on treatment type and decisions made during the biennial planning process. Harvest prescriptions and specific management actions at the stand-level will be detailed in ESRF

biennial operations plans following the objectives and management guidelines for intensive, extensive, and restoration treatments in reserve.

- H. Monitor criteria that trigger changes in experimental protocols, assess results; revisit E.
- I. Adapt treatments for remaining watersheds as needed based on monitoring results, analysis, consultation with Tribal Partners, and stakeholder input. See the framework for assessing the level of review for adaptive adjustment in ESRF research (Table 11.1) for a more detailed description.

The length of time during which this adaptive process will unfold is difficult to specify; approximately 10-20 years is estimated given tree growth and ecosystem response rates. Particular attention will be paid in the early years (1-5) when treatments are initially put on the ground. If concerns or problems arise during this stage, the ESRF will adjust accordingly using the process outlined above. As illustrated in Figure 11.1, this is an iterative process with more than one feedback loop. Depending on the results of ongoing monitoring and assessment, different pathways in the adaptive experimental design process may apply. For example, continued implementation of the experimental design may follow a tighter loop (Steps A, G, H, I) if minimal or no adjustments are needed. Adaptive experimental design may follow a larger loop (Steps A, D-I) if thresholds, criteria, or outcomes need to be adjusted.

## 11.2 Incorporating Other Ways of Knowing

Two-eyed seeing refers to learning to see from one eye with the strengths of Indigenous Knowledge and ways of knowing, and from the other eye with the strengths of Western knowledge and ways of knowing and learning to use both these eyes together for the benefit of all (Hatcher 2012; Reid et al. 2021). The “whole systems” and “ecological forestry” approaches that will be woven into research and management on the ESRF are often framed by Western science as relatively new and innovative, but are consistent with the way Indigenous cultures have interacted with the world since time immemorial. As such, two-eyed seeing and collaboration with Tribal partners to braid Indigenous Knowledge and western science into approaches for the research design and adaptive strategy will be vital components of ESRF planning.

The ESRF is committed to continuing to develop equitable and respectful Tribal relationships based on [best practices for partnering with Tribal Nations](#). Once these partnerships are formalized, researchers and program staff will look to Tribal partners to take a leading role in developing sustainable co-stewardship plans for the forest that honor and respect traditional Tribal cultural values and Sovereignty Rights. This includes adaptive stewardship to learn from each other and the forest over time while working within the context of a dynamic research forest.

## 11.3 Adaptive Experimental Design as a Foundation of the ESRF

Over the long-term, as Triad treatments in the MRW and restoration treatments in CRW and RCAs are ramped up, adaptive experimental design will be essential. The process described in Section 11.1 is envisioned as beginning with early implementation of the Triad experiment and restoration experiments, but the principles and steps apply to all aspects of the ESRF research management program. There are numerous benefits to this stepwise implementation plan, including:

- Increased opportunities for input from the broader research community and local and regional public entities with each progressive step.
- Collection of multiple years of pre-treatment, post-treatment, and reserve monitoring data with stand-level and subwatershed-level replicates to inform future applications of the research design.
- Development of a better understanding of the system we are experimenting within and the ability to design a study that is adaptive and flexible enough to withstand changes in social, economic, and ecological conditions over the very long life of a forest.
- Learning from multiple perspectives as collaborative partnerships are put in place.

The adaptive research strategy and implementation process outlined here utilizes triggers or specific indicator variables to examine and evaluate the need for changes in experimental protocols. These trigger conditions are often based on assumptions about cause-effect relationships between land management activities, the indicator variables themselves, and key processes or resources that researchers

and land managers wish to study and sustain over time. New information obtained from relevant scientific literature or derived from analyzing cause-effect relationships observed via direct monitoring and manipulative experiments will identify potential issues and may require changes to the target criteria or outcomes associated with individual indicator variables in order to stay consistent with the experimental design as implemented in the FMP. This is particularly true for target criteria and thresholds based on historical analogs, such as those used to characterize desired stand conditions and landscape-scale distributions of habitat types (e.g., early seral vs. mature and late-successional forests) for the Extensive treatment areas, RCAs, and restoration treatments in the CRW. Existing literature related to historic disturbance regimes and stand conditions in moist, westside forest ecoregions has often relied on broad, regional-scale assessments that draw conclusions based on mean conditions across multiple ecoregions while often failing to account for variability among ecoregions and landscapes within those ecoregions.

Recognizing the potential for ongoing research and discovery to provide an evolving understanding of links between ecosystem structure and functioning, particularly for historically understudied ecoregions such as the southern Coast Range, a process will be used for regular evaluation of whether the initial assumptions used to define the target criteria and outcomes for indicator variables associated with individual treatment types within the FMP were correct and to provide regular opportunities for revision of these target criteria and outcomes as the best available knowledge evolves over time. This process is critical to ensuring that the adaptive research strategy and implementation process is informed by the best available knowledge as it evolves over time.

Target levels set for individual indicator variables within the FMP will be subject to regular review as part of a formal monitoring process. Target levels may be revised in response to changes in the best available knowledge as described in published scientific literature, agency reports, and the results of ongoing monitoring on the ESRF. These reviews shall be conducted by a Monitoring Team consisting of the ESRF Scientific Advisory Committee, the Research Director of the ESRF, and representatives from the HCP Implementation and Adaptive Management Committee. Reviews will be conducted at least every 10 years, starting from the date of implementation of the FMP. The Monitoring Team may develop suggested revisions

to target criteria or outcomes associated with individual indicator variables based on changes in the state of the best available knowledge over time. Suggested revisions to target criteria or outcomes should provide a clear rationale for the suggested change and an explanation of how the new target levels will remain consistent with the experimental platform as described within the Research Proposal and FMP.

If and when decision triggers are reached, OSU and the ESRFA Board of Directors (BOD) may elect to hold public meetings and workshops to assess the state of knowledge and promote understanding and consensus regarding experimentally sound research options. The ESRF Research Director (PI) will coordinate with the ESRFA Executive Director to submit suggested revisions to the board of directors of the Elliott State Research Forest Authority for comment. The Monitoring Team will develop final changes to any target levels based on their review and feedback from the ESRFA Board of Directors. Revised target criteria or outcomes for individual indicator variables would not be considered a FMP amendment since these revisions would not represent any of the following: (1) a change to the fundamental experimental design or treatment framework for the ESRF as described in the ESRF Research Proposal and FMP, (2) a shift in the primary management direction for individual treatment areas as described within the FMP, or (3) changes to the conditions or conservation measures for covered species within the ESRF HCP. If an approved revision of target levels for one or more indicator variables would prompt an evaluation of changes in experimental protocols, any subsequent changes in experimental protocols would be required to pass through the full adaptive management process described in Figure 11.1 and may require an update to the FMP with approval from the ESRFA Board of Directors and the State Land Board.

To achieve the numerous and diverse research objectives laid out for the ESRF, it will be imperative to carefully consider the types and urgency of issues that might trigger the need for structured adaptive decision making. In other words, effective and efficient use of resources to implement the research program will require the flexibility to make routine adjustments and refinements of research and monitoring methods without triggering a complex structured adaptive review and decision-making process at every stage. To distinguish the level of review, structure, stakeholder involvement and deliberation appropriate for adaptive adjustments on the ESRF, we propose a tiered approach:

- Tier I: Scientific Experiment Adaptation
  - Approval is not required, but changes are reported to the ESRFA Board through biennial reports, biennial operations plans, and more frequent communications as needed.
  - This is an ongoing process with no set timeline.
  - The purpose is to adjust scientific experiments and monitoring needed due to acknowledged variability in ecological systems, funding, technological advancements, etc.
  - Examples include, but are not limited to, changes in the number of experimental replicates, changes to response variables, changes in technology or monitoring equipment, location adjustments due to disturbance or feasibility concerns, etc.
- Tier II: Minor Adaptive Changes to ESRF Research Management
  - May require approval from the ESRF Board of Directors.
  - The general timeline is every 2 years through biennial reports and operations plans.
  - Examples include, but are not limited to, changes to planned treatments in watersheds outside of the Triad experiment that do not impact ESA species, etc.
- Tier III: Substantial Changes to the Forest Management Plan
  - Most likely require a science review by an external peer science advisory group.
  - Legislatively, require approval from the ESRFA Board of Directors and the State Land Board.
  - The general timeline is every 10 years.
  - Examples include, but are not limited to, significant changes in Triad treatment allocations, any changes that would necessitate an ESRF HCP amendment, etc.

Examples of factors to consider when assessing the level of review necessary for adaptive adjustments are shown in Table 11.1. These factors are intended as general guidelines; individual factors may not be relevant or apply depending on the issue at hand.

Thresholds that trigger the need for an adjustment to the ESRF experimental design will vary with the level of planning at which adaptive research strategy and implementation is being considered, with major adjustments made at the ESRF forest management planning level and more minor adjustments made at the ESRF biennial operation plan level. Triggers may also change based on the results of research or new survey or monitoring results. For instance, species responsiveness or detectability may vary considerably year to year, or habitat response to silvicultural activities and monitoring of that response may take many years. Table 11.2 below describes triggers and adaptive experimental design responses, drawn from the ESRF FMP and ESRF HCP.

**Table 11.1.** Initial Framework for Assessing Level of Review for Adaptive Adjustment in ESRF Research Program and Protocols

Factor To Consider	Tier I	Tier II/Tier III
Spatial scale	- Localized site conditions - Single subwatershed	- Broad geographic scope - Multiple subwatersheds
Duration of effects	- Shorter-term effects	- Long-term effects
Risks; potential for unforeseen effects	- Generally low	- Higher risk; potential for significant unforeseen consequences
State of knowledge	- Braiding western and Indigenous Knowledge interpretation. Well-developed routine analysis - Professionally recognized science finding	-Emerging science or technology - Disputed findings and interpretation
Data availability	- Well developed data set - Generally accepted	- Significant data gaps - Arguably insufficient data - Highly disputed
Controversy	- Existing/potential for controversy is low	- Existing/potential for controversy is higher



**Table 11.2.** Initial Examples of Triggers and Adaptive Experimental Design Responses

Category	Potential Trigger	Adaptive Design Response Example
Wood Recruitment in Streams	Trend in large wood frequency/volume in streams is not increasing relative to controls in watersheds where wood is a limiting factor for covered fish species.	Revise near-term annual harvest plans to increase riparian management to incorporate additional wood enhancement in deficient stream reaches.
Stream Temperature	Temperature increases are detected relative to the controls in perennial streams within or above fish-bearing streams despite implementation of riparian conservation areas.	Consider targeted riparian conservation strategy adjustments in locations where temperature increases are detected and similar stream segments in the permit area. Potentially revise decadal harvest plan in particular watersheds to modify amount of harvest in an affected watershed.
Riparian Enhancement	Riparian enhancement projects are not being completed or are not achieving expected results. Biological return on investments not realized.	Identify and capture additional opportunities to fund and implement riparian enhancement. Increase number of riparian enhancement projects identified in near-term harvest plans. Apply lessons learned to selection and design of riparian enhancement projects to improve efficiency and effectiveness.
Riparian Buffers	Observed debris flows do not contain expected quantities of large wood.	Reconsider buffering strategy on specific non-fish bearing streams to address debris flow issues.
Road Improvement and Vacating	Sediment and flow impacts from roads documented within a catchment.	Identify opportunities for road improvement to treat problem areas, through adjustments to budgets and operations. Continually prioritize road locations causing ecological damage to address the most impactful first.
Fish Passage	Passage enhancement projects do not achieve intended results.	Apply lessons learned to selection and design of passage upgrades to improve efficiency and effectiveness of fish passage improvement projects.
Habitat for Covered Species (ESRF HCP)	Habitat levels, relative to controls, fall below stay-ahead commitments specified in ESRF HCP Chapter 7.	Increase number and extent of conservation treatments in near term management planning. Reevaluate and revise management prescriptions used in Douglas-fir plantations as new information comes available on the effectiveness of treatments on habitat development.
Douglas-fir plantation management	Results of habitat treatments (e.g., thinning) do not appear to be achieving the intended trend, relative to controls, in forest development and habitat improvement.	Adjust treatments through near-term harvest plans. Revise or adjust enhancement treatment prescriptions to improve efficiency and effectiveness.
Regeneration	Mean tree regeneration diversity and density in intensive and extensive harvested units are not meeting objectives.	Adjust harvest and post-harvest management activities based on identified source of regeneration issues (e.g., planting stock, species planted, natural regeneration targets, post-harvest vegetation management, herbicide use, wildlife browse, etc.) and goals/objectives for the treatment type.
Biodiversity	Mean percentage of acres that meet complex, early-successional; complex mature; and late-successional habitat definitions.	Consider whether there are adjustments needed in timing, configuration, or harvest prescriptions to meet landscape-level goals for successional stages across reserves, intensive, and extensive areas.

## 11.4 Adaptive Experimental Design Under the ESRF HCP

The ESRF HCP will be administered on the ESRF via prescribed monitoring and components of an adaptive experimental management framework. For the ESRF HCP, adaptive management is based on a flexible approach whereby actions can be adjusted as uncertainties become better understood or as assumptions change. The adaptive experimental design for the ESRF is intended to be consistent with and complement adaptive management as articulated in the ESRF HCP.

The ESRF HCP notes that adaptive management and monitoring are integrated processes, and that monitoring will inform and change management actions to continually improve outcomes for covered species. The ESRF HCP contains a range of specific monitoring criteria for each of the three species that it covers (northern spotted owl, marbled murrelet, Oregon Coast coho salmon) and their habitats. Monitoring for species in the ESRF HCP is a subset of a much more comprehensive monitoring plan for the ESRF as discussed in Chapter 10: *Monitoring*. However, for this chapter we will discuss monitoring for the ESRF HCP and how it is closely coupled with adaptive management steps to be taken if monitoring detects changes in habitats or populations of these species that need to be addressed.

A brief description of the adaptive approach in the ESRF HCP is provided below. For additional detail on monitoring relevant to the adaptive process, please see Chapter 10: *Monitoring* of this document and ESRF HCP Chapter 6: *Monitoring and Adaptive Management*.

### 11.4.1 ESRF HCP Monitoring

Management of species covered by an ESRF HCP must be linked to measurable biological goals and monitoring. Through time, monitoring goals for the ESRF HCP will remain focused on tracking progress towards the biological objectives. However, the monitoring program and priorities may evolve to align with research projects and employ the latest accepted techniques and technologies, with any substantive changes subject to review by the USFWS and NMFS.

The ESRF HCP notes that the context for management on the ESRF differs from that for most other areas covered by ESRF HCPs, in that research will be conducted on a range of natural resource topics, including the three covered species.

Thus, adaptive management on the ESRF for the purposes of the ESRF HCP will be informed by more information than is described in the ESRF HCP or Incidental Take Permits, and this information base will increase over time. Conservation measures will be modified in response to research findings if it would improve implementation of the ESRF HCP conservation strategy. Events or changes that could indicate the need to reevaluate and revise ESRF HCP conservation measures include:

- Future improvements in forest inventory methods and increased accuracy or precision of important metrics, or improvements in species habitat models, may result in different estimations of current and projected habitat trends.
- Results of effectiveness monitoring may indicate that some management techniques are more or less effective than anticipated, resulting in an increase or decrease in their use, or modifications to how they are implemented.
- Evolving science on the habitat requirements, life histories, and distributions of covered species may inform changes to the pattern of implementation of strategies on the landscape.
- Monitoring strategies themselves may change, as they are improved to better quantify or describe specific habitat metrics.

To address these uncertainties, the ESRF HCP monitoring and adaptive management program allows ESRF researchers and managers to learn from experience and reevaluate and revise the type, extent, and location of conservation measures when necessary to meet the biological goals and objectives of the ESRF HCP. If covered activities need to change, or revisions are significant enough to change the expected outcomes assessed in the ESRF HCP or ITPs, a formal amendment to the ESRF HCP may be needed. The ESRFA and ESRF staff will make that determination in coordination with and as approved by the USFWS and NOAA Fisheries, or the Services may indicate to the Executive Director and ESRF staff that an amendment is necessary before implementing any changes from the ESRF HCP.

The ESRF HCP adaptive management process will follow the conceptual model provided in the ESRF HCP Handbook (USFWS and NMFS 2016). The model includes a series of steps identifying problems and their sources, designing and implementing responses to problems, and evaluating the effectiveness of the responses, resulting in a cycle of continuous learning and improvement.

ESRF managers and staff will evaluate monitoring information to identify current and projected levels of accomplishment in achieving biological goals and objectives and where an adaptive management response may be appropriate. The ESRF will facilitate discussions among forest staff, the Executive Director, USFWS and NMFS to fully understand trends, evaluate options for potential adjustments and corrective actions, and if deemed appropriate, select an adaptive management response. If adjustments are needed the ESRF will coordinate with state and federal agencies to confirm adjustments meet the standards of the ESRF HCP and ITPs. The ESRF HCP notes that there will be continual learning about how resources are responding to management on the ESRF, since that is a core principle behind the research forest. This information will be continually considered in the ESRF HCP adaptive management process.

Under the ESRF HCP, adaptive management responses will be triggered when monitoring or other information indicates either of the following:

- Existing practices are under- or over-achieving the biological goals and objectives as illustrated in ESRF HCP Table 6-2.
- Alternative practices are available that can achieve biological goals and objectives more efficiently and effectively.

The ESRF HCP also addresses adaptive management in the context of climate change. Effects partially or wholly attributable to climate change that act as stressors on covered species or present risks to maintenance and enhancement of their habitats may be detected through monitoring and in turn trigger adaptive management responses. ESRF managers anticipate that adaptive responses to climate change will be informed through ongoing discussions and coordination at both state and federal levels with other major forest landowners in western Oregon, including private industrial forest landowners, federal land managers (BLM, USFS), Tribal governments and natural resource agencies.

In a key point, the ESRF HCP specifies that climate change research will be central to everything that occurs on the ESRF so adapting to new information that emerges from that research is part of the fabric of the research forest itself. Having multiple management approaches on the landscape that are constantly being monitored and benchmarked

against each other over time will provide valuable feedback and understanding about what management strategies are effective as novel conditions develop (Himes et al. 2022).

ESRF HCPs are required to identify specific changes and unforeseen circumstances affecting a species or geographic area of the plan and describe actions that ESRF managers will take in response. Changed and unforeseen circumstances recognized by the ESRF HCP are listed below. Climate change will likely be a driver for many of the changed circumstances described below, increasing the potential for these events to occur:

- New species listed under ESA
- Temporary change in species habitat quality from natural events – fire, storm events (e.g. wind), floods, invasive species, etc.
- Aquatic invasive plants, nonnative fish, and disease/parasites
- Stream temperature changes

It is important to note that the ESRF monitoring and adaptive experimental design process described in this chapter, and monitoring and adaptive management under the ESRF HCP, have been structured to create flexibility within the scope of the ESRF as a research forest. This flexibility is critical in order to design and maintain a statistically robust experiment, and in turn generate credible scientific findings that can be used to enhance natural ecological processes, support continued development of sustainable forestry practices, and thereby benefit a broad range of biodiversity (including but not limited to species covered under the ESRF HCP). Adaptive approaches to learning through scientific experimentation will be woven into the fabric of the ESRF, but an idealized, highly structured, “one size fits all” adaptive management process with rigidly defined steps and feedback loops is unlikely to be workable in this context.





# Chapter 12

## Disturbance, Forest Health and Resilience

Forest disturbances such as wildfire, wind, landslides, and insects and diseases are keystone ecological processes that are a natural part of forest life cycles, shaping and allowing for shifts in habitats and species that occupy forested areas. However, disturbances can also profoundly impact habitats for species of concern and the array of ecosystem services and products that humans rely on from forests, such as high quality water and air, sequestered carbon, wood fiber, culturally significant plants, recreation and cultural practices. With growing recognition of the potential for more severe and frequent disturbances related to climate change, researchers and managers are increasingly seeking to understand the relationships between disturbance, health and resilience in forest ecosystems (Millar and Stephenson 2015). To this must be added ecocultural dimensions that are central to Indigenous Knowledges and reciprocal human-nature relationships. As described in Chapter 3: *Managing a Research Forest for Multiple Values* and Appendix C, the ESRF will seek to partner with Tribal Nations and Indigenous Knowledge holders to bring together multiple perspectives on forest health and resilience in research forest operations.

## Perspectives on forest health and resilience

A forest area where disturbances threaten the sustainability of its biophysical processes or ability to meet management objectives, or where disturbances are more severe, frequent, or widespread than considered normal may be described as *unhealthy*. The term *forest health* has been widely adopted but has proven difficult to pin down, partly because interpretations vary with management goals for the forest area being considered. In some forest stands, *utilitarian* health indicators (e.g., tree diseases and growth rate, wood yield, carbon storage) are the primary concern. In other areas, the focus is on *ecological* indicators (e.g., seral stage diversity, patchiness, dead wood, community structure and diversity, soil quality, connectivity) (Kolb et al. 1994; Trumbore et al. 2015).

Shaw et al. (2022) observe that forest health is a subjective concept incorporating a range of themes including biodiversity, resilience, resistance, sustainability, ecosystem services, sustained productivity, human values, and land management objectives. In recent years, forest managers have shifted to framing many forest health concerns in terms of maintaining forest *resilience* – the capacity of an ecosystem to withstand and recover from disturbances – in response to increasingly serious threats to forest ecosystem integrity that are being exacerbated by climate change such as wildfire, drought and heat waves (Washington DNR 2023; Abrams et al. 2021).

Western science and associated management tend to assess forest health and resilience reductionistically, parsing measures such as tree crown condition, soil and water quality, and levels of infection by tree disease and insects. When informed by Indigenous Knowledges, a more holistic approach may prioritize maintaining reciprocal physical, cultural, social, and spiritual relationships between humans and the environment as these systems are inextricably linked. Indigenous Knowledges add a dimension that fully incorporates ecology, culture, and humans in a systems-based, holistic, and reciprocal relationship that management of the ESRF will aspire to embody. Disturbances will be placed within this context as Indigenous Knowledge is interwoven with research and management on the ESRF, including through adaptive strategies (Chapter 11: *Adaptive Research Strategy and Implementation*). Collaboration with Tribal partners to braid Indigenous Knowledges into strategies for enhancing forest health and resilience on the ESRF will be vital.

Sections below (drawn mainly from Western science) cover descriptions of *abiotic* (e.g., wildfire and wind) and *biotic* (e.g., tree diseases and insects) disturbance agents that can be expected to occur and interact to affect forest health across the ESRF. Next, some common classes of indicators used to assess different aspects of forest health, and a framework for tracking forest health-related data and information for the ESRF are described. The last sections lay out details regarding how forest health and resilience-related objectives will be operationalized across the different ESRF land allocations.

## 12.1 Abiotic Disturbances

Abiotic disturbances on the ESRF include wildfire, high wind events and mass wasting such as landslides. Abiotic agents cause more tree mortality than biotic agents and are the primary natural agents of stand-replacing disturbance on the forest. However, abiotic disturbances usually operate at intermediate levels of mortality, leaving substantial live legacies and altering pathways of forest structural and successional development (Reilly and Spies 2016).

### 12.1.1 Wildfire

Wildfire is the principal disturbance process that shapes the structure, composition, and dynamics of forest landscapes over time in temperate forests in the Pacific Northwest. Understanding fire and forest dynamics is thus critical to long-term management and conservation planning. However, datasets that describe the size, frequency, and severity of historical wildfires and how these fires influenced forest conditions and dynamics across landscapes are lacking. Thus, our understanding of the historical fire regime, which includes traditional burning by Indigenous Peoples, is still evolving in the Coast Range and in other Douglas-fir forests in the PNW. This section briefly reviews the fire ecology of Douglas-fir forests and summarizes results from a recent dendrochronological reconstruction of historical fires on the Elliott State Research Forest. See Appendix J for additional information describing historical fires and forest development history.

The influence of wildfire on a forest ecosystem is generally characterized in terms of its *fire regime* – a broad description of fire frequency, severity, and variability over time and across the landscape. The infrequent, high-severity fire regime has been broadly applied to moist Douglas-fir in the



western hemlock zone (Agee 1993, Franklin and Johnson 2012). This hypothesis was shaped by extensive high-severity fires in moist temperate Oregon and Washington forests in the 19th and early 20th century (Tepley 2010) including the 1868 fire that encompassed much of the ESRF (Phillips 1997). Aside from some limited evidence of at least one other fire between 1881-93, it has been tacitly assumed by western science that fire has otherwise not played a significant role in stand development on the ESRF (Biosystems et al. 2003, Oregon DSL and ODF 2011).

Under an infrequent *high-severity* fire regime, the absence of wildfire for centuries allows the development of mature and old-growth forests broadly across a landscape. Old-growth conditions, including large trees, canopy gaps, multi-story canopies, snags, logs, and mixed tree species composition, develop through a pathway involving competitive exclusion of the pioneer Douglas-fir cohort (Franklin et al. 2002) along with variable patches of tree damage and mortality caused by windthrow, snow and ice, and insects and disease. When severe drought, ignitions, and severe fire weather align, a large severe fire occurs and results in mortality of most mature trees. The postfire landscape is largely composed of early seral shrubs, herbs, grasses, and tree seedlings with abundant snags and logs.

Ecologists are increasingly recognizing that much of the Douglas-fir region was characterized by relatively frequent *mixed-severity* fires (Spies et al. 2018). In this regime, fire severity varies, resulting in low (<20%), moderate (20-70%), and high (>70%) mortality of mature trees. Spatial variability in fire frequency and severity mediates forest succession and conditions at relatively fine scales. Many mature and old forests have multiple shade intolerant and shade tolerant cohorts dating to past fires of low- and moderate-severity. This variability in the frequency and severity of past fires results in several fire-mediated forest successional pathways, each with distinct forest structure and composition at the old-growth stage (Tepley et al. 2013). Across a landscape, this “pyrodiversity” results in high diversity of forest conditions and successional histories among forest stands (Morrison and Swanson 1990, Tepley et al. 2013, Merschel 2021).

On the ESRF an infrequent 350-year fire return interval is still applied (LANDFIRE 2023), but this estimate is not based on direct and annually precise evidence of historical fires. To address this knowledge gap and improve our understanding of fire regimes in coastal PNW forests, the OSU College of Forestry collaborated with the USFS PNW

Research Station to reconstruct historical fire frequency and extent (using cross sections of stumps and logs with cambial fire-scars) and the age structure and establishment history of unmanaged stands (using tree cores) on the ESRF and adjacent areas. Objectives for this pilot study were to quantify fire frequency, fire extent, and to describe the age structure and establishment history of unmanaged stands. This combination of dendrochronological evidence allowed researchers to interpret and characterize how historical wildfires influenced forest conditions and dynamics on the ESRF. See Appendix J for a more detailed description of study methodology.

Prior to 1900, fires were frequent and occurred multiple times per century in much of the ESRF and surrounding lands. However, fire frequency was non-stationary over time, i.e. there were periods with several fires per century and periods with few or no fires per century. For example, at one reconstruction site there was evidence of a single fire from 1650-1750, but four fires occurred from 1750-1850. Across all study sites, fire frequency was relatively high from approximately 1700-1800, low from 1800-1848, and then high from 1849-1910 following an extensive fire in 1849. Fire frequency declined in the early 20th century although there was evidence of small fires from 1930 to 1970 that may have been related to slash clearing fires after logging.

Fire records suggested that most historical fires were relatively small (i.e. < 2500 acres), and included a substantial portion of low- to moderate- severity fire effects. In contrast, fires in 1849 and 1868 were extensive and relatively severe, burning across much of the ESRF and on both sides of the Umpqua River. Evidence in earlier centuries is relatively limited, but earlier fires in 1776 and 1628 may have been similar to the 1849 and 1868 fires. East wind events that support large, high-severity wildfires are relatively rare in the central Oregon Coast Range, but when these extreme fire weather events do occur meteorological records indicate they are relatively severe and of long duration (Reilly et al. 2021). Future fires on the ESRF burning under average weather conditions are likely to remain relatively small with mixed-severity effects. Nevertheless, there is a historical precedent and potential for extensive high-severity fire on the ESRF during synoptic east wind events.

Fire and forest development histories showed that fire severity varied spatially and this created a mosaic of stands with unique ages, development histories, and contemporary structure. For example, the 1849 fire was high-severity and initiated early seral conditions at some sites but burned at

low- to moderate-severity in the northeast part of the ESRF. Many of the fires documented in the late 19th and early 20th century appear to be reburns of the larger and relatively severe fires in 1849 and 1868. Within the 1849 and 1868 fire perimeters, these smaller reburns resulted in contemporary mature stands that may have multiple Douglas-fir cohorts. Most trees were established after fires in the late 19th century when fire frequency declined on the ESRF.

Old-growth stands and trees are rare on the ESRF, apparently owing to high-severity fires in the 19th century, and 20th century logging of stands that were unburned or burned at low- to moderate severity. Unharvested forests on the ESRF are a mosaic of ages created by variability in the timing, number, and severity of fires in the 19th century and early 20th century (Figure 12.1). Many young trees and stands established after the 1849 fire were likely killed by the 1868 fire. The 1868 fire then resulted in a broadly distributed age class that was again edited by smaller reburns in 1883, 1894, 1902, etc. The net effect of historical wildfires is that mature forests on the ESRF are composed of different aged stands. This pyrodiversity in mature forest ages is the product of severe fire followed by frequent reburns and gradual recruitment of a Douglas-fir during the early phases of forest succession.

The conventional wisdom that historical wildfires were infrequent and usually severe in moist forests is also rooted in the assumption that scarcity of lightning and anthropogenic ignitions, and generally moist fuels limited fire occurrence to periods of extreme drought that coincided with rare large-scale east wind events, e.g., the 2020 Labor Day fires. Despite acknowledgment of traditional burning by Native American cultures in prairies and major valleys in the PNW, literature that has guided policy in moist forests mostly assumes traditional burning had little influence on historical fire regimes (e.g., Agee 1991). However, a growing body of evidence, including the recent fire and forest development history on the ESRF (Appendix J), demonstrates that many Douglas-fir forests were characterized by frequent to moderately frequent mixed-severity wildfires that burned under a broad range of climatic and weather conditions. The frequency of historical fires and relatively low lightning activity on the ESRF directly challenges the assumption that traditional burning and Native American peoples did not shape the dynamics and characteristics of Douglas-fir ecosystems. It suggests an alternative hypothesis that many of the characteristics of old-growth forests are the product of recurrent mixed-

severity fires of which many may have been intentionally prescribed by Native Americans.

In recent decades wildfire activity has increased substantially across the western U.S., including total area burned, number of very large fires, and the length of fire seasons. Much of this increase is attributed to anthropogenic climate change. Wildfire frequency and severity in moist forests of the Oregon Coast Range are also likely to increase, although these forests are projected to be somewhat less vulnerable than drier interior forests (Buotte et al. 2019; Halofsky et al. 2020). However, it should be noted that accurately predicting wildfire probability for the coastal Oregon ecoregion is challenging because fires have been infrequent since the late 19th century, so data on past occurrence is sparse.

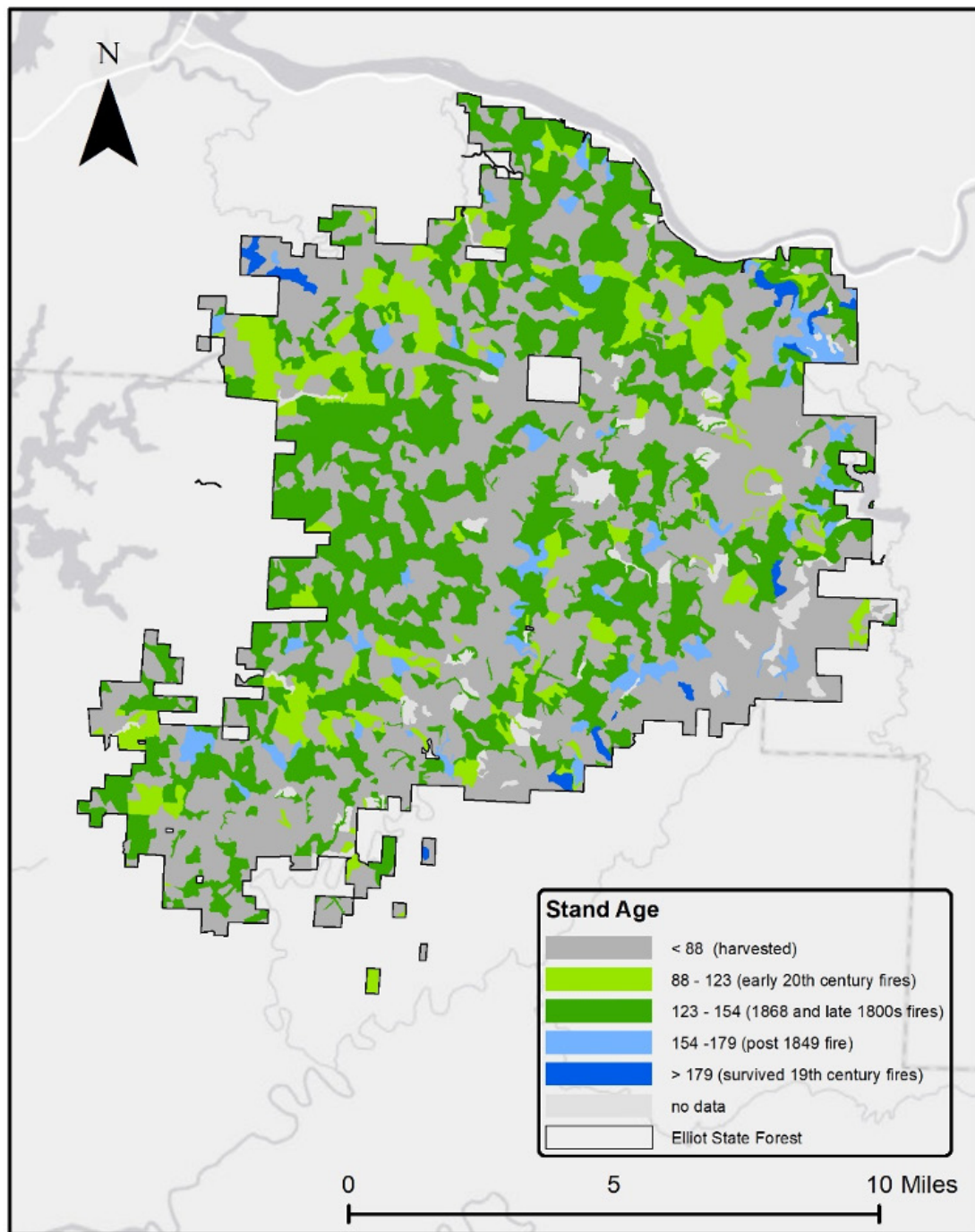
Dye et al. (2023) projected future burn probabilities for western Oregon using the FSim Large Fire Simulator (USDA Forest Service 2023a) to simulate wildfire ignition and spread under projected future climates. Simulation is driven with future projections of energy release component (ERC) for the mid-21st century (2035-2064) under RCP8.5 emissions scenario derived from downscaled global climate models (GCM). To build the projections, the FSim model simulates thousands of plausible fire seasons. For each day in each year ignitions are stochastically generated, and the growth and behavior of resulting wildfires are simulated as they burn across the landscape. Output is compared to a historical baseline to show how fire activity may change in the future as climate change effects intensify.

For the ESRF, annual burn probability is projected to almost double by mid-century. Specifically, the chance in any given year of a large wildfire burning across the ESRF would increase from 0.179% during the historical baseline (1992-2020; 558-year fire return interval) to a projected 0.339% by mid-century (2035-2064; 295-year fire return interval). The key message from this study is the near doubling of annual burn probability; the fire return intervals are subject to considerable uncertainty due to limitations in historical baseline data used for the projections.

### 12.1.2 Wind and Windthrow

Windstorms are a high-frequency, chronic disturbance agent in the Oregon Coast Range (Knapp and Hadley 2012), especially on west facing slopes directly in the path of Pacific Ocean storms. The largest of these storms periodically blow down large numbers of trees in stand replacing events, sometimes followed by outbreaks of





**Figure 12.1.** Stand ages on the ESRF (ODF data). Mature stands on the forest vary in age depending on whether the stand experienced high-severity fire in 1849 or 1868, and how it was influenced by smaller reburns of these fires in the late 19th and early 20th centuries. Old-growth stands that survived fires in the 19th century and harvest in the 20th century are rare. Mature and old-growth stand structure on the ESRF was shaped by high-severity fire and low- to moderate-severity fires.

insects that colonize the windthrown trees. More frequent, smaller-scale wind events create gaps in forest stands by toppling individual or small groups of trees weakened by insects or disease. In unmanaged forests, windthrow at all scales is a natural, recurring disturbance and a key driver in shaping forest stand diversity and structure. In managed stands, windthrow may be concentrated along forest edges created by harvesting (Sinton et al. 2000); mitigating for this is well-studied (e.g. Ruth et al. 1953; Mitchell et al. 2001). Wind interacting with wet snow and ice accumulations can cause extensive tree and stand damage including windthrow, partial to total crown breakage, and understory impacts from falling debris (section 12.1.6 below).

The most intense wind events that affect the ESRF are oceanic extratropical cyclones that develop over the Pacific Ocean. Such storms routinely produce winds up to 75 mph; the strongest are comparable to Category 2 or 3 hurricanes with sustained winds of over 100 mph. These very large-scale systems are most frequent and intense from November-February. Their strong, damaging winds are often accompanied by high rainfall. Zhang et al. (2019) found that 82% percent of atmospheric rivers are associated with an extratropical cyclone, while 45% of extratropical cyclones have an atmospheric river. Heavy autumn precipitation often saturates soils by mid-November, enhancing potential tree damage, since saturated soils lose adhesion and ability to hold roots. Substantial topographic relief in the Oregon Coast Range produces large spatial gradients in wind speed, resulting in localized areas of increased damage (Mass and Dotson 2010).

Severe windstorms have occurred in the Oregon Coast Range in 1971, 1973, 1981, 1983, 1995 and 2002, and during the “Great Coastal Gale” of 2007. The Columbus Day Storm of 1962 was the most damaging windstorm to strike the PNW in 150 years. At the Cape Blanco Loran Station on the southern Oregon coast, sustained winds reached well over 110 mph. On the ESRF, the 1962 storm blew down approximately 100 million board feet of timber and was followed by a period of intense road building to access and extract the windthrown trees. For more details on this period in the history of the ESRF, see Chapter 1: *Introduction and Background*.

The following discussion of specific effects of wind on forests is drawn from Mitchell (2013). Trees in sites with frequent wind adapt by growing shorter, thicker trunks and branches which better resist deflection and improve root anchorage. Trees that are broken or uprooted when

wind loading exceeds the resistance of stem or root/soil systems may knock branches off, break or uproot adjacent trees as they fall. Stand-level damage from windthrow ranges from creation of small canopy gaps to complete and extensive failure of the overstory canopy. Damage patterns within stands can be variable or uniform. The propagation of tree damage through a stand during a high wind event, and the consistency of this damage, depend partly on the variability among trees within the stand, and on variability in terrain (e.g., slope, aspect) and soil conditions (e.g., depth, saturation) that affect wind exposure and root anchorage.

Wind speeds attenuate rapidly within dense stand canopies where trees are partially sheltered by neighboring trees. Shade-grown trees allocate fewer resources to diameter growth than trees grown in full sunlight. In stands grown at high densities, stems become increasingly slender and crown centers of gravity shift higher. At some critical stand height, uniform stands may become mechanically unstable. This instability likely results from (1), the increased leverage of tall, high crowned trees, and (2) the potential for trees to “domino fall” during wind events rather than tipping into and being supported by their neighbors. Crop planning tools such as stand growth or density models coupled with windthrow models can aid in prediction of stand stability for different planting density or thinning regimes.

Because they are quite frequent and intense, wind events are important drivers of ecosystem processes in the Oregon Coast Range. Gaps created can be hundreds of acres, but a large majority involve only a few trees. At the landscape level, wind affects stand condition, patch size and distribution of stand types. At the stand level, windthrow damages the overstory and increases availability of light and soil resources to subcanopy and understory plants, moves foliage, branch, and stem material to the ground and upends and exposes soil profiles. At the microsite scale, downed stems and upturned rootwads create distinctive substrates and small topographic features that persist long after the material has decayed. Windthrow differs from other natural forest disturbance processes because of this combination of effects.

**Effects on stands:** Stand-level wind disturbances can be broadly categorized as resulting in (1) whole-stand, (2) cohort and (3) gap replacement of canopy trees. Each regime may interact with other natural disturbance agents in forest landscapes. In *whole-stand replacement*, virtually all overstory trees are damaged and a new dense cohort of trees is released or rapidly establishes by infill seed. In the Oregon Coast Range, early seral species often initially

occupy these large gaps. In *cohort replacement*, a substantial proportion of main canopy trees are damaged, often those that have developed large crowns or defective stems with age. *Gap-replacement* disturbances lead to canopy gaps from one to several mature tree crowns wide and are the most common mode of wind disturbance in forests.

**Effects on large wood:** An important ecological function of windthrow (often in concert with other forest disturbances) is the conversion of living trees to dead, broken, or downed large wood, which persists as a legacy of the previous stand. Dead standing and downed trees provide habitat and substrate for a succession of microbial, insect, plant and animal communities through progressive stages of decomposition. Large windthrown trees that become incorporated in stream channels contribute complexity to channel morphology and in-stream habitat.

**Effects on soil:** Windthrow profoundly affects forest soil properties by uprooting trees, upturning root systems, and exposing and inverting mineral soil and forest floor. As the roots decay, a pit-mound complex remains with the mound forming next to the pit from soil that was held by the rootwad. Pit-mounds introduce microtopographic and microclimatic complexity and may persist for hundreds of years. This microsite-level heterogeneity promotes understory floral diversity and influences successional pathways. The distinctive microsites and repeated soil turnover caused by recurrent windthrow also affect the nature and rate of soil formation, particularly in cool, moist climates. At the microsite scale, pits accumulate organic matter which gradually leads to differentiation of soil characteristics compared to adjacent mounds. At the site level, the pulse of downed branch and stem material, and inversion of soil during recurrent windthrow events, reverses podzolization (leaching of upper soil layers; accumulation of material in lower layers) and affects soil carbon and nutrient dynamics, site fertility and microbial communities.

### 12.1.3 Mass Wasting (Landslides and Debris Flows)

Owing to its abundant steep terrain, extensive soil cover, heavy wet-season precipitation, and sedimentary geology, mass wasting is an integral and frequent abiotic disturbance process in the Oregon Coast Range. These mass wasting events can be exacerbated by poor road construction and placement and timber harvest in absence of standard revegetation practices (Goodman et al. 2023). However, improved management practices, both existing and those

developed from research on the ESRF have potential to reduce undesired mass wasting events. The sediment from mass wasting events also serves aquatic ecosystems, often through debris flow events. In landscapes with soil cover, debris flows are believed to be the dominant process linking sediment from hillslopes with stream channels that have slopes of 10% or greater. These steep channels make up about 80% of the stream network in the Oregon Coast Range.

Debris flows, initiated by shallow landsliding in colluvial hollows, are rapid, episodic events that can deposit large amounts of material into stream tributaries. The resulting debris flow fans are persistent and prevalent features in the Oregon Coast Range and an important source of habitat-forming sediment and wood in streams (Beeson et al. 2018). Deep-seated landslides are also extensive throughout the Oregon Coast Range and also serve as sources of sediment, particularly those landslide features that are channel-adjacent and tend to show intermittent creep, either seasonally or following major precipitation events. Luna and Korup (2022) found landsliding in the PNW to be rare in summer and quite variable in winter, with some winters bringing hundreds of landslides and some very few. Their work showed landslide probability peaking in January and intensity in February, lagging winter rainfall peaks by 1-2 months and consistent with the understanding that landslide activity is highest after hillslopes become sufficiently saturated. For the same monthly rainfall, landslide intensity in February was up to 10 times higher than in November.

While relatively wet winters may result in distributed and diffuse shallow landslides and remobilization of deep-seated slow-moving landslides, extensive, concurrent landsliding in the Oregon Coast Range tends to be driven by atmospheric river and/or rain-on-snow events. With warming climatic conditions, heavier precipitation events and less snow are expected during winter (Dalton and Fleishman 2021). This suggests that landslide events, especially those with extensive shallow landslides and debris flows, are likely to become more commonplace (Barik et al. 2017).

The prevalence of landslide features varies across the ESRF. A landslide inventory for the forest was developed in 2022 to catalog the boundaries of past landslide features through interpretation of bare earth LiDAR collected in 2021 (Appendix O). This inventory was developed according to mapping protocols developed by the Oregon Department of Geology and Mineral Industries (DOGAMI) in accordance with Special Paper 42 (Burns and Madin 2009). As with most

landslide inventories created through interpretation and mapping of topographic features associated with a variety of landslide mechanisms, the age or activity of mapped features are largely unknown. However, these inventories do represent the general characteristics of mass wasting events and to some level, regions where landslide activity may be expected from extreme disturbance. As with all landslide inventories, there is likely censoring of smaller landslide features such as rockfalls and shallow landslides as digital elevation model resolution is limiting and the signatures of these scars do not last long on a landscape.

Overall, approximately 1,500 landslides were mapped within the perimeter of the ESRF (Figure 12.2), a majority of which were classified as deep-seated earthflows and complex movement mechanisms (e.g., a combination of movement mechanisms). Many of these features are collocated with the Elkton Formation, and although ongoing landslide activity is largely unknown, these features are expected to move relatively slowly and intermittently, as do many earthflow features in the Oregon Coast Range. Situated in Tyee Formation west of the WF Millicoma River are numerous deep-seated bedrock landslide features of unknown activity and modest size. Within this geologic unit are extensive fan-like features associated with relatively frequent debris flow events stemming from in-channel failures and/or shallow landslides stemming from unchanneled colluvial hollows. This landslide inventory serves as a starting point for understanding (1) the spatial distribution of mechanisms underlying landsliding in the ESRF, (2) generalized magnitude-frequency relationships for landslide size, (3) strategic locations for monitoring and site investigation associated with forest planning, and (4) a living database that can be updated to include future landslide events and associated controls to better constrain landslide rates.

### 12.1.4 Drought and Heat Waves

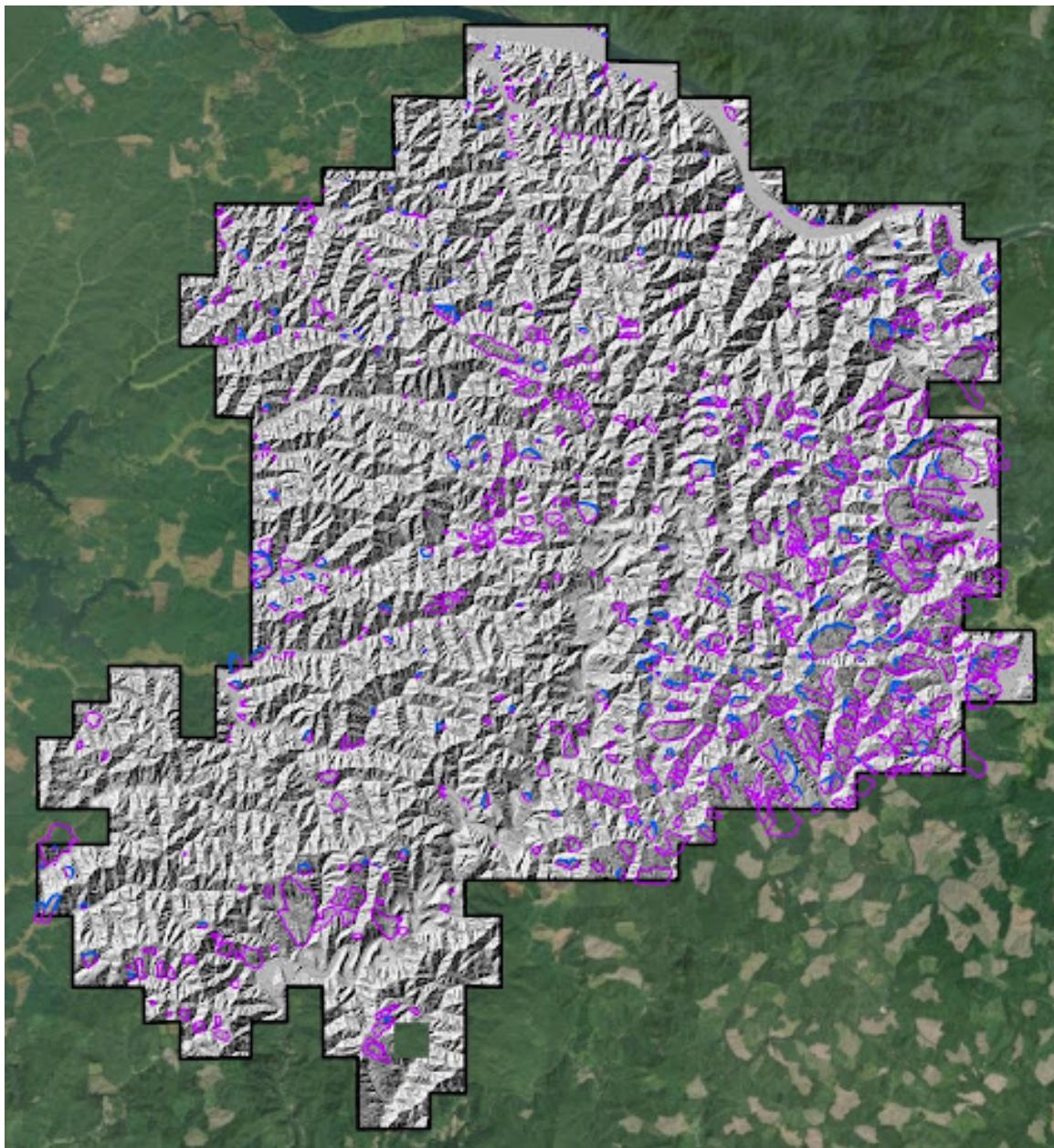
Drought and heat waves are normal components of climate cycles, but their occurrence and severity have increased with climate warming. Drought is a period of abnormally dry weather sufficiently prolonged for the lack of water to cause serious problems in the affected area. Heat waves are periods of consecutive days where conditions are excessively hotter than normal. Heat waves combined with drought are common and together produce positive feedbacks that intensify their effects. Higher temperatures increase atmospheric vapor pressure deficit, which increases evapotranspiration resulting in more rapid soil drying and increased drought severity.

Drought and heat-related forest stress and tree mortality are increasing across the west. Tree and forest stress may manifest initially as poor crown condition and/or a decline in leaf area, followed by a reduction in growth, and then by the potential increase in susceptibility to insects and fire. Trees are adapted to survive within a range of temperature and moisture conditions but may ultimately cross thresholds beyond which they are unable to recover. Mass tree mortality due to drought has occurred relatively rapidly across many forest biomes, including cool temperate forests. In the early phases of drought, younger trees may be more susceptible, but under more extended or extreme drought larger, older trees are also at risk (Van Mantgem et al. 2009; Stovall et al. 2020).

Trees have an intricate xylem “plumbing” system of hollow dead cells to transport water from soil to leaves. Tension created by transpiration pulls water upward through the xylem, enabling trees to lift vast volumes of water to the canopy at little energetic cost. Damage to this hydraulic supply network from severe water stress is a key mechanism in drought-related tree mortality. As drought progresses, xylem tension rises and eventually air gets pulled into xylem conduits, causing cavitation and breaking hydraulic connections between roots and above ground parts of the tree. This greatly reduces water delivery to the canopy, causing patchy branch death and marked reductions in canopy leaf area. During intense droughts, these air pockets (emboli) can spread throughout the entire water transport network, causing systemic failure of the vascular system and rapid mortality of the whole tree (Choat et al. 2018).

Short of catastrophic hydraulic failure, the need to regulate water loss during drought also compromises tree health through depletion of carbohydrate reserves. Trees respond to drought stress by closing the stomatal pores on their leaf surfaces, which substantially reduces dehydration but also causes rapid cessation of photosynthetic CO<sub>2</sub> take-up, depletion of non-structural carbohydrate pools and loss of canopy evaporative cooling through transpiration. Once their stomata close, trees begin to rely on stored carbohydrates. Over time, this reduces vigor and interferes with production of chemical defenses, making the trees more vulnerable to pests, pathogens and mortality. The fact that trees often close their stomata in response to moisture stress despite the physiological drawbacks of doing so indicates that avoidance of hydraulic collapse is fundamentally important for their long-term survival (Choat et al. 2018).





**Figure 12.2.** Landslide inventory within the perimeter of the ESRF. Purple polygons represent landslide deposits. Blue polygons represent headscarp flanks.

Adams et al. (2017) analyzed drought-related mortality in over two dozen tree species and found that hydraulic failure was almost universally present when trees died, while carbon starvation was a contributing factor roughly half of the time. One of the most certain predictions of climate models is an increase in the frequency, duration and intensity of heat waves. The rapid, widespread scorching of sunlit foliage after the June 2021 PNW heat event, which resembled scorch from wildfire, is another mechanism of climate and heat-related tree damage that can occur in addition to longer-term hydraulic damage (Still et al. 2023). Recent studies have highlighted the potential for warmer temperatures to compound the effects of severe drought events and exacerbate regional forest stress and die-off (Mildrexler et al. 2016). Arend (2021) found that tree-water relations decline in a nonlinear manner and that hydraulic collapse can occur rapidly during progression of severe drought. Considering these temporal dynamics will be critical for predicting tree conifer tree death related to drought and heat waves.

Longer-term drought interacting with generally higher temperatures and heat waves (“hotter drought”) is an especially potent threat to forest health that is receiving increasing attention (Millar and Stephenson 2015) and may be the climate-related changes most likely to affect the ESRF in coming decades. In recent years, much of the Douglas and Coos County area has faced significant periods of drought (US Drought Monitor 2023) and summers are becoming warmer and longer. With climate change effects on forests ever more apparent, it will be necessary to better understand how hydraulic failure, CO<sub>2</sub> starvation, foliage scorch, and secondary factors such as insects and disease interact to weaken and kill trees under drought and heat stress. Critical information needs that research on the ESRF aims to address include connections between hydraulic properties and heat tolerance that contribute to different tree species hydraulic conductivity “safety margins”, and how evolutionary lineages and functional traits affect environmental responses to heat and drought (Still et al. 2023).

### 12.1.5 Atmospheric Rivers, Extreme Precipitation and Flooding

Atmospheric rivers (ARs) are the cause of many of the most extreme precipitation and storm events along the U.S. west coast and a large majority of floods in the region. They are also often associated with the end of droughts. ARs are naturally occurring, transitory, long, narrow pathways of

water vapor transport that contain massive amounts of warm, moist air and strong winds, often connecting tropical and extratropical moisture sources to the western U.S. About 82% percent of atmospheric rivers are associated with an extratropical cyclone (Zhang et al. 2019). When an AR reaches Oregon, the fast moving, moisture-laden air usually flows up and over the Coast Range, producing intense and sustained orographic rain (Dettinger 2011, 2013; Gershunov et al. 2019). Integrated water vapor transport is expected to significantly increase along the west coast in coming decades, along with both winter average precipitation and extreme precipitation events associated with ARs (Warner et al. 2015).

Flooding, the submerging of normally dry land with a large amount of water, occurs regularly during winter storms in the Pacific Northwest. The effects of flooding can vary depending on drainage basin morphology and land use history. Flood magnitude and frequency can be estimated based on records of annual peak discharges. The WF Millicoma River gauging station, initially operated from 1955-1981, recorded peaks of 5,560 cubic feet/second (cfs) in December 1964, a flood return period of 2 years, and 8,100 cfs in November 1960, a return period of about 8 years (FEMA 2018). Based on this 27-year data set, Biosystems et al. (2003) observed no abnormally high peak flows, even when other Coast Range streams were experiencing them, and surmised that peak flows may not have been accurately recorded. After 2002 (when Coos Watershed Association reactivated the gauge) through 2021, annual peak discharge on the WF Millicoma ranged from 1380 cfs (2020) to 6870 cfs (2015) with an average for the period of about 3600 cfs.

While noting the limitations of available data and potential changes in the future, extensive flooding currently appears to be uncommon on the ESRF owing to its steep terrain and minimal floodplain area, with winter high flows mainly confined to existing channels. The most influential and notable effect of extreme precipitation on the forest may instead be increased probability and frequency of landsliding. Historically, peak flows and landslides helped shape aquatic habitat by impacting channel morphology, sediment and large wood transport and deposition, and adjacent stream vegetation. If predictions for more frequent ARs and increases in short-term extreme precipitation under climate warming are borne out, it is reasonable to expect higher rates of landsliding in the future than occurred historically.

### 12.1.6 Ice and Snow Events

An ice or glaze storm is a precipitation event during which a coating of ice forms on exposed surfaces by the freezing of supercooled water deposited by rain, drizzle, and/or fog. Ice storms are infrequent in the PNW but can cause significant, widespread tree damage with long-term impacts, especially in multi-aged stands. Phillips (1997) reports that the Elliott experienced a severe ice storm during the winter of 1929-30, breaking the tops of about 20% of 6"-16" trees 8'-20' off the ground in many stands, signs of which were still apparent during timber cruises in the 1960s.

The PNW region experienced five severe glaze events from 1949-2000. Snow loading, especially in stands that do not experience it regularly, can also damage trees. Snow accumulation on trees is strongly dependent upon weather and climatological conditions. Temperature influences the moisture content of snow and therefore the degree to which it can stick to and accumulate on branches. Wind can cause drier snow to be shed but can also lead to large accumulations of wet snow, rime or freezing rain (Nykänen et al. 1997). In the Oregon Coast Range wet snow is somewhat more frequent than ice.

Ice storms and wet snow loading modify forest structure by damaging trees and shrubs in all canopy levels. Damage occurs both directly when branches or trunks break, and indirectly when broken branches or tops fall on understory trees and shrubs. Ice glazing affects trees in several ways with varying degrees of severity, from breakage of branches to bending stems of smaller trees to the ground, to partial crown loss, to snapping of the trunk. Trees with lopsided crowns along stand edges, riparian areas or roads may be particularly vulnerable, as may open-grown trees with broad crowns. Severity of tree damage appears to be closely related to the intensity of winds following snow or ice accumulations (Irland 2000). In general, small trees appear to receive the least severe damage, intermediate-sized trees receive the most, and large trees an intermediate amount.

In November 2014, a major ice storm affected approximately 2760 ha (6820 acres) of central Oregon Coast Range forests, causing substantial overstory and understory damage. Priebe et al. (2018) studied the effects of this storm in stands of mostly 70-year-old planted Douglas-fir with a 21-year-old mixed conifer understory. Their findings suggest that on the ESRF, risk of tree damage from wet snow or glaze events may be greatest in established, younger stands with intermediate-sized trees. With its generally mild winter

climate, the risk of snow or ice events would also likely be greater at higher elevations on the forest. The risk of extensive damage to understory trees from ice storms could potentially be reduced by accelerating their growth into larger diameter-classes (Priebe et al. 2018).

Snow and especially ice storms are uncommon in the Oregon Coast Range, but are still of concern, especially in managed, younger stands. Most climate models predict warmer and wetter winters for the region (May et al. 2018) but conditions are also expected to become more variable, with increases in extreme weather events. Thus, it is possible that snow and ice events could still occur on the ESRF under climate change.

### 12.1.7 Timber Harvesting as Disturbance

Since 1950, roughly 50% of the ESRF has been clearcut and replanted into a patchwork of even-aged, mostly single-species stands which now span age classes from 10 – 65+ years. (See Chapter 4: *Research Platform and Experimental Design*, Figure 4.2.) In other areas, partial harvests from about 1958-1978 focused on “stand management” (Phillips 1997) have altered growth rates, stand structure and understory communities. Thus, understanding the effects of harvest in the context of modern disturbance theory, and integrating harvesting with natural disturbance are important for assessing and shaping the future of the forest.

Forest disturbances were historically viewed as uncommon, largely unpredictable and having mostly negative ecological and social effects. This has changed in recent decades with greater scientific understanding of the importance of disturbances in affecting forest structure, development and resilience, and the array of different habitats that support diverse populations of terrestrial and aquatic wildlife. This general shift in how disturbances are viewed has been accompanied by efforts to develop silvicultural prescriptions that better emulate natural disturbance and, where possible, direct planted stands on trajectories that maintain or restore ecosystem processes and biodiversity. A common approach to emulating natural disturbance is to design harvest treatments that leave residual forest structures similar to those resulting from natural disturbances (O'Hara and Ramage 2013). These methods are laid out in detail in Palik et al. (2021) and embodied on the ESRF in extensive research treatments, as well as restoration treatments in the CRW and RCAs (see Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, and Chapter 7: *Aquatic and Riparian Systems*).



Although disturbances are now recognized as important ecological processes, they are also still viewed as significant threats that can impact ecosystem services in major ways. A key element in the evolution of forestry has been the assessment and management of disturbance-related risks, and reduction of uncertainty associated with these risks. Going forward, risks to forest resources and ecosystem services posed by climate change will be increasingly important. A key goal of management on the ESRF will be implementing and researching treatments to make the forest more resilient to these changes by shifting stands to trajectories that achieve an expanded range of objectives.

Understanding of natural disturbance processes and stand structures, and of their historical ranges of variability (Keane et al. 2009) provide critical information to support forest management. However, there is strong evidence that our forest ecosystems are changing and that rates of change are likely to accelerate in the future. As these changes progress, management of increasingly novel ecosystems and disturbance interactions to meet societal needs will require new approaches, beyond simply looking to the past for guidance (O'Hara 2016). The ESRF will play a critical role in support of these new approaches through robust monitoring, work with process-based models, and research of biological and physical disturbance processes across the forest, from tree physiology to stream geomorphology to effects of different silvicultural treatments, in order to provide the knowledge base to enable forests to persist over the long-term.

## 12.2 Biotic Disturbances

Biotic forest disturbances include native and introduced tree diseases, tree insects, and parasitic and invasive plants. Compared to abiotic disturbances described above, biotic disturbances are usually smaller scale and more amenable to active management and control. Biotic disturbances also play critical roles in creating diverse forest structures that support biodiversity. This section provides an overview of the most significant (in terms of commonality and extent of influence) biotic disturbance agents likely to be present on the ESRF. Goheen and Willhite (2021) describe many additional species that occur in PNW conifer forests. Sources for material in this section include ODF and DSL (2011), Biosystems et al. (2003), ODF (2020) with additional references cited within species descriptions.

### 12.2.1 Swiss Needle Cast (*Nothophaeocryptopus gaeumannii*)

Swiss needle cast (SNC) is a fungal foliage disease that occurs only in Douglas-fir. Since the early 1990s SNC has rapidly increased in severity and extent in coastal PNW Douglas-fir plantations. Symptoms include chlorotic (yellowish) foliage, low needle retention, thin crowns, and reduced tree growth. The fungus occurs wherever Douglas-fir is grown but is only noticeable when it causes significant defoliation of 2- and 3-year-old needles. Importantly for managers, the fungus may be present and yet have no effect on Douglas-fir productivity.

The fungus lives inside Douglas-fir needles and impacts needle function when fungal fruiting bodies emerge into and plug the stomates (air pores on the underside of a needle), blocking gas exchange. At some point, so many stomates become plugged that the needle dies and is cast (dropped) from the branchlet. As needle retention decreases, there is a corresponding reduction in tree diameter and height growth, allowing needle retention to be used as a proxy for disease impacts. Stands most heavily infected by SNC are estimated to be losing about 50% of their potential cubic volume growth.

Swiss needle cast is now considered a top threat to Douglas-fir timber plantations, especially in coastal areas of the PNW. Since 1997, private forest landowners, federal and state agencies, and the OSU College of Forestry have participated in the Swiss Needle Cast Cooperative to coordinate monitoring, research, and develop SNC management practices. Aerial detection surveys indicated nearly 600,000 acres of forestland visibly affected by SNC in 2015. Subsequent declines in affected acreage are attributed to hotter and drier early summer weather in following years, and liquidation or conversion of many of the most heavily affected plantations to non-susceptible tree species (Ritóková et al. 2022).

Shaw et al. (2021) argue that “the tree microbiome is the new frontier of forest pathology, and knowledge of the dynamics of the entire microbial community of Douglas-fir foliage could lead to major breakthroughs in our understanding of SNC because interactions with other fungi and bacteria in the leaf may influence *N. gaeumannii*.” (p. 419.) On the ESRF, monitoring and research of the forest canopy microbiome (see Chapter 10: *Monitoring*) will address this emerging research focus area.



Experts hypothesize that several interacting factors can explain why the normally benign *N. gaeumannii* fungus now causes such severe impacts to Douglas-fir in coastal PNW forests. Forest management practices, combined with a conducive climate, seem to have shifted the ecological balance in favor of the pathogen. Over the past 50 years, most of the coastal Sitka spruce and western hemlock zones have been clearcut and planted to dense stands of Douglas fir. Often, these plantations were established from seed collected farther inland and at higher elevations than native coastal stands. A favorable climate combined with large increases in the amount and density of Douglas-fir in coastal areas, and slightly off-site seed sources may have set the stage for rapid and efficient spread of the fungus. As a result, the pathogen population may have increased to levels that can overwhelm naturally occurring mechanisms of disease tolerance in Douglas-fir. Apparently, prior to intensive forest management, and perhaps recent climate warming, the trees, fungus, and environmental factors were closer to equilibrium (Oregon DSL and ODF 2011).

Based primarily on interviews with ODF staff, Biosystems et al. (2003) found that SNC was mostly affecting younger plantations (less than 30 years) on the west side of the Elliott and some scattered stands in other areas. Inventories at the time indicated that the extent of SNC was increasing on the Elliott, but it did not appear to have impacted stands with the same severity or extent as locations in the northern Coast Range. More needle loss was occurring on stands on southern or western slopes or ridge tops, which are exposed to winds or have more moisture stress. Higher soil moisture, shelter from winds, and the diverse mix of species in riparian areas appeared to contribute to less extensive SNC damage in streamside forests (Biosystems et al. 2003). Aerial surveys conducted as part of annual monitoring efforts by the PNW Swiss Needle Cast Survey have continued to track incidence of SNC in the Oregon Coast Range, with the most recent surveys in 2022 indicating moderate SNC levels in parts of the ESRF. As part of a foliar microbiome diversity study (2022-2023), researchers collected canopy data from nine mature Douglas-fir trees. A preliminary analysis of SNC incidence of 3-year-old needles collected at five different canopy heights can be found in Appendix X, with significant differences detected between areas of higher and lower fog on the forest.

Because of SNC's impacts on growth response to intermediate treatments as well as total volume at rotation age, it is important to evaluate the severity and risk of SNC as part of operational planning and prescription

development. Managers will develop an understanding of which sites are highest risk based on species composition, slope, aspect, age class and historic observations. At the stand level, managers will assess the severity of SNC based on foliar retention and crown color.

Visible symptoms of SNC can vary greatly over the course of a year and between years, depending on timing of observations and seasonal weather patterns. Symptoms are most visible during the spring, just prior to budbreak and the flush of new growth, but accurate characterization of symptoms may be difficult due to the subjective nature of assessing color and needle retention. To reduce variability in conditions during assessment, it is important to be consistent in timing of observations or sampling from year to year. Annual trends, both regionally and locally, will be important to consider in understanding potential future impacts or current susceptibility of stands, so several years of observation coupled with risk assessment will be required to get a good understanding of operational implications.

Ritóková et al. (2022) provide guidance for managing SNC. They note that above all, a one-size-fits-all approach does not work; management must be nuanced and site-specific to succeed. They recommend a three-step process for deciding how to respond to SNC in forest plantations:

- **Site hazard assessment** can include aerial detection surveys, ground-based plot data, and general knowledge of the relationship between disease and geographic location. Growth impacts mostly decrease with increasing distance from the coast. The USFS Forest Health Protection group hosts a website showing maps of aerial detection survey data (USDA Forest Service 2023b).
- **Stand impact assessment** usually starts with visual assessment of stand conditions, including needle retention, stand/crown color and crown fullness to determine if growth losses are likely. If the presence of *N. gaeumannii* is confirmed, a quantitative stand assessment can demonstrate if growth impacts are occurring and to what degree.
- **Silvicultural decisions** depend on disease levels, stand age, and stand structure and composition. Options include thinning to encourage non-host tree species, pre-commercial thinning to maintain deep crowns, and harvesting severely infected stands and replanting with non-host species. The decision to plant Douglas-fir or an alternative species is critical at the time of stand

establishment or regeneration and is based on disease hazard, future value and other factors. If Douglas-fir is preferred, all evidence points to local seed sources as most tolerant to disease. Alternative species include western hemlock, Sitka spruce, western redcedar or red alder, although Sitka spruce appears to be a poor choice anywhere but the most coastally exposed sites primarily due to impacts of the Sitka spruce tip weevil (*Pissodes strobi*).

### 12.2.2 Douglas-fir Bark Beetle (*Dendroctonus pseudotsugae*)

The Douglas-fir beetle is a bark beetle that preferentially infests >10" dbh downed trees. At normal population levels, mortality from the beetle is scattered on the landscape and often present in stands weakened by root disease, drought stress, fire or wind damage. Adults emerge and find new host material as early as April at lower elevations or after mild winters. Douglas-fir beetle has one generation per year, but there are two flight periods when trees come under attack. The first occurs from April to early June and is generally the heaviest; the second occurs in July-August. Outbreaks typically last two to four years, though they can be prolonged when conditions are favorable. Maintaining tree vigor helps reduce susceptibility to attack.

Douglas-fir beetle outbreaks are often exacerbated by significant blowdown events, which increases the supply of beetle breeding logs from which the emerging brood then attacks nearby standing green trees. Foresters may address this by rapidly salvaging windthrown Douglas firs 10" and larger (ideally before the first April after a storm event) with the aim of reducing the areal extent and duration of beetle outbreaks. Removing downed trees at least before the second April can trap and remove beetles that have already infested the material. On the ESRF, any such salvage will occur within the salvage harvest requirements and exceptions outlined in the ESRF HCP.

If removal is delayed, a repellent pheromone may instead be applied to prevent infestation. This pheromone, methylcyclohexanone, is produced by Douglas-fir beetles and spruce beetles to tell other individuals of the same species that a tree is fully occupied and thus resources are too limited to support more bark beetle colonies. Incoming beetles picking up this scent then continue their search for an available tree within which to develop their brood. Continuous searching for a non-repellent (unprotected) tree exhausts beetle fat stores to the point of mortality or

redistributes them in the landscape, reducing pressure (or number of attacks) from Douglas-fir beetles in individual trees (ODF 2017a, b).

### 12.2.3 Laminated Root Rot (*Coniferiporia sulphurascens*; formerly *Phellinus weirii*, *P. sulphurascens*)

Laminated root rot, a native fungal disease affecting several conifer species, is the most widespread and destructive disease of Douglas-fir in the Oregon Coast Range. In many forests with long intervals between stand-replacing disturbances, it is the most important disturbance agent affecting stand structure and composition. The fungus is an efficient parasite that kills host trees of all ages and sizes, causes growth loss and predisposes trees to windthrow. It is relatively slow-moving and can persist for up to 50 years in stumps of cut trees and roots of dead trees.

Douglas-fir is particularly susceptible to this disease; thus fire suppression and domination by Douglas-fir in planted or natural stands have contributed to its spread. On average, it affects approximately five percent of the Douglas-fir forest land but is distributed unevenly. Because laminated root rot spreads from root to root and affects groups of trees, it commonly creates canopy openings of various shapes and sizes across the landscape. These openings allow light to reach the understory, stimulating growth of herbs, shrubs, and tree species resistant to the disease.

Trees killed by laminated root rot provide snags and downed logs that benefit certain wildlife species. Increased habitat diversity and benefits to wildlife are a counterpoint to economically valuable timber lost. Laminated root rot destroys major structural roots, which can contribute to hazardous situations in developed recreation sites.

Crown symptoms of trees affected by laminated root rot include reduced leader growth, short, sparse, and chlorotic faded foliage, and distress cone crops. Symptoms are usually not apparent until at least half of the tree's root system is affected. Laminated root rot can be distinguished from other root diseases that cause similar crown symptoms by the characteristic decay of root and butt wood, which separates readily at the annual rings with pits on both sides of the sheets. Reddish-brown, whiskery setal hyphae occur between the layers. A grayish-white, crusty mycelial sheath (ectotrophic mycelia) is found on root surfaces of young trees and within root bark crevices on old trees (Hadfield et al. 1986).

Laminated root rot intensifies on a site when Douglas-fir or other highly susceptible species are planted into an infested area, and the fungus (which survives for decades in buried roots) grows from infected roots onto the roots of newly established trees. Western hemlock and noble fir have intermediate susceptibility, pines and cedars are resistant, and hardwoods are immune.

Current management emphasizes planting or retaining resistant or immune species, and carefully designing silvicultural systems to prevent blowdown after thinning.

### 12.2.4 Armillaria Root Disease (*Armillaria ostoyae*)

Armillaria, a fungal root disease of conifers, is the most common and most widely distributed forest root disease in Oregon. The disease is often found affecting trees that have been weakened by other agents. Armillaria root disease is far less common and damaging than laminated root rot but can still have significant impacts in young Douglas-fir plantations. Root disease surveys show that in Oregon state forests, armillaria is widely scattered and occurs in very small patches, usually affecting only a few trees. Scattered dead trees killed by armillaria provide wildlife habitat benefits.

Symptoms include thin and/or chlorotic foliage; distress cone crops; abundant resin flow or leaching of brown liquid at tree bases; a yellow-stringy root and butt rot, especially in nonresinous conifers such as hemlock, and tree mortality often centered around large stumps. Crown and root collar symptoms occur on only 15 to 20 percent of the living infected trees within disease centers; infection in the remaining trees is virtually undetectable.

Tree killing by Armillaria root disease is frequently associated with conditions that stress trees, including poor planting, inappropriate seed source, soil compaction, or nutrient imbalance. Impacts appear to be most severe in even-aged plantations and on heavily disturbed sites, with mortality being most common in Douglas-fir plantations between the ages of 10 and 25. Tree killing after age 25 is uncommon unless the trees are stressed.

Mycelium of *A. ostoyae* can survive as long as 35 years in old growth stumps and roots before being replaced by other fungi and microorganisms. Large stumps and roots infected prior to harvesting provide more inoculum potential than do small stumps. Stumps of precommercial size are not effective inoculum sources. Tree killing by Armillaria root disease will often increase 1 to 2 years after severe

droughts. Affected trees can be windthrown but tend to die standing (Oregon DSL and ODF 2011; Hadfield et al. 1986).

### 12.2.5 Black Stain Root Disease (*Leptographium wageneri* var. *pseudotsugae*)

Black stain root disease, an insect-vectored fungal, wilt-like disease of conifers was largely unrecognized in the PNW before 1969. Since then, the disease has become widespread in Douglas-fir plantations in southwest Oregon, where Hessburg et al. (2001) detected it in 18.6% of 500, 10- to 30-year-old Douglas-fir plantations, compared to 1.2% of same with Armillaria root disease and 7.0% with laminated root rot. Past ODF surveys (1986 and 1993) found black stained root disease occurred at low levels on the Elliott, mostly confined to young trees experiencing stress along roads (Kanaskie and Irwin 1993, Biosystems et al. 2003). However, in recent years black stain root disease has increased dramatically in northwestern Oregon Douglas-fir forests (ODF 2020) and current information for its occurrence on the Elliott is lacking.

Black stain is a vascular wilt-type disease rather than a root rot. Hyphae grow through host tree tracheids, block them, and interfere with water uptake and movement. Infected trees experience severe moisture stress, decline rapidly, and die. Often, disease-weakened trees are infested by bark beetles and woodborers. Black stain root disease is transmitted over long distances by spore-carrying bark beetles and weevils. The fungus requires an existing opening to initiate an infection, and cannot decay wood or penetrate non-wounded host roots.

Black stain root disease typically appears in small patches and often occurs in complexes with other root disease fungi. These disease patches are encountered most frequently in areas with severe soil disturbance, in dense stands that have been pre-commercially thinned, along roads, and in stands with a history of tractor logging. The high frequency of black stain root disease centers in disturbed areas likely reflects insect preference for stressed or injured host trees. Thinning in mid-summer, avoiding site and tree damage, and favoring species other than Douglas-fir reduces the impact of this disease. (Hadfield et al. 1986; Ferguson 2009.)

### 12.2.6 Heterobasidion Root Disease (*Heterobasidion occidentale*)

Heterobasidion root disease, formerly known as annosus root disease, is a fungus that affects western hemlock,

mountain hemlock, grand fir, and noble fir. On the ESRF, western hemlock and grand fir are the principal hosts, with the most significant damage occurring on western hemlock. Most decay is associated with wounds and is confined to woody tissues present when the trees are wounded. Losses due to heterobasidion butt decay in hemlock stands tend to be small unless trees are older than 120 years or are badly wounded. Commercial thinning or partial cutting increases the potential for heterobasidion root disease. The disease may increase as thinning intensifies and stand ages increase.

Heterobasidion is more difficult to identify than other common root diseases. Many infected trees do not exhibit above ground symptoms. Those that do have symptoms similar to those from other root diseases. The most reliable way to diagnose is to find conks of the fungus on trees in advanced stages of decline, on dead trees, and inside stumps. Heterobasidion infects its hosts either by windblown spores being deposited and germinating on freshly exposed wood, or by mycelial growth from diseased roots to healthy roots via contacts. Infection of freshly cut stumps by spores is the major way that new disease centers develop. Mycelia from germinating spores grow into the stumps and after colonizing them spread out through the roots. The fungus can spread to other trees when susceptible, healthy roots contact infected roots. (Hadfield et al. 1986, Oregon DSL and ODF 2011, ODF 2020.)

### 12.2.7 Port-Orford-Cedar Root Disease (*Phytophthora lateralis*)

Port-Orford-cedar root disease is a non-native, aggressive, fungus-like water mold that lives and grows in the roots and lower stems of its host trees, survives in a resting state in soil, and actively travels in surface water. It threatens Port-Orford-cedar and, to some extent, Pacific yew in southwest Oregon. Naturally-established stands of Port-Orford-cedar occur in some scattered tracts of state forest lands to the south but have not been documented on the main block of the Elliott. However, two small stands (about 6 acres total) of Port-Orford-cedar were planted on the forest around 2002-2003. The only known location of Port-Orford-cedar root disease is in a 1-2 acre plantation on the lower end of Palouse Creek (ODF 2016). Pacific yew does occur as scattered individuals in the Elliott. As a result of the root disease, Port-Orford-cedar was once considered for candidate status under the state and federal ESAs but was never listed. There may be opportunities to plant additional stands of the species on the ESRF.

Port-Orford-cedar root disease can be transmitted in moving water and by logging machinery, vehicle traffic, and human and animal traffic. Its presence or absence can significantly affect forest management. Because its natural range reaches the southern boundary of the ESRF, Port-Orford-cedar can potentially be replanted there in low-risk areas away from infected drainages to aid in its conservation. Genetically resistant seedlings are available. (Oregon DSL and ODF 2011, Mellen-McLean et al. 2017.)

### 12.2.8 Schweinitzii Root Rot/Velvet Top Fungus (*Phaeolus schweinitzii*)

In western Oregon the *Phaeolus schweinitzii* fungus is a common cause of butt rot in Douglas-fir and Sitka spruce older than 150 years. Western hemlock can also be affected. *Phaeolus schweinitzii* is often difficult to detect and masked by Armillaria root disease which is easier to diagnose. The most obvious sign is the distinctive conk usually only found on or near large trees. Large (up to 10") annual conks appear in late summer and fall on the ground near or growing out of the base of infected trees and stumps. Conks on the ground presumably emerge from infected roots. Conks may also occur on infected trunks, appear as thin brackets, and often emerge from wounds or cracks. The tops of fresh conks are velvety (one common name is velvet-top fungus) and reddish-brown, greenish-brown, or yellow-brown, often with a yellow edge. Conks die after a few weeks, become dark brown and brittle, and resemble cow feces; another common name is cow-pie fungus. Conks produce microscopic basidiospores which percolate into the soil and infect fine roots. Fresh trunk wounds caused by mechanical injury or fire are likely not directly infected by spores, but wounds exacerbate decay in previously infected roots and butts. Infection of Douglas-fir and possibly other species results from direct invasion of root tips.

Douglas-fir and grand fir are tolerant of extensive root infection by the fungus, which can likely persist for decades in dead or cut trees and infect roots of adjacent developing trees. *P. schweinitzii*-killed or windthrown trees often are scattered throughout a stand rather than located in discrete pockets or centers as with Armillaria root disease or laminated root rot. Scattered diseased or decayed trees imply spore infections of roots rather than mycelial spread via root contacts or grafts with adjacent infected trees or stumps. Fresh wounds likely exacerbate decay in previously infected roots and butts, and diseased trees often have pronounced enlarged bases or butt swell.



Managing young forests with potential *P. schweinitzii* infection and decay is challenging because the disease usually shows no above-ground signs. Large residual trees or stumps with typical decay or conks may indicate that young surrounding trees are infected. Concern for infection and mortality of Douglas-fir or spruce regeneration following harvest of older trees is probably unwarranted if the replacement stand is to be harvested in less than 150 years. However, butt rot in older trees will likely be accompanied by considerable root rot. Seed tree or shelterwood prescriptions may result in windthrown leave trees.

Hollows in infected butts created by the fungus can provide good habitat for a variety of animals both in standing trees and in down logs. Infected trees can be retained in thinned or partially harvested stands to enhance wildlife habitat, especially if mostly down wood is desired (Hagle and Filip 2010).

### 12.2.9 Red Ring Rot; White Speck (*Porodaedalea* sp.; formerly *Phellinus pini*)

Red ring rot is a fungal heart rot that causes substantial stem decay in many conifer species including Douglas-fir, Sitka spruce, western hemlock, western redcedar and grand fir, primarily in older stands. Red ring rot can be found throughout the tree stem. Conks are brownish-black and rough on top, often formed at old branch stubs and occasionally on branches. Undersides are cinnamon- brown or gold with irregularly shaped pores. The decay column may extend several feet above or below a conk. Swollen knots filled with fungal tissue called “punk knots” are also common.

Basidiospores are produced on the underside of conks and spread by wind. Decay is initiated by spores entering mainly through branch stubs but also wounds. Incipient decay manifests as a red stain in the heartwood, often forming a well-defined ring, hence the common name red ring rot. Advanced decay results in small, spindle-shaped pockets filled with white fibers with firm wood in between; the wood may have a honeycombed appearance. Time from infection to conk production may be 10-20 years or more.

Decay is compartmentalized within the cylinder of heartwood that was present when the tree was infected. Hollows occur in advanced stages of decay when the cylinder of heartwood is weakened to the point that it collapses inside the tree. Red ring rot and other fungi that decay heartwood in living trees are very important in the formation of hollow trees and logs which are

critical components of habitat for many wildlife species. Woodpeckers, black bears, American martens, Vaux's swifts, bats, flying squirrels, and bushy-tailed woodrats are among the species that use hollow trees for dens, roosts, nests, and foraging sites (Mallams et al. 2010).

Taxonomy of fungi that cause red ring rot has shifted with use of molecular diagnostics and remains somewhat uncertain. Pathogens previously described (from Europe) as *Phellinus pini* are now placed in the genus *Porodaedalea*. Recent evidence suggests that *P. pini* does not occur in North America. Currently recognized are a wide ranging, morphologically variable species (*Porodaedalea piceina*) and another specific to true firs (*Porodaedalea cancriformans*) with tentative evidence of several more species yet to be defined (Brazee and Lindner 2013; Zhou et al. 2016; Worrall 2020).

### 12.2.10 Hemlock Dwarf Mistletoe (*Arceuthobium tsugense*)

Hemlock dwarf mistletoe is a flowering seed plant that parasitizes primarily western hemlock, but also true firs by growing root-like structures directly into branches of host trees to extract nutrients and water. This reduces tree growth, deforms tree form and crown structure, and reduces seed production. Hemlock dwarf mistletoe causes host trees to form dense, multi-branched structures known as witches' brooms, which grow at a faster rate than the rest of the tree, causing reduction in both tree stem diameter growth and height. Ultimately the brooms and mistletoe plants become such a drain on the host tree that both the tree vegetative and reproductive tissues die from the top down. Once the dwarf mistletoe has spread throughout the entire tree crown, it usually takes 10+ years for tree mortality to occur. Growth effects and mortality rates generally increase as site quality decreases. Effects are usually minor until host trees are older than 120 years of age.

Most spread occurs when seeds are cast from berries in infected overstory trees onto susceptible understory trees. When ripe, hydrostatic pressure builds up in the berry until it ruptures at the base, forcibly discharging the seed, occasionally over 15m. However, most seeds fall within 6m of their source. In heavily infested stands, hemlock dwarf mistletoe can significantly reduce wood volume. Infected trees are predisposed to damage from other stressors such as drought and bark beetles. Wildfire risk may increase because of dwarf mistletoe infestations. The large, pendulous brooms usually occur in the lower portion of the

crown and are filled with small twigs and dead needles that provide a fuel ladder for upward spread into tree crowns. Brooms broken off by winter storms accumulate around the base of infected trees and increase the fuels on site.

Despite their impacts on tree growth and survival, there is also increasing recognition of mistletoes as unique biological species and of their roles as functional components of ecosystems. Dwarf mistletoe seeds, shoots and brooms are used in a variety of ways by many animal species. Bird species, including black-capped chickadees, sparrows, ruffed grouse and blue grouse, are reported to eat dwarf mistletoe seeds, and porcupines and squirrels preferentially eat the bark associated with dwarf mistletoe infection. Cavity-nesting birds utilize trees killed by dwarf mistletoe. Witches' brooms provide cover and nesting sites for many different birds, including marbled murrelets, owls, songbirds, and also mammals. Deer and elk use areas beneath trees with very large, dense brooms as resting sites.

Because dwarf mistletoes are parasitic plants that require a living host to survive, clearcutting has been an effective control measure. Clearcutting, large fires, and short rotations have reduced the occurrence of hemlock dwarf mistletoe on much of the ESRF. Long rotations and partial cutting may increase hemlock dwarf mistletoe abundance. (Hoffman 2004, Oregon DSL and ODF 2011, Mellen-McLean et al. 2017).

### 12.2.11 Sudden Oak Death (*Phytophthora ramorum*)

Sudden Oak Death (SOD) is a disease caused by the water mold *Phytophthora ramorum*, an internationally quarantined plant pathogen that is killing tanoaks and infecting a wide array of other native plants in southern Oregon. First detected in Oregon in 2001, *P. ramorum* is thought to have been introduced through infected nursery plants. A plant quarantine was quickly instituted, then gradually expanded and now covers about 515 square miles in Curry County. State and federal agencies attempted to eradicate *P. ramorum* from infested sites by cutting and burning all infected host plants and adjacent uninfected plants. Between 2001 and 2010 eradication treatments were completed on about 3,200 acres of forest at an estimated cost of \$7 million. Despite this effort, the disease continued to expand slowly.

After eradication proved to be impossible, Oregon's SOD program switched to slowing the spread of Sudden Oak

Death. In 2010, a Generally Infested Area (GIA) within the quarantine area was created. Within that zone, where the disease is well established, eradication treatments are no longer required. As of 2020, the GIA covered 123 square miles within the quarantine area. Current control efforts focus on mitigating further spread by early detection and eradication of new infestations outside the GIA.

*P. ramorum* can kill highly susceptible tree species such as tanoak, coast live oak, and California black oak by causing lesions on the main stem. Tanoak is by far the most susceptible species, and the primary host and vector for *P. ramorum* in Oregon. *P. ramorum* also causes leaf blight or shoot dieback on other hosts including rhododendron, evergreen huckleberry, Douglas-fir, and Oregon myrtle. *P. ramorum* thrives in Oregon's cool, wet coastal climate and poses a substantial threat to the ecology of southwest Oregon forests that contain tanoak and other oaks. It spreads during rainy periods when spores produced on infected leaves or twigs are released into the air and are either washed downward or transported in air currents. *P. ramorum* also has a tough resting spore stage, called a chlamydospore, which allows the pathogen to survive harsh conditions for months or years in soil or plant parts.

At this writing, tanoak is not known to occur on the ESRF. Continued research, monitoring, eradication, and regulation to prevent spread on plant and wood products are essential to limiting the impact of SOD. Oregon regulations require a property officially confirmed as infested with the disease to undergo eradication treatments. Oregon's Interagency SOD Program works to slow the spread of SOD in the state by surveying for the disease and treating high-risk, infested sites on the leading edge of the infestation. Infected trees are detected using high-resolution aerial imagery as a part of annual USDA Forest Service/Oregon Department of Forestry Aerial Detection Surveys (Kline et al. 2018).

### 12.2.12 Sitka Spruce Weevil (*Pissodes strobi*)

The Sitka spruce weevil can significantly impact Sitka spruce regeneration in coastal Oregon. The weevil repeatedly infests and kills the leader of the tree and therefore slows growth and produces severe stem deformations. The tree usually survives but with repeated attacks, growth is reduced and the tree becomes crooked or bushy as one or more lateral shoots try to replace the killed terminal growth. The beetles specialize in attacking leaders of exposed, open-growing, vigorous trees from about 3 feet tall (1 meter) to

about 60 feet tall (18 meters). In plantations, trees most susceptible to heavy damage are about 5 to 30 feet tall and planted at low density.

The most severe damage from *P. strobi* occurs 10-25 miles from the coastline, along the eastern edge of the Sitka spruce range. On these eastern sites, it is recommended that other species be planted (e.g., SNC tolerant Douglas-fir, western hemlock, western redcedar, grand fir, red alder). Research suggests that a combination of higher planting densities, use of weevil-resistant seed (e.g., resistant strains from BC, Canada), and careful site selection may reduce the impact of infestations. (ODF 2020, Reeb and Shaw 2015).

### 12.2.13 Spruce Aphid (*Elatobium abietinum*)

The spruce aphid is a sap-sucking insect thought to have been introduced from Europe that has been established in Oregon since the 1920s. This aphid attacks both native and ornamentally planted species of spruce. Infestations cause fading and premature loss of older needles; repeated defoliation can cause some branches or the entire tree to die. Infestations are most severe on large Sitka spruce growing along the coast. In western Oregon, spruce aphids are present on trees year-round. The aphids reproduce asexually and in Oregon there are several generations per year. Aphid populations increase dramatically and can be found on the underside of needles in late February and early March. Aphids feed on the sap in needles, causing yellow patches at the feeding site. Needles fade or turn yellow and from May - June needles turn brown and fall from the tree. When damage is finally apparent aphids have usually already dispersed to other trees.

### 12.2.14 Balsam Woolly Adelgid (*Adelges piceae*)

The balsam woolly adelgid is an invasive species introduced from Europe that has caused significant mortality in true fir species in western forests. The adelgid infests branches and gradually reduces tree growth and vigor, eventually causing tree mortality. In more serious outbreaks, the adelgid attacks the main bole of the tree in large numbers, girdling the tree and causing death in two to three years. On the ESRF, grand fir at elevations lower than 1000' or along streams could be susceptible (Mellen-McLean et al. 2017).

### 12.2.15 Emerald Ash Borer (*Agrilus planipennis*)

The emerald ash borer (EAB) is an invasive species that was introduced to North America in 2002 and has since killed over 100 million ash trees across the U.S. EAB is

now considered the most destructive forest pest in North America. No effective native predators or parasites have been encountered, and, unlike in its native range, EAB aggressively kills both stressed and healthy trees. In June 2022, EAB was discovered in Forest Grove, Oregon, the first confirmation on the West Coast.

The Oregon ash (*Fraxinus latifolia*), an important riparian species in the Coast Range, is highly susceptible to EAB infestation. A widespread outbreak of emerald ash borer in Oregon has the potential to radically alter riparian forests and impact native bird and fish populations. The state is using the Emerald Ash Borer Readiness and Response Plan for Oregon (Bliss-Ketchum et al. 2021) as a guide in its response. While Oregon Ash is not widely present on the Elliott, individual trees or small pockets of ash may exist on parts of the forest including from plantings as part of past restoration projects completed by watershed councils. If Oregon ash is found on the forest during stand-level surveys and further data review, the species will be managed as outlined in Section 12.4.3.

### 12.2.16 Spongy Moth (*Lymantria dispar*)

Spongy moths (formerly gypsy moths) are invasive species whose caterpillars feed on approximately 500 tree and shrub species, including hardwoods and conifers. The European spongy moth – native to temperate forests of Western Europe and introduced to the eastern U.S. in 1869 – has spread to twenty states and four Canadian provinces. The flighted spongy moth complex (*L. dispar asiatica*, *L. dispar japonica*, *L. albescens*, *L. postalba*, and *L. umbrosa*) originate in Asia but are not yet known to be established in the United States. Flighted spongy moth complex females – unlike the European spongy moth – are active fliers. Their ability to fly long distances makes it probable that this moth complex could quickly spread. Washington has had more Asian spongy moth introductions than any state in the U.S (WSDA 2023). Any species of spongy moth would cause long-lasting effects on Oregon's forest ecology and economy if they were to establish in the state.

### 12.2.17 Mammals

All stages of tree regeneration are susceptible to damage from herbivorous mammals in the Oregon Coast Range. Damage to mature trees and non-merchantable species and plant communities can also occur at levels that reduce merchantability or alter plant community composition. Animal damage can reduce stocking, increase susceptibility to disease, increase windthrow and inhibit tree growth.

There are many species of wildlife in the ESRF, but the number of animals causing tree injuries of management concern is relatively small. Mountain beavers, black bear, deer, elk, porcupines, gophers, rabbits, squirrels, American beavers and various other rodents can cause damage to forest trees. Damage from these animals may include clipping, girdling, bark peeling, browse, or other physical damage such as trampling or rubbing.

Animal damage on the ESRF is generally sporadic and occurs in varying severity as animal populations or behaviors and susceptibility of age classes change over time. Most damage is expected to be at levels that are within tolerance of management objectives. Browse or other damage to newly established plantings is likely the biggest concern and protective measures may be necessary. Use of physical barriers, such as protective grow tubes for seedlings, or silvicultural approaches, such as minimizing rodent habitat in regenerated sites, may be employed in situations where there are lower tolerances for damage or higher risk of impacts. The OSU Forestry and Natural Resources Extension Program offers expertise and support for such efforts. Rodenticides will not be used on the ESRF.

## 12.3 Invasive Species

Invasive species, including invasive insects, fish and other animals, invasive plants and noxious weeds, and invasive tree pathogens are a growing problem on Oregon forest lands. Invasive species are capable of causing extinctions of native plants and animals, reducing biodiversity, competing with native organisms for limited resources, altering and degrading habitats, and exacerbating wildfire risks. Sections below provide details regarding invasive species of concern, and how management will address the spread of existing invasive species and seek to minimize the potential for introductions of new invasive species on the ESRF.

### 12.3.1 Invasive Plant Species

Invading non-native plants have significant effects on native biodiversity and forest and watershed management objectives. These plants compete with and can displace native vegetation and can significantly alter food webs and other aspects of forest ecosystems. Some species can exacerbate fuel loading and wildfire risk. Invasive plant species tend to be able to rapidly colonize areas, are pernicious (difficult to remove), and typically form monocultures.

As defined by the State of Oregon, *noxious weeds* are terrestrial, aquatic or marine plants designated by the State Weed Board under ORS 569.615 as among those representing the greatest public menace and as a top priority for action by weed control programs. Depending on the weed classification, managers of state lands are responsible for developing and implementing an eradication plan. Currently, roughly 120 species of noxious weed exist in Oregon. Many occur in state forests; the most common (e.g., Scotch broom, Himalayan blackberry, Canada thistle, bull thistle, Japanese knotweed) are well established there. Other state-listed noxious weeds are expanding in state forests (e.g., false brome, English ivy, garlic mustard, exotic geraniums). Some species not listed can nevertheless impact reforestation and harm wildlife (e.g. foxglove, woodland groundsel, oxeye daisy, English holly) (ODF 2020).

The Oregon Department of Agriculture (ODA) administers the state's Noxious Weed Control Program which focuses on control efforts by implementing early detection and rapid response projects for new invasive noxious weeds, biological control, statewide inventory and survey, assisting the public and cooperators through technology transfer and education, maintaining noxious weed data and maps for priority listed noxious weeds and assisting land managers and cooperators with integrated weed management projects. The program also supports the Oregon State Weed Board (OSWB) with administration of the OSWB Grant Program, developing statewide management objectives, developing weed risk assessments, and maintaining the state noxious weed list. Listed noxious weeds are categorized as "A", "B" or "T", as follows:

**"A" Listed Weed:** A weed of known economic importance which occurs in the state in small enough infestations to make eradication or containment possible; or is not known to occur, but its presence in neighboring states make future occurrence in Oregon seem imminent. *Recommended action:* Infestations subject to eradication or intensive control.

**"B" Listed Weed:** A weed of economic importance which is regionally abundant, but which may have limited distribution in some counties. *Recommended action:* Limited to intensive control at the state, county or regional level as determined on a site specific, case-by-case basis. Where implementation of a fully integrated statewide management plan is not feasible, biological control (when available) shall be the primary control method.



**“T”-Designated Weed:** A designated group of weed species selected from either the A or B list as a focus for prevention and control by the Noxious Weed Control Program. Action against these weeds will receive priority. T-designated noxious weeds are determined by the Oregon State Weed Board and directs ODA to develop and implement a statewide management plan.

Oregon implements biological control, or “biocontrol” as part of its integrated pest management approach to managing noxious weeds. This is the practice of using host-specific natural enemies such as insects or pathogens to control noxious weeds. The ODA Noxious Weed Program has adopted the International Code of Best Practices for biological control of weeds. Only safe, effective, and federally- approved natural enemies will be used for biocontrol.

Previously, ODF conducted weed surveys on the Elliott during flowering seasons for two species (gorse and Scotch broom), mapped sites where these species occurred by Global Positioning System and entered them into an ArcView database. The three introduced species of most concern on the Elliott at that time were Himalaya blackberry, Scotch broom, and gorse (Biosystems et al. 2003).

Himalaya blackberry (*Rubus armeniacus*) is an introduced species of blackberry. It may grow erect, but more frequently clambers and spreads over other plants, crushing and smothering them. It spreads laterally largely through tillering and is transmitted at greater distances from the source plant by birds, bears, and other animals eating the berries and excreting the seeds. The extent and distribution of this species on the Elliott has not been surveyed. Himalaya blackberry on the ESRF generally occurs in areas that were previously homesteaded and subsequently incorporated into the forest. From these source areas, it has spread up ridgelines. It has become a regeneration problem in some plantation areas by smothering newly planted trees. There is limited control of Himalaya blackberry on the forest, with most efforts occurring in harvest units where it is controlled until trees are free to grow. There are opportunities to collaborate on blackberry control and help restore riparian areas on former ranch and agricultural lands that have been incorporated into the Tenmile Region of the Elliott (e.g., along Roberts Creek and Johnson Creek).

Scotch broom (*Cytisus scoparius*) is a member of the pea (legume) family. Scotch broom was introduced into California from Europe as an ornamental in the nineteenth century, subsequently escaped cultivation and moved northward. It is an extremely aggressive weed that invades

non-wooded areas. While most Scotch broom surveys have been conducted by road during the flowering season, its import and spread throughout the forest is considered to have resulted from roads in two ways. First, vehicular traffic spreads seeds that are attached to mud or other parts of the vehicle. Secondly, and perhaps more perniciously, Scotch broom seeds may be incorporated into gravel when plants are adjacent to quarries. This gravel is then carried into and distributed throughout the forest during road construction and maintenance. Seeds of these roadside plants then spread by wind to adjacent areas. Scotch broom was considered the major weed species of concern on the Elliott by ODF staff.

Gorse (*Ulex europaeus*) is another member of the broom family and is a European transplant with vicious spines that otherwise resembles Scotch broom. As of 2003, it was known in three locations on the Elliott. When found, it was aggressively controlled. Gorse is implicated with rapid fire spread during an east wind event that burned Bandon, Oregon on September 27, 1936 (Reilly et al. 2020).

### 12.3.2 Other Invasive Species

As with most native species, detailed information regarding the diversity and extent of invasive animal species on the ESRF is limited.

The American bullfrog (*Rana catesbeiana*) is not known to occur on the ESRF but is expanding its range in Oregon. Native to the central and eastern U.S. the bullfrog was intentionally introduced into western states as a food source and for biological control of insects. Bullfrogs have voracious appetites and will eat anything they can fit into their mouths, including invertebrates, birds, bats, rodents, frogs, newts, lizards, snakes, and turtles. Bullfrog tadpoles mainly eat algae, aquatic plant material, and invertebrates, but they will also eat the tadpoles of other frog species. As a result of these feeding behaviors, all life stages of bullfrogs prey upon and are able to out-compete native frogs and other aquatic species.

The barred owl (*Strix varia*) is native to eastern North America and has been expanding westward for several decades. As an apex predator and fiercely territorial invader, barred owls at high densities have the potential to affect a variety of native wildlife through competition, niche displacement, and predation. Such impacts may be especially problematic for conservation of the federally threatened northern spotted owl including on the ESRF, as described in Chapter 9: *Species Conservation*.

Invasive crayfish can outcompete and displace native crayfish and also impact habitat for other aquatic species. Oregon has three species of invasive crayfish, the rusty crayfish (*Orconectes rusticus*), red swamp crayfish (*Procambarus clarkii*), and northern ringed crayfish (*Orconectes neglectus*). The status of these species on the ESRF is not known.

### 12.3.3 Best Practices for Minimizing Introduction and Spread of Invasive Species on the ESRF

The most common way for new invasive species or noxious weeds to be introduced to a forested area is through recreation, logging equipment, or worker transportation. With climate change and human activity on the ESRF, new invasive and noxious weed threats are likely to be introduced, which could have long-term negative impacts.

Because operational activity has the potential to exacerbate the impacts of noxious weeds, ESRF managers will consider the extent and composition of noxious weed communities in all operational planning areas. Formal survey or simple observation and assessment will be used to determine which weeds are present, which treatments may be appropriate, and how to reduce the potential for spread. Surveying and management of invasive plants and noxious weeds independent of other operations may be appropriate if the risk of damaging or diminishing ecological or economic values is unacceptable.

Best management practices are established to limit presence and minimize the impacts of noxious weeds and invasive species on the ESRF as follows:

- 1. Require all equipment be clean and free of soil, debris and plant matter prior to entering the property.** Heavy equipment used in logging, road building and other forest management activities frequently travels across ownerships, forest types and even regions. The accumulation of soil and plant matter that occurs on the equipment, especially during wet season ground-based operations, provides an effective vector for relocation of seed from one project site to another.
- 2. Develop standards and practices for workers, researchers, visitors and staff traveling and working in weed infested areas and across watersheds.** Humans are a primary vector for many invasive species and noxious weeds especially in forested settings where travel may occur

cross-country on foot or via road systems that harbor weed seed banks. Establishing standards for cleaning of vehicles, boots, waders, power saws, research equipment, hand tools or other tools and instruments will help maintain awareness of noxious weeds as well as reduce their spread associated with routine management and research.

**3. Discourage and monitor dump sites.** Illegal or unauthorized dumping of household debris often contains yard waste that may include noxious weeds such as English ivy, Japanese knotweed or others that are able to reproduce vegetatively or from viable seed crops. This can lead to establishment and spread of weeds spreading from the dump site into the surrounding forest.

**4. Maintain slash cover in clearcut and variable retention (VR) treatments to favor native shrub species.** A moderate to heavy slash load in recently disturbed sites such as clearcuts and variable retention harvest units provides a number of benefits to reforestation efforts, including increased soil moisture, decreased need for herbicide, and a barrier to the establishment of noxious weeds (Harrington et al. 2018). Maintaining slash will discourage weeds such as Scotch broom.

**5. Pre-treat areas to avoid mobilizing a seed bank.** Spread of noxious weeds such as false brome that have high seed production but short-lived seed viability can be controlled by pre-treating operation areas with herbicide prior to annual seed maturation. This approach reduces the overall volume of viable seed that may be moved throughout the operation area during harvest or other management activities.

**6. Use targeted roadside spray to reduce roadside weed populations.** Many of the noxious weeds present on the ESRF (Himalaya blackberry, Scotch broom, gorse) either require or thrive in high light conditions, such as roadsides or landings. The use of strategic, targeted roadside herbicide application can reduce these populations and spread of weeds throughout road systems.

**7. Incorporate site specific noxious weed survey and assessment prior to operations and employ appropriate measures for reducing spread.** Soil disturbance and changes in available resources (light, moisture, growing space) associated with stand treatments and road maintenance activities can benefit noxious weeds. Knowing what weeds are present in areas planned for treatment allows managers to anticipate potential outbreaks and take appropriate actions prior to disturbance or plan

for treatment after disturbance. Monitoring of noxious weeds may integrate with biodiversity or forest inventory monitoring (See Chapter 10: *Monitoring*).

**8. Use weed-free straw or hay for mulching:** The Oregon Department of Agriculture (ODA) manages a Weed Free Forage & Gravel Program as part of an integrated weed management approach to help limit the spread of noxious weeds. Certified weed free straw can be purchased if straw is needed for mulching associated with soil disturbing activities such as road decommissioning.

**9. Consider all available tools for control and develop treatment prescriptions based on site conditions, resource values and associated risk.** Manual and mechanical removal methods may be appropriate and effective in some instances. Herbicides are generally most reliable and effective in controlling noxious weeds. Prescriptions for control of noxious weeds should be site-specific and consider trade-offs associated with impacts to native plant communities resulting from the range of actions, from no-action to aggressive chemical application.

## 12.4 Forest Health and Resilience on the Elliott State Research Forest

This section covers indicators of forest health and resilience, current conditions, and how forest health and resilience will be described, assessed, improved and maintained across the different land allocations and research treatments on the ESRF.

### 12.4.1 Forest Health Indicators

Scientists and managers assess conditions in forests by tracking a range of health and resilience *indicators* – physical, ecological and other measurable parameters that help them detect meaningful changes. Trumbore et al. (2015) echo Kolb et al. (1994) by distinguishing a set of primarily *utilitarian* indicators (e.g., tree diseases, tree damage, tree growth rate, wood yield and supply, leaf area, drinking water quality, esthetic appearance, carbon storage) and *ecosystem* indicators (e.g., dead wood, disease resistance, genetic variability, habitat quality, community structure, soil quality, seral stage diversity, connectivity, patchiness, persistence, invasive species).

The USFS Forest Inventory and Analysis (FIA) Program monitors a smaller set of indicators across the U.S. using standardized protocols on an established network of FIA plots. While these indicators are applicable across the entire ESRF, interpretation of the health of a particular stand will vary according to land allocation, management context and goals for the stand. Indicators that may be useful and relevant to the ESRF include:

- **Crown condition:** The amount, condition, and distribution of foliage, branches, and growing tips of trees. Healthy, full crowns suggest carbon is being stored, the tree is growing, and there are no serious impacts from pathogens, air pollutants, or insects. Components measured are live crown ratio and crown dieback.
- **Tree damage:** The presence and type of damages from various causes. Allows for earlier identification of forest health problems, as collection will happen before tree mortality or stand-level effects are reached. On each tree, up to three damages may be selected from 24 categories derived from a list used by USFS forest health programs. Examples include “boring insects,” “root/butt diseases,” “wild animals,” and “unknown damage.”
- **Tree mortality and standing dead trees:** The number, size, and volume of trees that have died since the previous measurement. These measurements are also collected on new plots. Provides information on whether changes in abiotic or biotic stressors or stand development are creating conditions less favorable for tree growth and survival.
- **Down woody materials:** The amount and condition of dead and downed woody material, delineated as detrital components of forest ecosystems, including fallen twigs and small branches (fine woody debris, < 3” diameter) and fallen tree stems and large branches (coarse woody debris, > 3” diameter).
- **Vegetation profile:** assesses all vascular vegetation to record the arrangement of trees, shrubs, forbs and grasses. Additional levels provide data about the most abundant species in each growth habit; up to four species of large grasses, forbs, shrubs, small trees (< 5” diameter) and large trees with canopy cover of at least 3% of subplot area.
- **Soil quality:** Bulk density, soil texture, forest floor thickness, depth to any restrictive horizons, and compaction. Lab analyses: soil pH; carbon, nitrogen and phosphorus content; and extractable levels of major cations (sodium, potassium, calcium, magnesium, and

aluminum) and sulfur along with several micronutrients. While some of this data collection and analysis is part of the ESRF monitoring plan, quantification of other soil metrics may be part of specific research projects or dependent on additional funding.

- **Invasive plant species:** Percent cover and presence of select invasives, determined based on identification as being of regional concern on forested landscapes. Data provide information about invasive species presence, spread, and changing growing conditions to track the abundance and risk of these species in forests.
- **Regeneration and browse impact:** Assesses stresses on healthy young forest that will replace older forests as stand-initiation events occur. Tracks all established seedlings down to 2-inches tall and plot-level browse impacts.
- **Fragmentation and landscape context:** Forest patch size, degree of forest connectivity, local forest density), amount of interior or core forest, amount and type of forest edge. Landscape context indicators, such as landscape pattern type, describe local land cover around forest land and proportion that is natural, agricultural, or developed. On the ESRF the LiDAR inventory, HSI analysis, and modeling could be used to track fragmentation and connectivity.

Monitoring of forest health and resilience parameters on the ESRF can provide managers and researchers with valuable information regarding the roles and impacts of disturbance agents as well as management direction at the stand and subwatershed level. Forest health indicators may also be useful in tracking effects of climate change.

Forest health monitoring is not currently established as a formal research or monitoring effort. The FIA forest health indicators provide a framework for assessing the health of a stand or landscape, but there is no current intent to mimic FIA plot measurements for these indicators across the ESRF. Planned baseline and ongoing monitoring efforts (see Chapter 10: *Monitoring*) will likely produce data that are relevant to the indicators that can be compiled and leveraged to assess forest health and resilience management implications in the near term, and perhaps over time provide a foundation for more formal forest resilience monitoring and integrated assessment of climate change effects. Operational forest inventory measurements will also contribute to monitoring efforts and information relevant to forest health and resilience indicators, but in general would not have the same intensity or precision as data collected by other monitoring efforts.

Forest inventory and carbon monitoring, and biodiversity monitoring are two programs that will likely provide

**Table 12.1.** Forest health indicators, sources of monitoring information, and measured features

Forest Health Indicator	Relevant Monitoring Program/Activity	Measured Features
Crown condition	Forest Inventory and Carbon	live crown ratio, needle retention
Tree damage	Forest Inventory and Carbon	pest/pathogen impacts, storm damage, defect type
Tree mortality	Forest Inventory and Carbon	snags; change over time on permanent plots
Down woody materials	Forest Inventory and Carbon; Biodiversity	down wood, decay class, litterfall
Vegetation profile	Forest Inventory and Carbon	species composition, percent cover
Soil quality	Forest Inventory and Carbon; Biodiversity	soil morphology and carbon; soil microbial diversity and fauna, soil fungi
Invasive plant species	Forest Inventory, Biodiversity, Roads Monitoring, Operational Inventory	species, percent cover
Regeneration and browse impact	Forest Inventory and Carbon	stocking; browse severity; mortality rates



baseline and ongoing data that can support assessment of many forest health indicators. As the monitoring programs are further refined and sampling designs established, managers should provide input, if possible, to ensure they address forest health indicators by identifying gaps in necessary measured features. Other monitoring programs or research efforts under the broad ESRF research platform may also produce data that is useful and pertinent to forest health and resilience. If gaps are identified where no data exists to support a forest indicator, dedicated sampling may be necessary for monitoring purposes.

Interpretation of forest health and resilience indicators and the measured features relative to forest health will be based on land allocation and management context. How outputs or results are applied operationally will be up to the forest manager depending on objectives at the stand or subwatershed level.

### 12.4.2 Current Conditions

While it is reasonable to assume the biotic and abiotic factors listed above are all present on the ESRF at some baseline level, there is a lack of recent, robust monitoring data available to support firm conclusions regarding the presence, extent, or role of these disturbance factors.

The most recent assessment of forest health completed in 2011 by ODF supports current anecdotal observations indicating little evidence of major forest pest outbreaks, moderate levels of SNC, stable or infrequent levels of disease-induced mortality, and few insect problems in the mid to late-seral Douglas-fir forests. The forest appears intact, generally vigorous and stable, similar to other stands of comparable age and structure on the surrounding Coast Range landscape.

As management and research needs increase the monitoring and assessment of forest conditions over the coming years, forest health concerns may become apparent. However, defining a healthy forest based on resource values and management status will result in a range of acceptable conditions or thresholds across the ESRF.

### 12.4.3 Maintaining and Improving Forest Resilience on the ESRF to Meet Diverse Objectives

General descriptions of forest health and resilience concepts encompassing a spectrum of ecological and utilitarian

considerations are summarized in the introduction to this chapter. To apply these concepts at the stand level, managers must have well-defined objectives and a clear sense of the relative importance of resource values for that stand. Consideration must also be given to the tolerance or role of native and non-native biotic agents, and the natural ranges of variability of abiotic events. On the ESRF, this guidance is provided by the land management allocations and intent of management within the subwatersheds, described in detail in Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, and Chapter 7: *Aquatic and Riparian Systems*.

Sections below link this guidance with a more specific set of potential management actions related to maintaining and improving forest health and resilience in response to various forest disturbances, as appropriate for the particular stand. Some actions would apply forest-wide on the ESRF while others are tailored as appropriate for application in one or more of the intensive, extensive, reserve or RCA land allocations and research treatments. Description of specific actions and implementation, including identification of priorities for invasive weed control, animal damage control, fire risk abatement, and other opportunities or needs will be detailed in biennial operations plans.

#### 12.4.3.1 Commonalities In Approaches To Forest Health on the ESRF

Certain aspects of disturbance and forest health and resilience will be addressed with a consistent approach across the entire ESRF. This would be the case when a disturbance agent has a similar potential, regardless of land allocation, to disrupt or conflict with stand management objectives and the long-term functioning of the processes, organisms and trophic networks that constitute the stand. Wildfire is perhaps the best example of such a case.

Wildfire is a keystone disturbance process in forests, with a primary role in resetting and modifying stand structure, habitat, and species diversity across a range of spatial and temporal scales. However, wildfire can also fundamentally and broadly impact forest ecosystem services and values (e.g., water quality, fish and wildlife habitat, carbon sequestration, wood fiber supply, recreation) for decades after a fire occurs. With abundant, relatively continuous fuel and the potential for very dry fuel conditions occurring more frequently on the ESRF due to warmer, longer summers, a large, extremely intense wildfire is plausible on the forest and likely to become more plausible in coming decades

(McEvoy et al. 2020). Therefore, to the degree practicable, wildfire will be actively suppressed on all areas of the ESRF, in coordination with the Douglas Forest Protective Association and state and federal agencies.

Any confirmed infestation of invasive emerald ash borer or spongy moth, should one occur, would be treated as quickly and aggressively as possible, with the goal of rapid and complete eradication accompanied by active follow up monitoring. All confirmed infestations of Oregon Weed Control Board designated Class “T” weeds identified on the ESRF will be actively treated, with the goal of complete eradication, as stipulated by state law.

The types of actions taken to reduce, minimize or eliminate hydrologic connectivity and sediment inputs from forest roads to streams will be generally consistent across the entire ESRF.

In general, evaluations of disturbances on the ESRF must determine what level of change indicates a significant forest health trend within the context of normal and historical variability. In cases where a decision is made to actively intervene, restoring or maintaining forest health is usually accomplished through silvicultural manipulation of the forest at the stand or subwatershed scale to keep damage from native pests to acceptable levels. Non-native or invasive species often require special measures such as eradication, quarantine, or direct suppression.

#### **12.4.3.2 Forest Health and Intensive Research Treatments**

Approaches to forest health within subwatersheds receiving intensive research treatments are likely to approximate “utilitarian” descriptions of forest health, i.e., active mitigation and suppression of tree-damaging forest insects and pathogens to the degree practicable in order to optimize crop tree growth. Tenets of Integrated Pest Management (IPM) will be followed focusing on using creative techniques and strategies to decrease dependence on pesticides as the main tool for battling insects, weeds and plant diseases. This includes an explicit focus on identifying and researching alternatives that are viable in an intensive forestry context.

Salvage harvest will be allowed in MRW intensive stands, including using an experimental approach to study outcomes. Any salvage operations undertaken will consider the biological legacy of the stand prior to the disturbance event, and tree retention standards will be developed to support the maintenance of these legacy characteristics.

#### **12.4.3.3 Forest Health and Extensive Research Treatments**

Subwatersheds designated as extensive research treatment areas will be subject to management that mimics and preserves landscape processes, such as maintenance of legacy structures, promoting a range of age cohorts and maintaining and encouraging multiple species. Under this approach, a more ecosystem focused perspective to forest health is appropriate. Mortality resulting from various disturbance agents can be considered part of the stand structure when designing extensive treatments and a tolerance for disturbance will be higher than in intensive treatments.

Impacts of disturbance will be managed, and salvage harvest will be allowed in MRW extensive stands, including using an experimental approach to study outcomes. Any salvage operations undertaken will consider the biological legacy of the stand prior to the disturbance event (Palik et al. 2021) and the structural goals defined in the Extensive Silviculture approach outlined in Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*. Tree retention standards will be developed to support the maintenance of these legacy characteristics.

Under the longer (100-year average) return intervals in Extensive research treatments, native tree insects and diseases can be expected to infest a percentage of trees, which could then decline and eventually die to become snags. This will provide opportunities to increase diversity in stand structure and wildlife habitat during harvests by leaving such trees in place. With this goal in mind, infestations of tree diseases and insects, when detected, would be assessed in reference to best available information on historic range of variability (Keane et al. 2009) and degree of impact or benefit in the rest of the stand and management watershed, as a basis for decision making on whether active control would be warranted.

The default management strategy for infestations of non-native insects and pathogens would be to assess the level of risk they pose then actively treat and mitigate for them accordingly.

#### **12.4.3.4 Forest Health and Reserves**

Approaches to forest health in the CRW and MRW reserve stands will approximate the ecosystem perspective described by Kolb et al. (1994), focused primarily on restoring and maintaining native biodiversity, processes, and structural components. In most cases, natural/native disturbance agents (except for wildfire) would be

allowed to operate within their natural or historic range of variability (Keane et al. 2009), without active management intervention. Possible exceptions, where active control measures may be implemented, could include serious, direct threats posed by disturbance agents to key habitat components for ESA listed species covered under the ESRF HCP – the northwestern spotted owl, marbled murrelet, and coho salmon. Any such interventions would only be considered, designed and implemented after consultation with, and approval from NOAA-USFWS under guidance in the ESRF HCP.

Active restoration thinning treatments are planned for existing even-aged Douglas-fir plantations in reserve areas, with the goal of improving the status of ecological forest health indicators listed by Trumbore et al. (2015), including habitat quality, seral stage diversity, and community structure and patchiness, as described in Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.4.1.

Salvage harvest operations will not be conducted in reserves (CRW and MRW Reserve stands) in response to impacts from natural disturbance agents, with the following exceptions consistent with the ESRF HCP:

- Limited roadside tree removal needed to maintain public access and forest operations.
- Selective removal of cedar trees for indigenous cultural practices (See ESRF HCP Section 3.8, *Indigenous Cultural Use of Cedar Trees*).
- If an introduced, non-native insect or disease is found and removal of dead trees can aid in control. Depending on outcomes of risk assessment and review of management options, invasive forest pests and pathogens may be actively managed in reserve stands with treatments appropriate and tailored for the stand.

#### 12.4.3.5 Forest Health and Aquatic and Riparian areas, including Riparian Conservation Areas

Riparian areas – transition zones between fully terrestrial and fully aquatic systems – are complex, dynamic ecosystems that can be hotspots of biological diversity and biogeochemical processes. While relatively limited in areal extent compared to forest uplands, riparian areas are extraordinarily important because of their critical roles in maintaining aquatic and terrestrial habitats, biodiversity, and water quality. Functionally, riparian areas extend down into groundwater, up above the canopy, laterally into the terrestrial ecosystem and along the stream at variable width

(Ilhardt et al. 2000; Holmes et al. 2011). Managerially, riparian areas are usually defined by fixed width buffers which are less than ideal from an ecological perspective but straightforward to administer (Richardson et al. 2012). See Chapter 7: *Aquatic and Riparian Systems* for a description of ESRF Riparian Conservation Areas (RCAs).

Riparian areas on the ESRF encompass a considerable amount of forest and support the health of freshwater ecosystems by preventing excessive stream bank erosion, maintaining channel structure, shading streams, providing allochthonous energy subsidies and supplying large wood from riparian trees. Stream and riparian systems are strongly linked by cross-ecosystem subsidies of resources flowing in both directions and other processes that make it impossible to consider each subsystem in isolation (Richardson et al. 2010).

The terms *riparian health* and *stream health* are widely used in reference to the ecological integrity of stream systems. As with forest health, these terms are subjective and lack precision. In the context of the ESRF and its aquatic ecosystems, “healthy” streams are considered to be those with the capacity to (1) support native fish and macroinvertebrate populations, (2) maintain ecological and cultural integrity, including whole ecosystem functions, and, (3) maintain historic natural geomorphic processes that provide complex habitat and resilience in the abiotic conditions of the system to natural and anthropogenic disturbances. Thus, a range of indicators and processes are used to objectively assess the health, resilience and restoration needs of streams and riparian areas. Water quality monitoring parameters include dissolved oxygen, temperature, turbidity, and stream chemistry (See Chapter 10: *Monitoring*).

In addition to measuring abiotic features such as habitat or water quality, aquatic organisms that are sensitive to different kinds of disturbance – including amphibians (Welsh and Hodgson 2008), aquatic macroinvertebrate communities, and salmonid fish species – are also often used as *biological indicators* of stream health. The ESRF will focus aquatic biological monitoring on salmonid fish in the streams and amphibians in stream and riparian complexes, with more extensive assessments of aquatic macroinvertebrates, other fish and ecosystem processes in association with targeted research experiments.

The integrity of water quality and aquatic and riparian biological communities rests on a foundation of intact and functional physical processes occurring on a stream. Gregory (2000) defines healthy riparian areas as “naturally

functioning landscapes that function much as they would have without intensive land use and land conversion over the last two hundred years.” (p. 53.) Working from this premise, the *Proper Functioning Condition* (PFC) assessment method was created to evaluate these foundational physical processes- primarily the interactions of hydrology, stabilizing vegetation, and geomorphology (Dickard et al. 2015). A riparian area is said to be in PFC when adequate vegetation, landform, or woody material are present to:

- Dissipate stream energy associated with high waterflow, thereby reducing erosion and improving water quality.
- Capture sediment and aid floodplain development.
- Improve floodwater retention and ground-water recharge.
- Develop root masses that stabilize streambanks against erosion.
- Maintain channel characteristics.

Goals for riparian areas on the ESRF, including RCAs, are focused on the maintenance and restoration of ecosystem functions and geomorphic processes in aquatic/riparian ecosystems that are consistent with historic conditions in this region, and which support populations of native salmonids and other fish, and aquatic and riparian associated biota while providing opportunities for production of other ecosystem services such as clean water and recreation, and in selected adjacent stands, commercial wood fiber.

Proper function in some ESRF riparian areas and streams, particularly in reaches of the WF Millicoma River, has been compromised by past management practices such as historic forest clearing to the water’s edge, and removal of large wood by stream cleaning and splash damming, which led to loss of existing sediment and reduced capacity to retain sediment in the future (Biosystems et al. 2003). Before being removed, large wood attenuated current velocities, retained sediment, provided resting and cover areas for fish, and substrates for aquatic biofilms and invertebrates that fish and other animals feed on (Wohl et al. 2016).

Historic large-scale wood removal, log drives, and splash damming also negatively impacted stream health (as defined above) because the loss of wood and other large roughness elements in the stream led to loss of sediment and this sediment is critical to stream ecosystem function and thermal refugia for aquatic biota. Along many streams in the ESRF, sediment loss has been extreme and the river has scoured down to bedrock. In these areas with no or very little sediment, the stream loses its *hyporheic zone*. The hyporheic

zone is an area along the stream corridor where water moves into and through sediments and gravels adjacent to and below the channel and then back to the stream.

The hyporheic zone, where surface water and groundwater mix, is critically important in moderating stream temperatures, nutrient cycling, and providing unique habitats, especially for macroinvertebrates (USDA Forest Service 2023c). Hyporheic zones contribute to lower temperatures in many rivers, creating a longitudinal heterogeneous array of thermal refugia for fish and other aquatic organisms (Faulkner et al. 2020). In substantial reaches of the WF Millicoma River within the ESRF, the channel is now a bedrock streambed, incised into adjacent banks and disconnected from the floodplain, without hyporheic flow. The WF Millicoma River is a 303D-listed waterway, meaning it has a water quality impairment, in this case for temperatures that seasonally exceed those optimum for salmonids. Loss of hyporheic flow resulting from removal of large wood and the sediment it retains is likely a factor in this impairment and may be the dominant cause.

The distinct and diverse vegetation that characterizes riparian areas distinguishes them from upland habitats. Ecosystem function and biodiversity in riparian areas can be improved on the ESRF by intentionally incorporating understory plant communities into forest management (Hagar et al. 2012). As described in Chapter 7: *Aquatic and Riparian Systems*, structural diversity and plant community composition of riparian areas along a number of streams on the ESRF have been degraded as a result of historic timber harvesting to stream edges, and subsequent replacement of structurally and species-diverse riparian vegetation with Douglas-fir plantations or dense stands of hardwoods without a significant conifer component. In both cases, current riparian vegetation communities in these harvest areas have departed from historic conditions which, while spatially and temporally variable, were typically a mixture of conifer and hardwood tree species with complex canopy structure and highly diverse understories, especially near stream margins. Restoring stand structural complexity, and shifting the successional trajectory of these highly altered and simplified riparian stands to more closely emulate conditions prior to initial harvest is a key goal of research and restoration treatments planned for RCAs.

The simplification of streams and riparian forests is a common issue impacting the health and function of streams across the Pacific Northwest. Restoration, rehabilitation and actions that set a system on a trajectory of recovery



toward better stream health are therefore important to improving stream health throughout the region. As an experimental forest, the ESRF is a system in which research can be conducted to assess the effectiveness of established restoration techniques such as in-stream wood addition and also to explore novel restoration techniques that encompass the whole stream-riparian corridor as an integrated system.

Efforts to improve the health of ESRF streams and their riparian areas will involve an integrated and holistic approach consisting of monitoring to understand baseline conditions and track changes, protections for RCAs, and novel treatments designed to shift development of riparian conifer plantations and hardwood thickets toward conditions more likely to promote proper function, resilience and biodiversity. Large wood placements within stream channels, which increase sediment storage capacity and help restore hyporheic flow, have been completed in several drainages and additional such projects have been prioritized for the future (CoosWA 2015). Ongoing research is expected to yield fundamentally important, management-relevant insights from these actions. See Chapter 7: *Aquatic and Riparian Systems*, and Chapter 10: *Monitoring* for additional details on these restoration and monitoring actions.

Salvage harvest operations will not be conducted in Riparian Conservation Areas (RCAs) in response to impacts from natural disturbance agents, with the following exceptions consistent with the ESRF HCP:

- Limited roadside tree removal needed to maintain public access and forest operations.
- Selective removal of cedar trees for indigenous cultural practices (see ESRF HCP Section 3.8, *Indigenous Cultural Use of Cedar Trees*).
- If an introduced, non-native insect or disease is found and removal of dead trees can aid in control. Depending on outcomes of risk assessment and review of management options, invasive forest pests and pathogens may be actively managed in RCA stands with treatments appropriate and tailored for the stand.

### 12.4.3.6 Stand Level Responses to Disturbance Agents

Stand-level responses to disturbance agents will be determined by forest managers within the context of the land use allocation and the ESRF HCP. These decisions will also be based on stand attributes, severity of the disturbance, operational and economic considerations and research opportunities. General approaches to various disturbances within each land use allocation are summarized in Tables 12.2 and 12.3 below. For additional discussion of silvicultural approaches to disturbance agents, see Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*.

### 12.4.4 Forest Disturbance and Climate Change

The ESRF is being established against a backdrop of increasingly urgent concerns about changes in the PNW attributed to climate warming. The future health and resilience of regional forests is of particular concern, especially east of the Cascade crest where high fuel loadings, drought stress and tree pathogens interact in uncharacteristically severe wildfires, posing widespread, near-term threats. With abundant precipitation and a generally mild climate, coastal forests such as the ESRF are commonly assumed to be at lower risk of serious climate change impacts. In some instances, trees may benefit from elevated CO<sub>2</sub>, warmer temperatures and increased water-use efficiency. Trees can also compensate to some degree via physiological, morphological, and genetic mechanisms. Compared to drier inland areas, some projections suggest that wetter coastal forests may be more resilient under climate change, as a result of longer wildfire return intervals and moderating climate influence from the Pacific Ocean (e.g., Buotte et al. 2019).

**Table 12.2.** Stand-level responses to *biotic* disturbance agents based on land use allocation

Biotic Disturbance Agent	Land Use Allocation			
	Intensive	Extensive	Reserves	Riparian and RCA
Swiss needle cast	Maintain crown depth, individual tree vigor through silvicultural treatments. Consider growth impacts when determining rotation lengths; consider species composition and role of non-host species.	Maintain crown depth, individual tree vigor through silvicultural treatments. Promote mixed species stands including non-host species.	Accept baseline levels as part of the functional ecosystem.	
Sudden oak death	Implement aggressive control tactics with goal of eradication in all instances. Follow ODA and ODF guidelines.			
Other native fungal pathogens, root and stem rots	Select against affected trees during intermediate treatments. Consider impacts on rotation length and log quality when scheduling harvests. Consider converting to resistant or non-host species in high impact areas to decrease long-term impacts on site yields. Conduct salvage operations when economically viable.	Maintain mixed species stands to allow endemic levels of pathogen while minimizing risk of catastrophic outbreaks. Consider role of natural mortality in meeting structural and ecological objectives. Consider salvage when mortality or vigor is such that stand management goals cannot be met.	Accept pathogens as an important part of the functional ecosystem. Monitor impacts on surrounding managed stands.	
Class "T" weeds (currently gorse only)	Treat all instances aggressively with goal of eradication. Implement best practices as described in Section 12.3.			
Other invasive weeds	Prioritize treatment of species deemed highest impact that may be contained or locally eradicated (e.g.: Japanese knotweed). Implement best practices, including pre-operation assessment and treatments, as described in Section 12.3.		Weigh impacts of treatment vs no treatment on priority resources, respond accordingly. Implement best practices as described in Section 12.3.	
Emerald Ash Borer and Spongy Moth	Aggressive treatment with intent to eradicate using methods appropriate to risk and resource impact. Follow guidelines from ODA and ODF. Consider non-host alternatives for replacement of host species.			
Native beetles, weevils and other native insects	Accept insect damage at modest levels that have immaterial impacts on growth and yield; design silvicultural treatments to mitigate impacts on stand growth and vigor; consider impacts on rotation length and log quality when scheduling harvests. Consider planting resistant or non-host species in high impact areas to decrease long-term impacts on site yields. Conduct salvage operations following outbreaks to minimize impacts and capture value.		Accept native insects as an important part of functional ecosystem. Monitor impacts on surrounding managed stands.	

**Table 12.3.** Stand-level responses to *abiotic* disturbance agents based on land use allocation

Abiotic Disturbance Agent	Land Use Allocation			
	Intensive	Extensive	Reserves	Riparian and RCA
Wildfire	Suppress wildfire; assess economic viability of salvage, implement if economically viable or important for minimizing potential for pest and pathogen outbreak; rehabilitate site as appropriate, including mitigation, site preparation and planting.		Suppress wildfire; no salvage, replant if necessary to supplement natural regeneration, no intensive site preparation.	
Wind and Windthrow	Design silvicultural treatments to minimize susceptibility to windthrow events unless windfirmness objectives conflict with goals of research; assess economic viability of salvage, implement salvage operation if economically viable or important for minimizing pest and pathogen outbreak.		Accept windthrow as a natural disturbance agent contributing to structure and character of reserve and riparian forests; no salvage; consider supplemental planting for restoration if scale warrants it.	
Mass Wasting	Design silvicultural treatments to minimize potential for triggering mass wasting events unless retention and treatment patterns on the management unit is explicitly stated as an objective of research; design and maintain roads using BMPs for minimizing contribution to potential for mass wasting events.		Accept mass wasting as a natural disturbance agent contributing to structure and character of reserve and riparian forests; events triggered by roads may be an exception and warrant mitigation.	
Drought and Heat	Utilize silvicultural approaches to maintain species mix and tree vigor to mitigate for potential increases in occurrence and severity of drought and heat events; consider adjustments to seed zone assignments; assess economic viability of salvage if events lead to mortality events, implement salvage operation if economically viable or important for minimizing pest and pathogen outbreak.		Monitor resilience to drought and heat events and assess need for restoration activities if impacts exceed acceptable levels for functional ecological processes; no salvage.	
Ice and Snow Events	Design silvicultural treatments to encourage height-diameter ratio and crown structure that is resilient to ice and snow events; assess economic viability of salvage, implement salvage operation if economically viable or important for minimizing pest and pathogen outbreak.		Accept events as a natural disturbance agent contributing to structure and character of reserve and riparian forests; no salvage; consider restoration planting if scale and circumstance warrants it.	
Atmospheric Rivers, Extreme Precipitation and Flooding	Monitor storm events and impacts on stand structure and road system and potential to trigger mass wasting events.			

However, despite some potentially mediating factors, there are increasing indications that Oregon's coastal forests are not immune to serious climate change impacts. Recent studies document rising background mortality rates across many types of western forests, and more rapid mortality under hotter drought due to negative tree physiological responses and accelerated biotic attacks. Drought in the west is projected to continue to increase in frequency, intensity, and duration and current vegetation models do not inadequately represent tree mortality processes and hydraulic tipping points under moisture stress. Since early 2020, much of the Douglas and Coos County area has been in some stage of drought and in severe or extreme drought for extended periods (U.S. Drought Monitor 2023). The summer dry season in Oregon is becoming warmer and longer. To date, tree mortality and forest die-off have been most severe in more arid forests. But as temperatures continue to rise, temperate coastal forests are likely to be increasingly vulnerable during hotter droughts (Millar and Stephenson 2015, Allen et al. 2015).

Temperature in Oregon is projected to increase on average by 5°F by the 2050s and 8.2°F by the 2080s, with the greatest seasonal increases in summer (Dalton et al. 2021). But rather than a gradually changing average climate, it is high variability of climate extremes that will drive most ecosystem responses to climate-mitigated disturbance and plant dynamics (Keane et al. 2009). A sobering example of this occurred in June 2021, when the PNW experienced one of the most extreme heat waves ever recorded globally (Thompson et al. 2022) resulting in rapid and widespread crown damage in older trees and extensive mortality in younger stands. There are indications that Douglas-fir forests are in a decline spiral in the drier Klamath region to the south and east of the ESRF (Bennett et al. 2023). Climate change impacts in Douglas-fir and western hemlock forest types such as those on the ESRF are likely already occurring. In light of available evidence, it seems reasonable to expect that such stresses will accelerate with further warming.

Many facets of forest health and resilience in the CRW, MRW and RCA allocations are likely to be affected as climate change unfolds. These changes may be characterized as *direct effects* (e.g., effects of CO<sub>2</sub> and climate on tree physiology) or *indirect effects* (e.g., disturbance processes). Fundamental to management on the ESRF will be anticipating, preparing, and adaptively learning as climate change manifests across the forest's stands and habitats. A critical aspect of the ESRF mission is to rigorously monitor, research, analyze and better understand how Coast Range forests respond and can be managed for resiliency in the face of climate change.

There is general recognition that hotter, drier conditions regionally are leading to forest decline, increased susceptibility to pathogens and higher risk of dieoff. But much remains to be learned about how disturbance regimes shift and interact in coastal forests, thresholds beyond which trees cannot recover or species shifts occur, and best management strategies under increasingly novel conditions. The ESRF is an ideal testing ground for a broad range of research on climate resilience and forests including ecological forestry and silviculture, process-based forest carbon and growth models, and opportunities to mitigate climate risks and impacts.



## Appendix A. References Cited

81 FR 90780. 2016. Endangered and Threatened Species; Recovery Plan for Oregon Coast Coho Salmon ESU. Federal Register notice of adoption of final plan. National Marine Fisheries Service, National Oceanic and Atmospheric Administration.  
<https://www.federalregister.gov/documents/2016/12/15/2016-30126/endangered-and-threatened-species-recovery-plan-for-oregon-coast-coho-salmon-esu>

Abatzoglou, J.T. 2013. Development of gridded surface meteorological data for ecological applications and modeling. *International Journal of Climatology*, 33(1), pp.121-131.

Abrams, J., Greiner, M., Schultz, C., Evans, A. and Huber-Stearns, H. 2021. Can forest managers plan for resilient landscapes? Lessons from the United States national forest plan revision process. *Environmental Management*, 67, pp.574-588.

Adams, H.D., Zeppel, M.J., Anderegg, W.R., Hartmann, H., Landhäusser, S.M., Tissue, D.T., Huxman, T.E., Hudson, P.J., Franz, T.E., Allen, C.D. and Anderegg, L.D. 2017. A multi-species synthesis of physiological mechanisms in drought-induced tree mortality. *Nature Ecology & Evolution*, 1(9), pp.1285-1291.

Agee, J.K. 1991. Fire history of Douglas-fir forest in the Pacific Northwest. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H. Tech. Eds. *Wildlife and vegetation of unmanaged Douglas-Fir forests*. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 533p.

Agee, J.K. 1993. *Fire ecology of Pacific Northwest forests*. Washington, DC: Island Press. 493p.

Agne, M.C., Beedlow, P.A., Shaw, D.C., Woodruff, D.R., Lee, E.H., Cline, S.P. and Comeleo, R.L. 2018. Interactions of predominant insects and diseases with climate change in Douglas-fir forests of western Oregon and Washington, U.S.A. *Forest Ecology and Management* 409, 317-332.

Allbritten, M. 2002. Amphibian and western pond turtle surveys within the Elliott State Forest. Excel spreadsheet files. Oregon Department of Fish and Wildlife, Charleston OR. (As cited in Biosystems et al. 2003.)

Allen, C.D., Breshears, D.D. and McDowell, N.G. 2015. On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene. *Ecosphere*, 6(8), pp.1-55.

Allen, Q., Ballard, K., Howard, E., Johnson, E. and Lavoie, R. 2021. 2020 Southwest Oregon Community College F251 Elliott State Forest "Virtual" Roads and Trails Report. Oregon Websites & Watersheds Project, Inc., Philomath, Oregon: 35 pp.

Ameray, A., Y. Bergeron, O. Valeria, M. Montora Girona, and X. Cavard. 2021. Forest carbon management: A review of silvicultural practices and management strategies across boreal, temperate and tropical forests. *Current Forest Reports* 7: 245-266.

Anthony, M.A., Bender, S.F. and van der Heijden, M.G., 2023. Enumerating soil biodiversity. *Proceedings of the National Academy of Sciences*, 120(33), p.e2304663120.

Anthony, R.G., M.C. Hansen, K. Swindle, and A. Ellingson. 2000. Effects of Forest Stand Manipulations on Spotted Owl Home Range and Use Patterns: A Case Study. Final Draft. Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon. 27 pp. Submitted to: Oregon Department of Forestry, Salem, OR.

Appel, C.L., Lesmeister, D.B., Duarte, A., Davis, R.J., Weldy, M.J. and Levi, T., 2023. Using passive acoustic monitoring to estimate northern spotted owl landscape use and pair occupancy. *Ecosphere*, 14(2), p.e4421.

Apodaca, M., M. Tippie, A.M. Verde, V. Barandino, Jr., B. Jones and J. Rios. 2018. Guidelines for storing and decommissioning roads. USDA Forest Service, National Technology and Development Program. 1677–1804P–NTDP Transportation Management.

Ares, A., Berryman, S.D. and Puettmann, K.J. 2009. Understory vegetation response to thinning disturbance of varying complexity in coniferous stands. *Applied Vegetation Science*, 12(4), pp.472-487.

Ares, A., Neill, A.R. and Puettmann, K.J. 2010. Understory abundance, species diversity and functional attribute response to thinning in coniferous stands. *Forest Ecology and Management* 260, 1104-1113.

Asbeck, T., Messier, C. and Bauhus, J. 2020. Retention of tree-related microhabitats is more dependent on selection of habitat trees than their spatial distribution. *European Journal of Forest Research* 139, 1015-1028.

Atkinson, A.J., P.C. Trenham, R.N. Fisher, S.A. Hathaway, B.S. Johnson, S.G. Torres, and Y.C. Moore. 2004. Designing Monitoring Programs in an Adaptive Management Context for Regional Multiple Species Conservation Plans. US Geological Survey, California Department of Fish and Game, and U.S. Fish and Wildlife Service.

Bansal, S., Harrington, C.A. and St. Clair, J.B. 2016. Tolerance to multiple climate stressors: a case study of Douglas-fir drought and cold hardiness. *Ecology and Evolution* 6, 2074-2083.

Barik, M.G., Adam, J.C., Barber, M.E. and Muhunthan, B. 2017. Improved landslide susceptibility prediction for sustainable forest management in an altered climate. *Engineering Geology*, 230, pp.104-117.

Bateman, D.S., Chelgren, N.D., Gresswell, R.E., Dunham, J.B., Hockman-Wert, D.P., Leer, D.W. and Bladon, K.D., 2021. Fish response to successive clearcuts in a second-growth forest from the central Coast range of Oregon. *Forest Ecology and Management*, 496, p.119447.

Bateman, D.S., Sloat, M.R., Gresswell, R.E., Berger, A.M., Hockman-Wert, D.P., Leer, D.W. and Skaugset, A.E. 2016. Effects of stream-adjacent logging in fishless headwaters on downstream coastal cutthroat trout. *Canadian Journal of Fisheries and Aquatic Sciences*, 73(12), pp.1898-1913.

Bauhus, J., Puettmann, K., and Messier, C. 2009. Silviculture for old-growth attributes. *Forest Ecology and Management* 258:525-537.

Baxter, C.V., Fausch, K.D. and Saunders, W.C. 2005. Tangled webs: Reciprocal flows of invertebrate prey link streams and riparian zones. *Freshwater Biology*, 50(2), pp.201-220.

Beckmann, J.J., Sherriff, R.L., Kerhoulas, L.P., and Kane, J.M. 2021. Douglas-fir encroachment reduces drought resistance in Oregon white oak of northern California. *Forest Ecology and Management* 498, 119543.

Beese, W.J., Deal, J., Dunsworth, B.G., Mitchell, S.J., and Philpott, T.J. 2019. Two decades of variable retention in British Columbia: a review of its implementation and effectiveness for biodiversity conservation. *Ecological Processes* 8:33.

Beeson, H.W., Flitcroft, R.L., Fonstad, M.A. and Roering, J.J. 2018. Deep-seated landslides drive variability in valley width and increase connectivity of salmon habitat in the Oregon Coast Range. *JAWRA Journal of the American Water Resources Association*, 54(6), pp.1325-1340.

Benda, L., Hassan, M.A., Church, M. and May, C.L. 2005. Geomorphology of steepland headwaters: The transition from hillslopes to channels. *JAWRA Journal of the American Water Resources Association*, 41(4), pp.835-851.

Bennett, M., Shaw, D.C. and Lowrey, L. 2023. Recent Douglas-fir mortality in the Klamath Mountains ecoregion of Oregon: Evidence for a decline spiral. *Journal of Forestry*, 121(3), pp.246-261.

Betts, M. et al. 2021. Reconciling timber production and biodiversity conservation: Testing the Triad approach to providing ecosystem services. Personal Communication March 2022.

Betts, M., K. Nelson, J. Rivers, D. Roby and Z. Yang. 2021. Appendices 11; 11A: Potential marbled murrelet habitat distribution and research strategy at the Elliott State Forest, pp.93-97. In OSU (Oregon State University) College of Forestry. 2021. Proposal: Elliott State Research Forest. Updated April 2021.  
[https://www.forestry.oregonstate.edu/sites/default/files/041421\\_esrf\\_proposal.pdf](https://www.forestry.oregonstate.edu/sites/default/files/041421_esrf_proposal.pdf)

Betts, M.G., Hagar, J.C., Rivers, J.W., Alexander, J.D., McGarigal, K. and McComb, B.C. 2010. Thresholds in forest bird occurrence as a function of the amount of early-seral broadleaf forest at landscape scales. *Ecological Applications*, 20(8), pp.2116-2130.

Betts, M.G., J.M. Northrup, J.A. Bailey Guerrero, S.K. Nelson, J.L. Fisher, B.D. Gerber, M-S. Garcia-Heras, Z. Yang, D.D. Roby and J.W. Rivers. 2020. Squeezed by a habitat split: Warm ocean conditions and old-forest loss interact to reduce long-term occupancy of a threatened seabird. *Conservation Letters* 13: e12745.

Betts, M.G., Phalan, B.T. , Wolf, C. , Baker, S.C., Messier, C., Puettmann, K.J., Green, R., Harris, S.H., Edwards, D.P., Lindenmayer, D.B., A. Balmford. 2021. Producing wood at least cost to biodiversity: integrating Triad and sharing-sparing approaches to inform forest landscape management. *Biological Reviews* <https://doi.org/10.1111/brv.12703>

Bigelow, P.E., Benda, L.E., Miller, D.J. and Burnett, K.M. 2007. On debris flows, river networks, and the spatial structure of channel morphology. *Forest Science*, 53(2), pp.220-238.

Bilby, R.E., and P.A. Bisson. 1998. Function and distribution of large woody debris. Pages 324-346 in R. J. Naiman and R. E. Bilby, editors. *River Ecology and Management. Lessons from the Pacific Coastal Ecoregion*. Springer-Verlag, New York, N.Y.

Biosystems, Water Work Consulting, Coos Watershed Association, Alsea Geospatial, Inc. and Karen Bahun Technical Writing. 2003. Elliott State Forest watershed analysis. Submitted to Oregon Dept. of Forestry. Biosystems, Corvallis OR.

Black, T.A., R. Cissel, and C.H. Luce. 2012. The Geomorphic Road Analysis and Inventory Package (GRAIP) Volume 1: Data Collection Method. USDA Forest Service. General Technical Report RMRS- 280WWW. Rocky Mountain Experiment Station, Ft. Collins, CO. 110 pp.

Bliss-Ketchum, L., Draheim, R., Hepner, M. and Guethling, O. 2021. Emerald ash borer: Readiness and response plan for Oregon. Oregon Dept. of Agriculture. [https://static1.squarespace.com/static/58740d57579fb3b4fa5ce66f/t/60772a17647ad466155f74a7/1618422303582/March+2021\\_EAB.pdf](https://static1.squarespace.com/static/58740d57579fb3b4fa5ce66f/t/60772a17647ad466155f74a7/1618422303582/March+2021_EAB.pdf)

Boston, K. 2016. The potential effects of forest roads on the environment and mitigating their impacts. *Current Forestry Reports* 2:215–222.

Bowditch, E., Santopuoli, G., Binder, F., Del Rio, M., La Porta, N., Kluvankova, T., Lesinski, J., Motta, R., Pach, M., Panzacchi, P. and Pretzsch, H. 2020. What is Climate-Smart Forestry? A definition from a multinational collaborative process focused on mountain regions of Europe. *Ecosystem Services*, 43, p.101113.



Bracken, L.J. and J. Croke. 2007. The concept of hydrological connectivity and its contribution to understanding runoff-dominated geomorphic systems. *Hydrological Processes*. 21(13): 1749-1763.

Brazee, N.J. and Lindner, D.L. 2013. Unravelling the *Phellinus pini* sl complex in North America: A multilocus phylogeny and differentiation analysis of *Porodaedalea*. *Forest Pathology*, 43(2), pp.132-143.

Buotte, P.C., Levis, S., Law, B.E., Hudiburg, T.W., Rupp, D.E. and Kent, J.J. 2019. Near-future forest vulnerability to drought and fire varies across the western United States. *Global Change Biology*, 25(1), pp.290-303.

Burns, W.J. and Madin, I. 2009. Protocol for inventory mapping of landslide deposits from light detection and ranging (LiDAR) imagery. Special paper 42. Oregon Dept. of Geology and Mineral Industries. Portland, OR.

Bury, R.B. 1988. Habitat relationships and ecological importance of amphibians and reptiles. In *Proceedings: Streamside Management: Riparian Wildlife and Forestry Interactions*, 11–13 February 1987, Seattle, Wash. Edited by K.J. Raedeke. Institute of Forest Research, University of Washington, Seattle, Wash. Pp. 61–76.

Cahall, R., J. Hayes and M.G. Betts. 2013. If you build it will they come? Long-term response by forest birds to experimental thinning supports the “Field of Dreams” hypothesis. *Forest Ecology and Management* 304: 137–149.

Caldwell, L.K. and Courter, L.A. 2020. Abiotic factors influence surface water herbicide concentrations following silvicultural aerial application in Oregon's north coast range. *Integrated Environmental Assessment and Management*, 16(1), pp.114-127.

Carlson, D. and Miller, D. 2023. Modeling the sources of large wood recruited to fish-bearing streams by debris flow processes in the Oregon Coast Range. Manuscript in preparation.

Case, M.J., Johnson, B.G., Bartowitz, K.J. and Hudiburg, T.W. 2021. Forests of the future: Climate change impacts and implications for carbon storage in the Pacific Northwest, USA. *Forest Ecology and Management*, 482, p.118886.

Cassell, B.A., R.M. Scheller, M.S. Lucash, M.D. Hurteau, and E.L. Loudermilk. 2019. Widespread severe wildfires under climate change lead to increased forest homogeneity in dry mixed-conifer forests. *Ecosphere* 10(11):e02934. 10.1002/ecs2.2934

Chalfoun, A.D., Ratnaswamy, M.J. and Thompson III, F.R. 2002. Songbird nest predators in forest–pasture edge and forest interior in a fragmented landscape. *Ecological Applications*, 12(3), 858-867.

Chaney, N.W., Minasny, B., Herman, J.D., Nauman, T.W., Brungard, C.W., Morgan, C.L., McBratney, A.B., Wood, E.F. and Yimam, Y. 2019. POLARIS soil properties: 30-m probabilistic maps of soil properties over the contiguous United States. *Water Resources Research*, 55(4), pp.2916-2938.

Chmura, D.J., Anderson, P.D., Howe, G.T., Harrington, C.A., Halofsky, J.E., Peterson, D.L., Shaw, D.C., and Brad St Clair, J. 2011. Forest responses to climate change in the northwestern United States: ecophysiological foundations for adaptive management. *Forest Ecology and Management* 261, 1121-1142.

Choat, B., Brodribb, T.J., Brodersen, C.R., Duursma, R.A., López, R. and Medlyn, B.E. 2018. Triggers of tree mortality under drought. *Nature* 558 (7711), pp.531-539.

Chojnacky D.C., Heath L.S. and Jenkins J.C. 2014. Updated generalized biomass equations for North American tree species, *Forestry* 87(1):129–151. 10.1093/forestry/cpt053

Clark, J.S., Carpenter, S.R., Barber, M., Collins, S., Dobson, A., Foley, J.A., Lodge, D.M., Pascual, M., Pielke Jr, R., Pizer, W. and Pringle, C. 2001. Ecological forecasts: An emerging imperative. *Science* 293(5530), pp.657-660.

Clarke, S.E., Burnett, K.M. and Miller, D.J. 2008. Modeling streams and hydrogeomorphic attributes in Oregon from digital and field data. *JAWRA Journal of the American Water Resources Association*, 44(2), pp.459-477.

Coble, A.A., Silva-Sanchez, C., Arthurs, W.J. and Flinders, C.A. 2022. Detection and accumulation of environmentally-relevant glyphosate concentrations delivered via pulse-or continuous-delivery on passive samplers. *Science of The Total Environment*, 838, p.156131.

Cole, E. and Newton, M. 2009. Tenth-year survival and size of underplanted seedlings in the Oregon Coast Range. *Canadian Journal of Forest Research*, 39(3), pp.580-595.

CoosWA (Coos Watershed Association). 2015. Coos Model Watershed Program Supplemental Action Plan for the Millicoma Forks Coho Restoration Partnership.

CoosWA (Coos Watershed Association). 2022. Stream Data. Accessed October 2022. <http://streamdata.cooswatershed.org/download-data/download-data/http://streamdata.cooswatershed.org/gage/west-fork-gage/>

Creutzburg, M.K., Scheller, R.M., Lucash, M.S., LeDuc, S.D. and Johnson, M.G. 2017. Forest management scenarios in a changing climate: Trade-offs between carbon, timber, and old forest. *Ecological Applications*, 27(2), pp.503-518.

Crookston, N.L., Rehfeldt, G.E., Dixon, G.E. and Weiskittel, A.R. 2010. Addressing climate change in the forest vegetation simulator to assess impacts on landscape forest dynamics. *Forest Ecology and Management*, 260,7, P. 1198-1211.

Dalton, M. and E. Fleishman (Eds.) 2021. Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon.  
<https://blogs.oregonstate.edu/occri/oregon-climate-assessments/>.

Dalton, M.M., Mote, P.W. and Snover, A.K. 2013. *Climate Change in the Northwest: Implications for our landscapes, waters, and communities*. Island Press, Washington, DC. 271 pp.

Dalton, M.M, K.D. Dello, L. Hawkins, P.W. Mote and D.E. Rupp. 2017. *The Third Oregon Climate Assessment Report*, Oregon Climate Change Research Institute, College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, OR.

Daniels L.D., Maertens T.B., Stan A.B., McCloskey S.P.J., Cochrane J.D. and Gray R.W. 2011. Direct and indirect impacts of climate change on forests: Three case studies from British Columbia. *Canadian Journal of Plant Pathology*, 33, 108–116.

Data from Oregon Department of Forestry, Oregon Timber Harvest Data set. Accessed June 17, 2022.

Data from the U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages. Natural Resources here is defined as employment in Wood Products Manufacturing; Forestry and Logging; Fishing, Hunting, and Trapping; and Support Activities for Agriculture and Forestry. Accessed June 17, 2022.

Data from the U.S. Census Bureau, 2017-2021 American Community Survey 5-Year Estimates. Accessed August 18, 2023.

Davis, L.S., Johnson, K.N., Bettinger, P.S. and Howard, T.E. 2001. *Forest management: To sustain ecological, economic, and social values* (4th ed.). New York, NY: McGraw Hill Companies.

Davis, L.R. and Puettmann, K.J. 2009. Initial response of understory vegetation to three alternative thinning treatments. *Journal of Sustainable Forestry*, 28(8), pp.904-934.

Davis, L.R., Puettmann, K.J., and Tucker, G.F. 2007. Overstory response to alternative thinning treatments in young Douglas-fir forests of western Oregon. *Northwest Science* 81, 1-14.

Dawson, N., Coolsaet, B., Sterling, E., Loveridge, R., Nicole, D., Wongbusarakum, S., Sangha, K., Scherl, L., Phan, H. P., and Zafra-Calvo, N. 2021. The role of Indigenous peoples and local communities in effective and equitable conservation. *Ecology and Society* 26.

De Montigny, L.E. and Smith, N.J. 2017. The effects of gap size in a group selection silvicultural system on the growth response of young, planted Douglas-fir: A sector plot analysis. *Forestry: An International Journal of Forest Research*, 90(3), pp.426-435.

Deak, A., Lucash, M.S., Coughlan, M., Weiss, S. and Silva, L. In review. How much prescribed fire is needed to moderate wildfires and maintain carbon storage in a western landscape? *Ecological Applications*.

DeLuca, T.H. and C. Boisvenue. 2012. Boreal forest soil carbon: distribution, function and modelling. *Forestry* 85:161-184.

DeLuca, T.H., Pingree, M.R. and Gao, S., 2019. Assessing soil biological health in forest soils. In *Developments in Soil Science* (Vol. 36, pp. 397-426). Elsevier

DeLuca, T.H., S. Gao and M.R.A. Pingree. 2019. Assessing soil biological health in forest ecosystems. . Pages 397-426 in D. Page-Dumroese, M. Busse, C. Giardina, and D. Morris, editors. *Global Change and Forest Soils: Conservation of a Finite Natural Resource*. Cambridge, MA, New York.

Dettinger, M. 2011. Climate change, atmospheric rivers, and floods in California—a multimodel analysis of storm frequency and magnitude changes. *JAWRA Journal of the American Water Resources Association*, 47(3), pp.514-523.

Dettinger, M.D. 2013. Atmospheric rivers as drought busters on the US West Coast. *Journal of Hydrometeorology*, 14(6), pp.1721-1732.

Dettinger, M.D. 2013. Atmospheric rivers as drought busters on the US West Coast. *Journal of Hydrometeorology*, 14(6), pp.1721-1732.

Dickard, M., M. Gonzalez, W. Elmore, S. Leonard, D. Smith, S. Smith, J. Staats, P. Summers, D. Weixelman and S. Wyman. 2015. Riparian area management: Proper functioning condition assessment for lotic areas. Technical Reference 1737-15. Denver, CO: US Department of the Interior, Bureau of Land Management, National Operations Center.

Dodson, E.K., Ares, A. and Puettmann, K.J. 2012. Early responses to thinning treatments designed to accelerate late successional forest structure in young coniferous stands of western Oregon, USA. *Canadian Journal of Forest Research*, 42(2), pp.345-355.

Dodson, E.K., Burton, J.I., and Puettmann, K.J. 2014. Multiscale controls on natural regeneration dynamics after partial overstory removal in Douglas-fir Forests in western Oregon, USA. *Forest Science* 60, 953-961.



DOGAMI (Oregon Department of Geology and Mineral Industries). 2009. LiDAR remote sensing data collection: DOGAMI, South Coast study area. Oregon Department of Geology and Mineral Industries, Portland, Oregon.

DOGAMI (Oregon Department of Geology and Mineral Industries). 2021. LiDAR remote sensing data collection: DOGAMI, Elliott State Research Forest study area. Oregon Department of Geology and Mineral Industries, Portland, Oregon.

Dooley E, and Fairweather, S. 2016. Elliott State Forest Cruise Report for Oregon Department of State Lands. Mason, Bruce & Girard.

Duveneck, M.J. and R.M. Scheller. 2016. Measuring and managing resistance and resilience under climate change in northern Great Lake forests (USA). *Landscape Ecology* 31: 669-686.

Dye, A., J. Kim, M. Reilly, K. Riley, A. McEvoy, R. Lemons and B. Kerns. In preparation. Changing wildfire regimes for northwestern forests: New insights for the mid-21st century.

Dye, A.W., Rastogi, B., Clemesha, R.E., Kim, J.B., Samelson, R.M., Still, C.J. and Williams, A.P. 2020. Spatial patterns and trends of summertime low cloudiness for the Pacific Northwest, 1996–2017. *Geophysical Research Letters*, 47(16), p.e2020GL088121.

Ellis, T.M., and Betts, M.G. 2011. Bird abundance and diversity across a hardwood gradient within early seral plantation forest. *Forest Ecology and Management* 261: 1372-1381.

Ellis, T.M., Kroll, A.J., and Betts, M.G. 2012. Early seral hardwood vegetation increases adult and fledgling bird abundance in Douglas-fir plantations of the Oregon Coast Range, USA. *Canadian Journal of Forest Research* 42:918-933.

Erdozain, M., Kidd, K.A., Emilson, E.J., Capell, S.S., Luu, T., Kreutzweiser, D.P. and Gray, M.A. 2021. Forest management impacts on stream integrity at varying intensities and spatial scales: Do biological effects accumulate spatially?. *Science of The Total Environment*, 763, p.144043.

Eriksson, C.E., K.M. Moriarty, M.A. Linnell and T. Levi. 2019. Biotic factors influencing the unexpected distribution of a Humboldt marten (*Martes caurina humboldtensis*) population in a young coastal forest. *PLoS One* 14(5): e0214653.  
<https://doi.org/10.1371/journal.pone.0214653>

Etzwiler, K, Bartlett, S., Harvey, A. Altier, K., Black-Priest, H., Morrison, K. and Jones, G. 2019. 2019 SWOCC Elliot State Forest Draft Recreation Plan with Recommendations. Oregon Websites & Watersheds Project, Inc., Philomath, Oregon: 48pp.  
[http://www.orwww.org/Elliott\\_Forest/Recreation/2019\\_Plan/index.html](http://www.orwww.org/Elliott_Forest/Recreation/2019_Plan/index.html)

Evans Mack, D., W.P. Ritchie, S.K. Nelson, E. Kuo-Harrison, P. Harrison, and T.E. Hamer. 2003. Methods for surveying marbled murrelets in forests: A revised protocol for land management

and research. Pacific Seabird Group unpublished document. Available:  
<http://www.pacificseabirdgroup.org>.

Eve, M., D. Pape, M. Flugge, R. Steele, D. Man, M. Riley-Gilbert and S. Biggar (Eds). 2014. Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory. Technical Bulletin Number 1939. Office of the Chief Economist, U.S. Department of Agriculture, Washington, DC. 606pp.

Everest, F.H. and G.H. Reeves. 2007. Riparian and aquatic habitats of the Pacific Northwest and southeast Alaska: ecology, management history, and potential management strategies. Gen. Tech. Rep. PNW-GTR-692. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Fahey, R.T. and Puettmann, K.J. 2008. Patterns in spatial extent of gap influence on understory plant communities. *Forest Ecology and Management*, 255(7), pp.2801-2810.

Faulkner, B.R., Brooks, J.R., Keenan, D.M. and Forshay, K.J. 2020. Temperature decrease along hyporheic pathlines in a large river riparian zone. *Ecohydrology*, 13(1), p.e2160.

FEMA (Federal Emergency Management Agency). 2018. Flood Insurance Study Coos County, Oregon and incorporated areas. Vol. 1 of 2. U.S. Flood Insurance Study Number 41011CV001C.

FEMAT (Forest Ecosystem Management Assessment Team). 1993. Forest ecosystem management: An ecological, economic, and social assessment. Report 1993–793–071. USDA Forest Service, Washington, D.C.

Ferguson, B.A. 2009. Black stain root disease ecology and management. Chapter 11.7 Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern Region, State and Private Forestry. 12 pp.

Franklin, J.F. and Dyrness, C.T. 1988. Natural vegetation of Oregon and Washington. OSU Press. Oregon State University, Corvallis Oregon. 468 p. Reprint with updated bibliography and ~500 additional references. Originally published (1973) as: Gen. Tech. Rep. PNW-GTR-008. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 427 p.

Franklin, J.F. and Johnson, K.N. 2012. A restoration framework for federal forests in the Pacific Northwest. *Journal of Forestry*, 110(8), 429–439.

Franklin, J.F., Johnson, K.N., and Johnson, D.L. 2018. Ecological forest management. Long Grove, IL: Waveland Press.

Franklin, J.F., Spies, T.A., Van Pelt, R., Carey, A.B., Thornburgh, D.A., Berg, D.R., Lindenmayer, D.B., Harmon, M.E., Keeton, W.S., Shaw, D.C., Bible, K. and Chen, J. 2002. Disturbances and

structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. *Forest Ecology and Management* 155:399-423.

Frick, W. F., Kingston, T., & Flanders, J. 2020. A review of the major threats and challenges to global bat conservation. *Annals of the New York Academy of Sciences*, 1469(1): 5-25.

Fricker, G.A., J.D. Ventura, J.A. Wolf, M.P. North, F. W. Davis and J. Franklin. 2019. A Convolutional Neural Network Classifier Identifies Tree Species in Mixed-Conifer Forest from Hyperspectral Imagery. *Remote Sensing*. 11(19):2326.

Furniss, M.J., T.D. Roelofs, and C.S. Yee. 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. *American Fisheries Society Special Publications* 19:297–232.

Galbraith, S.M., Cane, J.H., Moldenke, A.R., and Rivers, J.W. 2019. Salvage logging reduces wild bee diversity, but not abundance, in severely burned mixed-conifer forest. *Forest Ecology and Management* 453(1):117622.

Gao, S. and T.H. DeLuca. 2020. Biochar alters nitrogen and phosphorus dynamics in a western rangeland ecosystem. *Soil Biology and Biochemistry* 148:107868.

Garber, S., Lam, T.Y. and Maguire, D.A. 2011. Growth and mortality of residual Douglas-fir after regeneration harvests under group selection and two-story silvicultural systems. *Western Journal of Applied Forestry*, 26(2), pp.64-70.

Garcia, T.S., Johnson, J., Jones, J. and Kroll, A.J. 2020. Experimental evidence indicates variable responses to forest disturbance and thermal refugia by two plethodontid salamanders. *Forest Ecology and Management*, 464, p.118045.

Gershunov, A., Shulgina, T., Clemesha, R.E., Guirguis, K., Pierce, D.W., Dettinger, M.D., Lavers, D.A., Cayan, D.R., Polade, S.D., Kalansky, J. and Ralph, F.M. 2019. Precipitation regime change in Western North America: the role of atmospheric rivers. *Scientific Reports*, 9(1), pp.1-11.

Glenn, E.M., M.C. Hansen and R.G. Anthony. 2004. Spotted owl home-range and habitat use in young forests of western Oregon. *Journal of Wildlife Management* 68:33-50

Goheen, E.M. and E.A. Willhite. 2021. Field guide to the common diseases and insect pests of Oregon and Washington conifers. Rev.ed. R6-FHP-RO-2021-01. Portland OR: USDA Forest Service Pacific Northwest Region. 325 p.

Gomi, T., Sidle, R.C., Woodsmith, R.D. and Bryant, M.D. 2003. Characteristics of channel steps and reach morphology in headwater streams, southeast Alaska. *Geomorphology*, 51(1-3), pp.225-242.

Goodman, A.C., Segura, C., Jones, J.A. and Swanson, F.J. 2023. Seventy years of watershed response to floods and changing forestry practices in western Oregon, USA. *Earth Surface Processes and Landforms*.

Gray, A.N. 2015. The role of old forests and big trees in forest carbon sequestration in the Pacific Northwest. In: Stanton, S.M.; Christensen, G.A., comps. 2015. *Pushing boundaries: New directions in inventory techniques and applications: Forest Inventory and Analysis (FIA) symposium 2015*. 2015 Dec. 8–10; Portland, OR. Gen. Tech. Rep. PNW-GTR-931. Portland, OR: U.S. Dept. of Agriculture, Forest Service, PNW Research Station: 153-158.

Gray, A.N., and Spies, T.A. 1996. Gap size, within-gap position and canopy structure effects on conifer seedling establishment. *Journal of Ecology*, 84(5), pp.635-645.

Gray, A.N., Spies T.A. and Monleon, V.J. 2009. Characteristics of remnant old-growth forests in the northern Coast Range of Oregon and comparison to surrounding landscapes. USDA Forest Service General Technical Report. PNW-GTR-790. Pacific Northwest Research Station, Corvallis, Oregon.

Gray, A.N., Spies, T.A. and Pabst, R.J. 2012. Canopy gaps affect long-term patterns of tree growth and mortality in mature and old-growth forests in the Pacific Northwest. *Forest Ecology and Management*, 281, pp.111-120.

Green, D. and M. Offer-Westort. 2018. 10 Things to Know About Adaptive Experimental Design. Accessed online 9-22-2022 at: <https://egap.org/resource/10-things-to-know-about-adaptive-experimental-design/>. Evidence in Governance and Politics (EGAP).

Gregory, S. 2000. Chapter 3.5: Summary of current status and health of Oregon's riparian areas. In: Risser, P.G., Arnold, S., Boggess, W., Gregory, S., Hulse, D., Jepson, P., Johnson, N., Lubchenco, J., Murtaugh, P., Pratt, J. and Vavra, M. 2000. *Oregon state of the environment report 2000*. Salem, OR: Oregon Progress Board.

Gupta R. and Sharma, L.K. 2019. The process-based forest growth model 3-PG for use in forest management: A review. *Ecological Modelling* 397:55–73. 10.1016/j.ecolmodel.2019.01.007

Gustafson, Eric J. 2013. When relationships estimated in the past cannot be used to predict the future: using mechanistic models to predict landscape ecological dynamics in a changing world. *Landscape ecology* 28, pp.1429-1437.

Hadfield, J.S., Goheen, D.J., Filip, G.M., Schmitt, C.L. and Harvey, R.D. 1986. *Root Diseases in Oregon and Washington Conifers-R6-FPM-250-86*. USDA Forest Service, Pacific Northwest Region: Portland, OR, USA.



Hagar, J., Yost, A. and Haggerty, P.K. 2020. Incorporating LiDAR metrics into a structure-based habitat model for a canopy-dwelling species. *Remote Sensing of Environment* 236:111–499. 10.1016/j.rse.2019.111499

Hagar, J.C. 2007. Wildlife species associated with non-coniferous vegetation in Pacific Northwest conifer forests: a review. *Forest Ecology and Management*, 246(1), pp.108-122.

Hagar, J.C., Eskelson, B.N., Haggerty, P.K., Nelson, S.K. and Vesely, D.G. 2014. Modeling marbled murrelet (*Brachyramphus marmoratus*) habitat using LiDAR-derived canopy data. *Wildlife Society Bulletin*, 38(2), pp.237-249.

Hagle, S.K. and G.M. Filip. 2010. Schweinitzii root and butt rot of western conifers. *Forest Insect & Disease Leaflet* 177. USDA Forest Service, Pacific Northwest Region (R6), Portland, Oregon.

Hall, M. 2018. Blue and yellow vane traps differ in their sampling effectiveness for wild bees in both open and wooded habitats: Blue vane traps better for bee sampling. *Agricultural and Forest Entomology* 20:487–495.

Hallerud M., Tosa, M., Kaur J., Levi, T., and Betts, M. 2023. Report to the Elliott State Research Forest: Biodiversity Surveys 2022.

Halofsky, J.E., Andrews-Key, S.A., Edwards, J.E., Johnston, M.H., Nelson, H.W., Peterson, D.L., Schmitt, K.M., Swanston, C.W. and Williamson, T.B. 2018. Adapting forest management to climate change: The state of science and applications in Canada and the United States. *Forest Ecology and Management*, 421, pp.84-97.

Halofsky, J.E., Peterson, D.L. and Harvey, B.J. 2020. Changing wildfire, changing forests: the effects of climate change on fire regimes and vegetation in the Pacific Northwest, USA. *Fire Ecology*, 16(1), pp.1-26.

Halofsky, J.E.; Peterson, D.L. and Gravenmier, R.A., eds. In press. Climate change vulnerability and adaptation in Coastal Oregon. Gen. Tech. Rep. PNW-GTR-xxx. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. [https://adaptationpartners.org/ocap/docs/OCAP\\_Assessment-Final\\_with\\_figures.pdf](https://adaptationpartners.org/ocap/docs/OCAP_Assessment-Final_with_figures.pdf)

Halpern, C.B., Antos, J.A., McKenzie, D. and Olson, A.M. 2016. Past tree influence and prescribed fire mediate biotic interactions and community reassembly in a grassland-restoration experiment. *Journal of Applied Ecology*, 53(1), pp.264-273.

Hammitt, W.E., Cole, D.N. and Monz, C.A. 2015. *Wildland recreation: Ecology and management*. John Wiley & Sons.

Hankin, D.G. and Reeves, G.H. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. *Canadian journal of fisheries and aquatic sciences*, 45(5), 834-844.

Hankins, D.L. 2013. The effects of indigenous prescribed fire on riparian vegetation in central California. *Ecological Processes* 2, 24.

Hanley, D.P., Baumgartner, D.M., and Raedeke, K.J. 2007. Coastal douglas-fir forests and fish & wildlife.

Hansen, E.M., Goheen, D.J., Jules, E.S. and Ullian, B. 2000. Managing Port-Orford-cedar and the introduced pathogen *Phytophthora lateralis*. *Plant Disease*, 84(1), pp.4-14.

Hansen, W.D., Abendroth, D., Rammer, W., Seidl, R. and Turner, M.G. 2020. Can wildland fire management alter 21st-century subalpine fire and forests in Grand Teton National Park, Wyoming, USA? *Ecological Applications* 30(2), p.e02030.

Hao, H., W. Li, X. Zhao, Q. Chang, and P. Zhao. 2019. Estimating the aboveground carbon density of coniferous forests by combining airborne LiDAR and allometry models at plot level. *Frontiers in Plant Science*, 10, p.917.

Harkema, P., Brownscombe, B. and Delahanty, A. 2018. Elliott State Forest: Next Step Considerations for Decoupling from Oregon's Common School Fund. An Oregon Consensus Assessment Report to the Oregon Department of State Lands and Oregon State Land Board. <http://oregonconsensus.org/wp-content/uploads/2018/03/OC-ESF-Decoupling-Summary-Report.pdf>

Harmon, M.E. and J. Sexton. 1996. Guidelines for measurementsof woody detritus in forest ecosystems. Publication No. 20. U.S. LTER Network Office: University of Washington, Seattle, WA, USA. 73 pp .

Harmon, M.E., Moreno, A. and Domingo, J.B. 2009. Effects of partial harvest on the carbon stores in Douglas-fir/western hemlock forests: a simulation study. *Ecosystems*, 12(5), 777-791.

Harr, R.D. 1982. Fog drip in the Bull Run Municipal Watershed, Oregon. *JAWRA Journal of the American Water Resources Association*, 18(5), pp.785-789.

Harrington, T.B. and Nicholas, G.E. 2007. Managing for wildlife habitat in Westside production forests. PNW-GTR-695, Pacific Northwest Research Station, U.S. Forest Service. 10.2737/PNW-GTR-695

Harrington, T.B., Peter, D.H. and Slesak, R.A. 2018. Logging debris and herbicide treatments improve growing conditions for planted Douglas-fir on a droughty forest site invaded by Scotch broom. *Forest Ecology and Management*, 417, pp.31-39.

Harris, S.G. and Betts, M.G. 2021. Bird abundance is highly dynamic across succession in early seral tree plantations. *Forest Ecology and Management*, Volume 483: 118902, <https://doi.org/10.1016/j.foreco.2020.118902>

Hatcher, A. 2012. Building cultural bridges with Aboriginal learners and their ‘classmates’ for transformative environmental education. *Journal of Environmental Studies and Sciences*, 2, pp.346-356.

Hawkins, H.J., Cargill, R.I., Van Nuland, M.E., Hagen, S.C., Field, K.J., Sheldrake, M., Soudzilovskaia, N.A. and Kiers, E.T. 2023. Mycorrhizal mycelium as a global carbon pool. *Current Biology*, 33(11), pp.R560-R573.

Hayes, J.P., S.P. Cross and McIntire, P.W. 1986. Seasonal variation in mycophagy by the western red-backed vole, *Clethrionomys californicus*, in southwestern Oregon. *Northwest Science* 60: 250–257.

He, Hong S. 2008. Forest landscape models: definitions, characterization, and classification. *Forest Ecology and Management* 254.3 pp. 484-498.

Hébert, P.N. and R.T. Golightly. 2007. Observations of predation by corvids at a marbled murrelet nest. *Journal of Field Ornithology* 78: 221-224.

Heimsath, A.M., W.E. Dietrich, K. Nishiizumi, and R.C. Finkel. 2001. Stochastic processes of soil production and transport: Erosion rates, topographic variation and cosmogenic nuclides in the Oregon Coast Range, *Earth Surf. Processes Landforms*, 26(5), 531–552

Henderson, E. 2019. Habitat maps for western pond turtle. Maps created for the US Forest Service, PNW Challenge Cost Share Supplemental Project Agreement 19\_CS\_11062754-056. Institute for Natural Resources, Oregon State University.

Hennon P.E., D’amore D.V., Schaberg P.G., Wittwer D.T. and Shanley C.S. 2012. Shifting climate, altered niche, and a dynamic conservation strategy for yellow-cedar in the North Pacific coastal rainforest. *BioScience*, 62, 147–158

Hessburg, P.F., Churchill, D.J., Larson, A.J., Haugo, R.D., Miller, C., Spies, T.A., North, M.P., Povak, N.A., Belote, R.T., Singleton, P.H. and Gaines, W.L., Keane R.E., Aplet G.H., Stephens S.L., Morgan P., Bisson P.A., Rieman B.E., Salter R.B., and Reeves, G.H. 2015. Restoring fire-prone Inland Pacific landscapes: Seven core principles. *Landscape Ecology*, 30, pp.1805-1835.

Hessburg, P.F., Goheen, D.J., and Koester, H. 2001. Association of black stain root disease with roads, skid trails, and precommercial thinning in southwest Oregon. *Western Journal of Applied Forestry* 16: 127-135.

Himes, A., Betts, M., Messier, C. and Seymour, R. 2022. Perspectives: Thirty years of triad forestry, a critical clarification of theory and recommendations for implementation and testing. *Forest Ecology and Management*, 510, p.120103.

Hoffman, J.T. 2004. Management guide for dwarf mistletoe *Arceuthobium* spp. Forest Health Protection and State Forestry Organizations.  
[https://www.fs.usda.gov/Internet/FSE\\_DOCUMENTS/stelprdb5187427.pdf](https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5187427.pdf)

Holling, C.S. and G.K. Meffe. 1996. Command and control and the pathology of natural resource management. *Conservation Biology* 10(No. 2): 328 - 337.

Holmes, K.L. and Goebel, P.C. 2011. A functional approach to riparian area delineation using geospatial methods. *Journal of Forestry*, 109(4), pp.233-241.

Holub, S.M. and J.A. Hatten. 2019. Soil carbon storage in Douglas-fir forests of Western Oregon and Washington before and after modern timber harvesting practices. *Soil Science Society America Journal* 83:S175-S186.

Holzfeind, T., Visser, R., Chung, W., Holzleitner, F. and Erber, G. 2020. Development and benefits of winch-assist harvesting. *Current Forestry Reports*, 6(3), pp.201-209.

Homann, P.S., P. Sollins, M. Fiorella, T. Thorson and J.S. Kern. 1998. Regional Soil Organic Carbon Storage Estimates for Western Oregon by Multiple Approaches. *Soil Science Society America Journal* 62:789-796.

Hoover, C., R. Birdsey, B. Goines, P. Lahm, Gregg Marland, D. Nowak, S. Prisley, E. Reinhardt, K. Skog, D. Skole, J. Smith, C. Trettin and C. Woodall. 2014. Chapter 6: Quantifying greenhouse gas sources and sinks in managed forest systems. In *Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory*. Technical Bulletin Number 1939, Office of the Chief Economist, U.S. Dept. of Agriculture, Washington, DC. 606p.

Hotta, M., Tsuyama, I., Nakao, K., Ozeki, M., Higa, M., Kominami, Y., Hamada, T., Matsui, T., Yasuda, M., and Tanaka, N. 2019. Modeling future wildlife habitat suitability: Serious climate change impacts on the potential distribution of the Rock Ptarmigan *Lagopus muta japonica* in Japan's northern Alps. *BMC Ecology* 19, 23.

Hudiburg T., Law, B.E., Turner, D. P., Campbell, J., Donato, D. and Duane, M. 2009. Carbon dynamics of Oregon and Northern California forests and potential land-based carbon storage. *Ecological Applications* 19 (1), 163-180. <https://doi.org/10.1890/07-2006.1>

Huhta, V., 2007. The role of soil fauna in ecosystems: A historical review. *Pedobiologia*, 50(6), pp.489-495.



Hunter, B.D., Roering, J.J., Almond, P.C., Chadwick, O.A., Polizzotto, M.L. and Silva, L.C. 2023. Pedogenic pathways and deep weathering controls on soil organic carbon in Pacific Northwest forest soils. *Geoderma*, 436, p.116531.

Hynicka, J.D., Pett-Ridge, J.C. and Perakis, S.S. 2016. Nitrogen enrichment regulates calcium sources in forests. *Global change biology*, 22(12), pp.4067-4079.

Juha Hyypä, Olavi Kelle, Mikko Lehtikainen, and Mikko Inkinen. A segmentation-based method to retrieve stem volume estimates from 3-d tree height models produced by laser scanners. *IEEE Transactions on geoscience and remote sensing*, 39(5):969–975, 2001.

Ilhardt, B.L., Verry, E.S. and Palik, B.J. 2000. Defining riparian areas. In: *Forestry and the riparian zone*, Conference Proceedings, University of Maine, Orono ME, 10-26-2000. pp.7-14.

Irland, L.C. 2000. Ice storms and forest impacts. *Science of the Total Environment*, 262(3), pp.231-242.

ISCO. 2023. Teledyne ISCO Portable Water Sampler Model 6712 (data sheet).  
<https://cclynch.com/wp-content/uploads/2020/09/ISCO-6712-Full-Size-Portable-Sampler-Datasheet-min.pdf>

IVUMC (Interagency Visitor Use Management Council). 2016. Visitor Use Management Framework: A Guide to Providing Sustainable Outdoor Recreation, Edition One. (USDI Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service; USDA Forest Service; U.S. Dept. of Commerce; U.S. National Oceanic and Atmospheric Administration; U.S. DOD U.S. Army Corps of Engineers.) 130p. <https://visitorusemanagement.nps.gov/VUM/Framework>

James, J. and R. Harrison. 2016. The effect of harvest on forest soil carbon: A meta-analysis. *Forests* 7:22.

James, J., D. Page-Dumroese, M. Busse, B. Palik, J. Zhang, B. Eaton, R. Slesak, J. Tirocke and H. Kwon. 2021. Effects of forest harvesting and biomass removal on soil carbon and nitrogen: Two complementary meta-analyses. *Forest Ecology and Management* 485:118935.

Jandl, R., Lindner, M., Vesterdal, L., Bauwens, B., Baritz, R., Hagedorn, F., Johnson, D.W., Minkinen, K. and Byrne, K.A. 2007. How strongly can forest management influence soil carbon sequestration?. *Geoderma*, 137(3-4), pp.253-268.

Jennings, L., Anderson, T., Martinez, A., Sterling, R., Chavez, D.D., Garba, I., Hudson, M., Garrison, N.A. and Carroll, S.R. 2023. Applying the ‘CARE Principles for Indigenous Data Governance’ to ecology and biodiversity research. *Nature Ecology & Evolution*, pp.1-5.

Johnson, S.L. 2004. Factors influencing stream temperatures in small streams: substrate effects and a shading experiment. *Canadian Journal of Fisheries and Aquatic Sciences*, 61(6), pp.913-923.

Johnston, A.N. and Moskal, L.M. 2017. High-resolution habitat modeling with airborne LiDAR for red tree voles. *The Journal of Wildlife Management*, 81(1), pp.58-72.

Johnstone, J.A. and Dawson, T.E. 2010. Climatic context and ecological implications of summer fog decline in the coast redwood region. *Proceedings of the National Academy of Science* 107: 4533-4538.

Jones, J.E., Kroll, A.J., Giovanini, J., Duke, S.D., Ellis, T.M. and Betts, M.G. 2012. Avian species richness in relation to intensive forest management practices in early seral tree plantations. *PLOS ONE* 7(8):e43290.

Joo, S., Mainwaring, D.B., Hann, D.W., Osborne, N.L. and Maguire, D.A. 2020. User's Manual for CIPSR Version 4.0.0. Center for Intensive Planted-forest Silviculture (CIPS) College of Forestry, Oregon State University. <https://cips.forestry.oregonstate.edu/cipsanon>

Kanaskie, A. and D. Baer. 1994. Occurrence and impact of laminated root rot on non-federal timberlands in Northwest Oregon. Oregon Department of Forestry, Salem, OR. Forest Health Report 94-4.

Kanaskie, A. and E. Irwin. 1993. Incidence of Black Stain Root Disease in 10- to 30-year-old Douglas-fir Stands on the Main Block of the Elliott State Forest. Oregon Department of Forestry Pest Management Report No 93-2. Oregon Department of Forestry, Salem, OR.

Kavanagh, P.S., K.K. Jones, C.H. Stein and P.S. Jacobsen. 2005. Fish habitat assessment in the Oregon Department of Forestry Elliott study area. Conservation and Recovery Program, Oregon Department of Fish and Wildlife, 28655 Highway 34, Corvallis OR 97333.

Keane, R.E., Hessburg, P.F., Landres, P.B. and Swanson, F.J. 2009. The use of historical range and variability (HRV) in landscape management. *Forest Ecology and Management*, 258(7), pp.1025-1037.

Kellar, E.A. and Swanson, F.J. 1979. Effects of large organic material on channel form and alluvial process. *Earth Surface Processes*, 4, pp.361-380.

Kelly, R.M., J. Kitzes, H. Wilson and A. Merenlender. 2016. Habitat diversity promotes bat activity in a vineyard landscape. *Agriculture, Ecosystems & Environment* 223:175–181.

Kern, C.C., Kenefic, L.S., Kuehne, C., Weiskittel, A.R., Kaschmitter, S.J., D'Amato, A.W., Dey, D.C., Kabrick, J.M., Palik, B.J. and Schuler, T.M. 2021. Relative influence of stand and site factors on

aboveground live-tree carbon sequestration and mortality in managed and unmanaged forests. *Forest Ecology and Management*, 493, p.119266.

Kéry, M., J.A. Royle and H. Schmid. 2005. Modeling avian abundance from replicated counts using binomial mixture models. *Ecological Applications* 15:1450–1461.

Kingfisher Ecological, Inc. 2016. Final Report: northern spotted owl Surveys on the Elliott State Forest. Prepared for: Oregon Department of Forestry Salem, Oregon. Coos Bay District, Coos Bay, Oregon. Prepared by: Kingfisher Ecological, Inc. Corvallis, Oregon

Kirk, R. and J. Franklin. 1992. *The Olympic rain forest: an ecological web*. University of Washington Press. 128 pp.

Kline, N., Navarro, S. and Shaw, D.C. 2018. *Sudden Oak Death: Prevention, Recognition, Restoration*. Oregon State University Extension Service.

Kluber, M.R., Olson, D.H. and Puettmann, K.J. 2008. Amphibian distributions in riparian and upslope areas and their habitat associations on managed forest landscapes in the Oregon Coast Range. *Forest Ecology and Management*, 256(4), pp.529-535.

Knapp, P.A. and Hadley, K.S. 2012. A 300-year history of Pacific Northwest windstorms inferred from tree rings. *Global and Planetary Change*, 92, pp.257-266.

Kolb, T.E., Wagner, M.R. and Covington, W.W. 1994. Concepts of forest health: Utilitarian and ecosystem perspectives. *Journal of Forestry*, 92.

Kronsberg, A., Boyd, T., Boone, M., Smith, C., Patton, D., Carr, C., Hofenbridl, M., Richcreek, M., Smith, M., Richards, A., Harkins, C. and Guthrie, S. 2018. 2018 Draft Elliott State Forest Recreation Plan. Oregon Websites & Watersheds Project, Inc., Philomath, Oregon: 65 pp. [http://www.orww.org/Elliott\\_Forest/Recreation/2018\\_Plan/](http://www.orww.org/Elliott_Forest/Recreation/2018_Plan/)

Kuehne, C., Weiskittel, A.R., Fraver, S. and Puettmann, K.J. 2015. Effects of thinning-induced changes in structural heterogeneity on growth, ingrowth, and mortality in secondary coastal Douglas-fir forests. *Canadian Journal of Forest Research*, 45(11), pp.1448-1461.

Lam, T.Y. and Maguire, D.A., 2011. Thirteen-year height and diameter growth of Douglas-fir seedlings under alternative regeneration cuts in the Pacific Northwest. *Western Journal of Applied Forestry*, 26(2), pp.57-63.

Latterell, J.J. and Naiman, R.J. 2007. Sources and dynamics of large logs in a temperate floodplain river. *Ecological Applications*, 17(4), pp.1127-1141.

Law, B.E., Berner, L.T., Buotte, P.C., Mildrexler, D.J. and Ripple, W.J. 2021. Strategic Forest Reserves can protect biodiversity in the western United States and mitigate climate change. *Communications Earth & Environment*, 2(1), pp.1-13.

Law, B.E., Hudiburg, T.W., Berner, L.T., Kent, J.J., Buotte, P.C. and Harmon, M.E. 2018. Land use strategies to mitigate climate change in carbon dense temperate forests. *Proceedings of the National Academy of Sciences*, 115(14), pp.3663-3668.

Law, B.E., Hudiburg, T.W., Berner, L.T., Kent, J.J., Buotte, P.C. and Harmon, M.E. 2018. Land use strategies to mitigate climate change in carbon dense temperate forests. *Proceedings of the National Academy of Sciences*, 115(14), pp.3663-3668.

Lee, E.H., Beedlow, P.A., Waschmann, R.S., Tingey, D.T., Wickham, C., Cline, S., Bollman, M., and Carlile, C. 2016. Douglas-fir displays a range of growth responses to temperature, water, and Swiss needle cast in western Oregon, USA. *Agricultural and Forest Meteorology* 221, 176-188.

Lesmeister, D.B., Davis, R.J., Singleton, P.H. and Wiens, J.D. 2018. Northern spotted owl habitat and populations: status and threats. *Synthesis of science to inform land management within the northwest forest plan area*, pp.245-299.

Lesmeister, D.B. and Swingle, J.K. 2017. Field guide to red tree vole nests. Interagency Special Status and Sensitive Species Program. USDA Forest Service, Pacific Northwest Region and USDI Bureau of Land Management, Oregon/Washington Portland, Oregon. 41 p.

Levin, S.A. 1992. The problem of pattern and scale in ecology. *Ecology* 73, 1943-1967.

Li, F., Zi, H., Sonne, C. and Li, X. 2023. Microbiome sustains forest ecosystem functions across hierarchical scales. *Eco-Environment & Health* 2(1), pp. 24-31.

Lindeburg, K.S., Almond, P., Roering, J.J. and Chadwick, O.A. 2013. Pathways of soil genesis in the Coast Range of Oregon, USA. *Plant and Soil*, 367, pp.57-75.

Littell J.S., Hicke J.A., Shafer S.L., Capalbo S.M., Houston L.L. and Glick P. 2013. Forest ecosystems: Vegetation, disturbance, and economics: Chapter 5. In: Dalton M.M., Mote P.W. and Snover A.K. (eds) *Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities*. Island Press: Washington, DC, 110–148.

Long, C.J., Whitlock, C., Bartlein, P.J. and Millsaugh, S.H. 1998. A 9000-year fire history from the Oregon Coast Range, based on a high-resolution charcoal study. *Canadian Journal of Forest Research*, 28(5), pp.774-787.

Loudermilk, E.L., Stanton, A., Scheller, R.M., Dilts, T.E., Weisberg, P.J., Skinner, C. and Yang, J. 2014. Effectiveness of fuel treatments for mitigating wildfire risk and sequestering forest



carbon: a case study in the Lake Tahoe Basin. *Forest Ecology and Management*, 323, pp.114-125.

Luginbuhl, J.M., Marzluff, J.M., Bradley, J.E., Raphael, M.G. and Varland, D.E. 2001. Corvid survey techniques and the relationship between corvid relative abundance and nest predation. *Journal of field Ornithology*, 72(4), 556-572.

Luna, L.V. and Korup, O. 2022. Seasonal landslide activity lags annual precipitation pattern in the Pacific Northwest. *Geophysical Research Letters*, 49(18), p.e2022GL098506.

Lurie, S. and Hibbard, M. 2008. Community-based natural resource management: Ideals and realities for Oregon watershed councils. *Society and Natural Resources*, 21(5), pp.430-440.

Macfarlane, W.W., J.T. Gilbert, M.L. Jensen, J.D. Gilbert, N. Hough-Snee, P.A. McHugh, J.M. Wheaton and S.N. Bennett. 2017. Riparian vegetation as an indicator of riparian condition: Detecting departures from historic condition across the North American West. *Journal of Environmental Management* 202: 447-460.

MacKenzie, D.I., Nichols, J.D., Lachman, G.B., Droege, S., Andrew Royle, J. and Langtimm, C.A. 2002. Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, 83(8), 2248-2255.

Maguire, D.A., Kershaw Jr, J.A. and Hann, D.W. 1991. Predicting the effects of silvicultural regime on branch size and crown wood core in Douglas-fir. *Forest Science*, 37(5), pp.1409-1428.

Mallams, K.M., K.L. Chadwick and P.A. Angwin. 2010. Decays of white, grand, and red firs. *Forest Insect & Disease Leaflet* 52. USDA Forest Service, Pacific Northwest Region (R6), Portland, Oregon.

Malt, J. and Lank, D. 2007. Temporal dynamics of edge effects on nest predation risk for the marbled murrelet. *Biological Conservation*, 140, 160–173.

Malt, J.M. and Lank, D.B. 2009. marbled murrelet nest predation risk in managed forest landscapes: Dynamic fragmentation effects at multiple scales. *Ecological Applications*, 19, 1274–1287.

Manning, T., Hagar, J.C. and McComb, B.C. 2012. Thinning of young Douglas-fir forests decreases density of northern flying squirrels in the Oregon Cascades. *Forest Ecology and Management* 264, 115-124.

Marks-Block, T. and Tripp, W. 2021. Facilitating prescribed fire in northern California through Indigenous governance and interagency partnerships. *Fire* 4, 37.

Martens, K.D., Devine, W.D., Minkova, T.V. and Foster, A.D. 2019. Stream conditions after 18 years of passive riparian restoration in small fish-bearing watersheds. *Environmental management*, 63(5), pp.673-690.

Martens, K.D., Donato, D.C., Halofsky, J.S., Devine, W.D. and Minkova, T.V. 2020. Linking instream wood recruitment to adjacent forest development in landscapes driven by stand-replacing disturbances: A conceptual model to inform riparian and stream management. *Environmental Reviews*, 28(4), pp.517-527.

Martin, M.E., M.S. Delheimer, M.W. Gabriel, G.M. Wengert and K.M. Moriarty. 2022. Combined field and clinical methods clarify mortality causes and survival patterns of Pacific martens. *The Journal of Wildlife Management* 86(1): e22131. <https://doi.org/10.1002/jwmg.22131>

Marzluff, J.M., J.J. Millspaugh, P. Hurvitz and M.S. Handcock. 2004. Relating resources to a probabilistic measure of space use: Forest fragments and Steller's Jays. *Ecology* 85:1411-1427.

Mason, K.E., S. Oakley, L. Street, M. Arróniz-Crespo, D.L. Jones, T.H. DeLuca and N. Ostle. 2019. Boreal forest floor greenhouse gas emissions across a *Pleurozium schreberi*-dominated, wildfire-disturbed chronosequence. *Ecosystems* 22:1381–1392.

Mass, C. and Dotson, B. 2010. Major extratropical cyclones of the northwest United States: Historical review, climatology, and synoptic environment. *Monthly Weather Review*, 138(7), pp.2499-2527.

Mater, M. 2023. Personal communication 4-4-2023. Tenmile Lakes Basin Partnership.

May C., Luce, C., Casola, J., Chang, M., Cuhaciyen, J., Dalton, M., Lowe, S., Morishima, G., Mote, P., Petersen, A., Roesch- McNally, G. and York, E. 2018. Northwest. In: Reidmiller, D.R., Avery, C.W., Easterling, D.R., Kunkel, K.E., Lewis, K.L.M., Maycock, T.K., and Stewart, B.C. (eds.). *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*. U.S. Global Change Research Program, Washington, DC, USA, pp. 1036–1100.

May, C.L. 2002. Debris flows through different forest age classes in the central Oregon Coast Range. *Journal of the American Water Resources Association*, 38(4), pp.1097-1113.

May, C.L. and Gresswell, R.E. 2003. Large wood recruitment and redistribution in headwater streams in the southern Oregon Coast Range, USA. *Canadian Journal of Forest Research*, 33(8), pp.1352-1362.

Mayer, T.D. 2012. Coquille River Basin Stream Temperature Assessment. [http://ecoadapt.org/data/documents/CoquilleRiverTemperatureAssessment\\_Dec2012.pdf](http://ecoadapt.org/data/documents/CoquilleRiverTemperatureAssessment_Dec2012.pdf)

McEvoy, A., Nielsen-Pincus, M., Holz, A., Catalano, A.J. and Gleason, K.E., 2020. Projected impact of mid-21st century climate change on wildfire hazard in a major urban watershed outside Portland, Oregon USA. *Fire*, 3(4), p.70.

McGarigal, K., Wan, H.Y., Zeller, K.A., Timm, B.C., and Cushman, S.A. 2016. Multi-scale habitat selection modeling: a review and outlook. *Landscape Ecology* 31, 1161-1175.

Mellen-McLean, K., B.G. Marcot, J.L. Ohmann, K. Waddell, E.A. Willhite, S.A. Acker, S.A. Livingston, B.B. Hostetler, B.S. Webb and B.A. Garcia. 2017. DecAID, the decayed wood advisor for managing snags, partially dead trees, and down wood for biodiversity in forests of Washington and Oregon. Version 3.0. USDA Forest Service, Pacific Northwest Region and Pacific Northwest Research Station; USDI Fish and Wildlife Service, Oregon State Office; Portland, Oregon. [https://apps.fs.usda.gov/r6\\_DecAID](https://apps.fs.usda.gov/r6_DecAID)

Merschel, A.G. 2021. Historical forest succession and disturbance dynamics in Coastal Douglas-fir forests in the southern western Cascades of Oregon. PhD Dissertation. Oregon State University, Corvallis, Oregon.

Millar, C.I. and Stephenson, N.L. 2015. Temperate forest health in an era of emerging megadisturbance. *Science*, 349(6250), pp.823-826.

Millar, C.I., Stephenson, N.L. and Stephens, S.L. 2007. Climate change and forests of the future: managing in the face of uncertainty. *Ecological Applications*, 17(8), pp.2145-2151.

Miller, D., Benda, L., DePasquale, J., and Albert, D. 2015. Creation of a digital flowline network from IfSAR 5-m DEMs for the Matanuska-Susitna Basins: A resource for update of the National Hydrographic Dataset in Alaska. Available online at: [https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/alaska/scak/Documents/Miller\\_et\\_al\\_MatSu\\_Elevation\\_Derived\\_Flow\\_Network\\_Report.pdf](https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/alaska/scak/Documents/Miller_et_al_MatSu_Elevation_Derived_Flow_Network_Report.pdf)

Mirus, B.B., J.B. Smith, J.W. Godt, R.L. Baum and J.A. Coe. 2018. Simulated effect of topography and soil properties on hydrologic response and landslide potential under variable rainfall conditions in the Oregon Coast Range, USA. In *Landslides and Engineered Slopes. Experience, Theory and Practice*, pp. 1431-1439.

Mitchell, S.J. 2013. Wind as a natural disturbance agent in forests: a synthesis. *Forestry: An International Journal of Forest Research*, 86(2), pp.147-157.

Mitchell, S.J., Hailemariam, T. and Kulis, Y. 2001. Empirical modeling of cutblock edge windthrow risk on Vancouver Island, Canada, using stand level information. *Forest Ecology and Management*, 154(1-2), pp.117-130.

Mladenoff, D.J. and He, H.S. 1999. Chapter 6: Design, behavior and application of LANDIS, an object-oriented model of forest landscape disturbance and succession. In *Spatial modeling of forest landscape change*. Cambridge University Press, Cambridge, UK, pp.125-162.

Mo, R., Lin, H. and Vitart, F. 2022. An anomalous warm-season trans-Pacific atmospheric river linked to the 2021 western North America heatwave. *Communications Earth & Environment*, 3(1), pp.1-12.

Moriarty, K.M., Verschuyt, J., Kroll, A.J., Davis, R., Chapman, J. and Hollen, B. 2019. Describing vegetation characteristics used by two rare forest-dwelling species: Will established reserves provide for coastal marten in Oregon? *PloS one*, 14(1), p.e0210865.

Morrison, P.H. and F.J. Swanson. 1990. Fire history and pattern in a Cascade Range landscape. USDA Forest Service General Technical Report. PNW-254. Pacific Northwest Research Station, Corvallis, Oregon.

Mote, P.W., Snover, A.K., Capalbo, S., Eigenbrode, S.D., Glick, P., Littell, J., Raymondi, R. and Reeder, S. 2014. Ch. 21: Northwest. *Climate Change Impacts in the United States: The Third National Climate Assessment*. In: Melillo, J.M., et al. (Eds.). U.S. Global Change Research Program. pp. 487–513.

Mucioki, M., Sowerwine, J., Sarna-Wojcicki, D., Lake, F.K. and Bourque, S. 2021. Conceptualizing Indigenous Cultural Ecosystem Services (ICES) and Benefits under Changing Climate Conditions in the Klamath River Basin and Their Implications for Land Management and Governance. *Journal of Ethnobiology* 41, 313-330, 18.

Murphy, G., Pikerton, S.J. 2011. Seasonal Impacts on Bark Loss for Douglas-fir and Ponderosa Pine Harvested on the Pacific Northwest Coast of the USA. *International Journal of Forest Engineering* 22(1):35-41. <https://doi.org/10.1080/14942119.2011.10702602>

Nadeau, T.L. and M.C. Rains. 2007. Hydrological connectivity between headwater streams and downstream waters: how science can inform policy. *JAWRA Journal of the American Water Resources Association* 43(1): 118-133.

Nagel, L.M., Palik, B.J., Battaglia, M.A., D'Amato, A.W., Guldin, J.M., Swanston, C.W., Janowiak, M.K., Powers, M.P., Joyce, L.A., Millar, C.I. and Peterson, D.L. 2017. Adaptive silviculture for climate change: A national experiment in manager-scientist partnerships to apply an adaptation framework. *Journal of Forestry*, 115(3), pp.167-178.

Naiman, R.J., Decamps, H. and McClain, M.E. 2010. *Riparia: Ecology, conservation, and management of streamside communities*. Elsevier.



Natesan, S., Armenakis, C. and Vepakomma, U. 2020. Individual tree species identification using Dense Convolutional Network (DenseNet) on multitemporal RGB images from UAV. *Journal of Unmanned Vehicle Systems*, 8(4), pp.310-333.

National Network for Collaboration. 1995. Collaboration framework – addressing community capacity. Retrieved 08/08/2023 from [https://www.uvm.edu/sites/default/files/media/Collaboration\\_Framework\\_pub.pdf](https://www.uvm.edu/sites/default/files/media/Collaboration_Framework_pub.pdf).

Neill, A., and Puettmann, K.J. 2013. Managing for adaptive capacity: Thinning improves food availability for wildlife and insect pollinators under climate change conditions. *Canadian Journal Forest Research* 43, 428-440.

Nelson, S.K. 2020. marbled murrelet version 1.0 in: *Birds of the World* (A.F. Poole and F.B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. <https://doi.org/10.2173/bow.marmur.01>.

Nelson, S.K. and T.E. Hamer. 1995. Nest success and the effects of predation on marbled murrelets. In: Ralph, C.J., Hunt Jr., G.L., Raphael, M.G., Piatt, J.F. (Eds.), *Ecology and Conservation of the marbled murrelet*. USDA Forest Service General Technical Report, PSW-GTR-152, Pacific Southwest Research Station, Albany, California, pp. 57–67.

Newton, M. and Cole, L. 2015. Overstory development in Douglas-fir-dominant forests thinned to enhance late-seral features. *Forest Science*, 61(4), pp.809-816.

NMFS (National Marine Fisheries Service). 2016a. Recovery Plan for Oregon Coast Coho Salmon Evolutionarily Significant Unit. National Marine Fisheries Service, West Coast Region, Portland, Oregon. <https://repository.library.noaa.gov/view/noaa/15986>

NMFS (National Marine Fisheries Service). 2016b. 2016 5-Year Review: Summary & Evaluation of Oregon Coast Coho Salmon. National Marine Fisheries Service, West Coast Region, Portland, Oregon. <https://repository.library.noaa.gov/view/noaa/17023>

NOAA (National Oceanic and Atmospheric Administration). 2015. Final Programmatic Environmental Impact Statement for habitat restoration activities implemented throughout the coastal United States. Office of Habitat Conservation, NOAA Restoration Center. June 2015. <https://repository.library.noaa.gov/view/noaa/1246>

Noon, B.R., McKelvey, K.S. and Dickson, B.G. 2008. Multispecies conservation planning on US federal lands [Chapter 3]. *Models for planning wildlife conservation in large landscapes*, pp.51-83.

Nykänen, M.L., Peltola, H., Quine, C., Kellomäki, S. and Broadgate, M. 1997. Factors affecting snow damage of trees with particular reference to European conditions. *Silva Fennica* 31(2) pp. 193-213. The Finnish Society of Forest Science.

O'Hara, K.L. and Ramage, B.S. 2013. Silviculture in an uncertain world: utilizing multi-aged management systems to integrate disturbance. *Forestry* 86:401-410.

OAR chapter 629, division 25. Department of Forestry, Forest Park and Recreation Areas.

ODF (Oregon Department of Forestry). 2000. Forest road management guidebook. Oregon Forest Practices Program. <https://www.oregon.gov/odf/Documents/workingforests/forest-road-management-guidebook.pdf>

ODF (Oregon Department of Forestry). 2005. Oregon's timber harvests: 1849-2004. <https://www.oregon.gov/odf/Documents/workingforests/oregonstimberharvests.pdf>

ODF (Oregon Department of Forestry). 2016. Coos District 2016 Annual Operating Plan.

ODF (Oregon Department of Forestry) 2017a. Forest Health Fact Sheet: Douglas-fir beetle. <https://www.oregon.gov/odf/Documents/forestbenefits/Douglas-fir-beetle.pdf>

ODF (Oregon Department of Forestry). 2017b. Forest Health Fact Sheet: MCH for Doug-fir beetle management. [https://www.oregon.gov/odf/Documents/forestbenefits/MCH\\_2016.pdf](https://www.oregon.gov/odf/Documents/forestbenefits/MCH_2016.pdf)

ODF (Oregon Department of Forestry). 2019. Forest Practices Technical Note Number 2, Version 2.0. High landslide hazard locations, shallow, rapidly moving landslides and public safety: Screening and practices. Effective January 1, 2003, revised January 24, 2019. <https://www.oregon.gov/odf/Documents/workingforests/HighLandslideHazardLocationsTechNote2.pdf>

ODF (Oregon Department of Forestry). 2020. Western Oregon State Forest Management Plan. Draft final plan. <https://www.oregon.gov/odf/board/Documents/fmp-ESRF HCP/Western-Oregon-State-Forest-Management-Plan-Final-Draft.pdf>

ODFW (Oregon Department of Fish and Wildlife). 2015. Guidance for conserving Oregon's native turtles including best management practices. 99 pp. Oregon Department of Fish and Wildlife, Salem, Oregon.

ODFW (Oregon Department of Fish and Wildlife). 2019. Oregon Fish Passage Barriers. <https://nrimp.dfw.state.or.us/nrimp/default.aspx?pn=fishbarrierdata#:~:text=Oregon%20Fish%20Passage%20Barriers,that%20is%20stewarded%20by%20ODFW>

ODFW (Oregon Department of Fish and Wildlife). 2021. List of sensitive species. [https://www.dfw.state.or.us/wildlife/diversity/species/docs/Sensitive\\_Species\\_List.pdf](https://www.dfw.state.or.us/wildlife/diversity/species/docs/Sensitive_Species_List.pdf)

ODFW (Oregon Department of Fish and Wildlife). 2021. Biological Assessment of the marbled murrelet (*Brachyramphus marmoratus*) in Oregon and evaluation of criteria to reclassify the species from threatened to endangered under the Oregon Endangered Species Act. Report

prepared for the Oregon Fish and Wildlife Commission, June 2021. Oregon Department of Fish and Wildlife, Salem, Oregon.

ODFW (Oregon Department of Fish and Wildlife). 2022. Oregon Furbearer Trapping and Hunting Regulations July 1, 2022 through June 30, 2024. Oregon Dept. of Fish and Wildlife, Salem OR. [https://www.dfw.state.or.us/resources/hunting/small\\_game/regulations/docs/furbearer\\_regulations.pdf](https://www.dfw.state.or.us/resources/hunting/small_game/regulations/docs/furbearer_regulations.pdf)

ODFW (Oregon Department of Fish and Wildlife). 2023. Oregon Connectivity Assessment and Mapping Project: Technical Report. Oregon Department of Fish and Wildlife, Wildlife Division. Salem, OR. 61p.

O'Hara, K.L. 2016. What is close-to-nature silviculture in a changing world? *Forestry*, 89(1), pp.1-6.

O'Hara, K.L. and Ramage, B.S. 2013. Silviculture in an uncertain world: utilizing multi-aged management systems to integrate disturbance. *Forestry*, 86(4), pp.401-410.

Ohmann, J.L. and M.J. Gregory. 2002. Predictive mapping of forest composition and structure with direct gradient analysis and nearest-neighbor imputation in coastal Oregon, U.S.A. *Canadian Journal of Forest Research*, 32, 725-741.

Ohmann, J.L., M.J. Gregory and H.M. Roberts. 2014. Scale considerations for integrating forest inventory plot data and satellite image data for regional forest mapping. *Remote Sensing of Environment* 151: 3-15.

O'Neill, K.P., M.C. Amacher and C.J. Palmer. 2005. Developing a national indicator of soil quality on US forestlands: Methods and initial results. *Environmental Monitoring and Assessment* 107:59-80.

Ontl, T.A., Janowiak, M.K., Swanston, C.W., Daley, J., Handler, S., Cornett, M., Hagenbuch, S., Handrick, C., McCarthy, L. and Patch, N. 2020. Forest management for carbon sequestration and climate adaptation. *Journal of Forestry*, 118(1), pp.86-101.

Oregon Biodiversity Information Center. 2019. Rare, Threatened and Endangered Species of Oregon. Institute for Natural Resources, Portland State University, Portland, Oregon. 133 pp.

Oregon Conservation Strategy. 2023. Priority wildlife conservation areas. <https://oregonconservationstrategy.org/success-story/priority-wildlife-connectivity-areas-pwcas/>. Accessed 11-17-2023.

Oregon DEQ (Department of Environmental Quality) 2008. Temperature water quality standard implementation – A DEQ internal management directive. <https://www.oregon.gov/deq/Filtered%20Library/IMDTemperature.pdf>

Oregon DEQ (Department of Environmental Quality) 2022. Oregon's nonpoint source management program plan. Oregon DEQ Water Quality Division.  
<https://www.oregon.gov/deq/FilterDocs/npsplanF.pdf>

Oregon DLCD (Department of Land Conservation and Development). 2022. Goal 5: Natural Resources, Scenic and Historic Areas, and Open Spaces.  
<https://www.oregon.gov/lcd/OP/Pages/Goal-5.aspx>

Oregon DSL (Department of State Lands). 2022. Elliott State Forest Public Ownership Project, Elliott State Forest Expenses. Accessed 2-18-2023.  
<https://www.oregon.gov/dsl/Land/Elliott%20Forest%20Library/ElliottExpensesOverview.pdf>

Oregon DSL (Department of State Lands). 2022. Elliott State Research Forest ESRF HCP. Public Draft Habitat Conservation Plan. <https://www.fws.gov/project/elliott-state-research-forest-habitat-conservation-plan>

Oregon DSL and ODF (Department of State Lands and Oregon Department of Forestry). 2011. Elliott State Forest Management Plan. <https://digital.osl.state.or.us/islandora/object/osl:88828>

Oregon Global Warming Commission. 2023. Oregon Climate Action Roadmap to 2030: Commission Recommendations. March 2023.

Oregon State University. 2016. Research Office Policy 16-001: Roles and Responsibilities. Corvallis, OR: Oregon State University. 4p. Retrieved 08/08/2023 from [https://research.oregonstate.edu/sites/research.oregonstate.edu/files/osu\\_roles\\_and\\_responsibility\\_document\\_0216.pdf](https://research.oregonstate.edu/sites/research.oregonstate.edu/files/osu_roles_and_responsibility_document_0216.pdf).

Oregon Watershed Enhancement Board (OWEB). 1999. Oregon watershed assessment manual. Prepared by Watershed Professionals Network.  
<https://digital.osl.state.or.us/islandora/object/osl:18907>

Orland, E., Roering, J.J., Thomas, M.A. and Mirus, B.B. 2020. Deep learning as a tool to forecast hydrologic response for landslide-prone hillslopes. *Geophysical Research Letters*, 47(16), p.e2020GL088731.

Osborne, N.L. 2015. CIPSR 2.2.4. Interface to an individual tree, empirical, spatially implicit, forest growth, yield and wood quality simulator for the Pacific Northwestern United States. <https://r-forge.r-project.org/projects/cipsr/>

OSU (Oregon State University) College of Forestry. 2019a. Elliott Forest Listening Sessions Summary. Corvallis, OR: Oregon State University. 19p.

OSU (Oregon State University) College of Forestry. 2019b. Education Liaison – Elliott State Research Forest, updated (November 19, 2019). Corvallis OR: Oregon State University. 3p.



OSU (Oregon State University) College of Forestry. 2019c. Tribal Liaison – Elliott State Research Forest, updated (October 29, 2019). Corvallis OR: Oregon State University. 3p.

OSU (Oregon State University) College of Forestry. 2021. Proposal: Elliott State Research Forest. Updated April 2021.  
[https://www.forestry.oregonstate.edu/sites/default/files/041421\\_esrf\\_proposal.pdf](https://www.forestry.oregonstate.edu/sites/default/files/041421_esrf_proposal.pdf)

OSU (Oregon State University) College of Forestry. 2022. What is recreation management?  
<https://cf.forestry.oregonstate.edu/recreation/recreation-management>

OSU (Oregon State University) College of Forestry. 2023. Principles and Best Practices for Working with Indigenous Knowledge and Partnering with Tribal Nations and Indigenous Peoples. Volume I: Principles. Corvallis, OR: College of Forestry, Oregon State University. 8 pp. Retrieved 08/08/2023 from  
<https://www.forestry.oregonstate.edu/sites/default/files/Principles%20and%20Best%20Practices%20Volume1%20Final.pdf>

Palik, B.J., D'Amato, A.W., Franklin, J.F., and Johnson, K.N. 2021. Ecological silviculture: Foundations and applications. Long Grove, IL: Waveland Press.

Parton, W.J., J.W.B. Stewart and C.V Cole. 1988. Dynamics of C, N, P and S in grassland soils: a model. *Biogeochemistry* 5:109–131.

Parton, W.J., Ojima, D.S., Cole, C.V. and Schimel, D.S. 1994. A general model for soil organic matter dynamics: sensitivity to litter chemistry, texture and management. *Quantitative Modeling of Soil Forming Processes* 39: pp.147-167.

Penaluna, B.E., Allen, J.M., Arismendi, I., Levi, T., Garcia, T.S. and Walter, J.K. 2021. Better boundaries: Identifying the upper extent of fish distributions in forested streams using eDNA and electrofishing. *Ecosphere*, 12(1), p.e03332.

Perakis, S.S., Maguire, D.A., Bullen, T.D., Cromack, K., Waring, R.H. and Boyle, J.R. 2006. Coupled nitrogen and calcium cycles in forests of the Oregon Coast Range. *Ecosystems*, 9, pp.63-74.

Perakis, S.S., Sinkhorn, E.R. and Compton, J.E. 2011.  $\delta^{15}\text{N}$  constraints on long-term nitrogen balances in temperate forests. *Oecologia*, 167, pp.793-807.

PFA (Conservation Coalition and Working Forest Coalition). 2022. Private Forest Accord. Report presented to the Oregon Legislature, Oregon Governor Kate Brown and Oregon Board of Forestry, February 2, 2022. 196p. <https://www.oregon.gov/odf/aboutodf/documents/2022-odf-private-forest-accord-report.pdf>

Phalan, B.T., Northrup, J.M., Yang, Z., Deal, R.L., Rousseau, J.S., Spies, T.A., and Betts, M.G. 2019. Impacts of the Northwest Forest Plan on forest composition and bird populations. *PNAS* 116(8) 3322-3327.

Phillips, J. 1997. Caulked boots and cheese sandwiches. A forester's history of Oregon's first state forest. Self-published, Butler's Pronto Print, Coos Bay OR.

Pickering, C., Rossi, S.D., Hernando, A. and Barros, A. 2018. Current knowledge and future research directions for the monitoring and management of visitors in recreational and protected areas. *Journal of Outdoor Recreation and Tourism*, 21, pp.10-18.

Poggio, L., De Sousa, L.M., Batjes, N.H., Heuvelink, G., Kempen, B., Ribeiro, E. and Rossiter, D. 2021. SoilGrids 2.0: producing soil information for the globe with quantified spatial uncertainty. *Soil*, 7(1), pp.217-240.

Pollock, M.M., G. Lewallen, K. Woodruff, C.E. Jordan and J.M. Castro (Eds.) 2015. The beaver restoration guidebook: Working with beaver to restore streams, wetlands, and floodplains. Version 1.02. United States Fish and Wildlife Service, Portland, Oregon. 189 pp.

Poudel, K.P., H. Temesgen and A.N. Gray. 2018. Estimating upper stem diameters and volume of Douglas-fir and Western hemlock trees in the Pacific northwest. *For. Ecosyst.* 5(1):16.

Poudel, K.P., Temesgen, H., Radtke, P.J. and Gray, A.N. 2019. Estimating individual-tree aboveground biomass of tree species in the western USA. *Canadian Journal of Forest Research*, 49(6), pp.701-714.

Powers, J.S., Sollins, P., Harmon, M.E., and Jones, J.A. 1999. Plant-pest interactions in time and space: a Douglas-fir bark beetle outbreak as a case study. *Landscape Ecology* 14, 105-120.

Prichard, S.J., Kennedy, M.C., Andreu, A.G., Eagle, P.C., French, N.H., and Billmire, M. 2019. Next-Generation Biomass Mapping for Regional Emissions and Carbon Inventories: Incorporating Uncertainty in Wildland Fuel Characterization. *Journal of Geophysical Research: Biogeosciences* 124, 3699-3716.

Priebe, J.E., Powers, M.D. and Cole, E.C. 2018. Species, tree size, and overstory environment affect likelihood of ice storm damage to understory trees in a mature Douglas-fir forest. *Forest Ecology and Management*, 409, pp.777-788.

Puettmann, K.J. and Tappeiner, J.C. 2014. Multi-scale assessments highlight silvicultural opportunities to increase species diversity and spatial variability in forests. *Forestry*, 87(1), pp.1-10.

Puettmann, K.J., Ares, A., Burton, J.I. and Dodson, E.K. 2016. Forest restoration using variable density thinning: Lessons from Douglas-fir stands in western Oregon. *Forests*, 7(12), p.310.

Puettmann, K.J., Coates, K.D. and Messier, C. 2009. *A Critique of Silviculture: Managing for Complexity*. Island Press, Washington, DC.

Pulido-Chavez, M.F., Alvarado, E.C., DeLuca, T.H., Edmonds, R.L. and Glassman, S.I. 2021. High-severity wildfire reduces richness and alters composition of ectomycorrhizal fungi in low-severity adapted ponderosa pine forests. *Forest Ecology and Management*, 485, p.118923.

Reeb, J.E. and Shaw, D.C. 2015. Common insect pests and diseases of Sitka spruce on the Oregon coast. EM 9015. Oregon State University Extension Service.  
<https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em9105.pdf>

Reeve, T. and Warren, R. 2015. Are we doing our best to restore watersheds? Lessons from a 10-year watershed restoration strategy. *Solutions*, Jan-Feb 2015. <https://www.b-e-f.org/wp-content/uploads/2021/04/BEF-Solutions-Article.pdf>

Reeves, G.H., Burnett, K.M. and McGarry, E.V. 2003. Sources of large wood in the main stem of a fourth-order watershed in coastal Oregon. *Canadian Journal of Forest Research*, 33(8), pp.1363-1370.

Reid, A.J., Eckert, L.E., Lane, J.F., Young, N., Hinch, S.G., Darimont, C.T., Cooke, S.J., Ban, N.C. and Marshall, A. 2021. “Two-Eyed Seeing”: An Indigenous framework to transform fisheries research and management. *Fish and Fisheries*, 22(2), pp.243-261.

Reilly, M.J. and Spies, T.A. 2016. Disturbance, tree mortality, and implications for contemporary regional forest change in the Pacific Northwest. *Forest Ecology and Management*. 374: 102–1931 110.

Reilly, M.J., Glavich, D., Acker, S.A., Kearns, H., Willhite, E., Kim, J., Kerns, B., Donaldson, C., Halofsky, J.E. In press. Climate, disturbance, and vegetation change in the Oregon Coast. Chapter 5 in Halofsky, J.E.; Peterson, D.L.; Gravenmier, R.A., eds. In press. *Climate change vulnerability and adaptation in Coastal Oregon*. Gen. Tech. Rep. PNW-GTR-xxx. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Reilly, M.J., Halofsky, J.E., Krawchuk, M.A., Donato, D.C., Hessburg, P.F., Johnston, J.D., Merschel, A.G., Swanson, M.E., Halofsky, J.S., and Spies, T.A. 2021. Fire ecology and management in Pacific Northwest forests. In: Greenberg, C.H., and Collins, B. Eds. *Fire ecology and management: Past, present, and future of US forested ecosystems*. New York: Springer. p. 393-435

Reilly, M.J., Zuspan, A., Halofsky, J.S., Raymond, C., McEvoy, A., Dye, A.W., Donato, D.C., Kim, J.B., Potter, B.E., Walker, N. and Davis, R.J., Dunn, C.J., Bell, D.M., Gregory, M.J., Johnston, J.D., Harvey, B.J., Halofsky, J.E and Kerns, B.K. 2022. Cascadia Burning: The historic, but not historically unprecedented, 2020 wildfires in the Pacific Northwest, USA. *Ecosphere*, 13(6), p.e4070

Remsoft. 2023. Intelligent Planning Solutions for Forestry. <https://remsoft.com/>

Reneau, S.L. and Dietrich, W.E. 1991. Erosion rates in the southern Oregon Coast Range: Evidence for an equilibrium between hillslope erosion and sediment yield. *Earth Surface Processes and Landforms*, 16(4), pp.307-322.

Rhoades, A.M., Jones, A.D., Srivastava, A., Huang, H., O'Brien, T.A., Patricola, C.M., Ullrich, P.A., Wehner, M. and Zhou, Y. 2020. The shifting scales of western US landfalling atmospheric rivers under climate change. *Geophysical Research Letters*, 47(17), p.e2020GL089096.

Richardson, J.S., Naiman, R.J. and Bisson, P.A. 2012. How did fixed-width buffers become standard practice for protecting freshwaters and their riparian areas from forest harvest practices? *Freshwater Science*, 31(1), pp.232-238.

Richardson, J.S., Taylor, E., Schluter, D., Pearson, M. and Hatfield, T. 2010. Do riparian zones qualify as critical habitat for endangered freshwater fishes? *Canadian Journal of Fisheries and Aquatic Sciences*, 67(7), pp.1197-1204.

Ritóková, G., D.C. Shaw and D. Mainwaring. 2022. Silvicultural decision guide for Swiss needle cast in coastal Oregon and Washington. Oregon State University Extension Service.

Robbins, W.G. 2006. *Hard times in paradise: Coos Bay, Oregon*. University of Washington Press.

Roberts, S.D. and Harrington, C.A. 2008. Individual tree growth response to variable-density thinning in coastal Pacific Northwest forests. *Forest Ecology and Management*, 255(7), pp.2771-2781.

Robison E.G., K. Mills, J. Paul, L. Dent and A. Skaugset. 1999. Storm impacts and landslides of 1996. Forest Practices Technical Report #4, Forest Practices Monitoring Program. Oregon Department of Forestry, Salem.

Roni, P.I., T.J. Beechie, R.E. Bilby, F.E. Leonetti, M.M. Pollock and G.R. Pess. 2002. A review of stream restoration techniques and hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. *North American Journal of Fisheries Management* 22:1–20.

Rosenberger, R.S., White, E.M., Kline, J.D. and Cvitanovich, C. 2017. Recreation economic values for estimating outdoor recreation economic benefits from the National Forest System. Gen. Tech. Rep. PNW-GTR-957. US Department of Agriculture, Pacific Northwest Research Station.

Rosenvald, R. and Lohmus, A. 2008. For what, when and where is green-tree retention better than clear-cutting? A review of the biodiversity aspects. *Forest Ecology and Management* 255:1-15.



Royle, J.A. 2004. N-Mixture Models for Estimating Population Size from Spatially Replicated Counts. *Biometrics* 60:108–115.

Royle, J.A. and Nichols, J.D. 2003. Estimating abundance from repeated presence–absence data or point counts. *Ecology*, 84(3), pp.777-790.

Ruth, R.H., Forest, P.N. and Yoder, R.A. 1953. Reducing wind damage in the forests of the Oregon Coast Range. Research Paper No. 7. USDA Forest Service, PNW Forest and Range Experiment Station. Portland, OR July 1953.

Ruwaldt, M. 2011a. Project Completion Report: Upper Dean Creek Instream Restoration Phase II. OWEB Project # 210-2040. Partnership for Umpqua Rivers.

Ruwaldt, M. 2011b. Project Completion Report: Charlotte/Luder Instream Restoration. OWEB Project # 210-2037. Partnership for Umpqua Rivers.

Salathé, E.P., Hamlet, A.F., Mass, C.F., Lee, S.Y., Stumbaugh, M. and Steed, R. 2014. Estimates of twenty-first-century flood risk in the Pacific Northwest based on regional climate model simulations. *Journal of Hydrometeorology*, 15(5), pp.1881-1899.

Sanz, B., Malinen, J., Sirparanta, S., Peuhkurinen, J., et al. 2021. Integrating Detailed Timber Assortments into Airborne Laser Scanning (ALS)-Based Assessments of Logging Recoveries. *Forests* 2021, 12, 1221. <https://doi.org/10.3390/f12091221>

Sarr, D.A. and Hibbs, D.E. 2007. Multiscale controls on woody plant diversity in western Oregon riparian forests. *Ecological Monographs*, 77(2), pp.179-201.

Sarr, D.A., Hibbs, D.E., Shatford, J.P. and Momsen, R. 2011. Influences of life history, environmental gradients, and disturbance on riparian tree regeneration in Western Oregon. *Forest Ecology and Management*, 261(7), pp.1241-1253.

SB 1546. Relating to Elliott State Research Forest; and prescribing an effective date. 81st Oregon Legislative Assembly--2022 Regular Session.  
<https://olis.oregonlegislature.gov/liz/2022R1/Downloads/MeasureDocument/SB1546/Enrolled>

SB 2841. Relating to the release of animal data; creating new provisions; amending ORS 192.345; and declaring an emergency. 80th Oregon Legislative Assembly--2019 Regular Session.  
<https://olis.oregonlegislature.gov/liz/2019R1/Downloads/MeasureDocument/HB2841/Enrolled>

Scheller, R.M., A.M. Kretchun, S. Van Tuyl, K.L. Clark, M.S. Lucash and J. Hom. 2012. Divergent carbon dynamics under climate change in forests with diverse soils, tree species, and land use histories. *Ecosphere* 3:art110.

Scheller, R.M., D. Hua, P.V. Bolstad, R.A. Birdsey and D.J. Mladenoff. 2011. The effects of forest harvest intensity in combination with wind disturbance on carbon dynamics in Lake States Mesic Forests. *Ecological Modelling* 222:144–153.

Scheller, R.M., J.B. Domingo, B.R. Sturtevant, J.S. Williams, A. Rudy, E.J. Gustafson, and D.J. Mladenoff. 2007. Design, development, and application of LANDIS-II, a spatial landscape simulation model with flexible temporal and spatial resolution. *Ecological Modelling* 201:409–419.

Schmitt, K.M., Ontl, T.A., Handler, S.D, Janowiak, M.K., Brandt, L.A., Butler-Leopold, P.R., Shannon, P.D., Peterson, C.L. and Swanston, C.W. 2021. Beyond planning tools: Experiential learning in climate adaptation planning and practices. *Climate* 9(5):76.  
<https://doi.org/10.3390/cli9050076>

Scholl, A.E. and Taylor, A.H. 2010. Fire regimes, forest change, and self-organization in an old-growth mixed-conifer forest, Yosemite National Park, USA. *Ecological Applications*, 20(2), pp.362-380.

Schrott, G.R. and J. Shinn. May 2020. A Landscape Connectivity Analysis for the Coastal Marten (*Martes caurina humboldtensis*). U.S. Fish & Wildlife Service, Arcata, CA. 123 pp.

Seidl, R., Rammer, W., Scheller, R.M. and Spies, T.A. 2012a. An individual-based process model to simulate landscape-scale forest ecosystem dynamics. *Ecological Modelling*, 231, pp.87-100.

Seidl, R., Spies, T.A., Rammer, W., Steel, E.A., Pabst, R.J. and Olsen, K. 2012b. Multi-scale drivers of spatial variation in old-growth forest carbon density disentangled with Lidar and an individual-based landscape model. *Ecosystems* 15, pp.1321-1335.

Seymour, R. and Hunter, M. 1999. Principles of ecological forestry. In: Hunter, M.L. Jr., ed. *Maintaining biodiversity in forest ecosystems*. Cambridge, UK: Cambridge University Press. p. 22-61.

Shaffer, T.L. 2004. A unified approach to analyzing nest success. *The Auk* 121: 526-540.

Shaw, D.C., Ritóková, G., Lan, Y.H., Mainwaring, D.B., Russo, A., Comeleo, R., Navarro, S., Norlander, D. and Smith, B. 2021. Persistence of the Swiss needle cast outbreak in Oregon Coastal Douglas-fir and new insights from research and monitoring. *Journal of Forestry*, 119(4), pp.407-421.

Shonfield, J. and E.M. Bayne. 2017. Autonomous recording units in avian ecological research: current use and future applications. *Avian Conservation and Ecology* 12: 14.

Siah, K.G., Perakis, S.S., Pett-Ridge, J.C. and van der Heijden, G. 2023. Nitrogen-bedrock interactions regulate multi-element nutrient limitation and sustainability in forests. *Biogeochemistry*, pp.1-25.

Sibley, A., Schulze, M., Jones, J., Kennedy, A. and Still, C. 2022. Canopy wetting patterns and the determinants of dry season dewfall in an old growth Douglas-fir canopy. *Agricultural and Forest Meteorology*, 323, p.109069.

Sinton, D.S., Jones, J.A., Ohmann, J.L. and Swanson, F.J. 2000. Windthrow disturbance, forest composition, and structure in the Bull Run basin, Oregon. *Ecology*, 81(9), pp.2539-2556.

Smith, J.B., Godt, J.W., Baum, R.L., Coe, J.A., Burns, W.J., Lu, N., Morse, M.M., SenerKaya, B. and Kaya, M. 2013. Hydrologic monitoring of a landslide-prone hillslope in the Elliott State Forest, Southern Coast Range, Oregon, 2009–2012. US Geological Survey Open-File Report, 1283, 61p.

Smith, L.T. 2012. *Decolonizing methodologies: Research and indigenous peoples*, 2nd edition. New York, NY: Zed Books Ltd.

Snyder, K., T. Sullivan, D. Moore, and R. Raymond. 2006. Lower Umpqua River Watershed Assessment. Prepared by E&S Environmental Chemistry, Inc. for the Umpqua Basin Watershed Council, Roseburg, OR.

Snyder, M.A., Sloan, L.C., Diffenbaugh, N.S. and Bell, J.L. 2003. Future climate change and upwelling in the California Current. *Geophysical Research Letters*. 30(15): 1823.doi:10.1029/2003GL017647

Souder, J.A. 2008. Coos Watershed Association: Model Watershed Program. Coos Watershed Association. 32p.

Souder, J. and Strimbu, B. 2021. Forest Chemicals. In: *Trees to tap: How forest practices affect Oregon’s municipal water*. Oregon State University Extension and Oregon Forest Resources Institute. <https://catalog.extension.oregonstate.edu/em9295-0>

Spies, T.A., Franklin, J.F. and Klopsch, M. 1990. Canopy gaps in Douglas-fir forests of the Cascade Mountains. *Canadian Journal of Forest Research* 20, 649-658.

Spies, T.A., Hessburg, P.F., Skinner, C.N., Puettmann, K.J., Reilly, M.J., Davis, R.J., Kertis, J.A., Long, J.W. and Shaw, D.C. 2018. Chapter 3: Old growth, disturbance, forest succession, and management within the Northwest Forest Plan Area. In: Spies, T.A., Stine, P.A., Gravenmier, R., Long, J.W., Reilly, M.J., and Mazza, R. Tech Coords. Synthesis of science to inform land management within the Northwest Forest Plan area. General Technical Report PNW-GTR-970. Portland, OR: USDA Forest Service Pacific Northwest Research Station .

Spies, T.A., McComb, B.C., Kennedy, R.S.H., McGrath, M.T., Olsen, K. and Pabst, R.J. 2007. Potential effects of forest policies on terrestrial biodiversity in a multi-ownership province. *Ecological Applications* 17(1):48-65.

Spies, T.A., Stine, P.A., Gravenmier, R., Long, J.W., Reilly, M.J. and Mazza, R., tech. coords. 2018. Synthesis of science to inform land management within the Northwest Forest Plan area. Gen. Tech. Rep. PNW-GTR-970. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 186 p.

Spycher, S., Mangold, S., Doppler, T., Junghans, M., Wittmer, I., Stamm, C. and Singer, H. 2018. Pesticide risks in small streams—how to get as close as possible to the stress imposed on aquatic organisms. *Environmental Science and Technology* 52: 4526-4535

State of California Native American Heritage Commission. 2023. Understanding Cultural Resources. <https://nahc.ca.gov/resources/understanding-cultural-resources/>. Accessed 8-28-23.

Steel, E.A., Muldoon, A., Flitcroft, R.L., Firman, J.C., Anlauf-Dunn, K.J., Burnett, K.M. and Danehy, R.J. 2017. Current landscapes and legacies of land-use past: understanding the distribution of juvenile coho salmon (*Oncorhynchus kisutch*) and their habitats along the Oregon Coast, USA. *Canadian Journal of Fisheries and Aquatic Sciences*, 74(4), pp.546-561.

Steen-Adams, M.M., Charnley, S., McLain, R.J., Adams, M.D.O. and Wendel, K.L. 2019. Traditional knowledge of fire use by the Confederated Tribes of Warm Springs in the eastside Cascades of Oregon. *Forest Ecology and Management*, 450(May), 117405.

Stepp Consulting. 1998. A cultural resources literature search for potential sites on the Elliott State Forest, Oregon. Stepp Consulting Report No. 10. Oregon Department of Forestry.

Still, C.J., Sibley, A., DePinte, D., Busby, P.E., Harrington, C.A., Schulze, M., Shaw, D.R., Woodruff, D., Rupp, D.E., Daly, C. and Hammond, W.M. 2023. Causes of widespread foliar damage from the June 2021 Pacific Northwest Heat Dome: More heat than drought. *Tree Physiology*, 43(2), pp.203-209.

Stone, J.K., Coop, L.B. and Manter, D.K. 2008. Predicting effects of climate change on Swiss needle cast disease severity in Pacific Northwest forests. *Canadian Journal of Plant Pathology*, 30(2), pp.169-176.

Stovall, A.E., Shugart, H. and Yang, X. 2019. Tree height explains mortality risk during an intense drought. *Nature Communications*, 10(1), p.4385.

Strimbu, B.M., Innes, J.L. and Strimbu, V.F. 2010. A deterministic harvest scheduler using perfect bin-packing theorem. *European Journal of Forest Research* 129-5:961-974



Strimbu, V.F. and B.M. Strimbu. 2015. A graph-based segmentation algorithm for tree crown extraction using airborne LiDAR data. *ISPRS Journal of Photogrammetry and Remote Sensing*. 104:30–43.

Susaeta, A., Klizentyte, K., Sharma, A. and Adams, D.C. 2021. Can uneven-aged management improve the economic performance of longleaf pine? *Canadian Journal of Forest Research*, 51(9), pp.1307-1315.

Swanson, F.J. and Dyrness, C.T. 1975. Impact of clear-cutting and road construction on soil erosion by landslides in the western Cascade Range, Oregon. *Geology*, 3(7), 393-396.

Swanson, M.E., Studevant, N.M., Campbell, J.L. and Donato, D.C. 2014. Biological associates of early-seral pre-forest in the Pacific Northwest. *Forest Ecology and Management* 324:160-171.

Swanston, C.W.; Brandt, L.A.; Butler-Leopold, P.R.; Hall, K.R.; Handler, S.D.; Janowiak, M.K.; Merriam, K.; Meyer, M.; Molinari, N.; Schmitt, K.M.; Shannon, P.D.; Smith, J.B.; Wuenschel, A.; Ostoja, S.M. 2020. Adaptation strategies and approaches for California forest ecosystems. USDA California Climate Hub Technical Report CACH-2020-1. Davis, CA: U.S. Dept. of Agriculture, Climate Hubs. 65 p.

Swanston, C.W.; Janowiak, M.K.; Brandt, L.A.; Butler, P.R.; Handler, S.D.; Shannon, P.D.; Derby Lewis, A.; Hall, K.; Fahey, R.T.; Scott, L.; Kerber, A.; Miesbauer, J.W.; Darling, L.; Parker, L. and St. Pierre, M. 2016. Forest adaptation resources: Climate change tools and approaches for land managers, 2nd ed. Gen. Tech. Rep. NRS-GTR-87-2. Newtown Square, PA: U.S. Dept of Agriculture, Forest Service, Northern Research Station. 161 p. <https://doi.org/10.2737/NRS-GTR-87-2>

Swartz, A., Roon, D., Reiter, M. and Warren, D. 2020. Stream temperature responses to experimental riparian canopy gaps along forested headwaters in western Oregon. *Forest Ecology and Management*, 474, p.118354.

Tatum, V.L., Jackson, C.R., McBroom, M.W., Baillie, B.R., Schilling, E.B., Wigley, T.B. 2017. Effectiveness of forestry best management practices (BMPs) for reducing the risk of forest herbicide use to aquatic organisms in streams. *Forest Ecology and Management* 404, 258-268.

Tepley, A.J. 2010. Age Structure, Development Pathways, and Fire Regime Characterization of Douglas-fir/Western Hemlock Forests in the Central Western Cascades of Oregon. PhD Dissertation. Oregon State University, Corvallis, Oregon.

Tepley, A.J., Swanson, F.J. and Spies T.A. 2013. Fire-mediated pathways of stand development in Douglas-fir/western hemlock forests of the Pacific Northwest, USA. *Ecology*, 94(8), 1729–1743.

Thies, J.E., 2015. Molecular approaches to studying the soil biota. *Soil microbiology, ecology, and biochemistry*, pp.151-185.

Thomas, J.W., Franklin, J.F., Gordon, J. and Johnson, K.N., 2006. The Northwest Forest Plan: origins, components, implementation experience, and suggestions for change. *Conservation Biology*, 20(2), pp.277-287.

Thompson, V., Kennedy-Asser, A.T., Vosper, E., Lo, Y.E., Huntingford, C., Andrews, O., Collins, M., Hegerl, G.C. and Mitchell, D. 2022. The 2021 western North America heat wave among the most extreme events ever recorded globally. *Science Advances*, 8(18), p.eabm 6860.

Thorson, T.D., Bryce, S.A., Lammers, D.A., Woods, A.J., Omernik, J.M., Kagan, J., Pater, D.E. and Comstock, J.A. 2003. Ecoregions of Oregon (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,500,000)

TLBP (Tenmile Lakes Basin Partnership). 2002. Tenmile Lakes Watershed Assessment. [http://www.orwww.org/Elliott\\_Forest/Recreation/Tenmile\\_Lakes/Mader\\_et\\_al\\_ca\\_2002.pdf](http://www.orwww.org/Elliott_Forest/Recreation/Tenmile_Lakes/Mader_et_al_ca_2002.pdf)

Tohver, I.M., Hamlet, A.F. and Lee, S.Y. 2014. Impacts of 21st-century climate change on hydrologic extremes in the Pacific Northwest region of North America. *JAWRA Journal of the American Water Resources Association*, 50(6), pp.1461-1476.

Torresan, C., Benito Garzón, M., O'grady, M., Robson, T.M., Picchi, G., Panzacchi, P., Tomelleri, E., Smith, M., Marshall, J., Wingate, L. and Tognetti, R. 2021. A new generation of sensors and monitoring tools to support climate-smart forestry practices. *Canadian Journal of Forest Research*, 51(12), pp.1751-1765.

Tosa, M.I., E.H. Dziedzic, C.L. Appel, J. Urbina, A. Massey, J. Ruprecht, C.E. Eriksson, J.E. Dolliver, D.B. Lesmeister, M.G. Betts, C.A. Peres, and T. Levi. 2021. The rapid rise of next-generation natural history. *Frontiers in Ecology and Evolution* 9:698131.

Tosa, M.I., Lesmeister, D.B., Levi, T., Li, Y., Devenish, C., Luo, M., Bell, D.M., Greenfield, P., Pichler, M., Douglas, Yu, D.W., Betts, M.G., Kim, H. and Hallerud, M. 2022. Biodiversity Monitoring Report for the Elliott State Research Forest.

Trumbore, S., Brando, P. and Hartmann, H. 2015. Forest health and global change. *Science*, 349(6250), pp.814-818.

Tucker, J.M., Moriarty, K.M., Ellis, M.M. and Golding, J.D. 2021. Effective sampling area is a major driver of power to detect long-term trends in multispecies occupancy monitoring. *Ecosphere*, 12(5), p.e03519.

U.S. (United States) Drought Monitor. 2023. Data > time series > area type: county > Coos County, Oregon, Douglas County, Oregon. National Drought Mitigation Center, University of

Nebraska-Lincoln. In partnership with USDA and NOAA.

<https://droughtmonitor.unl.edu/DmData/TimeSeries.aspx>. Accessed 3-16-2023.

Ure, D.C. and C. Maser. 1982. Mycophagy of red-backed voles in Oregon and Washington. *Canadian Journal of Zoology* 60:3307–3315.

Urgenson, L.S., Halpern, C.B. and Anderson, P.D. 2012. Twelve-year responses of planted and naturally regenerating conifers to variable-retention harvest in the Pacific Northwest, USA. *Canadian Journal of Forest Research* 43, 46-55.

US Environmental Protection Agency. 2019. Handbook for citizen science: Quality assurance and documentation. EPA 206-B-18-001. Washington, DC: United State Environmental Protection Agency. 32p. <https://go.usa.gov/xEw43>

USDA (United States Dept of Agriculture) Forest Service. 1990. Recreation Opportunity Spectrum Primer and Field Guide. [https://www.fs.usda.gov/Internet/FSE\\_DOCUMENTS/stelprdb5335339.pdf](https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5335339.pdf)

USDA (United States Department of Agriculture) Forest Service. 2019. Recreation Opportunity Spectrum (ROS) Mapping Protocol. [https://www.fs.usda.gov/Internet/FSE\\_DOCUMENTS/fseprd684754.pdf](https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd684754.pdf)

USDA (United States Department of Agriculture) Forest Service. 2020. Forest Ecosystem Health Indicators. FS-1151, March 2020. R.S. Morin, compiler. [https://www.fs.usda.gov/sites/default/files/fs\\_media/fs\\_document/17827%20Forest%20Service\\_Forest%20Ecosystem%20Health%20Indicators%20508.pdf](https://www.fs.usda.gov/sites/default/files/fs_media/fs_document/17827%20Forest%20Service_Forest%20Ecosystem%20Health%20Indicators%20508.pdf)

USDA (United States Department of Agriculture) Forest Service. 2022. Forest Operations Equipment Catalog. <https://www.fs.usda.gov/forestmanagement/equipment-catalog/index.shtml>

USDA (United States Department of Agriculture) Forest Service. 2023. Aerial detection surveys. Pacific Northwest Region. <https://www.fs.usda.gov/detail/r6/forest-grasslandhealth/insects-diseases/?cid=stelprdb5286951>

USDA (United States Department of Agriculture) Forest Service. 2023. Hyporheic zones and mountain streams. Aquatic Ecology and Management Team, Pacific Northwest Research Station, Corvallis Forest Sciences Lab, Corvallis, Oregon. Accessed 5-8-2023. <https://www.fs.usda.gov/pnw/lwm/aem/projects/hyporheic.html>

USDA (United States Dept of Agriculture) Forest Service. 2023. FSim-Wildfire Risk Simulation Software. Missoula Fire Sciences Laboratory, Rocky Mountain Research Station (RMRS) Fire, Fuel, and Smoke Science (FFS) Program. <https://www.firelab.org/project/fsim-wildfire-risk-simulation-software>

USFWS (U.S. Fish and Wildlife Service). 2011. Revised Recovery Plan for the northern spotted owl (*Strix occidentalis caurina*). U.S. Fish and Wildlife Service, Portland, Oregon. xvi + 258 pp.

USFWS (U.S. Fish and Wildlife Service). 2012. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the northern spotted owl. 50 CFR Part 17. Federal Register / Vol. 77, No. 233 / Tuesday, December 4, 2012.

USFWS (U.S. Fish and Wildlife Service). 2020. Endangered and Threatened Wildlife and Plants; 12-Month Finding for the northern spotted owl. 85 FR 81144, Docket No. FWS-R1-ES-2014-0061.

USFWS (United States Fish and Wildlife Service). 2022. Federally listed, proposed, candidate, delisted species and species of concern under the jurisdiction of the US Fish and Wildlife Service which may occur within Oregon. USFWS Portland Office.  
<https://www.fws.gov/media/oregonspeciesstatelistpdf>

USFWS and NMFS (U.S. Fish and Wildlife Service and National Marine Fisheries Service). 2016. Habitat Conservation Planning and Incidental Take Permit Processing Handbook. December 21, 2016

USGS (United States Geological Survey) Forest and Rangeland Ecosystem Science Center. 2018. Effects of Experimental Removal of Barred Owls on Population Demography of northern spotted owls in the Pacific Northwest. <https://www.usgs.gov/centers/forest-and-rangeland-ecosystem-science-center/science/effects-experimental-removal-barred#overview>

Vähä-Konka, V., Maltamo, M., Pukkala, T. and Kärhä, K. 2020. Evaluating the accuracy of ALS-based removal estimates against actual logging data. *Annals of Forest Science* 77: 84.  
<https://doi.org/10.1007/s13595-020-00985-7>

Valente, J.J., J.W. Rivers, Z. Yang, S.K. Nelson, J.M. Northrup, D.D. Roby, C. Meyer and M.G. Betts. In Review. Fragmentation effects on an endangered species across a gradient from the interior to edge of its range. *Conservation Biology*.

Van Mantgem, P.J., Stephenson, N.L., Byrne, J.C., Daniels, L.D., Franklin, J.F., Fulé, P.Z., Harmon, M.E., Larson, A.J., Smith, J.M., Taylor, A.H. and Veblen, T.T. 2009. Widespread increase of tree mortality rates in the western United States. *Science*, 323(5913), pp.521-524.

Van Rooyen, J.C., J.M. Malt and D.B. Lank. 2011. Relating microclimate to epiphyte availability: edge effects on nesting habitat availability for the marbled murrelet. *Northwest Science*. 85: 549–561

Van Wagner, C.E. 1968. The line intersect method in forest fuel sampling. *Forest science*, 14(1), pp.20-26.



Wang, T., Hamann, A., Spittlehouse, D. and Carroll, C. 2016. Locally downscaled and spatially customizable climate data for historical and future periods for North America. *PloS one*, 11(6), p.e0156720.

Wang, Y., Braghiere, R.K., Longo, M., Norton, A.J., Köhler, P., Doughty, R., Yin, Y., Bloom, A.A. and Frankenberg, C., 2023. Modeling global vegetation gross primary productivity, transpiration and hyperspectral canopy radiative transfer simultaneously using a next generation land surface model—Clima Land. *Journal of Advances in Modeling Earth Systems*, 15(3), p.e2021MS002964.

Warner, M.D., Mass, C.F. and Salathé, E.P. 2015. Changes in winter atmospheric rivers along the North American west coast in CMIP5 climate models. *Journal of Hydrometeorology*, 16(1), pp.118-128.

Warren, D.R., Keeton, W.S., Kiffney, P.M., Kaylor, M.J., Bechtold, H.A. and Magee, J. 2016. Changing forests—changing streams: Riparian forest stand development and ecosystem function in temperate headwaters. *Ecosphere*, 7(8), p.e01435.

Washington DNR (Department of Natural Resources). 2016. Olympic experimental state forest ESRF HCP planning unit forest land plan. Washington Department of Natural Resources, Olympia, WA. [https://www.dnr.wa.gov/publications/lm\\_oesf\\_flplan\\_final.pdf](https://www.dnr.wa.gov/publications/lm_oesf_flplan_final.pdf)

Washington DNR (Department of Natural Resources). 2023. Forest resilience division. <https://www.dnr.wa.gov/ForestHealth>

Watson, P., Wilson, J., Thilmany, D. and Winter, S. 2007. Determining economic contributions and impacts: What is the difference and why do we care? *Journal of Regional Analysis & Policy*, 37(2), pp.140-146.

Welsh, J.R., and H.H. Hodgson, G.R. 2008. Amphibians as metrics of critical biological thresholds in forested headwater streams of the Pacific Northwest, USA. *Freshwater Biology*, 53(7), pp. 1470-1488.

West, J. 2018. Importance of Amphibians: A Synthesis of Their Environmental Functions, Benefits to Humans, and Need for Conservation. In Bridgewater State University Honors Program Theses and Projects. Item 261. Available at: [http://vc.bridgew.edu/honors\\_proj/2](http://vc.bridgew.edu/honors_proj/2)

West, T. 2023. iLand Pacific Northwest variant, version 1.0+. Management, Algorithms, and Remote Sensing Lab, College of Forestry. Oregon State University. <https://github.com/OSU-MARS/iLand>

West, T. and Strimbu, B.M. 2023. Generalizing DBH and height prediction in coast Douglas-fir and red alder. Growth and Yield Innovations Conference and Western Mensurationists Joint Meeting. Canmore, Alberta, June 18–21, 2023.

West, T., Sessions, J. and Strimbu, B.M. 2021. Heuristic optimization of thinning individual Douglas-fir. *Forests*; 12: 280.

West, T., Sessions, J. and Strimbu, B.M. 2022. Steep slope harvest system models for small to large trees. *Forests*, 13(2), p.305.

Wheaton J.M., Bennett S.N., Bouwes, N., Maestas J.D. and Shahverdian S.M. (Eds). 2019. Low-Tech Process-Based Restoration of Riverscapes: Design Manual. Version 1.0. Utah State University Restoration Consortium. Logan, UT. 286 pp.

Whereat Phillips, P. 2016. Ethnobotany of the Coos, Lower Umpqua, and Siuslaw Indians. Corvallis, OR: Oregon State University Press.

White, E.M. and D. Stynes. 2008. National forest visitor spending averages and the influence of trip-type and recreation activity. *Journal of Forestry* Jan/Feb: 17-24.

Wiens, J.D., Anthony, R.G. and Forsman, E.D. 2014. Competitive interactions and resource partitioning between northern spotted owls and Barred Owls in western Oregon. *Wildlife Monographs*, 185(1), pp.1-50. <https://wildlife.onlinelibrary.wiley.com/doi/10.1002/wmon.1009>

Wiens, J.D., Dugger, K.M., Higley, J.M., Lesmeister, D.B., Franklin, A.B., Hamm, K.A., White, G.C., Dilione, K.E., Simon, D.C., Bown, R.R. and Carlson, P.C. 2021. Invader removal triggers competitive release in a threatened avian predator. *Proceedings of the National Academy of Sciences*, 118(31), p.e2102859118.

Wiens, J.D., R.G. Anthony, and E.D. Forsman. 2011. Barred Owl occupancy surveys within the range of the northern spotted owl. *The Journal of Wildlife Management* 75: 531-538.

Wigington Jr, P.J., Ebersole, J.L., Colvin, M.E., Leibowitz, S.G., Miller, B., Hansen, B., Lavigne, H.R., White, D., Baker, J.P., Church, M.R. and Brooks, J.R. 2006. Coho salmon dependence on intermittent streams. *Frontiers in Ecology and the Environment*, 4(10), pp.513-518.

Wilkinson, M.D., Dumontier, M., Aalbersberg, I.J., Appleton, G., Axton, M., Baak, A., Blomberg, N., Boiten, J.W., da Silva Santos, L.B., Bourne, P.E. and Bouwman, J. 2016. The FAIR Guiding Principles for scientific data management and stewardship. *Scientific Data*, 3(1), pp.1-9.

Williams, N.G. and Powers, M.D. 2019. Carbon storage implications of active management in mature *Pseudotsuga menziesii* forests of western Oregon. *Forest Ecology and Management*, 432, pp.761-775.

Williamson, C.R., Campa III, H., Locher, A.B., Winterstein, S.R. and Beyer JR., D.E. 2021. Applications of Integrating Wildlife Habitat Suitability and Habitat Potential Models. *Wildlife Society Bulletin* 45, 70-84.

Wilson, D.S. and Puettmann, K.J. 2007. Density management and biodiversity in young Douglas-fir forests: Challenges of managing across scales. *Forest Ecology and Management* 246, 123-134.

Wilzbach, M.A., Harvey, B.C., White, J.L. and Nakamoto, R.J. 2005. Effects of riparian canopy opening and salmon carcass addition on the abundance and growth of resident salmonids. *Canadian Journal of Fisheries and Aquatic Sciences*, 62(1), pp.58-67.

Wimberly, M.C. and Spies, T.A. 2002. Landscape-vs gap-level controls on the abundance of a fire-sensitive, late-successional tree species. *Ecosystems*, 5(3), pp.232-243.

Wimberly, M.C., Spies, T.A., Long, C.J. and Whitlock, C. 2000. Simulating historical variability in the amount of old forests in the Oregon Coast Range. *Conservation Biology* 14(1): 167-180.

Winn, L. 2009. Project Completion Report: Upper Dean Creek Instream Restoration PHASE I, OWEB Project # 209-2047 Structure Placement 2009. Partnership for Umpqua Rivers.

Wohl, E., Bledsoe, B.P., Fausch, K.D., Kramer, N., Bestgen, K.R. and Gooseff, M.N. 2016. Management of large wood in streams: An overview and proposed framework for hazard evaluation. *JAWRA Journal of the American Water Resources Association*, 52(2), pp.315-335.

Wolock, D.M. 2003. Base-flow index grid for the conterminous United States. U.S. Geological Survey Open-File Report 03-263. U.S. Geological Survey. Reston, Virginia.  
<http://water.usgs.gov/lookup/getspatial?bfi48grd>

Worrall, J. 2020. *Porodaedalea* in North America.  
<https://forestpathology.org/blog/porodaedalea-north-america/>

WSDA (Washington State Department of Agriculture) 2023. Invasive moths: Asian spongy moth. <https://agr.wa.gov/departments/insects-pests-and-weeds/insects/invasive-moths/moth-101/asian-spongy-moth>. Accessed 3-03-2023.

Yamada, S., 1999. The role of soil creep and slope failure in the landscape evolution of a head water basin: field measurements in a zero-order basin of northern Japan. *Geomorphology*, 28(3-4), pp.329-344.

Yang, P., Prikaziuk, E., Verhoef, W. and van Der Tol, C. 2021. SCOPE 2.0: A model to simulate vegetated land surface fluxes and satellite signals. *Geoscientific Model Development*, 14(7), pp.4697-4712.

Zhang, Z., Ralph, F.M. and Zheng, M. 2019. The relationship between extratropical cyclone strength and atmospheric river intensity and position. *Geophysical Research Letters*, 46(3), pp.1814-1823.

## Appendix B. Glossary of Terms

**Abiotic disturbance:** Disturbance caused by non-living factors, including wildfire, wind, landslides and temperature extremes. Abiotic disturbances are a natural and integral part of forest ecosystems that can have major impacts, positive and negative. They influence forest structure, composition and functioning and can be important for maintaining biological diversity and facilitating regeneration.

**Adaptive experimental design:** An experimental approach that may, based on interim analysis of information and a defined process, adjust parameters if the experimental design is not meeting key targets or if there are major changes over the life of the experiment. Adaptive designs have the potential to allow detection of changes in outcomes that may otherwise have been missed or detect the best-performing treatments more quickly than a static design.

**Age class:** An age grouping of trees according to an interval of years, usually 20 years. A single age class has trees that are within 20 years of the same age, such as 1-20 years or 21-40 years.

**Aggradation:** The geologic process by which a stream bottom or floodplain is raised in elevation by the deposition of material.

**Aggregated retention:** The retention of structures or biological legacies as (typically) small, intact forest patches within the harvest unit.

**Aggregates:** Unharvested areas that are intentionally left within a management unit to maintain intact patches of vegetation. Synonymous with leave island or skip.

**Allochthonous:** In ecology, material originating in a place other than where found. In riparian areas and streams, allochthonous material is critical to nutrient input and cycling, and includes leaves, branches and trees that fall or are washed into the water, and dissolved organic matter (DOM) carried into the stream by overland or subsurface flow.

**Alluvial:** Deposited by running water.

**Anadromy:** Life history where a fish is born in freshwater, migrates to the ocean to forage and mature, then returns to freshwater to spawn.

**Assisted migration:** Deliberate movement of a species to a different habitat.

**Baseline conditions:** Refers to resource conditions (e.g., stand age, species composition, or stand densities) prior to the initiation of experimental treatments on the ESRF using 2020 as the baseline index year.



**Beaver Dam Analog (BDA):** A human-made structure designed to mimic the form and function of a natural beaver dam. BDAs can influence hydraulic, geomorphic and hydrologic processes to facilitate restoration goals, and can also be used to increase the probability of successful beaver translocation by creating immediate deep-water habitat that reduces the risk of predation.

**Bioacoustic monitoring:** The recording and analysis of the sounds animals use for communication, echolocation, sexual display, and territorial defense to infer species distribution, physiological state, abundance, and behavior.

**Bioeconomy:** Economic activity derived from the use of renewable biological resources to produce food, materials, and energy.

**Biological goal:** For the ESRF HCP, broad guiding principles based on the conservation needs of the covered species. A biological goal is included for each covered species.

**Biological legacy:** An organism, a reproductive portion of an organism, or a biologically derived structure or pattern inherited from a previous ecosystem. Biological legacies often include large trees, snags, and down logs left after harvesting to provide refugia and to structurally enrich the new stand. (P)

**Biological objective:** For the ESRF HCP, conservation targets or desired conditions. Objectives are measurable and quantitative when possible; they clearly state a desired result that collectively will achieve the biological goals and that can be monitored over the permit term. There are often multiple biological objectives needed to fully achieve a biological goal.

**Biotic disturbance:** Insects, pathogens, and parasitic plants that cause tree decline, mortality, and affect forest ecosystem processes. Biotic disturbances can alter forest structure and the capability of forests to deliver ecosystem services, but also create and contribute to species habitat and diversity.

**Blowdown:** Trees uprooted and felled, or branches broken and felled by strong gusts of wind. Also called *windthrow*. (NOAA)

**Camera trap:** Stationary cameras that are triggered automatically, usually by an infrared sensor, when an animal moves into a predetermined position.

**Canopy:** The forest cover of leaves, branches, and foliage formed by tree crowns. There may be several canopy layers.

**Carbon flux:** The transfer of carbon between different stocks or pools, e.g. the transfer of atmospheric carbon dioxide into growing trees via photosynthesis.

**Carbon offset:** 1. A reduction in GHG emissions – or an increase in carbon storage (e.g., through land restoration or the planting of trees) – that is used to compensate for emissions that occur

elsewhere. 2. An action intended to compensate for the emission of carbon dioxide into the atmosphere as a result of industrial or other human activity, especially when quantified and traded as part of a commercial program.

**Carbon offset credit:** 1. A transferrable instrument certified by governments or independent certification bodies to represent an emission reduction of one metric ton of CO<sub>2</sub>, or an equivalent amount of other GHGs. 2. A tradable certificate or permit representing the right to emit a set amount of carbon dioxide or the equivalent amount of a different greenhouse gas. Also referred to as simply a carbon credit.

**Carbon pool:** A reservoir where carbon is stored in a particular place for a period of time. In a forest ecosystem carbon is stored in five different pools: *aboveground biomass* (e.g., leaves, trunks, limbs), *belowground biomass* (e.g., roots), *deadwood* (downed logs, standing dead trees and snags), *litter* (e.g., fallen leaves, stems), and *soils*. Forest carbon may also be stored offsite in harvested wood products.

**Carbon sequestration:** The process of storing carbon in a carbon stock or pool. Also termed *carbon uptake*.

**Carbon sink:** A stock or pool wherein the gains of carbon are greater than the losses of carbon over a specified period.

**Carbon source:** A stock or pool wherein the losses of carbon are greater than the gains of carbon over a specified period.

**Carbon stock:** Measured, estimated, or modeled quantity of carbon held in a particular pool.

**Cavity:** A semi-enclosed hole in a tree often used by wildlife species, usually birds, for resting, nesting, roosting, and reproduction.

**Climate-smart forestry (CSF):** An emerging branch of sustainable adaptive forest management aimed at enhancing the potential of forests to adapt to and mitigate climate change.

**Coarse sediment:** Generally, greater than 2mm diameter, i.e. includes gravel, cobbles, or boulders. Contrast with: *fine sediment*.

**Cohort:** A group of individuals (e.g., trees) of the same age, recruited into a population at the same time.

**Colluvial hollow:** *Convergent* (concave) hillslope feature, distinguished from *divergent* (convex) hillslope *noses* (shared with adjacent basins) and located between intervening planar (flat) *side slopes*. Colluvial hollows are primary locations for sediment storage between disturbance events and are common features of soil mantled hillslopes, accumulating sediment and water

that are episodically mobilized in landslides and debris flows which act as significant geomorphic agents. See also: *headwall*.

**Colluvium:** Unconsolidated sediments deposited at the base of side slopes in headwater basins by rainwash, sheetwash, slow continuous downslope creep or some combination of these elements.

**Commercial treatment:** A silvicultural treatment where a portion of the cut trees are removed from the stand for timber volume. Commercial treatments are generally designed so that logging, hauling, and road costs are less than the estimated stumpage value of the timber to be harvested.

**Competition-based mortality:** In forest stands tree death that results from competition for limiting resources.

**Complex adaptive system:** As it pertains to forestry, considering a forest as composed of heterogeneous assemblages of individual agents, including plants, animals and humans, closely interacting through flows involving markets, goods, and various other ecosystem services, with a capacity to self-organize following disturbance, and that displays nonlinear behaviors.

**Complex Early Successional Forests:** Predominantly open areas in the forest of contiguous areas greater than or equal to 2 acres in size. Must contain at least 5 ft<sup>2</sup> of basal area per acre in retention at the time of harvest in living or dead standing overstory trees and at least 10% canopy cover in hardwoods or shrubs. Roads, quarries and other non-forest areas do not qualify.

**Complex Mature and Late Successional Forests:** Include a variety of structural features that require prolonged periods to develop following stand-replacing disturbances such as: large-diameter live trees, varied tree diameters, a multi-storied canopy structure, some trees with complex crowns and branching structures including broken tops and significant amounts of epicormic branching, a range of tree, shrub, and herbaceous species in varied densities and spatial patterns, high volumes of large-diameter deadwood, and varied canopy cover including canopy gaps and openings interspersed among patches of higher canopy cover with mean canopy cover > 40% at the stand-scale. Stands dominated by older trees (i.e., > 65 years old) or large-diameter trees, but otherwise lacking several listed features may be mature, but do not qualify as “complex” mature or late-successional forests.

**Complexity:** In reference to forest stands, refers to a measure of the number of different structural attributes present, and the relative abundance of each of these attributes.

**Conservation Core Area:** Portion of the forest that is managed for the benefit of northern spotted owl and marbled murrelet to maintain occupied sites and high-quality nesting habitat. Silvicultural practices and other management activities in those areas will be limited and focused on improving habitat quality.

**Conservation Research Watershed (CRW):** Watershed within the ESRF where research may take place, but active management generally does not (after initial; first 20 years during which restoration treatments could occur). See also *Management Research Watershed*.

**Contracted Acres:** Harvest acres included in new contracts or new modifications to existing contracts fully executed (awarded and approved) in a given calendar year or decade, recognizing that typical timber sale contracts allow multiple years for cutting and removal of wood products.

**Crossdating:** A technique that uses the hydroclimatic sensitivity of annual growth rings in trees to climate to precisely assign individual annual growth rings to calendar years. By crossdating annual growth rings researchers can identify the exact year each growth ring on a tree formed even if that tree has been dead for hundreds of years. Crossdating is used to determine the exact year of disturbances including fires, floods, and windstorms that are recorded within annual rings.

**Crown class:** A class of tree based on crown position relative to the crowns of adjacent trees. Classes include:

*Emergent:* Trees with crowns completely above the general level of the main canopy receiving full light from above and from all sides.

*Dominant:* Trees with crowns extending above the general level of the main canopy of even-aged stands or, in uneven-aged stands, above the crowns of the tree's immediate neighbors, and receiving full light from above and partly from the sides.

*Codominant:* Trees with crowns forming the general level of the main canopy in even-aged stands or, in uneven-aged stands, the main canopy of the tree's immediate neighbors, receiving full light from above and partly from the sides.

*Intermediate:* Trees with crowns extending into the lower portion of the main canopy of even-aged stands or, in uneven-aged stands, into the lower portion of the canopy formed by the tree's immediate neighbors, but shorter in height than the codominants. They receive little direct light from above and none from the sides.

*Overtopped (suppressed):* Trees of varying levels of vigor that have their crowns completely covered by the crowns of one or more neighboring trees.

**Crown fire:** A fire that spreads across the tops of trees or shrubs more or less independently of a surface fire. (P)

**Debris fan:** A deposit formed when a debris flow comes to rest. Fans are typically composed of poorly sorted boulders in soil and may also include woody material.

**Debris flow:** A highly mobile slurry of rock, soil, wood, and water that can travel hundreds to



thousands of feet on steep slopes or in steep channels. There are two types of debris flows: open-slope debris flows and debris torrents. Debris flows are shallow, rapidly moving landslides.

**Debris torrent:** A debris flow confined within a channel or draw. They often scour the channel to bedrock, increasing in size as they travel hundreds or thousands of feet beyond the site of initial failure, delivering significant volumes of material to their deposition area.

**Dendrometer:** Band or sensor installed on a tree to obtain precise measurements of diameter growth and water use. Manual units may be measured at regular intervals (e.g., at the beginning and end of the growing season) using precision digital calipers. Automated units connected to a data logger can record measurements ranging from small daily expansion and contraction in plant tissues (to assess water status and tree health) to growth over weeks and months.

**Disturbance:** 1. Change in environmental conditions that affects the structure or function of an ecosystem. 2. Any relatively discrete event in time that disrupts ecosystems, community, or population structure and changes resources, substrate availability, or the physical environment. Disturbance a) is a key driver of ecological dynamics and diversity; b) can be caused by natural or human factors, such as wind, fire, drought, disease, or land use; c) can occur over short or long periods of time; d) can have positive or negative impacts on biodiversity.

**Duff:** The partially decomposed organic material of the forest floor beneath the litter of freshly fallen twigs, needles and leaves.

**Early successional:** Forest communities characterizing early stages of ecosystem development following a disturbance. See also Complex Early Successional Forests.

**Ecocultural restoration:** The science and practice of restoring not only ecosystems but human and cultural relationships to place, so that cultures are strengthened and revitalized along with the lands to which they are inextricably linked.

**Ecological forestry:** Recognition that forests are ecosystems with diverse biota, complex structure, and multiple functions, and not simply collections of trees valuable primarily for production of wood. Ecological forestry seeks to maintain the fundamental capacities (integrity) of the forest ecosystems to which it is applied.

**Ecological silviculture:** An approach for managing forest ecosystems, including trees and associated organisms and ecological functions, based on emulation of natural models of development and that explicitly incorporates principles of *continuity* (legacy management), *complexity/diversity* (variety and heterogeneity of structure, diversity of species), *timing* (basing actions on ecological queues) and *context* (considering landscape context) into prescriptions.  
(P)

**Ecosystem function:** Refers to the various ecological processes, such as water and nutrient cycling, primary productivity, and decomposition, which occur in an ecosystem. (P)

**Ecosystem structure:** Refers to the biotic (e.g., plants, animals, primary producers, decomposers) and abiotic components (e.g., water, nutrients) of an ecosystem. (P)

**eDNA:** Environmental DNA; is nuclear or mitochondrial DNA released from an organism into the environment, including feces, mucus, shed skin and hair; and carcasses. Aquatic inventory and monitoring protocols using eDNA allow for efficient collection of data about species distribution and relative abundance, especially for small, rare, secretive, and other difficult to detect species.

**Endangered species:** “... any species [including subspecies or qualifying population] which is in danger of extinction throughout all or a significant portion of its range.” (Section 3[6] of ESA)

**Ephemeral stream:** A stream system that, in normal water years, flows only in direct response to precipitation, receiving no water from springs or melting snow, with the stream channel above the water table (not in contact with groundwater) at all times.

**Even-aged:** A forest, stand, or forest type in which relatively small age differences exist between individual trees. The differences in age permitted are usually 10-20 years; if the stand will not be harvested until it is 100 to 200 years old, larger differences up to 25% of the rotation age may be allowed.

**Evolutionarily significant unit (ESU):** The U.S. National Oceanic and Atmospheric Administration (NOAA) definition of a distinct population segment that is the smallest biological unit that will be considered to be a “species” under the U.S. Endangered Species Act. A population is considered to be an ESU if (1) it is substantially reproductively isolated from other conspecific population units, and (2) it represents an important component in the evolutionary legacy of the species. (WSS)

**Equipment limitation zone (ELZ):** For the purposes of the ESRF HCP, zones within 35 feet of certain Oregon FPA-defined stream types where use of ground-based and cable yarding equipment will be limited to further promote the ecological function of RCAs and streamside processes by limiting ground disturbance.

**Feller-buncher:** A machine which fells trees using a mechanical shear or a disc saw as an attachment. A feller-buncher may accumulate several trees before creating just the right size bunch for a grapple skidder to take to the landing.

**Fine sediment:** Generally, less than 2mm diameter, typically composed of clay, silt, or sand. Contrast with: *coarse sediment*. (NOAA)

**Fire intensity:** The rate of heat energy released by the fire, and more precisely, the energy released per unit time per unit area of actively burning fire. It is closely related to the amount of fuel available to burn. Also related to, but not synonymous with fire *severity*.

**Fire interval:** The number of years between two successive fire events for a given area, at the scale of a point, stand or relatively small landscape area. Also referred to as *fire-return interval*.

**Fire regime:** Description of the nature of fire over time for a given ecosystem or defined area, often characterized by fire frequency, size, intensity and severity. A fire regime is a generalization based on fire histories at individual sites. Fire regimes can often be described as cycles because some parts of the histories usually get repeated, and the repetitions can be counted and measured, such as fire return interval.

**Fire scar:** A distinct injury to a tree bole caused by lethal heating of cambial tissue during a fire event. Fire scars only form when a tree is not killed by a fire and is able to compartmentalize or heal over a portion of the tree cambium that was killed by a fire.

**Fire severity:** 1. The degree of environmental change caused by fire. 2. The effect of a fire on ecosystem properties, usually described by the degree of soil heating or mortality of vegetation. Related to, but not synonymous with fire *intensity*.

**Fish-bearing stream (FB):** Streams on ESRF inhabited at any time of the year by anadromous or game fish species or fish that are listed as threatened or endangered species under the federal or state Endangered Species Act. Encompasses the distal limit of resident cutthroat trout (*Oncorhynchus clarkii clarkii*) in Oregon Coast Range stream networks.

**Forest decline:** 1. A long-lasting deterioration in visible features of trees associated with a loss of growth. 2. Tree canopy loss associated with a complex interaction of biotic and abiotic factors leading to decreasing tree vigor and increasing mortality; forest decline is not associated with fire, wind, harvest, or land use changes. (Shaw 2022)

**Forest health:** A subjective concept incorporating themes such as biodiversity, resilience, resistance, sustainability, ecosystem services, sustained productivity, human values, and land management objectives. (Shaw 2022)

**Forwarder:** A machine with a crane which can load logs onto its chassis and piggy-back them to a road where it can sort and pile them or load them directly onto a truck.

**Fragmentation:** The breaking up of larger contiguous areas of forest cover or habitat into smaller, more isolated patches.

**Fry:** Stage of development in young salmon or trout reflecting a recently hatched fish that can swim and catch its own food. During this stage the fish is usually less than one year old, has

absorbed its yolk sac, is rearing in the stream, and is between the alevin and parr stage of development. (WSS)

**Full potential wood recruitment:** An estimate of the potential total annual large wood quantity expected to be delivered to a wood recruitment target [within or adjacent to a stream], given reference forest stand conditions.

**Functional connectivity:** Refers to how well genes, propagules, individuals, or populations are able move through the landscape. Functional connectivity results from ways that an organism, via its habitat preferences and dispersal ability, interacts with structural characteristics of the landscape. Compare with *structural connectivity*.

**Fungi:** Simple plant-like organisms that lack chlorophyll. Fungi obtain nutrition from living on or in other organisms (parasitically), from living with other organisms (symbiotically), or by breaking down dead organic materials (saprophytically). An example are microscopic mycorrhiza which live off the tree, while fixing nitrogen for the tree.

**Gap:** An opening in the forest canopy created by the death of one or more overstory trees.

**Habitat conservation plan (ESRF HCP):** A comprehensive planning document that is a mandatory component of an incidental take permit application pursuant to section 10(a)(2)(A) of the ESA.

**Headwall:** Colloquial term defined in Oregon Forest Practices Act as a steep, concave slope that can concentrate subsurface water, which can lead to increased landslide susceptibility. Headwalls are typically located at the head of stream channels, draws, or swales and have slope gradients of 65 percent or greater in the Tyee Core Area (which includes the ESRF) as measured in the axis of the headwall. Landslides that occur in headwalls are more likely to initiate channelized debris flows that can travel down streams (also known as debris torrents) than landslides that occur in other areas of the slope. See also *colluvial hollow*.

**Headwater stream:** First-order stream representing upper reaches of a given watershed and stream network.

**High severity:** Disturbance that kills the majority of vegetation, such as a crown fire.

**Historic range of variability (HRV):** Variability over time and space in an ecosystem or ecological parameter that would occur when natural disturbance regimes and biological processes prevail, usually described in terms of landscape *composition* (e.g., vegetation types or structural stages) and *structure* (e.g., patch characteristics, landscape pattern). The theory behind HRV is that the broad historical envelope of possible ecosystem conditions (within which the system is self-sustaining, and beyond which it transitions to disequilibrium) provide a representative time series of reference conditions to guide land management.



**Hydrologic disconnection:** The removal of direct routes of drainage or overland flow of forest road runoff to adjacent streams.

**Hyporheic flow:** The transport of surface water through sediments and gravels adjacent to and below the stream in flow paths that return to surface water. Hyporheic flow is exchanged back and forth across the streambed interface, typically at scales of centimeters to tens of meters, whereas groundwater recharge or discharge travels unidirectionally over much longer distances.

**Hyporheic zone:** A unique hydrochemical and biological region beneath and lateral to a streambed, where there is mixing of groundwater and surface water.

**Incidental take:** Take of any federally listed wildlife species that is incidental to, but not the purpose of, otherwise lawful activities.

**Incidental Take Permit (ITP):** Federal exemption to take prohibition of section 9 of the ESA; permit is issued by the USFWS pursuant to section 10(a)(1)(B) of the ESA. The ITP for the ESRF allows forest research and management activities that could otherwise result in the unlawful take of listed species to move forward having the assurance that such take will not be in violation of the ESA.

**Independent population:** In salmonid ecology, populations of fish that historically would have had a high likelihood of persisting in isolation from neighboring populations for 100 years and that provide diversity in the genetic “portfolio” that makes up the larger Evolutionarily Significant Unit (ESU).

**Indigenous Knowledge:** Indigenous Knowledge (IK, which encompasses Traditional Ecological Knowledge and Indigenous Ecological Knowledge) is knowledge and practices passed from generation to generation informed by cultural memories, sensitivity to change, and values that include *reciprocity* (defined as taking with the moral responsibility of giving back in equal measure). IK observations are qualitative and quantitative and illustrate that objectivity/subjectivity is a false dichotomy in knowledge generation.

**Integrated Vegetation Management:** Activities designed to promote diverse, healthy, and resilient plant communities through the use of a suite of treatment methods tailored to reduce the use of pesticides. Treatment methods may include any combination of biological, chemical (i.e., herbicide), cultural, manual, mechanical, and prescribed burning.

**Intermittent stream:** A stream system that flows only at certain times when it receives water from springs, discharge from groundwater, or extended snowmelt, generally due to fluctuations whereby part of the time the streambed is below the water table and part of the time above it. May lack biological and hydrological characteristics commonly associated with continuous streamflow and the channel may or may not be well defined. Intermittent streams generally flow continuously at least one month most years.

**Ladder fuels:** Fuels, such as branches, shrubs or an understory layer of trees, which allow a fire to spread from the surface to the canopy.

**Large wood:** Logs, limbs, or root wads 10 cm or larger in diameter, delivered to river and stream channels from streamside forests (in the riparian or upslope areas) or from upstream areas. Large wood provides streambed stability and increases habitat diversity by forming large roughness elements that create local turbulence and prevent uniform flow, thereby increasing the complexity of channel form through scour and deposition.

**Large wood recruitment:** The processes whereby streamside forests supply large wood to the stream channel to replenish what is lost by decay, downstream transport or purposeful removal (i.e. stream cleaning).

**Legacy trees:** Trees, usually mature or old-growth, that are retained on a site after harvesting or natural disturbance to provide a biological legacy.

**LiDAR:** *Light Detection and Ranging*, a remote sensing system that uses a pulsed laser to measure and map variation in distances to the earth. These light pulses, combined with other data recorded by the airborne system, generate precise, three dimensional information including vegetation height, density and other characteristics across a region.

**Life history:** The events that make up the life cycle of an animal including migration, spawning, incubation, and rearing. There is typically a diversity of life history patterns both within and between populations. Life history can refer to one such pattern, or collectively refer to a stylized description of the ‘typical’ life history of a population.

**Litter:** Recently fallen plant material, including leaves, needles, fine twigs, and other organic material on the forest floor that is only partially decomposed and is still discernible.

**Low severity:** Disturbance that only partially disturbs a given ecosystem, such as a wind downburst or a fire that kills <30% of mature trees. (P)

**Management Research Watershed (MRW):** Watershed within the ESRF where both research and active management may be conducted. (See also *Conservation Research Watershed*.)

**Management Research Watershed (MRW) Partial:** Management Research Watershed that is either less than 400 acres or not fully contained within the ESRF’s boundaries, resulting in multiple ownership.

**Management Unit:** The whole area associated with the planning and implementation of individual silvicultural activities. Management units may comprise multiple stands.

**Megapit:** Temporary soil pit, usually about 6-7 feet in depth and located in the locally dominant soil type, from which soil and root samples are collected, characterized and archived for the National Science Foundation's National Ecological Observatory Network (NEON).

**Mixed-severity:** Disturbance regime characterized by variation in disturbance severity that can be observed at the intermediate or meso-scale. (P) For example, a mixed-severity *fire* exhibits a wide range of fire severity as a result of surface fire in some patches, burning others with stand-replacement severity, and thinning the overstory in other patches.

**Moderate-severity:** A disturbance that removed 30-70% of the mature trees over a defined area. Mixed-severity fires have distinct outcomes and effects on forest dynamics and structure in comparison to low- and high-severity fire.

**Non-Commercial Treatment:** A silvicultural treatment where none of the cut trees are removed from the stand for timber volume.

**Nest Site:** For protection and management of the northern spotted owl and marbled murrelet under the ESRF HCP, the nest site means the nest tree and other trees within 300 feet of the nest tree.

**Noxious weed:** As defined by the State of Oregon, *noxious weed* means a plant designated by the Oregon State Weed Board under ORS 569.615 as among those representing the greatest public menace and as a top priority for action by weed control programs.

**Off-channel area:** Any relatively calm portion of a stream outside of the main flow. (WSS)

**Other non-fish-bearing streams (XNFB):** Streams on the ESRF not classified as FB, PNFB, or WNFB. XNFB streams may be seasonal, intermittent, or ephemeral, and are usually located in the colluvial hollows of stream networks.

**Outbreak:** Explosive epidemic behavior, where the population of a biotic disturbance agent (e.g., bark beetle) exceeds a control threshold and can significantly increase its population.

**Parr:** The developmental life stage of salmon and trout between alevin and smolt, when the young have developed parr marks and are actively feeding in freshwater.

**Patch:** 1. A small area distinct from that around it. 2. A small part of a stand or forest. 3. An ecosystem element, such as an area of vegetation that is relatively homogeneous internally and differs from surrounding elements.

**Perennial non-fish-bearing [stream] (PNFB):** On the ESRF, an administrative stream protection class; a subclass of all perennial streams that *does not include perennial WNFB streams*. PNFB streams have flowing water throughout the year and are presumed to be absent of fish or are deemed fishless based on gradient or other barriers.

**Perennial stream:** A stream or stretch of stream that flows continuously for most of most years, generally fed in part by springs or discharge from groundwater, with the streambed located below the water table (in contact with groundwater) for most of the year. Ground water supplies baseflow for perennial streams during dry periods, supplemented by stormwater runoff and snowmelt. A perennial stream exhibits the typical biological, hydrological, and physical characteristics commonly associated with continuous streamflow.

**Plantation:** A stand composed primarily of trees established by planting or artificial seeding.

**Planted forest:** Forest originating primarily from artificial regeneration.

**Pool:** A relatively deep, still section in a stream. Pools provide resting areas and cover for salmonids.

**Potential wood recruitment:** The quantity of large wood that could be recruited to a specified aquatic ecosystem, given the existence of certain conditions.

**Protected potential wood recruitment:** An estimate of the quantity of potential annual wood recruitment protected by specified conservation strategies, such as recruitment protected within RCAs, the CRW, and MRW reserve allocations.

**Pyrodiversity:** 1. The spatial or temporal variability in fire effects across a landscape. 2. The degree of variation in post-fire landscape characteristics that leads to biodiversity. Pyrodiversity begets biodiversity in the sense that a high amount of variability in fire effects over time and space results in high biodiversity.

**Reach:** A geomorphically similar stream section or a section of stream as defined by two selected points.

**Rearing:** Refers to the amount of time that juvenile fish spend feeding in nursery areas of rivers, lakes, streams and estuaries before migration.

**Reciprocity:** In the context of many Indigenous cultures and Indigenous Knowledge, reciprocity embodies the idea that the land provides for people and that people, in turn, must care for the land. A reciprocal worldview positions people as just one part of the natural world, co-existing in a web of relations that includes land, water, animals, plants and other non-human entities, including spirit beings. Reciprocity resembles a circle in which two parties indefinitely care for one another, without an end point in mind. As opposed to emphasizing human power over the environment, reciprocal relations focus on maintaining interdependent familial relationships with the natural world that are mutually respectful and balanced.

**Redd:** A nest of fish eggs consisting of gravel, typically formed by digging motion performed by an adult female salmon. Redds are typically located at the tails of pools where water movement through gravel will be continuous.



**Relative [stand] density (RD):** Indicates how fully the trees occupy a site. A measure of the number and average size of trees growing in a stand compared to the maximum possible number of trees of the same average size that the site could support (a biological limitation).

**Resilience:** The capacity of a plant community or ecosystem to recover pre-disturbance ecosystem structure and function following a disturbance.

**Resistance:** The ability of a plant community or ecosystem to avoid alteration of its present state by a disturbance.

**Response:** Range of reactions to environmental change among species that contribute to the same ecosystem function.

**Retention harvest:** Silvicultural method that retains forest structural elements, such as large living and dead trees, at the time of harvest to serve as biological legacies in the resulting forest or cohort.

**Return interval:** the number of years between successive disturbances of a defined type within a defined area.

**Riparian area:** 1. Transition zone between fully terrestrial and fully aquatic systems, including . streambanks, floodplains, wetlands, the channel migration zone and vegetation directly adjacent to the water body that influences channel habitat through alteration of microclimate or input of large wood. 2. The terrestrial-aquatic interface; the part of a terrestrial landscape that exerts a direct influence on, and is influenced by, stream channels or lake margins, and the water or aquatic ecosystems.

**Riparian Conservation Area (RCA):** On the ESRF, protective corridors of prescribed widths along each side of specified stream classes where timber harvest and other site-disturbing activities are restricted or prohibited.

**Rotation:** In even-aged silvicultural systems, the period between regeneration establishment and final cutting. May be based on many criteria including culmination of mean annual increment, mean size, age, attainment of particular minimum physical or value growth rate, and biological condition.

**Rotation age:** The planned number of years between the formation or regeneration of a crop or stand of trees and its final cutting at a specified stage or maturity.

**Salvage harvest:** The removal of dead trees or trees damaged or dying in the aftermath of a disturbance event, such as insects, disease, wildfire, or severe weather such as wind or ice. Salvage harvest uses the same equipment and methods as other types of harvest and ranges from selective harvest of individual trees to clearcut harvest depending on the magnitude of the disturbance event and forest management goals.

**Sidecast:** Uncompacted excavated fill material pushed onto the downhill side of the road during forest road construction, often implicated in road-related landsliding. Contrast with *endhaul* construction wherein excavated material is hauled off site to a more stable location.

**Silvicultural prescription:** A planned series of treatments designed to change current forest stand structure to one that meets management goals and objectives. The prescription normally considers ecological, economic and social constraints.

**Site preparation:** A hand or mechanized manipulation of a site designed to enhance the success of tree regeneration. Treatments may include bedding, burning, chemical spraying, chopping, disking, drainage, raking, and scarifying. All treatments are designed to modify the soil, litter, and vegetation and to create microclimate conditions conducive to the establishment and growth of desired species.

**Skip:** Unharvested area that is intentionally left within a management unit to maintain an intact patch of vegetation and associated structures and processes. Synonymous with aggregate or leave island.

**Stand:** In *classic silviculture*, a contiguous group of trees sufficiently uniform in age class distribution, composition, and structure, and growing on a site of sufficiently uniform quality, to be a distinguishable operational or management unit. In *ecological silviculture*, forest areas that incorporate the structure, age, composition, and spatial pattern of trees of natural ecosystems, as determined by underlying geomorphic, soil, or disturbance templates. When managing to create significant within-stand structural variability, stands (as classically described) become increasingly challenging to distinguish from one another over time, and the boundaries of management units will often overlap with multiple mapped “stands”. In this FMP, the term *stand* is generally used to distinguish mappable forest inventory units while the term *management unit* generally refers to the unit of planning and implementation for silvicultural activities and forest operations (see also *management unit*).

**Stand development:** The growth of a stand through its various developmental stages- from seedling or coppice through thicket, sapling, and pole to the tree stage, i.e. to maturity and finally to overmaturity.

**Stand-replacing:** Disturbance that kills the majority of trees and other vegetation on a given site.

**Stocking:** An indication of growing-space occupancy relative to a pre-established standard. Common indices of stocking are based on percent occupancy, basal area, relative density, and crown competition factor.

**Stream cleaning:** Practice of actively removing log jams, large wood, boulders, and other perceived impediments from stream channels, widely practiced in the Pacific northwest, mainly

in the 1950s-1970s and often using heavy equipment, usually under the misguided assumption that doing so would improve fish passage.

**Stream energy:** A measure of a stream's ability to erode and transport sediment that is equal to the product of shear stress and velocity. Also referred to as *stream power*.

**Stream protection class:** Administrative stream attribute used on the ESRF for the specification of Riparian Conservation Areas which are based on biophysical attributes of each stream segment: *fish-bearing* (FB); *wood-delivery non-fish-bearing* (WNFB); *perennial non-fish-bearing* (PNFB); and *other non-fish-bearing* (XNFB). Also see *watershed protection zone*.

**Stream restoration:** The return of stream ecosystem structure and function to a state that is more reflective of conditions prior to significant anthropogenic disturbance. *Form-based* restoration focuses on physical interventions (e.g., large wood placements) in a stream to improve conditions. *Process-based* restoration focuses on restoring hydrological and geomorphological processes (e.g., sediment transport, channel-floodplain connectivity).

**Stringer:** Relatively narrow area suitable to be occupied by forested plant associations within a landscape that is otherwise unsuitable due to site or environmental factors.

**Structural complexity:** Degree of heterogeneity in living and dead components in a forest.

**Structural connectivity:** Physical characteristics of a landscape that facilitate movement of animals and plants, including topography, hydrology, vegetative cover, and patterns of human land use. Compare with *functional* connectivity.

**Structure:** 1. The horizontal and vertical distribution of components of a forest stand including the height, diameter, crown layers and stems of trees, shrubs, herbaceous understory, snags, and down woody debris. 2. The quantity and spatial arrangement of forest components, including stems, branches, leaves, and air.

**Surface fire:** A fire that burns only surface fuels such as litter, loose debris, and small vegetation.

**Take:** For the purposes of the ESA and Habitat Conservation Plans, defined as, "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." Incidental take is an unintentional, but not unexpected, taking.

**Thinning:** A treatment made to reduce stand density of trees primarily to improve growth, enhance forest health, or to recover potential mortality. Types of thinning include:  
Crown thinning (thinning from above): Removal of trees from the dominant and co-dominant crown classes in order to favor the best trees of those same crown classes.

- *Free thinning:* Removal of trees to control stand spacing and favor desired trees using a combination of thinning criteria without regard to crown position.

- **Low thinning** (thinning from below): Removal of trees from the lower crown classes to favor those in the upper crown classes.
- **Selection thinning**: Removal of trees in the dominant crown classes to favor those in the lower crown classes. (Palik)

**Threatened species:** A species that is likely to become endangered within the foreseeable future.

**Treated Portion:** Encompasses the entire operational area associated with a given management unit, including skips or aggregates to be retained within areas designated for harvesting, site preparation activities, release treatments, planting or seeding, prescribed burning, and other silvicultural treatments.

**Triad:** An intermediate forest management strategy that utilizes reserves, intensive management and ecological forestry. Contrast with (1) conserving nature in reserves and supplying wood by intensifying production in tree plantations and (2) reducing local harvest impacts using ecological forestry but expanding harvests across a larger proportion of the landscape to meet wood demand.

**Variable-density thinning:** Thinning to promote greater heterogeneity in ecological conditions by varying the intensity of removal of overstory trees across a stand. This includes retention of dense areas, as well as creation of harvest gaps.

**Variable retention harvest:** A type of regeneration harvest method that includes the selective retention of forest structures, species, age classes or biological legacies (trees, snags, logs, etc.) at the time of harvest to provide continuity in ecological functioning across harvest cycles.

**Vigor:** A subjective assessment of the health of individual trees or other plants in similar site and growing conditions, or a more precise measure based upon a specific facet of growth. In researching how different events (e.g., defoliation, thinning) impact tree productivity and survival, vigor is the *ratio of the annual growth of wood on the stem per unit of leaf area*. Vigorous trees grow more wood than less vigorous trees for the same amount of leaf area, and are often less vulnerable and more resilient to insects and pathogens.

**Watershed:** A region or area that is bounded peripherally by a drainage divide and that drains ultimately to a particular watercourse or body of water; a drainage basin for a stream or a catchment.

**Watershed protection zone:** Administrative stream attribute used on the ESRF for the specification of Riparian Conservation Areas which reflects the research and protective status of the watershed in which a stream segment is located. Watershed protection zones are classified according to (1) whether they are in a Conservation Research Watershed (CRW) or a Management Research Watershed (MRW); (2) whether they are a full research watershed or a



partial watershed and; (3) for MRW watersheds, whether they *are*, or *are not* tributary to the WF Millicoma River downstream of Elk Creek. Also see *stream protection class*.

**Whole-systems approach:** A holistic approach to forest and aquatic ecosystem management and restoration. A whole systems perspective focuses on understanding how ecosystem components and processes are related, and how they influence one another within a whole. Recognizing the complexity, dynamic interactions and emergent properties of ecosystems, a whole-systems approach consists in identifying the various components of forest, riparian and stream systems and assessing the nature of the links and relationships between each of them.

**Windthrow:** A disturbance process that involves the uprooting of a whole tree by wind at the interface of the trunk with the soil, which may involve the lifting of roots, the snapping of roots or the failure of the trunk at the soil surface. Windthrown trees may themselves also be referred to, either singly or in groups, as windthrow. Also called blowdown.

**Wood-delivery non-fish-bearing [stream] (WNFB):** On the ESRF, any non-fish-bearing stream (perennial or non-perennial) that delivers greater than a threshold quantity of large wood to fish-bearing streams by debris flow processes.

**Woody material:** Pieces of wood in a stream that affect channel morphology by splitting flows, dissipating stream energy, and capturing and storing sediment/bedload. Beyond a minimum threshold, size varies with stream size but generally can be described as large enough to have a low probability of being moved by the stream.

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## Appendix C.

# PRINCIPLES AND BEST PRACTICES

## for Working with Indigenous Knowledge and Partnering with Tribal Nations and Indigenous Peoples



### Volume 1: Principles



College of Forestry Dean Tom DeLuca collecting soil data with Savannah Spottedbird as part of the BLM Pacific Northwest (PNW) Tribal Forest Restoration and Native Seed Project led by the College of Forestry. Read about this project and more at <https://tek.forestry.oregonstate.edu/tek-lab-projects>

*How do we see the world, through what windows of language, story, and cultural practice? When Native Americans and European Americans peer out through the matrices of their beliefs and assumptions, do we all see the world? If, despite our different practices, our worlds are really the same, how can that world be described without distorting or diminishing it? And if our worlds are different worlds, what are those differences, what do we make of them, how can we celebrate and honor them, what can we learn from them about how we ought to live?*

*Words of V.F. Cordova*

## Introduction

In recent years, partnerships in natural resource research and adaptive management have been growing between Indigenous Peoples and universities. Often supported by federal or state funding, these partnerships bring together multiple ways of knowing to develop solutions to urgent natural resource problems and help create a more sustainable future. However, there remains widespread lack of institutional and academic professional understanding about how to partner ethically with Indigenous Peoples. The College of Forestry strives to be an inclusive, diverse, and caring community of interdisciplinary, multi-cultural scholars who respect and value Tribal partnerships, Indigenous ways of knowing, and relationships with Indigenous Peoples. The principles below provide an effective, proactive, and mutually supportive process built on prioritizing deepening intercultural relationships and helping them flourish in a reciprocal manner. They are intended to apply to all programs in the College of Forestry, including, research, extension, and pedagogy. These principles provide critically important direction for the college when building trusting and sustained relationships with Tribes and Indigenous Peoples.<sup>1</sup>

In November 2022, the United States White House issued directives that all federal and state agencies shall incorporate Indigenous Knowledge (IK) ethically in all programs.<sup>2</sup> This has resulted in rapid expansion of opportunities to partner across cultures with Indigenous Peoples. As a global leader in forestry and sustainability actively engaged in projects that include Indigenous Peoples, the College of Forestry must prioritize defining, establishing, and following exemplary ethical principles and best practices for such partnerships. In response to a request from Dean Thomas H. DeLuca in January 2023, the College of Forestry Diversity, Equity, and Inclusion Work Group created the IK and Best Practices for Partnering with Indigenous Communities Task Force. The group's first task was to draft principles and best practices for Government-to-Government partnerships. Such partnerships are relationships in joint work between a federal or state institution, such as Oregon State University and its employees, with Tribal Nations and their members, which involve knowledge transfer including data, written material, guidance, and/or pedagogy. This document represents Volume I: Principles. It will be followed by Volume II: Best Practices, to be drafted in Fall 2023.

## Background

The College of Forestry is part of Oregon State University, a land-grant institution established through the Morrill Acts of 1862 and 1890. These acts granted federally controlled land to states to support the creation of institutions of higher education. These lands, which were stolen from Indigenous Peoples through genocide and forcible removal to reservations, were sold to raise funds to establish and endow land-grant colleges. This was an outcome of the Doctrine of Discovery, a policy used for centuries to justify colonial conquest of lands that belonged to Indigenous Peoples. Settler colonialism, defined as the act of a settler society stealing the land of an Indigenous population and erasing its culture—using power and authority to develop or exploit the colonized to benefit the colonizers—involves modernizing and/or destroying colonies by force, including genocide. It resulted in the passing of the 1862 and 1890 Morrill Acts, with the objective of eliminating Indigenous societies.<sup>3</sup> Decolonization means reversing the erasure of Indigenous languages, culture, beliefs, and resource stewardship practices; pernicious institutional structures, deep ecological degradation, and intergenerational human trauma created by settler colonialism. Because we live in a settler-colonial world, where all systems are based on settler-colonial practices such as capitalism, decolonization requires systems-based institutional changes.

Oregon State University sits on the traditional lands of the Mary's River, or Ampinefu, Band of the Kalapuya who lived here for millennia. They were forcibly removed to reservations in Western Oregon, and their living descendants are part of the Confederated Tribes of Grand Ronde Community of Oregon and the Confederated Tribes of the Siletz Indians. The College of Forestry community, which includes Extension faculty throughout Oregon, can go beyond the land acknowledgement by accepting the damage done to the Kalapuya and other Indigenous Peoples, and initiate healing by establishing respectful relationships with their descendants that fully acknowledge and honor the sovereignty provided to Tribal Nations by the Tribal Self Governance Act of 1994.<sup>4</sup> Tribal Sovereignty is defined as the right of Indigenous Peoples to Self-Governance and Self-Determination. For non-federally recognized Indigenous communities, rights of Self-Governance and Self-Determination also must be respected.

<sup>1</sup> Cordova, V. F., et al. 2007. edited by Moore, K. D., Peters, K., Jojola, T., Lacy, A., Hogan, L. 2007. *How it Is: The Native American Philosophy of V. F. Cordova* Oregon State University Press.

<sup>2</sup> White House OSTP CEQ 2022a; 2022b

<sup>3</sup> Pope Alexander VI 1493 ; Miller 2011; Veracini 2011

<sup>4</sup> U.S. Congress 1887; U.S. Congress 1994



## Multiple Ways of Knowing

Indigenous Knowledge (IK, which encompasses Traditional Ecological Knowledge and Indigenous Ecological Knowledge) is knowledge and practices passed from generation to generation informed by cultural memories, sensitivity to change, and values that include reciprocity (defined as taking with the moral responsibility of giving back in equal measure). IK observations are qualitative and quantitative and illustrate that objectivity/subjectivity is a false dichotomy in knowledge generation. IK observations are long-term, often made by persons who hunt, fish, and gather for subsistence and often passed down through generations over millennia. Most importantly, IK is inseparable from a culture's spiritual and social fabric, offering irreplaceable ecocultural knowledge that can be thousands of years old, spanning many generations. Moral values, such as kinship with nature and reciprocity, which can help restore ecosystems, are intertwined in IK systems. IK land-care practices include prescribed burning, and adjusting timber harvest to create more sustainable communities of culturally significant traditional plants that provide wildlife habitat, and in turn, food, medicines, and products for humans.<sup>5</sup>

Scientific Knowledge (SK, also known as Western science) is an inquiry system shaped by Aristotelian logic, Cartesian dualism, empirical observations, and hypothesis testing. In contrast to IK, key attributes of SK are singularity of truth (monism) and objectivity. It is characterized by synchronic (short-term) studies that strive to be value-free (unbiased, amoral) and ideally use systematic, replicated experimentation conducted in isolation, accurate measurements, and empirical tests, which lead to predictive, generalizable statistical models that have credibility and legitimacy.

One of the cornerstones of settler colonialism is singularity of truth—there is one truth to righteously be imposed on the world. SK expresses this belief in many ways. Decolonization involves including, respecting, and honoring multiple ways of knowing. IK and SK represent two very different worldviews that, when braided together, can help us develop the solutions we need to create holistic socio-ecological systems more resilient to global change and heal the damage done by settler colonialism.<sup>6</sup> In basic scientific contexts, such as physics and chemistry, natural laws exist, followed by actions/reactions that are reproducible and measurable objectively in lab settings. In natural scientific contexts (i.e., those outside lab or controlled settings, meaning that they exist in the real world of multiplicity), there may be incomplete SK generation. Other ways of knowing are needed to complement SK. Because of its basic principles, SK has gaps in its effectiveness in informing our understanding of how the world works. IK can fill those gaps and do much more, because it is the original knowledge, developed over millennia of adaptive management of the natural world by humans. Therefore, embracing multiple ways of knowing that provide fuller, more holistic, and richer knowledge is necessary to help guide policy and management for a sustainable future.

## Emerging Policies to Create Environmental Justice for Tribal Nations and Indigenous Peoples

In 2021, the Office of Science and Technology Policy (OSTP) and the Council on Environmental Quality (CEQ) convened an Interagency Working Group with representatives from more than 25 federal departments and agencies. The group sought input from Tribal Nations and Indigenous Peoples through Tribal consultation and listening sessions. Over a one-year period, they engaged over 1,000 individuals, organizations, and Tribal Nations in this process. The resulting Office of the President Memorandum to heads of agencies, published in November 2022, outlines requirements for federal departments and agencies on partnering with Tribal Nations. Presidential Memoranda are documents directed to, and that govern actions by, government officials and agencies, but are less formal than executive orders and not required to be published in the Federal Register.

Framed as a series of “should” statements, the November 2022 Presidential Memorandum, Guidance for Federal Agencies and Departments on Indigenous Knowledge, contains emerging policy promising a new era of Indigenous Self-Determination and Tribal Sovereignty in the U.S. While some of the laws ostensibly supporting Indigenous Self-Determination and Tribal Sovereignty have been in place for well-over a century, such as the Dawes Act of 1887,<sup>7</sup> they have been enforced very poorly and inconsistently, without inclusive practices. The latest federal policy memoranda pertaining to IK and Tribal partnerships make the strongest statements to date in the U.S. about the importance of IK and the need to respect the rights of Indigenous Peoples. These memoranda give standing and validity to IK that is equal to SK. This is the first time the Office of the President has issued such decolonized statements in the form of Presidential Memoranda.<sup>8</sup>

<sup>5</sup> *Kimmerer 2013*

<sup>6</sup> *Kimmerer 2000; Mason et al. 2011*

<sup>7</sup> *U.S. Congress, Dawes Act of 1887*

<sup>8</sup> *White House OSTP CEQ 2021a, 2021b; White House OSTP CEQ 2022a, 2022b*

# Principles and Best Practices for Working with Indigenous Knowledge and Partnering with Tribal Nations and Indigenous Peoples

## Volume 1: Principles

The following principles are specific to the College of Forestry and reflect our unique identity as a global leader in forestry and interdisciplinary, multi-cultural, systems-thinking sustainability science. The college's Principles and Best Practices for Working with Indigenous Knowledge and Partnering with Tribal Nations and Indigenous Peoples are strongly informed by: 1) White House OSTP CEQ policies; 2) the [College of Forestry Strategic Plan 2023 – 2027](#) Vision, Mission, and Goals, which are strongly infused with Diversity, Equity, and Inclusion (DEI) values; and 3) interdisciplinary STEM education, research, and applied science interests of the college community.<sup>9</sup> They apply broadly to Indigenous Peoples globally with whom the college may want to partner. This engagement should not be limited to federally recognized Tribal Nations, and should include Native Hawaiians, and other Indigenous Peoples.

These principles fully support academic freedom. They resemble the rules and regulations that must be observed to secure a permit to do research on federal or state land. As is the case with federal or state research permits, Volume I: Principles, provides clear ethical standards. These standards will be further elucidated and illustrated with examples in Volume II: Best Practices.

To grow and maintain relationships supporting IK, it is essential to:

- 1 ..... Acknowledge the historical context of past injustice: genocide, ethnocide, and ecocide.**<sup>10</sup> Historic federal legislation, such as the Morrill Act, had the goal of recognizing Tribal Sovereignty and subsequently systematically assimilating and displacing Indigenous Peoples and eradicating their cultures. Tribal Nations and Indigenous Peoples continue to experience the impacts of intergenerational trauma resulting from this violent legacy.
- 2 ..... Practice early and sustained engagement with Tribal Nations and/or Tribal knowledge holders.** Engagement should begin before the earliest phase of developing a research proposal, management plan or outreach effort, with foundational relationship-building activities that will then support joint efforts. In the context of Oregon State University College of Forestry member actions, listening instead of telling is important, as is asking what is desired by the Tribal members in terms of a relationship. This cultural humility also pertains to planning community events with Tribal partners, developing OSU Extension projects with or led by Tribal communities, and asking Indigenous individuals for advice about IK.
- 3 ..... Earn and maintain trusting relationships by being transparent, open about ideas and agendas, and honest at all times, in all forms of communication.** Earning this trust requires creating a decolonized, safe space for engagement of Tribal Nations and other Indigenous Peoples. It also requires allowing ample time for them to respond. It is exploitative to approach a Tribal Nation or Indigenous colleague at the last moment with a fully drafted research proposal and ask them to sign on as a Tribal partner or co-principal investigator. This is an inappropriate way to secure funding for research because it tokenizes Tribal Nations and Indigenous Peoples. Intentionality to partner ethically should be expressed as early as possible and should be stated as part of the impact statement that is typically required for proposals.
- 4 ..... Respect different processes and worldviews.** Indigenous communities may have vastly different and diverse ways of doing business than how business is done in the settler-colonial world. These differences include an expectation that the entire Tribal community be involved in decision-making, including Elders and youth. This inclusiveness is vital to Tribal Governance and community. Each Tribal Nation and Indigenous community has different culture and governance policies. Deliverables and products that are part of Tribal partnerships may be on a longer timeframe than the two-to-three-year timeframe common in SK, because Tribal Nations and Indigenous Peoples carefully guard information about their homelands and their cultural connections to them. To avoid unintentional cultural appropriation and exploitation, recognize and respect divergent processes and worldviews, and the sensitivity of Tribes about sharing certain information.

<sup>9</sup>College of Forestry Strategic Plan 2023 – 2027 <https://www.forestry.oregonstate.edu/about/strategic-plan>

<sup>10</sup>Ecocide is defined as unlawful or wanton acts committed with knowledge that there is a substantial likelihood of severe and either widespread or long-term damage to the environment being caused by those acts (Sarliève 2021).

- 5 ..... Recognize, respond to, and adapt to challenges with cultural humility.** These challenges include: deep mistrust; lack of funding, personnel, and capacity among Tribes and Indigenous Peoples to respond to external requests to engage; lack of coordination and communication between external government agencies or external partners in reaching out to Tribes and Indigenous Peoples; changes in external and Tribal political administrations, budgets, and leadership priorities; and poor telecommunications infrastructure in rural areas. Some of these challenges arise from settler colonialism. Those seeking to partner with Tribal Nations and Indigenous Peoples must be dedicated to responding to these challenges at individual and institutional levels with cultural humility. Cultural humility is the ongoing process of self-exploration and self-critique and willingness to learn from others. In entering a relationship with another person, it involves honoring their values, beliefs, and customs, and accepting that person for who they are.
- 6 ..... Consider supporting co-management and co-stewardship structures.** These approaches bring Tribal Nations directly into decision-making. Co-management is a partnership whereby the government shares power with resource users, with clearly specified rights and responsibilities for each party relating to management and decision-making. Co-stewardship is broader and refers to a range of working relationships with Tribal Nations, as well as Tribal consortia and Tribal-led entities exercising the delegated authority of federally recognized Tribes. Tribal co-management and co-stewardship require a Memorandum of Understanding (MOU), defined as a Government-to-Government agreement that establishes standards of partnership; or a Memorandum of Agreement (MOA), defined as a document written between parties to cooperatively work on an agreed upon project that involves a transfer of funds.<sup>11</sup> Resulting partnerships may help avoid challenges around and breaches of confidentiality or data, and imbalances in power and resources. Co-stewardship can be part of relationships building. Co-management must be consistent and relevant and may not be feasible in all scenarios.
- 7 ..... Pursue co-production of knowledge. Knowledge co-production is a research framework based on equity and the inclusion of multiple knowledge systems.** It requires full partnership of Tribes and Indigenous Peoples in all aspects of a research endeavor from the outset, including ensuring that Tribal and Indigenous collaborators are compensated for their work. True knowledge co-production requires participation of a Tribal Nation in project leadership and decision-making from the genesis of research ideas to project completion, and authorship in publications. This participation continues through implementation/application of said knowledge (e.g., adaptive-management plans).
- 8 ..... Provide ample funding to Tribal Nations and Indigenous Peoples for involvement at each step of partnership and knowledge co-creation.** Only engage with a Tribal Nation or Indigenous individual in a research partnership if you are prepared to fund their participation in any partnerships created. A primary goal of all research proposals that include Tribal Nations and Indigenous Peoples should be to build capacity within these communities by providing funding (e.g., jobs, fully funded STEM education, and other opportunities for personal and professional growth). Partnership outcomes should support the Tribe's social, economic, and cultural goals and priorities. For example, a project could take steps to incorporate youth engagement, support intergenerational knowledge transfer, or otherwise support the health and wellbeing of Tribal members. The project may also be adjusted to support decision-making, applications, and power-sharing aligned with the Tribe's goals.
- 9 ..... Share power and decision-making authority with partnering Tribes and Indigenous Peoples.** Be honest and transparent about any limitations regarding the ability to share such power. Avoid creating expectations regarding future outcomes that project leadership is not certain of achieving or is not within your authority to grant. When developing methods and data-collection protocols, researchers and managers should consider using Indigenous methodologies and incorporating Indigenous metrics and indicators to fully include IK in the research results. Tribal partners and Indigenous Peoples will have strong sensitivity around sharing IK with external partners until trust is built. Building trust requires creating supporting legal documents for work on Tribal lands, or that involves IK obtained from Tribal knowledge keepers on non-Tribal lands, such as an MOU and Data Sharing Agreement (DSA), defined as a formal contract that clearly documents the data being shared and the parameters under which those data may be used, or a Non-disclosure Agreement (NDA), defined as a contract by which one or more parties agree not to disclose confidential information that they have shared with each other as a necessary part of working together. At the conclusion of the research, the results should be reviewed by the partnering Tribe or Indigenous Peoples and shared in ways that are meaningful and useful to them and the broader scientific community. This includes having Tribal members and Indigenous Peoples as co-authors of published peer-reviewed literature.

<sup>11</sup>Nie 2008

Clearly established policies, as described in the above principles, that acknowledge and respect Sovereignty Rights and enter into Government-to-Government relations with MOUs, MOAs, DSAs, and other types of formal legal agreements are essential to creating healthy intercultural relationships. Because funding is frequently provided for research by federal or state agencies, these policies apply to scientists and all types of faculty and students working within academic institutions and non-governmental organizations intending to partner with Tribal Nations or Indigenous Peoples.<sup>12</sup>

## Conclusion

In the introduction to the College of Forestry Strategic Plan 2023 – 2027, Dean DeLuca states that, “This is a pivotal time for forestry and humankind and the College of Forestry’s leadership is needed more than ever before. . . We are committed to building an inclusive culture at the college and identifying and removing barriers to provide equitable access to research, learning, and engagement. We are ready to accelerate our work to create thriving ecosystems, economies, and communities.”<sup>13</sup>

The Principles and Best Practices for Working with Indigenous Knowledge and Partnering with Tribal Nations and Indigenous Peoples were drafted in direct response to the College of Forestry Strategic Plan 2023 – 2027 call to action to help us move into a more equitable and inclusive future. Meaningful adoption of these policies and principles will require significant learning, investment, and adaptation of existing procedures within our institution. The college is moving boldly into the future by continuing to strengthen our research centers, institutes, laboratories, and programs, and build research partnerships to advance knowledge and co-create sustainable and equitable solutions to issues facing forest landscapes, ecosystems, societies, and communities. To fully support the innovative, interdisciplinary, intercultural work we are doing together, individuals at all levels of the College of Forestry must develop a strong commitment to incorporating the principles and practices for partnering with Tribal Nations and Indigenous Peoples, and to embracing Native values of reciprocity, humility, and respect.



*College of Forestry Indigenous Natural Resource Office staff and TEK Lab students in April 2023, left to right: Brooklyn Richards, Allison Monroe, Ashley Russell, Dr. Cristina Eisenberg, Dr. Gail Woodside, Tessa Chesonis*

<sup>12</sup>Moller 2004; Mason et al. 2012; Lake et al. 2017; Lake 2021

<sup>13</sup>College of Forestry Strategic Plan 2023 – 2027



## Literature Cited:

- Cordova, V. F., edited by K. D. Moore, K. Peters, T. Jojola,, A. Lacy; with foreword by L. Hogan. 2007. *How it Is: The Native American Philosophy of V. F. Cordova* (Corvallis, Oregon: Oregon State University Press).
- Kimmerer, R. 2000. Native knowledge for native ecosystems. *Journal of Forestry* 98 (8):4-9.
- Kimmerer, R. W. (2015). *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge, and the Teachings of Plants* (Minneapolis, Minnesota: Milkweed Editions).
- Lake, F. 2021. Indigenous fire stewardship: federal/Tribal partnerships for wildland fire research and management. *Fire Management Today*. 79(1): 30-39.
- Lake, F., V. Wright, P. Morgan, M. McFadzen, D. McWethy, and C. Stevens-Rumann. 2017. Returning fire to the land: celebrating traditional knowledge and fire. *Journal of Forestry* 115 (5):343-353.
- Mason, L., G. White, G. Morishima, E. Alvarado, L. Andrew, F. Clark, M. Durglo Sr., et al. 2012. Listening and learning from traditional knowledge and Western science: A dialogue on contemporary challenges of forest health and wildfire. *Journal of Forestry* 110 (4):187-193.
- Miller, R. J. 2011. American Indians, the doctrine of discovery, and manifest destiny. *Wyoming Law Review* 11:329.
- Moller, H., F. Berkes, P. O'Brian Lyver, and M. Kislalioglu. 2005. Combining science and traditional ecological knowledge: monitoring populations for co-management. *Ecology and society* 9(3).
- Nie, M. 2008. The use of co-management and protected land-use designations to protect tribal cultural resources and reserved treaty rights on federal lands. *Natural Resources Journal*: 585-647.
- Oregon State University, College of Forestry Strategic Plan 2023 – 2027, accessed April 8, 2023 at: <https://www.forestry.oregonstate.edu/about/strategic-plan>
- Pope Alexander VI. 1493. The Doctrine of Discovery. Accessed April 8, 2023 at: <https://www.gilderlehrman.org/history-resources/spotlight-primary-source/doctrine-discovery-1493>
- Sarliève, M. 2021. Ecocide: Past, Present, and Future Challenges. In: Leal Filho, W., Azul, A.M., Brandli, L., Lange Salvia, A., Wall, T. (eds) *Life on Land. Encyclopedia of the UN Sustainable Development Goals*. Springer, Cham <https://doi.org/10.1007>
- U.S. Congress. 1887. General Allotment Act or Dawes Act of 1887. Statutes at Large 24, 388-91, NADP Document A1887. Retrieved December 27, 2022 from <https://www.ourdocuments.gov/doc.php?flash=false&doc=50>
- U.S. Congress. 1994. Tribal Self Governance Act of 1994. Retrieved March 3, 2023 from <https://www.congress.gov/bill/103rd-congress/house-bill/3508>
- Veracini, L. 2010. *Settler colonialism*. (Houndmills, UK: Palgrave Macmillan).
- White House Office of Science and Technology Policy (OSTP) Council on Environmental Quality (CEQ). 2021a *America the Beautiful Initiative, Tribal Consultation, Defining Co-Management*, October 28, 2021. Retrieved on October 30, 2022 from <https://www.doi.gov/priorities/america-the-beautiful>
- White House Office of Science and Technology Policy (OSTP) Council on Environmental Quality (CEQ). 2021b. *Indigenous Traditional Ecological Knowledge and Federal Decision Making*, November 15, 2021. Retrieved on November 16, 2022 from <https://www.whitehouse.gov/wp-content/uploads/2021/11/111521-OSTP-CEQ-ITEK-Memo.pdf>
- White House Office of Science and Technology Policy (OSTP) Council on Environmental Quality (CEQ). 2022a. *Guidance for Federal Agencies and Departments on Indigenous Knowledge*, November 22, 2022. Retrieved on February 1, 2023 from <https://www.whitehouse.gov/wp-content/uploads/2022/12/OSTP-CEQ-IK-Guidance.pdf>
- White House Office of Science and Technology Policy (OSTP) Council on Environmental Quality (CEQ). 2022b. *Implementation of Guidance for Federal Agencies and Departments on Indigenous Knowledge*, November 22, 2022. Retrieved on February 1, 2023 from <https://www.whitehouse.gov/wp-content/uploads/2022/12/IK-Guidance-Implementation-Memo.pdf>

## Appendix D. Activities Not Covered Under the ESRF HCP

Some activities are not covered under the ESRF HCP because they do not meet the criteria described in ESRF HCP Section 3.1. ESA compliance for activities not covered will be achieved through either take avoidance or through additional consultations with the Services. The following summarizes the activities that are not covered under the ESRF HCP.

### *Recreational Activities and Infrastructure*

Recreational activities are not a covered activity under this ESRF HCP. Recreation use is a year-round activity and is unrestricted except in cases where roads are gated and locked to limit access to capital facilities such as transmission towers. Current information regarding recreational use is limited, but overall use is relatively low due to the remote location and there being no established hiking trails or developed campgrounds. Development of recreational trails and infrastructure has not yet been planned, although recreation is an important aspect of the Forest Management Plan, which will be prepared for consistency with the ESRF HCP, and any additional ESA permit coverage would be obtained on a project-specific basis, as needed. Individual actions of members of the public are not covered, whether or not those activities are conducted in a manner that complies with applicable law. This includes, but is not limited to, hunting, fishing, shooting, driving automobiles or OHVs, firewood harvesting, hiking, swimming, and wading. DSL assumes that these activities in the permit area would follow all applicable state regulations (e.g., hunting and fishing licenses, all-terrain vehicle [ATV] permit).

### *Pesticide Use*

As defined by the Environmental Protection Agency, a pesticide is any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest, any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant, and any nitrogen stabilizer. Herbicides are included within this broader category. Pesticide application using either aerial application methods (i.e., fixed-wing airplane, helicopter, unmanned aerial system) or ground is not a covered activity under the ESRF HCP. DSL Pesticide application may be used in compliance with Oregon FPA regulations and with the ESA through take avoidance.

### *Fire Suppression*

Fire suppression is not a covered activity because of the difficulty in defining the anticipated extent, location, and intensity of fire on the ESRF. The frequency and magnitude of fire suppression activities will be determined by the timing and impact of fires on the forest.

### *Easement Use*

Certain parties have easements providing access and use of lands within the plan area. Uses of lands within the plan area by easement holders or other parties that are not representatives of or contractors to the Permittee are not covered activities.

### *Water Developments*

Water developments for drafting and other uses are all located at springs and have been in place for many years, and are managed by the Coos Forest Protection Association. No additional water developments have been included as ESRF HCP covered activities.

### *Research Involving Handling or Other Disturbance to Covered Species*

For any research that requires capturing covered species or other invasive techniques, ESA compliance will be completed separately from the ESRF HCP, although specifications may be added to the ESRF HCP in consultation with the Services as part of the amendment process described in Chapter 7: *Implementation and Assurances*.

### *Passive Research*

Passive research is observational research where the researcher is applying techniques to detect changes in the environment but without physical manipulation of the environment itself. Passive research is not a covered activity because this type of research would not affect covered species in ways that would likely rise to the level of take.

## Appendix E. ESRF Budget Model (DRAFT)

ESRFA Budget Model Draft (October 2023)				
<i>Note: Personnel costs = salary + OPE. All costs provided by Department of State Lands</i>				
ESRFA (Agency) Budget	Description		Cost	Notes
	Agency Head 7/Executive Director		\$169,139	
	Executive Assistant		\$101,961	
	Operations & Policy Analyst 3 (0.5 FTE)		\$62,303	
	4100 - Instate Travel		\$33,250	
	4150 - Employee Training		\$1,250	
	4175 - Office Expenses		\$833	
	4200 - Telecomm/Tech S&S		-	
	4225 - State Government Service Charge		\$44,630	
	4225 - Attorney Generation Legal Fees		\$16,000	
	4425 - Lease Payments & Taxes		\$25,320	
	4650 - Other Services and Supplies		\$6,250	
	4715 - IT Expendable Property		\$9,333	
	5100 - Office Furniture and Fixtures		\$5,000	
	ESRFA Total		\$475,269	



ESRF Budget Model (Full Capacity) (October 2023)				
<i>Note: Personnel costs = salary + OPE (OSU salary structure; rounded values). Assume 20 people for space, supplies, materials calculations (17 permanent and 3 rotating for grad/intern positions).</i>				
Description		Cost	Notes	Details
Operations personnel	Forester (Lead/Manager)	\$168,000		Manager 1- Unit Administration Position (Salary \$108,600; OPE \$59,730)
	Forester	\$143,000		Specialist 2-Forestry (Salary \$91,200; OPE \$51,984)
	Forest Engineer	\$152,000		Specialist 2-Forestry (Salary \$96,600; OPE \$55,062)
	Forestry Technician	\$95,000		Biological Science Research Technician Level 3 (Salary \$55,500; OPE \$39,960)
	GIS/Inventory	\$152,000		Specialist 2-Forestry (Salary \$96,600; OPE \$55,062)
	Business/Log Accounting	\$126,000		
	Partnership Coordinator	\$113,000		Prog Coordinator (Salary \$68,700; OPE \$44,655)
		<b>\$949,000</b>		

ESRF Budget Model (Full Capacity) (October 2023)				
<i>Note: Personnel costs = salary + OPE (OSU salary structure; rounded values). Assume 20 people for space, supplies, materials calculations (17 permanent and 3 rotating for grad/intern positions).</i>				
Research Personnel	Research Lead (PI)	\$264,000		Administration 1 - Res Ctr/Inst (Salary \$182,112; OPE \$81,950)
	Research Communications Specialist	\$113,000		Prog Coordinator (Salary \$68,700; OPE \$44,655)
	Data Specialist	\$123,000		Specialist 2 - IT Research (Salary \$74,400; OPE \$48,360)
	Professorial Research Faculty (TT, Physical)	\$182,000		Associate Faculty (Salary \$117,324; OPE \$64,528)
	Professorial Research Faculty (TT, Biological)	\$182,000		Associate Faculty (Salary \$117,324; OPE \$64,528)
	Professorial Research Faculty (TT, Social)	\$182,000		Associate Faculty (Salary \$117,324; OPE \$64,528)
	Research Scholar (Indigenous Knowledge)	\$182,000		Associate Faculty (Salary \$117,324; OPE \$64,528)
	Research Technician (Faculty Research Assistant) (OSU/CTCLUSI/Tribal Partner)	\$95,000		Faculty Research Assistant (Salary \$55,500; OPE \$39,960)
	Research Technician (Faculty Research Assistant) (OSU/CTCLUSI/Tribal Partner)	\$95,000		Faculty Research Assistant (Salary \$55,500; OPE \$39,960)
	Research Technician (Faculty Research Assistant) (OSU/CTCLUSI/Tribal Partner)	\$95,000		Faculty Research Assistant (Salary \$55,500; OPE \$39,960)
	Research Technician (Faculty Research Assistant) (OSU/CTCLUSI/Tribal Partner)	\$95,000		Faculty Research Assistant (Salary \$55,500; OPE \$39,960)
	Graduate Research Assistant	\$57,000		Graduate Research Assistant (Salary \$27,554; OPE \$9,919; Tuition \$19,213)
	Graduate Research Assistant	\$57,000		Graduate Research Assistant (Salary \$27,554; OPE \$9,919; Tuition \$19,213)
	Graduate Research Assistant	\$57,000		Graduate Research Assistant (Salary \$27,554; OPE \$9,919; Tuition \$19,213)
	Student Intern (OSU/CTCLUSI/ Tribal Partner)	\$13,000		Intern - Student (700 hours of work * \$16/hour +10%OPE)
	Student Intern (OSU/CTCLUSI/ Tribal Partner)	\$13,000		Intern - Student (700 hours of work * \$16/hour +10%OPE)
	Student Intern (OSU/CTCLUSI/ Tribal Partner)	\$13,000		Intern - Student (700 hours of work * \$16/hour +10%OPE)
		<b>\$1,818,000</b>		

ESRF Budget Model (Full Capacity) (October 2023)				
<i>Note: Personnel costs = salary + OPE (OSU salary structure; rounded values). Assume 20 people for space, supplies, materials calculations (17 permanent and 3 rotating for grad/intern positions).</i>				
Operating Expenses for Research & Management	Services & Supplies (**)	\$68,000	Office supplies, computers, maintenance, small equipment purchases, training & development	OSU #s for S&S+T&D (\$3,000/person * 18 personnel)+(\$7,000/executive or lead personnel * 2 people [Research PI & Lead Forester]) = \$68,000
	Rent/Leasing Space (**)	\$100,000	Will depend on temporary space and final lease agreement for permanent facilities	\$2.11/sqft (DAS); 2,000 sqft office space for 20 people, plus OSU proposed space for labs, instrumentation/equipment, coolers, storage, conference room, kitchen, group space, classroom, housing
	Equipment and Vehicle Reserve Fund (**)	\$57,000	Estimated as an annual expense, allowing for replacement of vehicles and equipment every 10 years (based on OSU depreciation schedule)	8 year rotations per OSU rec. with estimated new set of tires each 1-2 years for backup (8 trucks). Prices current factory price from OSU Motorpool 2023 purchase (i.e. 1 new F250 truck/yr @ \$42,000/truck+\$5,000/canopy+8 sets of tires*\$1500/set+\$725 for tool box/radio/accessories) = \$56,725
	Vehicle Maintenance and Fuel (**)	\$63,000	8 vehicles, annual maintenance and fuel based on 2023 GSA rate (\$.655)	0.655 (current GSA rate) *12,000 miles/truck/yr * 8 trucks = \$62,880
	Recreational Expenses	\$30,000	To be revised based on ESRF Recreation Plan, once developed (TBD)	Estimated value for signs, cleanup, events, etc. Update dependent on ESRF Recreation Plan.
	ODF Wildfire protection (**)	\$393,000	Updated January 2023; \$4.76/acre	
	Tribal Engagement (Research, Monitoring, Management)	\$25,000		Consultation with Tribal partners needed to refine this number. Estimate from C. Eisenberg: \$1,000/day plus food/travel expenses.
	Cultural Resources	\$40,000	Cultural resource surveys	
	HCP Monitoring (outside scope of ESRF research program monitoring and other personnel/operational costs) (**)	\$335,000		Updated based on August 2023 costs in draft HCP. Although the annual cost is noted here as \$335,000, this number fluctuates based on a 3-year cycle for aquatic monitoring needs in the HCP. Effectiveness monitoring for NSO and MAMU is currently estimated at \$85,000 and \$150,000, respectively. For coho, effectiveness monitoring in Years 1 and 2 of a three-year cycle a total \$50,000 is required for water quality monitoring. In Year 3, \$200,000 is required to also include surveys in the three independent coho populations (\$150,000). To simplify representation of coho effectiveness monitoring in this annual budget estimate, the coho monitoring costs are spread over three years.
	Roads Operations & Maintenance (O&M) (**)	\$400,000	Additional road expenses associated with harvesting are accounted for in revenue analysis	Confirmed with R. Singleton (DSL) February 2023

ESRF Budget Model (Full Capacity) (October 2023)				
<i>Note: Personnel costs = salary + OPE (OSU salary structure; rounded values). Assume 20 people for space, supplies, materials calculations (17 permanent and 3 rotating for grad/intern positions).</i>				
Operating Expenses for Research & Management	Sheriff Patrol Agreements for Coos and Douglas Counties (**)	\$15,000		Confirmed with R. Singleton (DSL) February 2023
	Assessments (OSU overhead for admin services) (**)	\$164,700	3% of total ESRF expenses, not including the contingency fund	
	Contingency Fund (*)	\$540,000	Reserve fund for unforeseen expenses, capital expenses, natural disasters, revenue downturns (approximately 10% of research operations budget)	
		<b>\$2,230,700</b>		
Research Expenses	Research/ HCP Monitoring & Equipment Replacement	\$547,000	Estimate based on: 160K for inventory (Lidar, satellite imagery, ground surveys, equipment updates), 40K for C, 100K for aquatic, 227K for biodiversity, 20K for human dimensions	Approximate cost estimates and categories coordinated with start-up cost estimates provided by researchers working in each area of expertise, and are connected with the FMP monitoring chapter framework. This line item funds equipment replacement, equipment calibration, surveys, and field crews.
	IT/Data Storage/Software/QA/QC	\$600,000		2020 estimate from HJ Andrews Forest, adjustments needed for inflation and other tech considerations
	Research Equipment Maintenance Fund	\$50,000		Ongoing monitoring equipment maintenance, batteries, software updates, etc.
		<b>\$1,197,000</b>	<b>\$1,532,000</b>	
	<b>Total</b>	<b>\$6,194,700</b>		
	<b>Total ESRF and ESRFA Budget</b>	<b>\$6,669,969</b>		



#### Additional Notes

This budget scenario is based on the McDonald-Dunn Research Forest and HJ Andrews Research Forest as initial examples, and incorporates additional input from foresters, researchers, and budget specialists.

Salary rates (and exact OPE) will depend on the person hired into each position and their qualifications. The estimates in this budget scenario reflect the mid- to high- end of the appropriate salary range for each classification given the desire to attract high quality people and build in appropriate flexibility.

(\*) The contingency fund is described as part of the ESRF budget model as it is a core research forest operations expense. The contingency fund is held in an account by the ESRFA Board.

(\*\*) indicates a fixed cost. Some of these costs are per unit of personnel, others are per acre or mile on the forest.

HCP Monitoring cost (Line 60) may change if adjustments are made on NSO survey requirements in the current draft (10.18.23)

The Tribal Engagement budget (Line 39) will be further refined through continued consultation with Tribal partners.

ESRFA Budget Model (October 2023)			
<i>Note: Personnel costs = salary + OPE. All costs provided by Department of State Lands</i>			
ESRFA (Agency) Budget	Description	Cost	Notes
	Agency Head 7/Executive Director	\$169,139	
	Executive Assistant	\$101,961	
	Operations & Policy Analyst 3 (0.5 FTE)	\$62,303	
	4100 - Instate Travel	\$33,250	
	4150 - Employee Training	\$1,250	
	4175 - Office Expenses	\$833	
	4200 - Telecomm/Tech S&S	-	
	4225 - State Government Service Charge	\$44,630	
	4225 - Attorney Generation Legal Fees	\$16,000	
	4425 - Lease Payments & Taxes	\$25,320	
	4650 - Other Services and Supplies	\$6,250	
	4715 - IT Expendable Property	\$9,333	
	5100 - Office Furniture and Fixtures	\$5,000	
	ESRFA Total	\$475,269	

ESRF Budget Model (Reduced) (October 2023)			
<i>Note: Personnel costs = salary + OPE (OSU salary structure; rounded values). Assume 11 people for space, supplies, materials calculations.</i>			
Description	Cost	Notes	Details
Operations personnel	Forester (Lead/Manager)	\$168,000	Manager 1- Unit Administration Position (Salary \$108,600; OPE \$59,730)
	Forester	\$143,000	Specialist 2-Forestry (Salary \$91,200; OPE \$51,984)
	Forest Engineer	\$152,000	Specialist 2-Forestry (Salary \$96,600; OPE \$55,062)
	Forestry Technician	\$95,000	Biological Science Research Technician Level 3 (Salary \$55,500; OPE \$39,960)
	GIS/Inventory	\$152,000	Specialist 2-Forestry (Salary \$96,600; OPE \$55,062)
	Business/Log Accounting	\$126,000	Admin Spec - Bus & Finance (Salary \$76,512; OPE \$49,733)
	Partnerships Coordinator	\$113,000	Prog Coordinator (Salary \$68,700; OPE \$44,655)
	<b>\$836,000</b>		

ESRF Budget Model (Reduced) (October 2023)				
Note: Personnel costs = salary + OPE (OSU salary structure; rounded values). Assume 11 people for space, supplies, materials calculations.				
Research Personnel	Research Lead (PI)	\$264,000		Administration 1 - Res Ctr/Inst (Salary \$182,112; OPE \$81,950)
	Research Communications Specialist	\$113,000		Prog Coordinator (Salary \$68,700; OPE \$44,655)
	Data Specialist	\$123,000		Specialist 2 - IT Research (Salary \$74,400; OPE \$48,360)
	Professorial Research Faculty (TT, Physical)	\$182,000		Associate Faculty (Salary \$117,324; OPE \$64,528)
	Professorial Research Faculty (TT, Biological)	\$182,000		Associate Faculty (Salary \$117,324; OPE \$64,528)
	Professorial Research Faculty (TT, Social)	\$182,000		Associate Faculty (Salary \$117,324; OPE \$64,528)
	Research Scholar (Indigenous Knowledge)	\$182,000		Associate Faculty (Salary \$117,324; OPE \$64,528)
	Research Technician (Faculty Research Assistant) (OSU/CTCLUSI/Tribal Partner) (**)	\$95,000		Faculty Research Assistant (Salary \$55,500; OPE \$39,960)
	Research Technician (Faculty Research Assistant) (OSU/CTCLUSI/Tribal Partner) (**)	\$95,000		Faculty Research Assistant (Salary \$55,500; OPE \$39,960)
	Research Technician (Faculty Research Assistant) (OSU/CTCLUSI/Tribal Partner)	\$95,000		Faculty Research Assistant (Salary \$55,500; OPE \$39,960)
	Research Technician (Faculty Research Assistant) (OSU/CTCLUSI/Tribal Partner)	\$95,000		Faculty Research Assistant (Salary \$55,500; OPE \$39,960)
	Graduate Research Assistant	\$57,000		Graduate Research Assistant (Salary \$27,554; OPE \$9,919; Tuition \$19,213)
	Graduate Research Assistant	\$57,000		Graduate Research Assistant (Salary \$27,554; OPE \$9,919; Tuition \$19,213)
	Graduate Research Assistant	\$57,000		Graduate Research Assistant (Salary \$27,554; OPE \$9,919; Tuition \$19,213)
	Student Intern (OSU/CTCLUSI/ Tribal Partner)	\$13,000		Intern - Student (700 hours of work * \$16/hour +10%OPE)
	Student Intern (OSU/CTCLUSI/ Tribal Partner)	\$13,000		Intern - Student (700 hours of work * \$16/hour +10%OPE)
	Student Intern (OSU/CTCLUSI/ Tribal Partner)	\$13,000		Intern - Student (700 hours of work * \$16/hour +10%OPE)
		<b>\$768,000</b>		



ESRF Budget Model (Reduced) (October 2023)				
Note: Personnel costs = salary + OPE (OSU salary structure; rounded values). Assume 11 people for space, supplies, materials calculations.				
Operating Expenses for Research & Management	Services & Supplies (**)	\$41,000	Office supplies, computers, maintenance, small equipment purchases, training & development	OSU #s for S&S+T&D (\$3,000/person * 9 personnel)+(\$7,000/executive or lead personnel * 2 people [Research PI & Lead Forester]) = \$41,000
	Rent/Leasing Space (**)	\$100,000	Will depend on temporary space and final lease agreement for permanent facilities	\$2.11/sqft (DAS); 2,000 sqft office space for 20 people, plus OSU proposed space for labs, instrumentation/equipment, coolers, storage, conference room, kitchen, group space, classroom, housing
	Equipment and Vehicle Reserve Fund (**)	\$41,000	Estimated as an annual expense, allowing for replacement of vehicles and equipment every 8 years (based on OSU depreciation schedule)	Used 8 year rotations per OSU rec. with estimated new set of tires each 1-2 years for backup (6 trucks). Prices current factory price from OSU Motorpool 2023 purchase (i.e. 1 new F250 truck/yr @ \$42,000/truck+\$5,000/canopy+6 sets of tires*\$1500/set+\$725 for tool box/radio/accessories) = \$40,400
	Vehicle Maintenance and Fuel (**)	\$47,500	5 vehicles, annual maintenance and fuel based on 2023 GSA rate (\$.655)	0.655 (current GSA rate) *12,000 miles/truck/yr * 6 trucks = \$47,160
	Recreational Expenses	\$30,000	*To be revised based on ESRF Recreation Plan, once developed (TBD)	Estimated value for signs, cleanup, events, etc. Update dependent on ESRF Recreation Plan.
	ODF Wildfire Protection (**)	\$393,000	Updated January 2023; \$4.76/acre	
	Tribal Engagement (Research, Monitoring, Management)	\$25,000		Consultation with Tribal partners needed to refine this number. Estimate from C. Eisenberg: \$1,000/day plus food/travel expenses.
	Cultural Resources	\$40,000	Cultural resource surveys	
	HCP Monitoring (outside scope of ESRF research program monitoring and other personnel/operational costs) (**)	\$335,000		Updated based on August 2023 costs in draft HCP. Although the annual cost is noted here as \$335,000, this number fluctuates based on a 3-year cycle for aquatic monitoring needs in the HCP. Effectiveness monitoring for NSO and MAMU is currently estimated at \$85,000 and \$150,000, respectively. For coho, effectiveness monitoring in Years 1 and 2 of a three-year cycle a total \$50,000 is required for stream temperature monitoring. In Year 3, \$200,000 is required to also include surveys in the three independent coho populations (\$150,000). To simplify representation of coho effectiveness monitoring in this annual budget estimate, the coho monitoring costs are spread over three years.

ESRF Budget Model (Reduced) (October 2023)				
Note: Personnel costs = salary + OPE (OSU salary structure; rounded values). Assume 11 people for space, supplies, materials calculations.				
Operating Expenses for Research & Management	Roads Operations & Maintenance (O&M) (**)	\$400,000	Additional road expenses associated with harvesting are accounted for in revenue analysis	Confirmed with R. Singleton (DSL) February 2023
	Sheriff Patrol Agreements for Coos and Douglas Counties (**)	\$15,000		Confirmed with R. Singleton (DSL) February 2023
	Assessments (OSU overhead for admin services) (**)	\$127,155	3% of total ESRF expenses, not including the contingency fund.	
	Contingency Fund (*)	\$410,000	Reserve fund for unforeseen expenses, capital expenses, natural disasters, revenue downturns (approximately 10% of research operations budget)	
		<b>\$2,004,655</b>		
Research Expenses	Research Monitoring & Equipment Replacement	\$517,000	Estimate based on: 160K for inventory (Lidar, satellite imagery, ground surveys, equipment updates), 40K for C, 70K for aquatic, 227K for biodiversity, 20K for human dimensions	Approximate cost estimates and categories coordinated with start-up cost estimates provided by researchers working in each area of expertise, and are connected with the FMP monitoring chapter framework. This line item funds equipment replacement, equipment calibration, surveys, and field crews.
	IT/Data Storage/Software/QA/QC (**)	\$600,000		2020 estimate from HJ Andrews Forest, adjustments needed for inflation and other tech considerations
	Research Equipment Maintenance Fund	\$50,000		Ongoing monitoring equipment maintenance, batteries, software updates, etc.
		<b>\$1,167,000</b>		
	<b>ESRF Total</b>	<b>\$4,775,655</b>		
	<b>Total ESRF and ESRFA Budget</b>	<b>\$5,250,924</b>		

#### Additional Notes

This budget scenario is a leaner version of Scenario 1, which is based on the McDonald-Dunn Research Forest and HJ Andrews Research Forest as initial examples, and incorporates additional input from foresters, researchers, the ESRF advisory committee, and budget specialists. Adjustments were made to personnel and associated services & supplies based on the goal of creating a lower budget scenario that still meets research and HCP commitments. Personnel that have been removed from this budget (in comparison to the full capacity budget) are noted in gray text.

Line items in gray are not included in total budget calculations. Red line items are still included but adjustments have been made that reduce the numbers compared to Scenario 1. Purple line items were added back in based on 4/17-4/18 board retreat discussions.

Salary rates (and exact OPE) will depend on the person hired into each position and their qualifications. The estimates in this budget scenario reflect the mid- to high- end of the appropriate salary range for each classification given the desire to attract high quality people and build in appropriate flexibility.

(\*) The contingency fund is described as part of the ESRF budget model as it is a core research forest operations expense. The contingency fund is held in an account by the ESRFA Board.

(\*\*) indicates a fixed cost. Some of these costs are per unit of personnel, others are per acre or mile on the forest.

HCP Monitoring cost (Line 60) may change if adjustments are made on NSO survey requirements in the current draft (10.18.23)

The Tribal Engagement budget (Line 39) will be further refined through continued consultation with Tribal partners.

## Appendix F. Triad Treatment Allocation Process (MRW, Subwatershed-Level)

Initial MRW treatment allocations were assigned using the process described in the ESRF Research Proposal Appendix 4, with stand age (based on a 2015 ODF inventory) as a primary screening tool. In this first phase, subwatersheds and stands within subwatersheds were assigned to the treatments by optimizing the following:

- Prohibit any harvesting in stands that predate the 1868 fire. There are approximately 400 acres (0.5%) that remain from the nearly 5,000 acres of forests that predated the 1868 fire, when the Elliott State Forest was established. They are the remaining link to the past, are culturally and socially significant, and serve as an essential control to scientific study.
- Focus harvests in stands that have had prior clearcut harvests and regenerated with a focus on wood production (primarily less than 65 years old in 2020 since harvests started in approximately 1955).
- Limit harvesting of stands greater than 65 years in 2020 to extensive treatments. No forests older than 65 years in 2020 will be assigned to the intensive treatment. We will include only forests that were clear-cut, starting in approximately 1955, in the intensive treatments going forward.
- Extensive harvests that are in stands greater than 65 years will be preferentially done in stands closest to 65 years in 2020, and the older stands (90-152 years), once identified, that have had a prior thinning. Thereby preserving the oldest unlogged forests in reserves to the greatest extent possible.
- Any stand that we determine predates the 1868 fire will be placed in reserve. In the case of Extensive subwatersheds (where there are no reserves), these stands are in a special category called 'Extensive Reserve'. Based on the 2015 ODF inventory, 164 acres were identified in this category.

In the second phase of treatment allocation completed in 2022, additional criteria were used to make adjustments that built on the first phase while incorporating further analysis. No adjustments were made in the 100% Extensive subwatersheds because there were no changes possible between treatments in these subwatersheds. The criteria considered when making adjustments in Phase 2 (in no particular order) are:

- Silvicultural Suitability. Align outcomes described under goals and objectives for intensive, extensive, and reserve treatments with anticipated feasibility of the treatments based on the starting conditions of the stand.
- Operational/Economic Feasibility. Identify operational considerations that would support the treatment assignment (i.e., existing roads, stands with prior harvests, etc). Further analysis, inclusion of data from assessments described in this FMP, and work in the field by the ESRF team will need to be included in operational feasibility decisions.



- northern spotted owl and marbled murrelet Habitat. Adjustments must maintain protections for these covered species under the ESRF HCP. Acres with designated habitat are not moved into the intensive category. marbled murrelet habitat acres may only be moved from reserve to extensive treatment allocation if the same number of marbled murrelet habitat acres are moved from extensive to reserve.
- Stakeholder Input. Work with stakeholders to understand any additional concerns (e.g., habitat, older forest, scenic values, recreation) and make adjustments where possible under the research design laid out in the ESRF Research Proposal and ESRF HCP.
- Colluvial Hollows and Steep Slopes. Incorporate additional information on slope stability, steepness, and shallow translation landslides within the framework described in the ESRF HCP and FMP. In balance with other criteria, adjustments in Phase 2 aimed to move acres with very steep slopes (i.e., greater than 80% slope) to a treatment with greater retention where possible (i.e., intensive changed to extensive or reserve; extensive changed to reserve) except in situations where there are safety concerns.
- Fragmentation and Connectivity. Reduce fragmentation where possible by eliminating small fragments of stand-level treatments, and considering connectivity both within and between subwatersheds.

Adjustments using Phase 2 criteria were made within the following guidelines:

- A swap between intensive, extensive or reserve can be made if the stand is less than 65 years old (as of 2020).
- A swap between extensive and reserve can be made if the stand is greater than 65 years old (as of 2020) and it reduces fragmentation.
- The % treatment allocation (approximate, in acres) at the subwatershed scale must be maintained.
  - Reserve with intensive: 50% reserve, 50% intensive
  - TRIAD-I: 20% extensive, 40% intensive, 40% reserve
  - TRIAD-E: 60% extensive, 20% intensive, 20% reserve

Further adjustments to these allocations, including fine-scale adjustments, may be made within the guidelines in the FMP and ESRF HCP and based on continued incorporation of decision-making criteria, including: (1) continuing to work with Tribal Nations and Indigenous Peoples (see Chapter 3: *Managing a Research Forest for Multiple Values*, Section 3.1.1 for guiding principles and practices, Chapter 6: *Silviculture, Harvest Systems and Operations Planning*, Section 6.1.4 for Cultural Resources) to bring a co-stewardship perspective and ensure that appropriate care is taken to avoid culturally significant areas and spiritual places, (2) adaptation through biennial operations plans and future updates to the FMP, and in alignment with Chapter 11: *Adaptive Research Implementation Strategy* and (3) ongoing fieldwork by ESRF foresters, researchers, and technicians to include more information on considerations such as operational capabilities and within-stand variation are taken into account during biennial operations planning.

# Appendix G: D-optimal mixture design idea

Dusty Gannon

2023-05-18

## 1 Background for mixture experiments

Triad is a mixture design where the mix of each land-use strategy is constrained to sum up to 1 (or 100%). This creates some challenges from a design standpoint because we cannot vary each factor independently. After we decide the levels of two components of the mixture, the third is automatically determined. However, there is a wealth of research into the design of mixture experiments (Cornell 2011).

Because we are interested in moving toward a regression approach due to the constraints on replication of the Triad treatments, we need to look into optimal designs for estimating response curves in mixtures. There are two classic models for response curves in mixture experiments: the Scheffé model and the Cox model. Considering the Triad framework with three components in the mixture: proportion of land reserve ( $x_1$ ), intensive ( $x_2$ ), and extensive ( $x_3$ ), the first order Scheffé model can be reached by starting with a standard linear model

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \epsilon$$

where  $y$  is the response variable of interest,  $\epsilon$  is a random error term, and the  $\beta_i$  are parameters to be estimated. Substituting in the known constraint that  $\sum_{i=1}^3 x_i = 1$ , we arrive at the first order Scheffé model:

$$\begin{aligned} y &= \beta_0(x_1 + x_2 + x_3) + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \epsilon \\ &= (\beta_0 + \beta_1)x_1 + (\beta_0 + \beta_2)x_2 + (\beta_0 + \beta_3)x_3 + \epsilon \\ &= \sum_{i=1}^3 \alpha_i x_i + \epsilon \end{aligned} \quad (1.1)$$

With this model,  $\alpha_i = \beta_0 + \beta_i$  is the expected response for a unit composed purely of component  $i$ . Similar algebra yields the second-order Scheffé model

$$y = \sum_{i=1}^3 \alpha_i x_i + \sum_{i=1}^2 \sum_{j=i+1}^3 \alpha_{ij} x_i x_j + \epsilon. \quad (1.2)$$

The Scheffé approach models the response curve over the entire space of the simplex, but suffers from poor interpretability. For example, the first order model parameters are not interpreted in the usual way of a linear model in which  $\beta_1$  would represent the expected change in the response with a one-unit change in  $x_1$  (holding the other mixture

components constant), but rather as the mean response for a pure mixture of  $x_1$  (i.e.,  $x_1 = 1$ ;  $x_2 = x_3 = 0$ ).

The Cox approach on the other hand models a *slice* of the response curve when adjusting a specific component of interest, keeping the others in the same relative proportions (the current design of the ESRF triad experiment places design points along the Cox direction for extensive forestry, defining a land sparing versus sharing trade-off). The second-order Cox model can be expressed as

$$y = \gamma_0 + \sum_{i=1}^3 \gamma_i x_i + \sum_{i=1}^3 \sum_{j=1}^3 \gamma_{ij} x_i x_j + \epsilon \quad (1.3)$$

where we use different symbols for parameters in order to highlight that the interpretation of the parameters differs between the Cox and Sheffé models. Specifically, the interpretation of the parameters in the Cox model is dependent on a given reference point on the simplex,  $\mathbf{s} = (s_1, s_2, s_3)$  (in the ESRF, this would be  $\mathbf{s} = (0.5, 0, 0.5)$  for 50:50 reserve:intensive plots). Given the reference point, we apply the constraints that  $\sum_i \gamma_i s_i = 0$  and that  $\sum_i \sum_j \gamma_{ij} s_i s_j = 0$  such that  $\gamma_0$  is the expected response at the reference point. The interpretation of the remaining parameters is that for a given change in component  $i$  along the Cox direction (a given increase in extensive forestry subject to equal yield), then the response is expected to change by

$$\frac{d\mu}{d\delta_i} = \frac{\gamma_i}{1 - s_i} + 2 \frac{\gamma_i}{(1 - s_i)^2} \delta_i$$

where  $\delta_i$  is a deviation from the reference point along the *Cox direction* of mixture component  $i$ . When  $s_i = 0$ , then  $\gamma$  can be interpreted exactly as the coefficients in a standard polynomial regression model.

## 2 Designing the experiment

If the design points cannot fall along the Cox direction for the extensive component, then we are better off fitting the Scheffé model, then converting the parameters of the Scheffé model to those of the Cox model using a linear mapping from  $\alpha \rightarrow \gamma$  (Smith and Beverly 1997). This should yield unbiased estimates (assuming the model is appropriate). However, this begs the question of whether the current design is a “good” design for estimating the parameters in the Scheffé model. Below, I compare the current (as of 15 May 2023) design options with the added constraint of no cutting within the GT65 stands, as well as a *D-optimal* design (defined below).

### 2.1 Why do the other components need to be in the model?

At first glance, it might seem unnecessary to include all components of the mixture in the model (*why not just fit a model with the proportion extensive as the only predictor variable, treating that as the gradient of interest?*). Indeed, if all design points fall on the equal yield line (Cox direction for extensive), this is a possibility because we have

added constraints to the model that effectively reduce the degrees of freedom in the design space to one (upon defining the extensive proportion, we know what the other two have to be). However, this is not the case when the design points deviate from the equal yield line because we end up with a violation of the *strict exogeneity* assumption of the OLS estimator. This results in biased parameter estimates because we begin to attribute effects of interaction terms to the first and second order variables in the model (assuming non-linear response curves). Furthermore, the bias seems to depend on which points we sample in the simplex (Figure G-1).

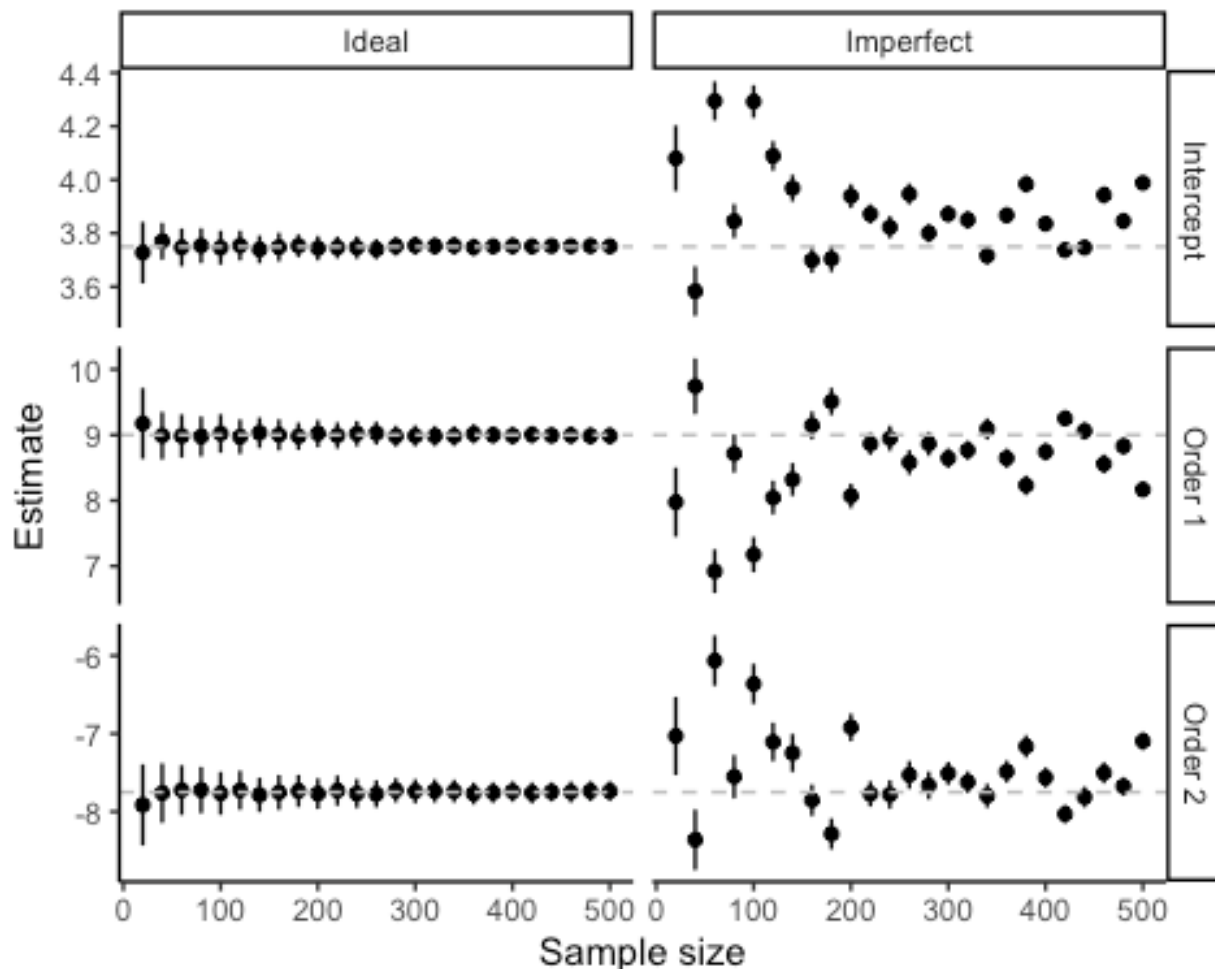


Figure G-1: Estimates of second-order polynomial coefficients with increasing sample size and different designs. The *ideal* design is one in which all design points fall on the Cox line, while the *imperfect* design is one in which the design points are allowed to deviate from the Cox line. Points and error bars show mean estimates and standard deviations from 100 replicate datasets with each design matrix.

## 2.2 Comparing the current designs to a D-optimal design

When an experiment has many constraints, it can be difficult to identify a powerful design. One approach to identifying a good design to use a search algorithm to search through the possible designs and find one that maximizes the determinant of the



*information matrix*,  $\mathbf{X}^{\top}\mathbf{X}$ , where  $\mathbf{X}$  is the design matrix of the experiment. This is called a *D-optimal* design. When there is confounding, some of the Eigen values in the information matrix tend toward zero, shrinking the determinant. So, a D-optimal design seeks to minimize the covariance (and therefore confounding) of the variables of interest under the constraints of the experiment or system. It's important to note, however, that D-optimal designs may not be unique, and the algorithm may get stuck in a local optimum and fail to find the absolute best design.

The Appendix includes code for identifying a D-optimal design under some constraints in the 3D simplex of the 3-component mixture, and Figure G-2 shows the three designs I compared.

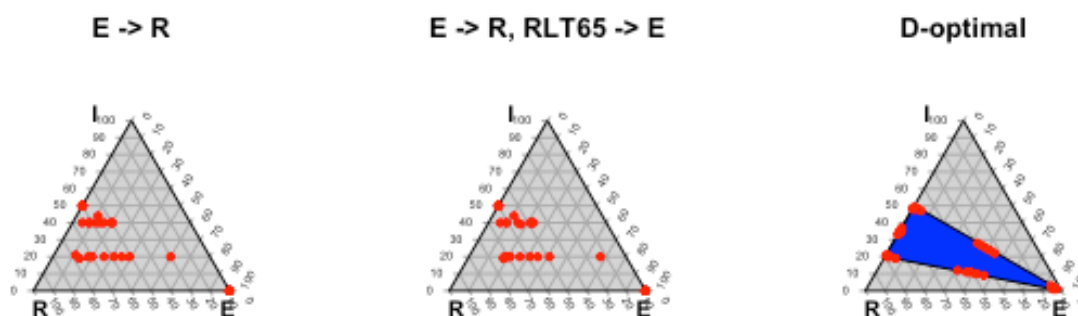


Figure G-2: Design options based on the GT65 constraints and the designs discussed in the 15 May 2023 meeting, as well as a D-optimal design constrained to a similar region in the simplex.

I generated 1000 parameter vectors for the quadratic Scheffé model, then simulated a dataset from each design matrix using each parameter vector. I set error variance to  $\sigma^2 = 0.2$  for each simulated dataset. I then fit the quadratic Scheffé model to each dataset using the each design and calculated the width of the confidence interval for each parameter in the model. Overall, the D-optimal design allows for greater confidence in the parameter estimates (Figure G-3). A notable exception is in the estimates for the  $\alpha_2$  parameter. Recall that the interpretation for this parameter is that it is the expected response for a pure mixture with  $x_2 = 1$  (i.e., extensive treatments). Because I allowed the algorithm to place all 40 design points in a different spot when

identifying a D-optimal design, but for the other two designs we have replication at the  $x = (0,1,1)$  extensive treatment, I believe we get better resolution on  $\alpha_2$  using the other two designs. However, the parameters in the Cox model are linear combinations of multiple Scheffé parameters, so this doesn't outweigh the overall reduction in variance when using the D-optimal design.

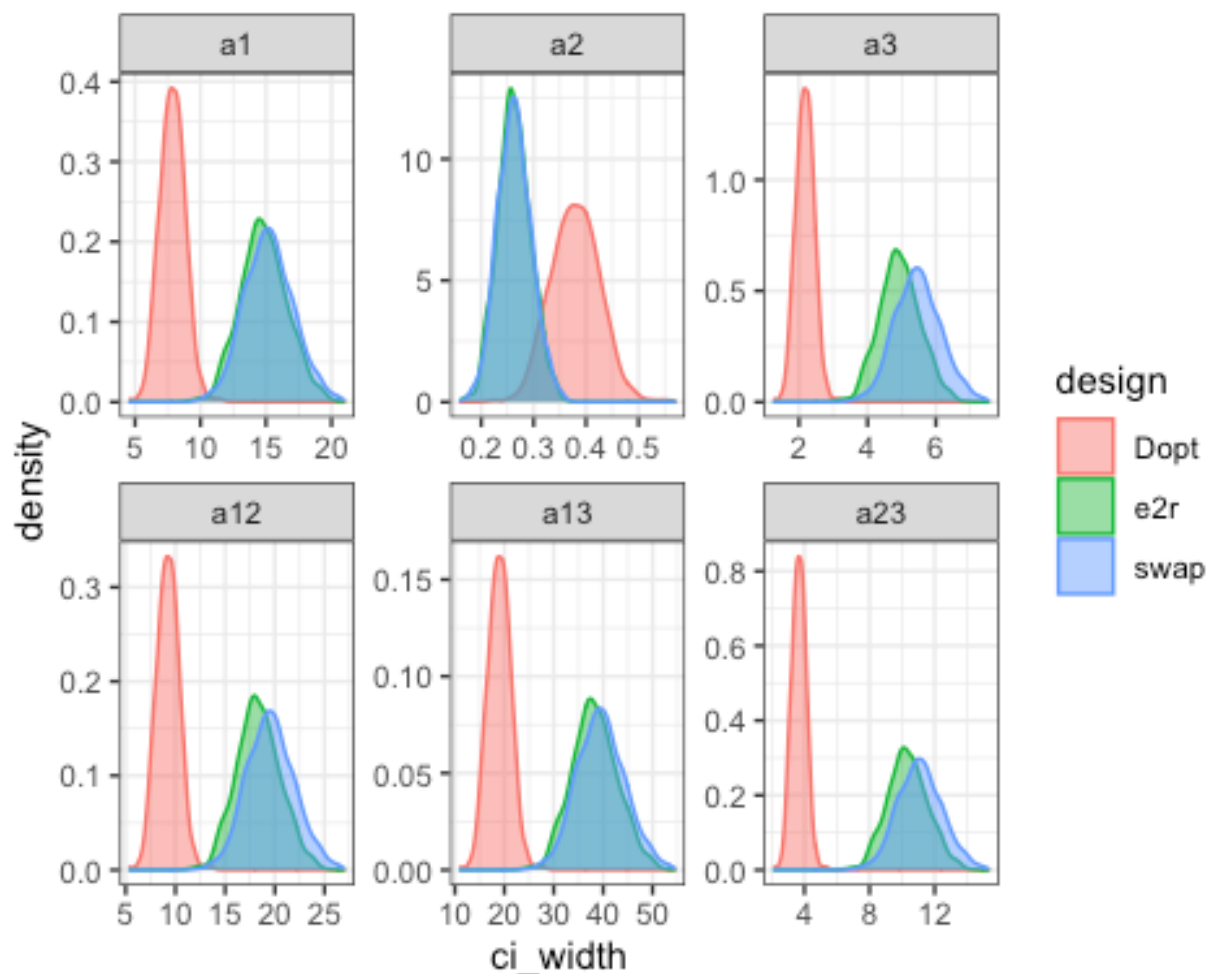


Figure G-3: Distributions of the widths of 95% confidence intervals for each of the parameters in the quadratic Scheffé model using each design.

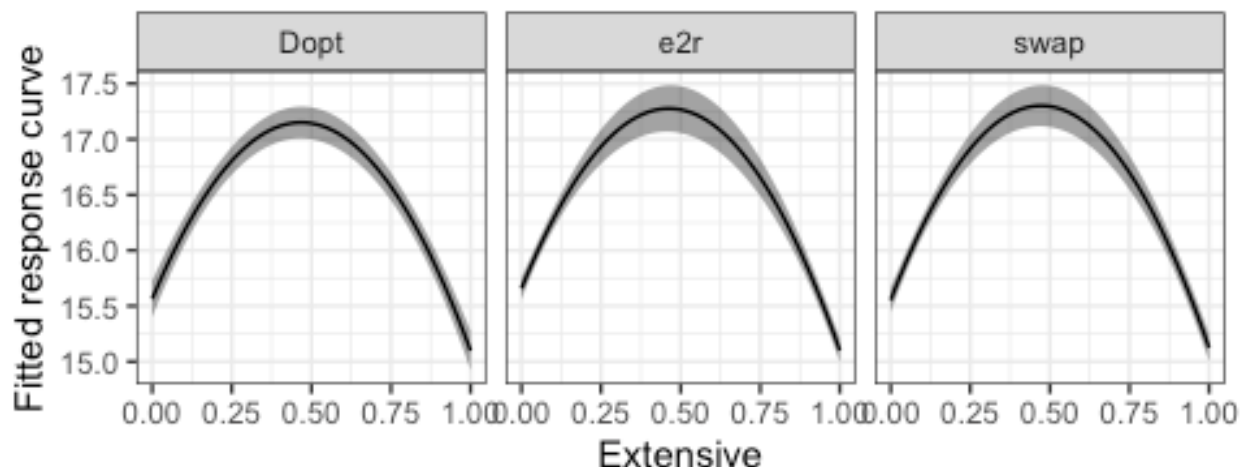


Figure G-4: Example conversion from the Scheffé model parameters to an effect plot over the gradient of interest (sharing versus a reference sparing regime of 50:50).

## 3 Appendix

### 3.1 Dependencies

```
library(Ternary)
library(mixexp)
library(AlgDesign)
library(tidyverse)
library(here)
# user-defined function to convert scheffe parameters
# available in GitHub repo
funcs <- list.files(path = here("R/"), full.names = T)
lapply(funcs, source)
```

### 3.2 Identifying D-optimal designs

```
# defining the D-optimal design based on some simple constraints
# create grid
full_space <- expand.grid(
  int = seq(0, 1, 0.01),
  ext = seq(0, 1, 0.01),
  res = seq(0, 1, 0.01)
)

# constrain to simplex
simplex <- full_space[apply(full_space, 1, function(x){sum(x) == 1}), ]

# further constraints
# define further constrained space
constrained_space <- cbind(
  c(0.5, 0, 0.5),
  c(0.2, 0, 0.8),
```

```
c(0, 1, 0),  
c(0.5, 0, 0.5)  
)  
# add constraints to the data based on the polygon  
exp_space <- simplex[  
  apply(simplex, 1, function(x){  
    (x[1] / x[3]) < 1 &  
    x[1] + 0.2 * x[2] > 0.2  
  }),  
]  
  
# solve for D-optimal design  
df_Dopt <- optFederov(  
  ~ -1 + int + ext + res +  
    int:ext + int:res + ext:res, data=exp_space, nTrials=40,  
  nRepeats = 1  
)$design
```

### 3.3 Code for Analysis 1

```
# set seed  
set.seed(5216)  
  
# reps for each n  
r <- 100  
  
# different sample sizes to try  
ns <- rep(  
  seq(20, 500, by = 20),  
  each = r  
)  
  
# reps for each n  
r <- 100  
  
# scale for random errors  
sigma <- 0.2  
  
# reference point  
s <- c(0.5, 0, 0.5)  
  
# define arbitrary Scheffé parameter vector  
Scheff_params <- c(2, 5, 6, 10, -1, 5)  
  
# convert to Cox params for later use  
Cox_params <- scheff2cox(Scheff_params, s = s, order = 2)  
  
# construct design matrices  
des_pnts <- map(  
  ns,
```



```
~ {
  x2 <- seq(0, 1, length.out = .x)
  df <- as.data.frame(cbind(
    (1 - x2) / 2,
    x2,
    (1 - x2) / 2
  ))
  names(df) <- c("x1", "x2", "x3")
  df
}
)

# convert into model matrices
mms <- map(
  des_pnts,
  ~ model.matrix(
    ~ -1 + x1 + x2 + x3 + x1:x2 + x1:x3 + x2:x3,
    data = .x
  )
)

# create datasets
y <- map(
  mms,
  ~ .x %*% Scheff_params + rnorm(nrow(.x), sd = sigma)
)

# fit the single variable polynomial model
estims1 <- map2(
  des_pnts,
  y,
  ~ lm(.y ~ x2 + I(x2^2), data = .x)$coefficients
)

# put into df for plotting
results <- data.frame(
  n = rep(ns, each = 3),
  param = rep(c("Intercept", "Order 1", "Order 2"), length(ns)),
  estim = unlist(estims1)
) %>% group_by(param, n) %>%
  summarise(
    mean_estim = mean(estim),
    se = sd(estim)
  )

# add in true values
results <- ungroup(results) %>% mutate(
  true = rep(Cox_params[c(1,3,6)], each = length(unique(ns)))
)
```

```
### now a dataset if we cannot stay on the line ###

# construct design points for imperfect design
des_pnts_imp <- map(
  unique(ns),
  ~ {
    x2 <- seq(0, 1, length.out = .x)
    df <- as.data.frame(cbind(
      (1 - x2) / 2 + runif(length(x2), min = -(1 - x2) / 2, max = (1 - x2) /
2),
      x2
    ))
    names(df) <- c("x1", "x2")
    df <- df %>% mutate(x3 = 1 - x1 - x2)
    df
  }
)

des_pnts_imp <- des_pnts_imp[rep(1:length(des_pnts_imp), each = r)]

# convert into model matrices
mms_imp <- map(
  des_pnts_imp,
  ~ model.matrix(
    ~ -1 + x1 + x2 + x3 + x1:x2 + x1:x3 + x2:x3,
    data = .x
  )
)

# create datasets
y_imp <- map(
  mms_imp,
  ~ .x %**% Scheff_params + rnorm(nrow(.x), sd = sigma)
)

# fit the naive model to each dataset
estims_imp <- map2(
  des_pnts_imp,
  y_imp,
  ~ lm(.y ~ x2 + I(x2^2), data = .x)$coefficients
)

# Estimates for imperfect design
results_imp <- data.frame(
  n = rep(ns, each = 3),
  param = rep(c("Intercept", "Order 1", "Order 2"), length(ns)),
  estim = unlist(estims_imp)
) %>% group_by(param, n) %>%
```

```
summarise(
  mean_estim = mean(estim),
  se = sd(estim)
) %>% ungroup()

# combine the results into one dataframe
results <- results %>% mutate(
  design = "Ideal"
)
results_imp <- results_imp %>% mutate(
  true = results$true,
  design = "Imperfect"
)
results <- rbind(
  results,
  results_imp
)

saveRDS(results, file = here("Data/naive_model_fits.rds"))
```

### 3.4 Code for Analysis 2

```
set.seed(5260)

reps <- 1000

# Load different datasets
df_list <- readRDS(file = here("Data/design_points_dfs.rds"))

# convert dfs into a list of model matrices
scheff_mod <- "~ -1 + int + ext + res + int:ext + int:res + ext:res"
designs <- map(
  df_list,
  ~ model.matrix(as.formula(scheff_mod), data = .x)
)

# generate 1000 different Scheffé parameter sets
rScheff_params <- map(
  1:reps,
  ~ rnorm(6, mean = 10, sd = 3)
)

# create nested list of datasets
dat <- map(
  designs,
  function(x, params = rScheff_params){
    map(
      params,
      function(alpha){
        as.double(x %*% alpha) + rnorm(nrow(x), sd = 0.2)
      }
    )
  }
)
```

```

    }
  )
}
)

# fit the model for each case and compute width of CI
scheff_ciw <- map2(
  designs,
  dat,
  function(X, ys){
    map(
      ys,
      function(y){
        mod <- lm(y ~ -1 + X)
        a <- mod$coefficients
        ses <- sqrt(diag(vcov(mod)))
        return(
          width = (a + 2 * ses) - (a - 2 * ses)
        )
      }
    )
  }
)

# convert to a dataframe
results2 <- data.frame(
  param = rep(c("a1", "a2", "a3", "a12", "a13", "a23"), length(rScheff_params
)),
  e2r = unlist(scheff_ciw$e2r),
  swap = unlist(scheff_ciw$swap),
  Dopt = unlist(scheff_ciw$Dopt)
)

# pivot longer and summarize
results2_long <- results2 %>% pivot_longer(
  cols = e2r:Dopt,
  values_to = "ci_width",
  names_to = "design"
)
results2_long$param <- factor(
  results2_long$param,
  levels = c("a1", "a2", "a3", "a12", "a13", "a23")
)

eg <- 320

# example of how this translates to the cox direction response curve
egfits <- map2(
  designs,

```



```

    c(dat$e2r[eg], dat$swap[eg], dat$Dopt[eg]),
    ~ lm(.y ~ -1 + .x)
  )

# convert to cox models
egfits_cox <- map(
  egfits,
  function(fit){
    estims <- fit$coefficients
    V <- vcov(fit)
    scheff2cox(alpha = estims, s = c(0.5, 0, 0.5), order = 2, V = V)
  }
)

cox_true <- scheff2cox(rScheff_params[[eg]], s = c(0.5, 0, 0.5), order = 2)

# new values over which to predict
X_new <- cbind(
  rep(1, 100),
  rep(0, 100),
  seq(0, 1, length.out = 100),
  matrix(0, nrow = 100, ncol = 2),
  seq(0, 1, length.out = 100)^2,
  matrix(0, nrow = 100, ncol = 4)
)

# dataframe for plotting
df_egplot <- data.frame(
  Extensive = rep(X_new[,3], 3),
  true = as.double(X_new %*% cox_true),
  design = rep(c("e2r", "swap", "Dopt"), each = 100),
  pred = unlist(
    map(
      egfits_cox,
      ~ as.double(X_new %*% .x$estims)
    )
  ),
  se = unlist(
    map(
      egfits_cox,
      ~ as.double(sqrt(diag(X_new %*% .x$V %*% t(X_new))))
    )
  )
) %>% mutate(
  low = pred - 2 * se,
  high = pred + 2 * se
)

save(results2_long, df_egplot, file = here("Data/ci_widths_and_egplot.rds"))

```

## Appendix G: References

Cornell, John A. 2011. *Experiments with Mixtures: Designs, Models, and the Analysis of Mixture Data*. John Wiley & Sons.

Smith, Wendell F., and Todd A. Beverly. 1997. "Generating Linear and Quadratic Cox Mixture Models." *Journal of Quality Technology* 29 (2): 211–24.  
<https://www.proquest.com/docview/214489944/abstract/E28C82DDE8514C57PQ/1>.

## Appendix H. Estimated Harvest Based on Age Class Distribution, Harvest Scenarios 1 and 2

*Prepared by Deanne Carlson and Katy Kavanagh, Oregon State University College of Forestry*

The purpose of the two modeled harvest scenarios described here is to project decadal timber harvest (in acres) by allocation category over the 80-year term of the ESRF HCP in order to facilitate the analysis of potential financial, operational, and environmental outcomes of implementation of the ESRF Research Proposal. While these scenarios inform implementation planning for the ESRF, they are based on preliminary data and preliminary operating assumptions, have not been subject to the formal ESRF planning process, and are not intended to serve as implementation blueprints.

The two harvest scenarios are identical except in how the Flex50 allocation category is considered. The Flex50 category was created as part of ESRF HCP planning, and the name refers to the minimum rotation length in intensive treatments described for these stands by the ESRF HCP. However, under this FMP, intensive stands in this category will be managed using a 60-year rotation. The Flex50 allocation occurs on 5,757 acres of stands  $\leq 65$  years of age that are primarily located in the MRW partial watersheds (Figure 4.3, Figure 4.4). In the ESRF HCP, this allocation is described as providing research and management flexibility in areas outside of the Triad research watersheds, and the ESRF HCP permits harvest in stands as young as 50 years of age for intensive harvest. The Flex50 allocation also permits long-rotation, variable retention harvest. *Scenario One* models Flex50 as intensive harvest with a 60-year rotation, while *Scenario Two* models Flex50 using the same parameters as extensive harvest: a 100-year rotation with 50% retention.

In order to meet experimental design criteria for replication between treatments even-flow harvest was not a scheduling constraint. The primary criterion for scheduling harvest under both scenarios was stand age, which results in variation in decadal harvest due to the uneven age structure of the forest (Figure H-1). Intensive and Flex50 intensive allocations were scheduled for regeneration harvest in the year a subject stand reaches 60 years of age, and extensive allocations (which includes VRH allocations) were scheduled for regeneration harvest in the year a subject stand reaches 100 years of age. Extensive stands were scheduled for thinning 40 years after the scheduled regeneration harvest. Existing extensive stands less than 65 years of age were scheduled for maintenance thinning in the year a subject stand reaches 50 years of age, with stands currently between 50 and 60 years of age scheduled for thinning in the first decade of implementation. All CRW Thin stands were scheduled for the first two decades of implementation, after which no harvest in the CRW was scheduled. No thinning was scheduled for intensive allocations, or for Flex50 allocations scheduled as intensive in Scenario One. Flex 50 was scheduled for thinning as extensive in Scenario Two.

Regeneration harvest of the approximately 1,900 acres of extensive acres currently greater than 100 years of age was spread out over the first four decades of implementation. Similarly, MAMU experiment allocations were spread out to occur in the first, third, and fifth decade of implementation.

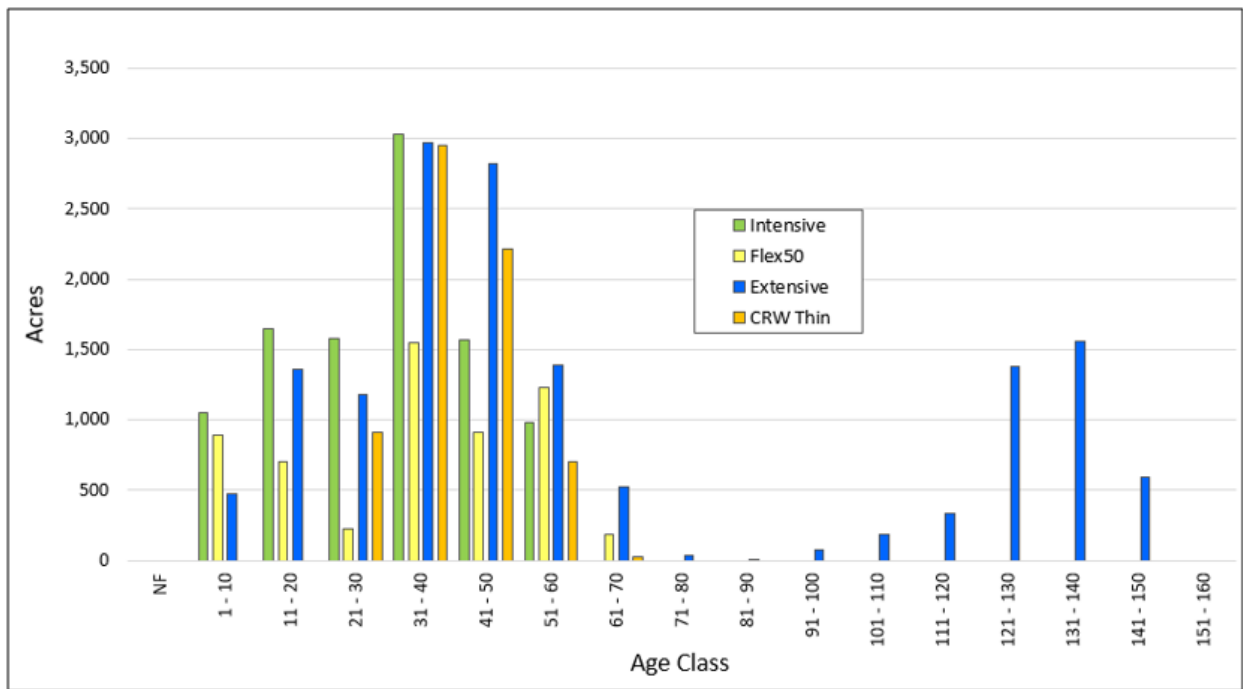


Figure H-1. Current age class distribution of stands allocated to the long-term ESRF harvest base, and to restoration thinning of existing planted forests <=65 years of age in the CRW, by acres. The Intensive allocation occurs in the Triad research watersheds, and represents production-oriented commercial forestry operations. Extensive allocations occur on Triad research watersheds, and in the Upper Big Creek, Alder Creek, Hakki, and Flex (Palouse Creek) allocations (see Figure 4.4), and are broadly described as variable-retention silvicultural systems with post-harvest retention of pre-harvest stand density ranging between 20 and 80 percent. Flex50 is intended to provide management flexibility, and may include either intensive and extensive/variable retention silvicultural systems, depending on research objectives. The CRW Thin allocation comprises existing “plantation” stands <= 65 years of age within the CRW that are candidates for restoration thinning.

Table H-1. Harvest Scenario One: Acres **eligible** for harvest. The total acres eligible for harvest is based on stand age criteria, but does not account for the reduction in harvestable acres attributable to marbled murrelet occupancy, steep slopes, buffers adjacent to murrelet-occupied habitat, or, in the case of scheduled thinning, stands that do not require thinning.



Acres Eligible for Harvest: Flex50 as 60-year rotation Intensive (Harvest Scenario One)								
	2024-2033	2034-2043	2044-2053	2054-2063	2064-2073	2074-2083	2084-2093	2094-2104
MAMU_ Experiment Regen	518.8	0.0	431.7	0.0	419.0	0.0	0.0	0.0
Extensive_ ConMAMU Regen	517.5	490.3	465.0	416.8	0.0	0.0	0.0	0.0
Extensive Regen	146.1	0.0	59.7	385.2	1,334.1	2,634.4	1,427.8	1,477.5
Flex50 Regen (60-year Intensive)	1,919.8	1,329.3	861.3	390.7	877.8	377.9	1,919.8	1,522.2
Intensive Regen	1,314.0	2,492.3	2,177.3	1,961.5	1,708.9	206.5	1,314.0	2,492.3
AC_VRH100 Regen	0.0	0.0	0.0	44.0	24.9	871.9	106.1	0.0
UBC_VRH100 Regen	0.0	0.0	0.0	0.0	164.5	293.6	69.9	8.9
Flex_VRH100 Regen	792.4	23.0	174.5	4.5	0.0	52.5	9.0	0.0
Hakki_VRH100 Regen	0.0	0.0	0.0	0.0	101.0	179.4	138.3	0.0
Extensive Thin	3,968.4	1,427.8	1,388.1	1,014.9	306.3	0.0	59.7	385.2
Extensive_ ConMAMU Thin	0.0	0.0	0.0	0.0	517.5	490.3	465.0	416.8
AC_VRH100 Thin	896.8	106.1	0.0	0.0	21.8	0.0	0.0	44.0
UBC_VRH100 Thin	458.1	69.9	8.9	17.6	0.0	0.0	0.0	0.0
Flex_VRH100 Thin	52.5	9.0	0.0	25.1	792.4	23.0	174.5	4.5
Hakki_VRH100 Thin	280.4	138.3	0.0	0.0	0.0	0.0	0.0	0.0
CRW_THIN Thin	2,771.7	2,849.8	0.0	0.0	0.0	0.0	0.0	0.0
Total Eligible Acres	13,636.5	8,935.8	5,566.7	4,260.3	6,268.1	5,129.5	5,684.1	6,351.4

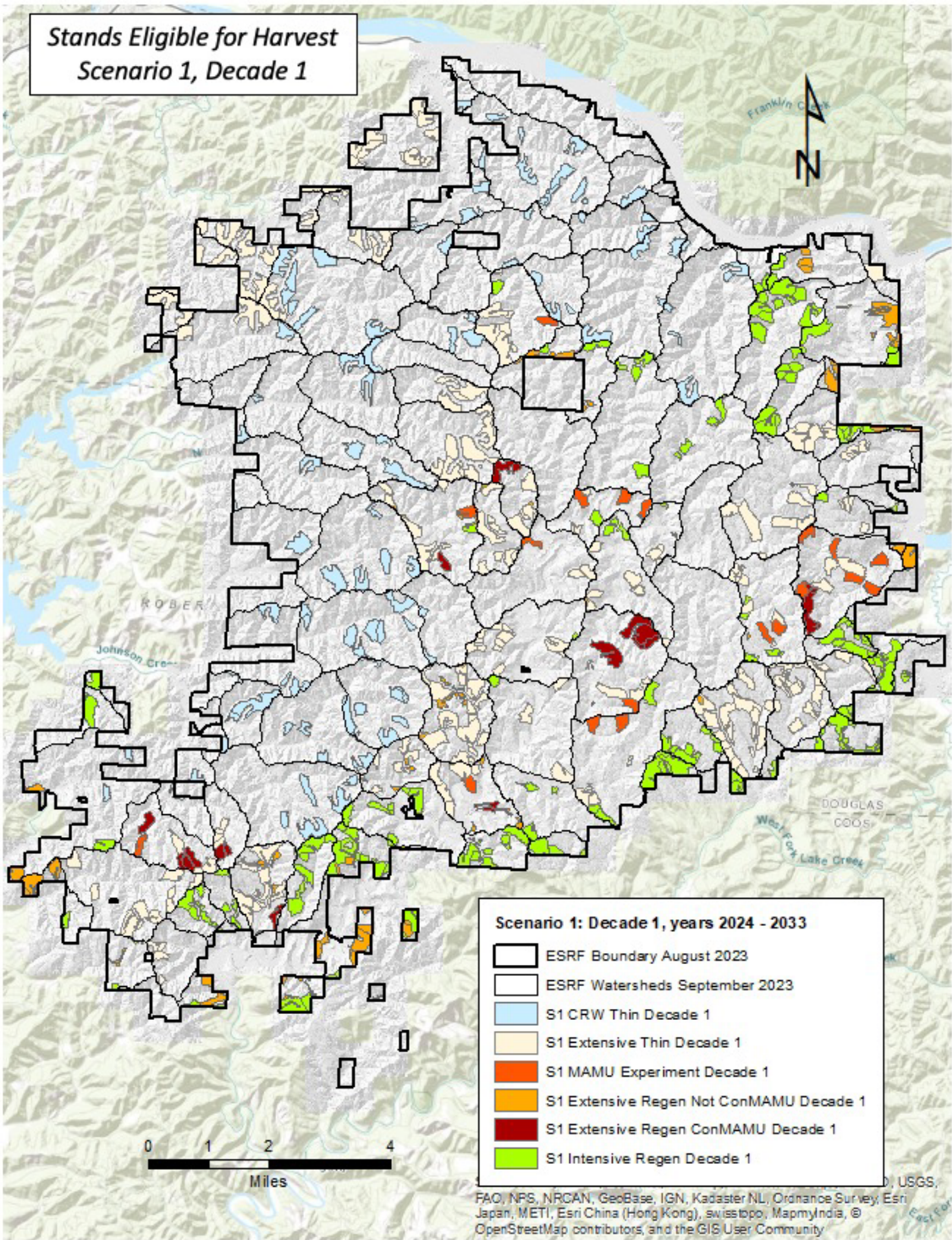
Table H-2. Harvest Scenario One: Acres **scheduled** for harvest. Total acres scheduled for harvest accounts for the reduction in harvestable acres attributable to marbled murrelet occupancy, steep slopes, buffers adjacent to murrelet-occupied habitat, or, in the case of scheduled thinning, stands that do not require thinning. Silvicultural specifications are displayed in the lower table.

Scenario One Modeled Harvest Schedule (Acres)								
	2024-2033	2034-2043	2044-2053	2054-2063	2064-2073	2074-2083	2084-2093	2094-2104
MAMU_ Experiment Regen	518.8	0.0	431.7	0.0	419.0	0.0	0.0	0.0
Extensive_ConMAMU Regen	258.7	245.1	232.5	208.4	0.0	0.0	0.0	0.0
Extensive Regen	146.1	0.0	59.7	385.2	1,334.1	2,634.4	1,427.8	1,477.5
Flex50 Regen	1,727.8	1,196.4	775.2	351.6	790.0	340.1	1,727.8	1,370.0
Intensive Regen	1,314.0	2,492.3	2,177.3	1,961.5	1,708.9	206.5	1,314.0	2,492.3
AC_VRH100 Regen	0.0	0.0	0.0	39.6	22.4	784.7	95.5	0.0
UBC_VRH100 Regen	0.0	0.0	0.0	0.0	148.0	264.2	62.9	8.0
Flex_VRH100 Regen	396.2	11.5	87.3	2.2	0.0	26.3	4.5	0.0
Hakki_VRH100 Regen	0.0	0.0	0.0	0.0	101.0	179.4	138.3	0.0
Extensive Thin	3,571.6	1,285.0	1,249.3	913.4	275.6	0.0	53.7	346.6
Extensive_ConMAMU Thin	0.0	0.0	0.0	0.0	258.7	245.1	232.5	208.4
AC_VRH100 Thin	807.1	95.5	0.0	0.0	19.6	0.0	0.0	39.6
UBC_VRH100 Thin	412.3	62.9	8.0	15.8	0.0	0.0	0.0	0.0
Flex_VRH100 Thin	26.3	4.5	0.0	12.6	396.2	11.5	87.3	2.2
Hakki_VRH100 Thin	280.4	138.3	0.0	0.0	0.0	0.0	0.0	0.0
CRW_THIN Thin	2,771.7	2,849.8	0.0	0.0	0.0	0.0	0.0	0.0
Regen Total	4,361.7	3,945.3	3,763.7	2,948.5	4,523.4	4,435.6	4,770.8	5,347.8
Thin Total	7,869.3	4,436.0	1,257.4	941.8	950.2	256.7	373.5	596.9
Annual Regen	436.2	394.5	376.4	294.9	452.3	443.6	477.1	534.8
Annual Thin	786.9	443.6	125.7	94.2	95.0	25.7	37.3	59.7
Scenario One Intensive	3,041.8	3,688.6	2,952.5	2,313.1	2,498.9	546.6	3,041.8	3,862.3
Scenario One Extensive (Includes thinning)	6,417.5	1,842.9	2,068.6	1,577.2	2,974.7	4,145.6	2,102.5	2,082.5
Scenario One CRW Thin	2,771.7	2,849.8	0.0	0.0	0.0	0.0	0.0	0.0

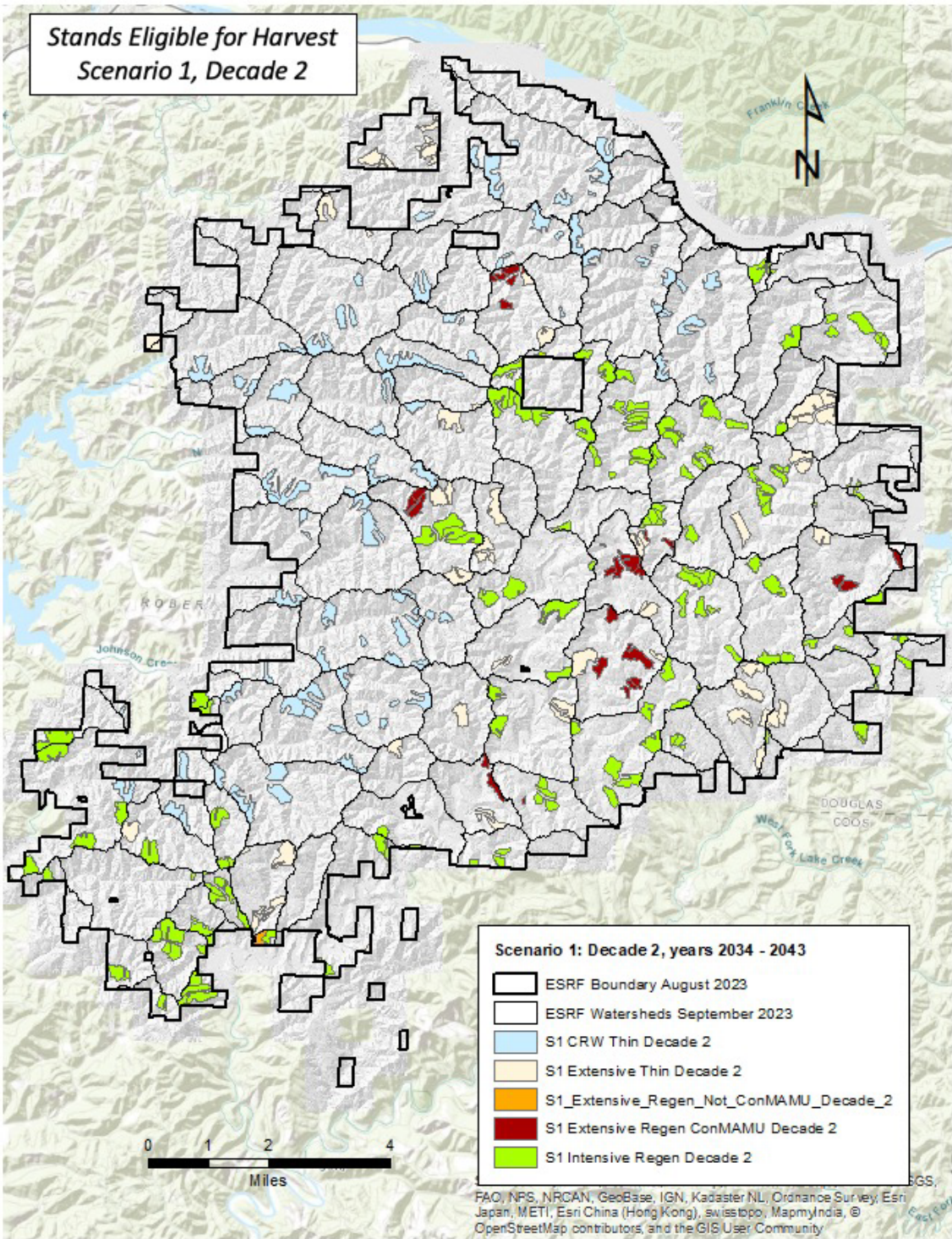
Category	Scenario Assumptions
MAMU_ Experiment Regen	Extensive silviculture 80% retention regeneration harvests in the 1400-acre MAMU experiment
Extensive_ConMAMU Regen	Extensive silviculture regeneration harvests in the MAMU consolidated layer (modeled potential high value habitat), 50% average retention
Extensive Regen	Extensive silviculture regeneration in stands outside of MAMU occupied and modeled potential habitat, average rotation length 100 years, 50% average retention
Flex50 Regen	Intensive regeneration harvest in the MRW Partial (MRW Flexible), 60-year rotation
Intensive Regen	Intensive regeneration harvest at a 60-year rotation
AC_VRH100 Regen	Alder Creek extensive regeneration, 50% retention
UBC_VRH100 Regen	Upper Big Creek extensive regeneration, 50% retention
Flex_VRH100 Regen	Extensive silviculture regeneration (20-80% retention of existing stand density) in GT65 MRW Partial, average rotation length 100 years, 50% retention
Hakki_VRH100 Regen	Extensive silviculture regeneration (20-80% retention of existing stand density) in East Hakki Ridge, average rotation length 100 years, 50% retention
Extensive Thin	Extensive silviculture thinning, 12mbf/acre
Extensive_ConMAMU Thin	Extensive silviculture thinning in the MAMU consolidated layer (modeled potential high value habitat), 12mbf/acre
AC_VRH100 Thin	Extensive silviculture thinning in Alder Creek, 12mbf/acre
UBC_VRH100 Thin	Extensive silviculture thinning in Upper Big Creek, 12mbf/acre
Flex_VRH100 Thin	Extensive silviculture thinning in MRW Partial (MRW Flexible), 12mbf/acre
Hakki_VRH100 Thin	Extensive silviculture thinning in East Hakki Ridge, 12mbf/acre
CRW_THIN Thin	Restoration thinning in CRW plantations LT65 (as of 2020), 12mbf/acre

The following figures (Figures H-2a, H-2b, H-2c, H-2d) illustrate the potential spatial and temporal scale of harvest operations on the ESRF for the first four decades of implementation of Harvest Scenario One, showing all stands eligible for harvest during the subject decade. Operational constraints and opportunities may change the order, location, and size of individual stand harvest entries described in these draft figures. This illustration does not show percent retention in extensive harvests and includes all potential stands, recognizing that this may change depending on outcomes of the experiment.

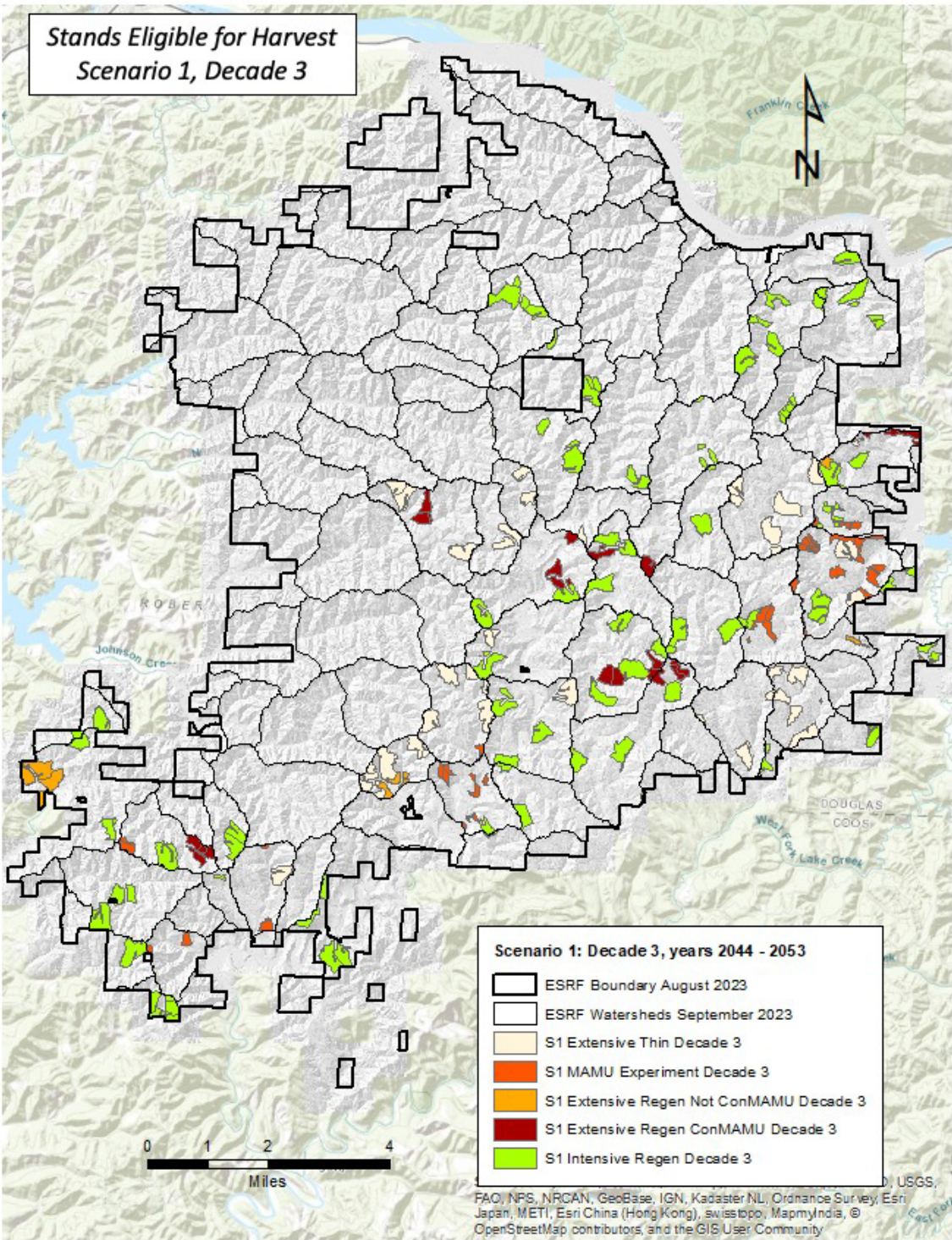
Average annual intensive harvest under Scenario One over the 80-year evaluation period is 275 acres, and average annual extensive harvest is 290 acres.













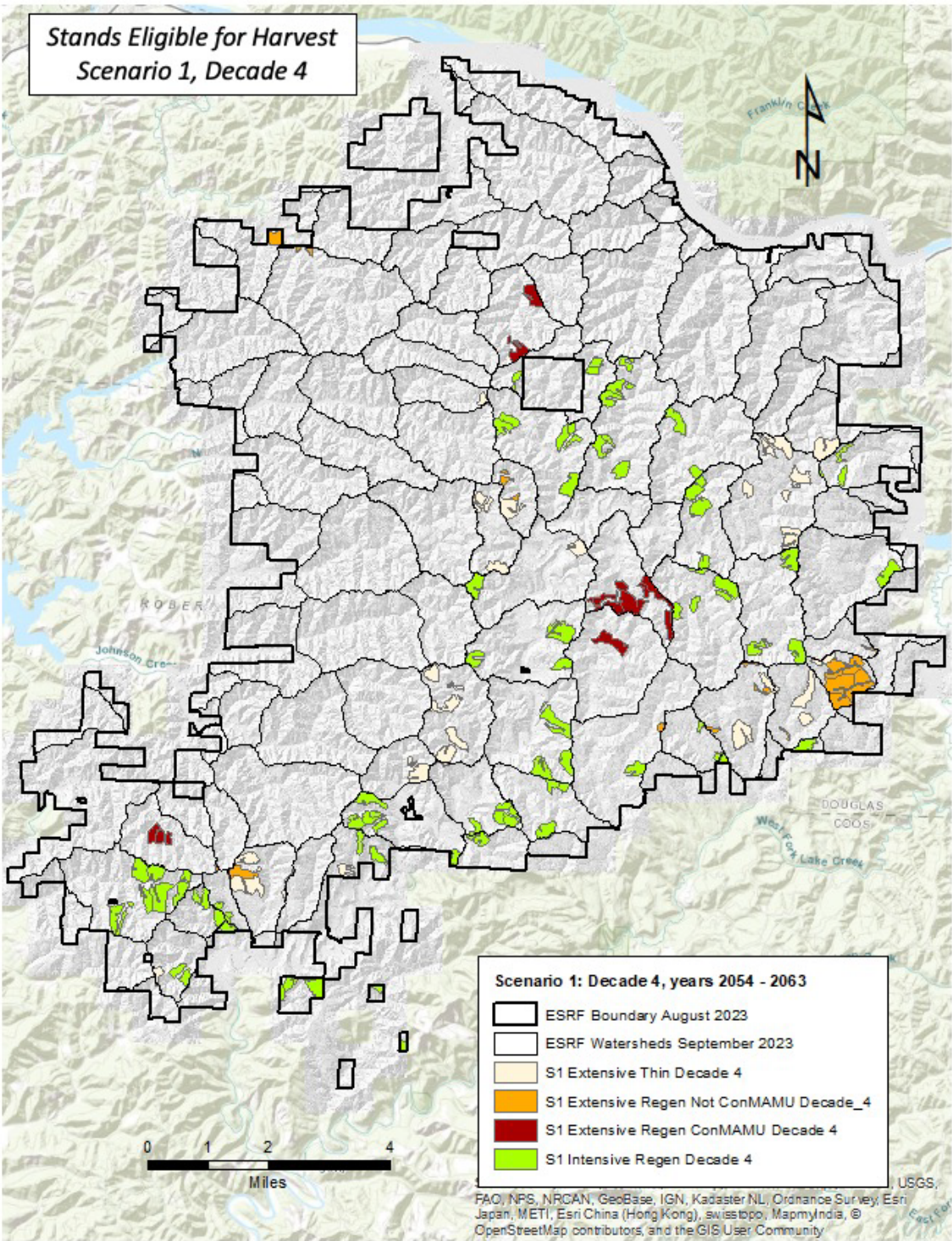


Table H-3. Harvest Scenario Two: Acres **eligible** for harvest. The total acres eligible for harvest is based on stand age criteria but does not account for the reduction in harvestable acres attributable to marbled murrelet occupancy, steep slopes, buffers adjacent to murrelet-occupied habitat, or, in the case of scheduled thinning, stands that do not require thinning.

Acres Eligible for Harvest: Flex50 as 100-year rotation VRH (Harvest Scenario Two)								
	2024-2033	2034-2043	2044-2053	2054-2063	2064-2073	2074-2083	2084-2093	2094-2104
MAMU_ Experiment Regen	518.8	0.0	431.7	0.0	419.0	0.0	0.0	0.0
Extensive_ConMAMU Regen	517.5	490.3	465.0	416.8	0.0	0.0	0.0	0.0
Extensive Regen	146.1	0.0	59.7	385.2	1,334.1	2,634.4	1,427.8	1,388.1
Flex50 Regen (100-year VRH)	0.0	0.0	0.0	508.7	1,370.1	1,321.0	861.3	390.7
Intensive Regen	1,314.0	2,492.3	2,177.3	1,961.5	1,708.9	206.5	1,314.0	2,492.3
AC_VRH100 Regen	0.0	0.0	0.0	44.0	24.9	871.9	106.1	0.0
UBC_VRH100 Regen	0.0	0.0	0.0	0.0	164.5	293.6	69.9	8.9
Flex_VRH100 Regen	792.4	23.0	174.5	4.5	0.0	52.5	9.0	0.0
Hakki_VRH100 Regen	0.0	0.0	0.0	0.0	101.0	179.4	138.3	0.0
Extensive Thin	3,968.4	1,427.8	1,388.1	1,014.9	306.3	0.0	59.7	385.2
Extensive_ConMAMU Thin	12.0	0.0	0.0	0.0	517.5	490.3	465.0	416.8
AC_VRH100 Thin	896.8	106.1	0.0	0.0	21.8	0.0	0.0	44.0
UBC_VRH100 Thin	458.1	69.9	8.9	17.6	0.0	0.0	0.0	0.0
Flex_VRH100 Thin	52.5	9.0	0.0	25.1	792.4	23.0	174.5	4.5
Hakki_VRH100 Thin	280.4	138.3	0.0	0.0	0.0	0.0	0.0	0.0
Flex50 VRH100 Thin	2,691.1	861.3	390.7	877.8	377.9	0.0	0.0	508.7
CRW_THIN Thin	2,771.7	2,849.8	0.0	0.0	0.0	0.0	0.0	0.0
Total Eligible Acres	14,419.8	8,467.9	5,096.1	5,256.1	7,138.3	6,072.6	4,625.7	5,639.3

Table H-4. Harvest Scenario Two: Acres **scheduled** for harvest. Total acres scheduled for harvest accounts for the reduction in harvestable acres attributable to marbled murrelet occupancy, steep slopes, buffers adjacent to murrelet-occupied habitat, or, in the case of scheduled thinning, stands that do not require thinning. Silvicultural specifications are displayed in the lower table.

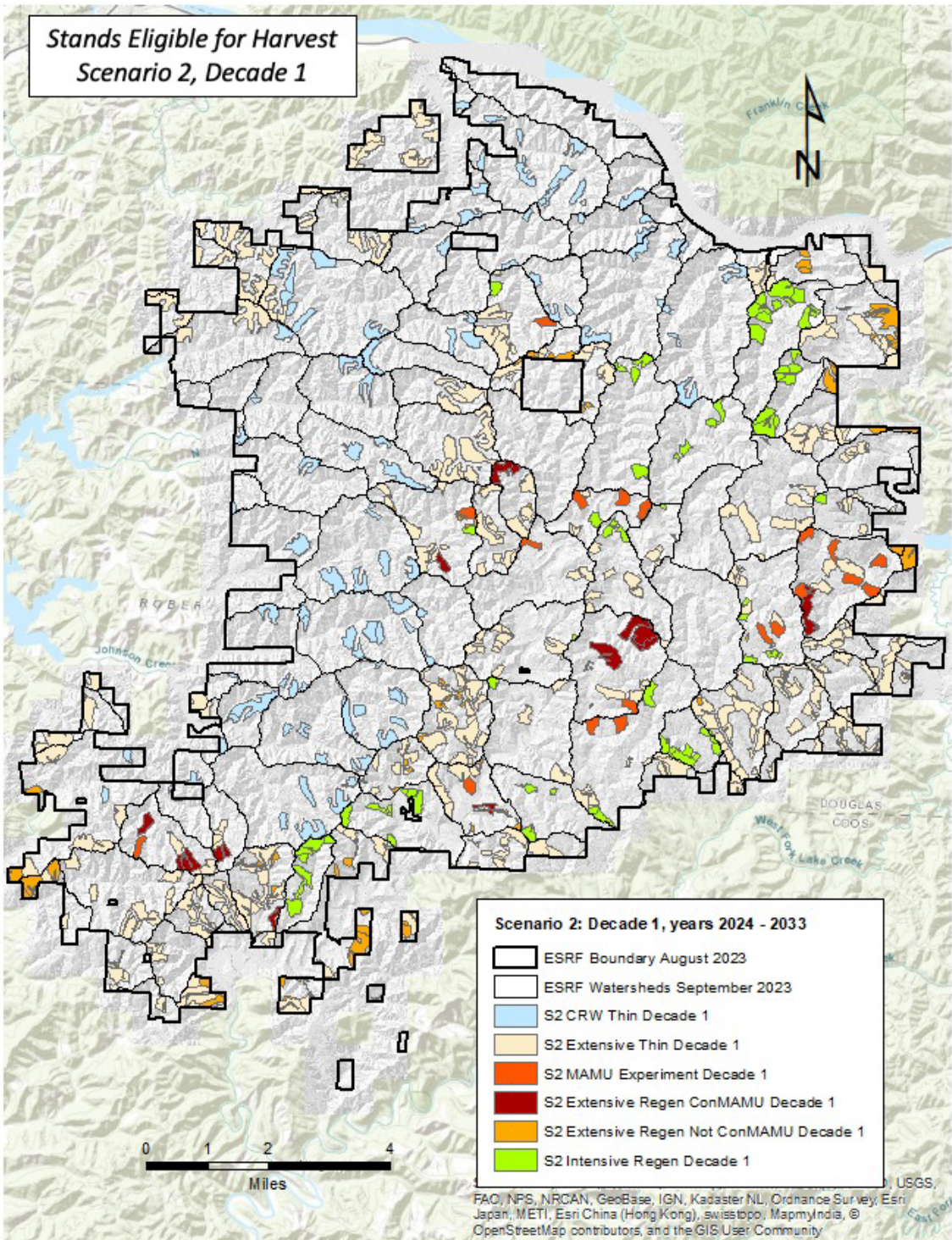


Scenario Two Modeled Harvest Schedule (Acres)								
	2024-2033	2034-2043	2044-2053	2054-2063	2064-2073	2074-2083	2084-2093	2094-2104
MAMU_ Experiment Regen	518.8	0.0	431.7	0.0	419.0	0.0	0.0	0.0
Extensive_ConMAMU Regen	258.7	245.1	232.5	208.4	0.0	0.0	0.0	0.0
Extensive Regen	146.1	0.0	59.7	385.2	1,334.1	2,634.4	1,427.8	1,388.1
Flex50 VRH100Regen	0.0	0.0	0.0	508.7	1,370.1	1,321.0	861.3	390.7
Intensive Regen	1,314.0	2,492.3	2,177.3	1,961.5	1,708.9	206.5	1,314.0	2,492.3
AC_VRH100 Regen	0.0	0.0	0.0	35.2	19.9	697.5	84.9	0.0
UBC_VRH100 Regen	0.0	0.0	0.0	0.0	131.6	234.9	55.9	7.2
Flex_VRH100 Regen	396.2	11.5	87.3	2.2	0.0	26.3	4.5	0.0
Hakki_VRH100 Regen	0.0	0.0	0.0	0.0	101.0	179.4	138.3	0.0
Extensive Thin	3,174.7	1,142.2	1,110.5	811.9	245.0	0.0	47.8	308.1
Extensive_ConMAMU Thin	6.0	0.0	0.0	0.0	258.7	245.1	232.5	208.4
AC_VRH100 Thin	717.4	84.9	0.0	0.0	17.4	0.0	0.0	35.2
UBC_VRH100 Thin	366.5	55.9	7.2	14.1	0.0	0.0	0.0	0.0
Flex_VRH100 Thin	26.3	4.5	0.0	12.6	396.2	11.5	87.3	2.2
Hakki_VRH100 Thin	224.3	110.6	0.0	0.0	0.0	0.0	0.0	0.0
Flex50 VRH100 Thin	2,152.9	689.1	312.6	702.3	302.3	0.0	0.0	407.0
CRW_THIN Thin	2,771.7	2,849.8	0.0	0.0	0.0	0.0	0.0	0.0
Regen Total	2,633.9	2,748.9	2,988.5	3,101.2	5,084.6	5,300.0	3,886.7	4,278.3
Thin Total	9,439.8	4,937.1	1,430.2	1,540.8	1,219.7	256.7	367.5	961.0
Annual Regen	263.4	274.9	298.9	310.1	508.5	530.0	388.7	427.8
Annual Thin	944.0	493.7	143.0	154.1	122.0	25.7	36.8	96.1
Scenario Two Intensive	1,314.0	2,492.3	2,177.3	1,961.5	1,708.9	206.5	1,314.0	2,492.3
Scenario Two Extensive (Includes thinning)	7,988.0	2,343.9	2,241.4	2,680.6	4,595.4	5,350.1	2,940.3	2,747.0
Scenario Two CRW Thin	2,771.7	2,849.8	0.0	0.0	0.0	0.0	0.0	0.0

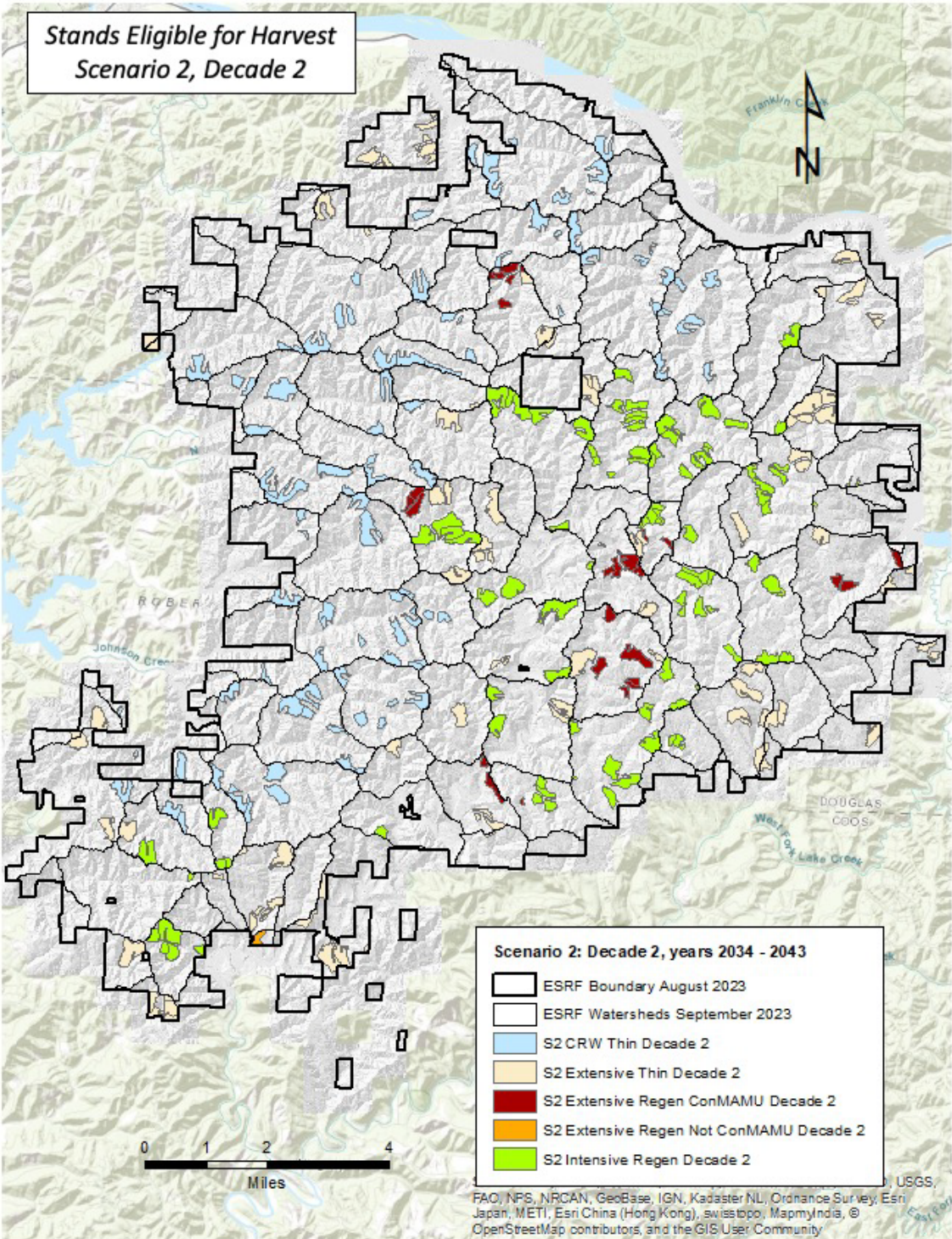
Category	Scenario Assumptions
MAMU_ Experiment Regen	Extensive silviculture 80% retention regeneration harvests in the 1400-acre MAMU experiment
Extensive_ConMAMU Regen	Extensive silviculture regeneration harvests in the MAMU consolidated layer (modeled potential high value habitat), 50% average retention
Extensive Regen	Extensive silviculture regeneration in stands outside of MAMU occupied and modeled potential habitat, average rotation length 100 years, 50% average retention
Flex50 Regen	Intensive regeneration harvest in the MRW Partial (MRW Flexible), 60-year rotation
Intensive Regen	Intensive regeneration harvest at a 60-year rotation
AC_VRH100 Regen	Alder Creek extensive regeneration, 50% retention
UBC_VRH100 Regen	Upper Big Creek extensive regeneration, 50% retention
Flex_VRH100 Regen	Extensive silviculture regeneration (20-80% retention of existing stand density) in GT65 MRW Partial, average rotation length 100 years, 50% retention
Hakki_VRH100 Regen	Extensive silviculture regeneration (20-80% retention of existing stand density) in East Hakki Ridge, average rotation length 100 years, 50% retention
Extensive Thin	Extensive silviculture thinning, 12mbf/acre
Extensive_ConMAMU Thin	Extensive silviculture thinning in the MAMU consolidated layer (modeled potential high value habitat), 12mbf/acre
AC_VRH100 Thin	Extensive silviculture thinning in Alder Creek, 12mbf/acre
UBC_VRH100 Thin	Extensive silviculture thinning in Upper Big Creek, 12mbf/acre
Flex_VRH100 Thin	Extensive silviculture thinning in MRW Partial (MRW Flexible), 12mbf/acre
Hakki_VRH100 Thin	Extensive silviculture thinning in East Hakki Ridge, 12mbf/acre
CRW_THIN Thin	Restoration thinning in CRW plantations LT65 (as of 2020), 12mbf/acre

The following figures (Figures H-3a, H-3b, H-3c, H-3d) illustrate the potential spatial and temporal scale of harvest operations on the ESRF for the first four decades of implementation of Harvest Scenario Two, showing all stands eligible for harvest during the subject decade. Operational constraints and opportunities may change the order, location, and size of individual stand harvest entries described in these draft figures. This illustration does not show percent retention in extensive harvests and includes all potential stands, recognizing that this may change depending on outcomes of the experiment.

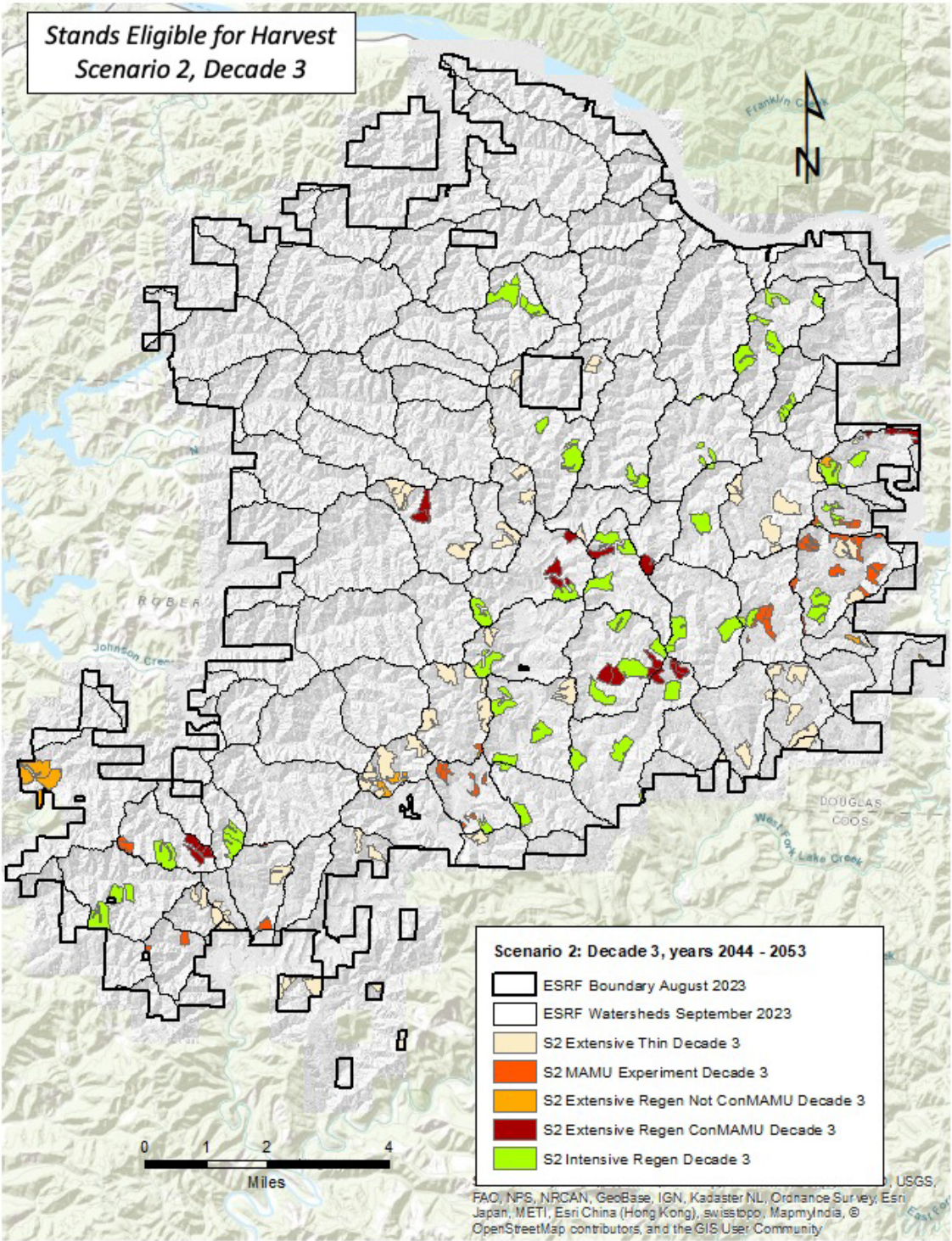
Average annual intensive harvest under Scenario Two over the 80-year evaluation period is 171 acres, and average annual extensive harvest is 386 acres.



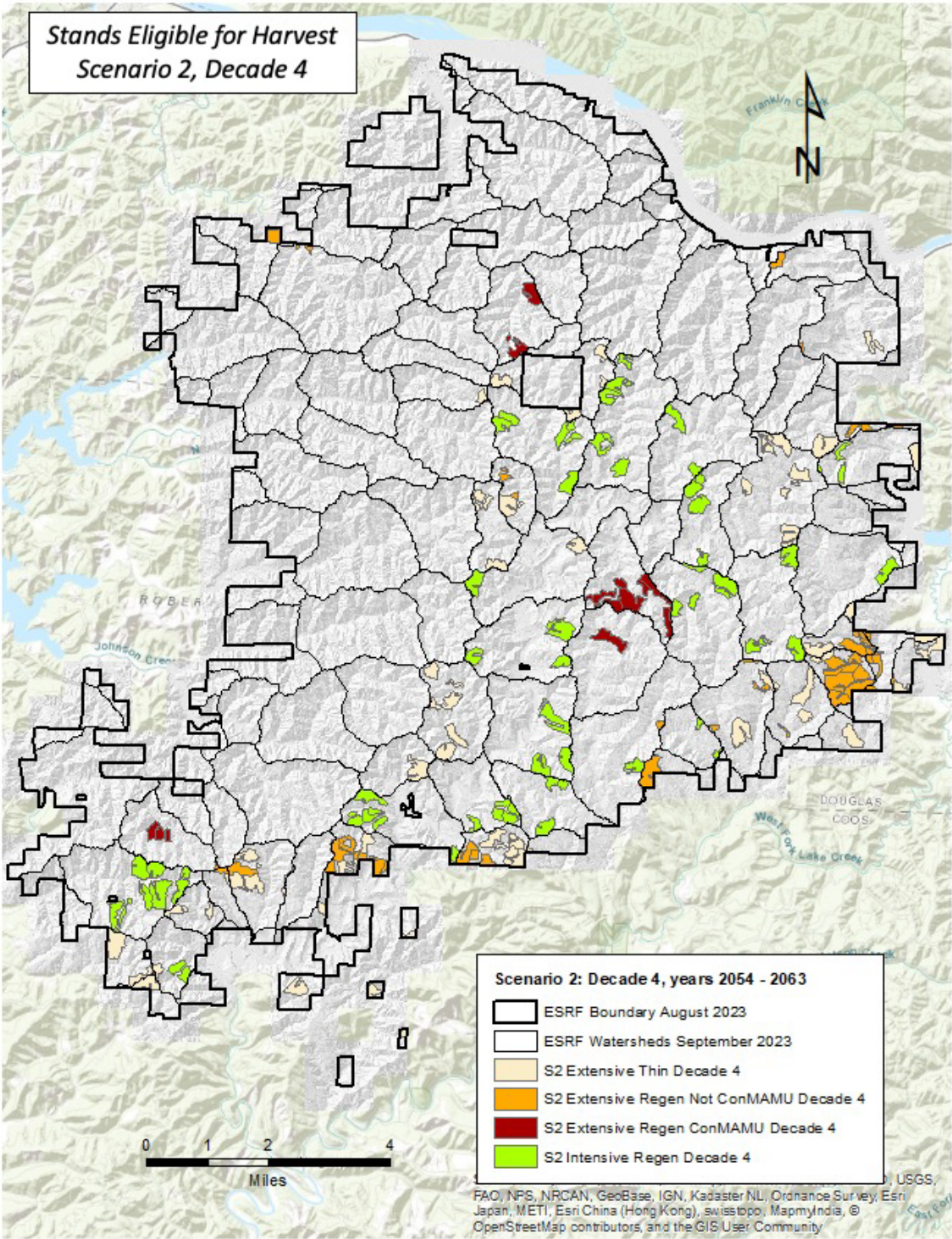










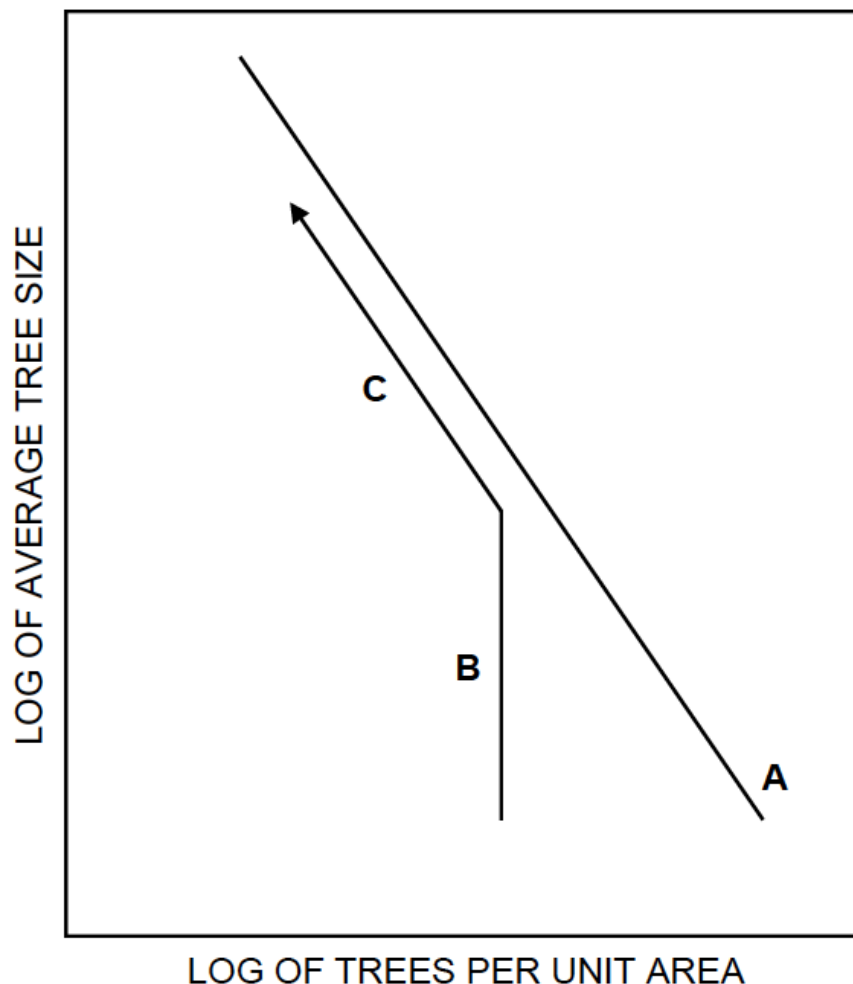


## Appendix I. Relative Density

*Author: Katy Kavanagh, Oregon State University College of Forestry*

The purpose of this appendix is to clarify and define the term *relative density* or RD. Relative density is used as a measure of stand density and thus is frequently associated when defining extensive harvests and thinnings.

One of the foundational principles of plant biology is the maximum size-density relationship or in a forest the maximum number of trees of a given size that can fit in a unit area (Figure I-1 line A). As trees increase in size (Figure I-1, Line B), vigor declines and stress related mortality caused by insects, disease, or drought occurs. The stand density declines (Figure I-1 Line C), maintaining size-density relationship below the maximum. At any point in the growth of a forest, current density (a combination of average tree size and number of trees per acre) can be expressed relative to the maximum density for that species and can provide a numerical index for describing some stand structural conditions. This index is called relative density or percent relative density (RD). Percent relative density = (current density/maximum density)\*100.



**Figure 1** – Hypothetical development of an even-aged tree stand (adapted from Dean and Baldwin 1993). This figure shows two lines. Line “A” shows the maximum size-density boundary; in this document, it refers to the full-stocking density level. The maximum size-density relationship is a species-specific boundary line that forms the basis for indexing relative density, i.e., for stands without stockability limitations (MacLean and Bolsinger 1973), the ratio of actual SDI to the full-stocking SDI can be used as a stocking level. The full-stocking line is a logarithmic relationship with a negative slope (it’s sloping downward rather than upward), which means that more trees are associated with a smaller size and less trees with a larger mean size. This negative relationship between mean size and density exists for all self-thinning plant populations, regardless of their life-form (tree, shrub, herb). The second line shows a hypothetical even-aged stand. Line segment “B” shows the period in stand development characterized by *free growth*, where trees are growing as fast as possible for prevailing site conditions. The early portion of this period, when trees fill unoccupied growing space prior to crown closure and the onset of competition, is known as “open growth” (Oliver and Larson 1996). Line segment “C” shows a change in trajectory after the stand enters the self-thinning zone and density-related competition causes tree mortality. After self-thinning begins, a stand is constrained by the full-stocking boundary (the “A” line) and its future trajectory will then remain below, but track along, that line. These developmental processes hold for all forests, although low-productivity sites progress at slower rates than high sites (Westoby 1984).

**Figure I-1.** Hypothetical development of an even-aged forest on a logarithmic scale. Line A is the maximum size-density relationship. Note line A is sloping downward, indicating that increasing numbers of trees per unit area, results in smaller mean tree size. Line B represents the trajectory of a stand as the average tree size increases, but competition-related mortality has not yet occurred. Line C demonstrates competition-related mortality. At this point the average tree size is continuing to increase (though more slowly) as the number



of trees declines. Lines are drawn crossing the points where the relative density is 35, 55, and 80% of maximum. For the description of stand structural conditions at these relative densities see text below. The dashed line is the trajectory of the stand if the initial number of trees per unit area is significantly lower than Line B. Note the average tree size along the dashed line relative to Line B when full site occupancy occurs (35%) and mortality begins (55%). Age is not represented on this figure. The age of a stand as it passes through these stages is a function of density. Lines as drawn are not to scale. Adapted from Powell (1999).

Stages of forest growth and stand structural characteristics expressed in terms of percent relative density:

- **1-10%** The individual trees are free to grow resource limitations are minimal. Understory plant growth is rapid.
- **15-25%** Onset of competition between the individual trees and understory shading. Crown closure and self-pruning of tree limbs begins.
- **35%** Full site occupancy by trees is evident. Increasing competition as indicated by more self-pruning, competition, and understory growth stops except in gaps. Trees allocate growth to height preferentially to maintain competitive advantage with neighboring trees, therefore becoming more susceptible to wind events.
- **50%** Mean live crown ratio typically 40% of the tree. Crowns lifting as trees grow taller and self-pruning continues. Limb mortality occurs in the lower canopy before large diameter limbs can develop. Trees develop a mutual support system thus reducing the likelihood of wind causing uprooting or breakage. Therefore, thinning can increase risk of wind damage if high winds occur before trees have an opportunity to increase diameter relative to height.
- **55-60%** Increasing competition for limiting resources among trees reduces growth rates of individual trees and can magnify stressors such as drought. Mortality begins primarily in the smaller trees that are most heavily shaded often referred to as self-thinning. Understory almost disappears except the most shade tolerant species. The number of trees per acre declines but mean diameter increases as the smaller trees die preferentially.
- **80%** Maximum site occupancy occurs, continued growth of surviving trees can only occur as trees die. Mean live crown ratio has declined to 20-30%.
- **100%** Theoretical maximum density. Rarely observed due to continuous mortality of individual trees freeing up some resources for survivors.

Percent relative density is a tool that is suitable for setting targets and for assessing current stand conditions. For example, to maintain trees in a free to grow condition where individual tree size is maximized, wind firmness is maintained, understory growth is possible, and branches are maintained so mean branch size can increase with age, a relative density of 35% or below may be a suitable target. However, if your target is to maximize wood production, a target between 35-55% may be more suitable.

Setting targets based on RD is very useful in a planning document such as a Forest Management Plan. The index is quantitative and can be readily measured. Stand structural development as a function of RD, is surprisingly consistent across sites and species (except on some sites with highly limiting resources for growth). You can set multiple RD targets at the stand, watershed, and landscape scale thus, achieving targets across multiple scales. However, the likelihood of achieving the desired target within any individual stand will be dependent on current stand conditions. As the desired targets are applied, stand density and mean tree size prior to treatment must be measured, and in some cases, adjustments made before initiating treatments. As an example, if your target RD is 35% and your current RD is 20%, You would not do a harvest to reduce RD in this stand at this time. On the other hand, if your target RD is 35% and your current RD is 50%, you could harvest a portion of the trees and obtain your target. A final example is if your target is complex early seral (or a RD of 15%) and your current density in your Douglas-fir plantation is 65% you will have to select your leave trees very carefully to ensure they have the maximum likelihood of standing long enough so that your residual trees survive to provide the canopy complexity desired.

In closing, RD is a useful tool to set targets for restoration thinning ( Ch6.4.1.4, Ch 7.6.1) and extensive treatments (Ch6 obj 2.2) but it is not the only consideration when planning and implementing a plan. Setting and achievement of RD targets needs to be placed into the proper context by integrating with other opportunities, constraints, and operational considerations.

## **Appendix J References Cited**

Powell, D. 1999. Suggested Stocking Levels for Forest Stands in Northeastern Oregon and Southwestern Washington: An implementation Guide for the Umatilla National Forest. USDAFS Technical publication F14-SO-TP-03-99.

For further reading on this subject:

Competition and Density in <https://catalog.extension.oregonstate.edu/em9206/html>

<https://cmapspublic3.ihmc.us/rid=1N4TTFQMM-25JRP8J-14WL/Stand%2520density%2520management-%2520an%2520alternative%2520approach%2520and%2520its%2520application%2520to%2520Douglas-fir%2520plantations.pdf>

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## Appendix J.

### **Appendix J: A Dendrochronological History of Fire and Tree Establishment on the ESRF**

#### **Introduction**

Fire is the principal disturbance process that shapes the structure, composition, and dynamics of forests landscapes over time in temperate forests in the Pacific Northwest. Understanding fire and forest dynamics is thus critical to long-term management and conservation planning. However, datasets that describe the size, frequency, and severity of historical fires and how these fires influenced forest conditions and dynamics across landscapes are lacking. Thus, our understanding of historical fires and the historical fire regime, which includes traditional burning by Indigenous peoples, is still evolving. This appendix provides a brief introduction to fire ecology in the Pacific Northwest and summarizes a recent dendrochronological or tree ring reconstruction of historical fires on the Elliott State Research Forest (ESRF) that clarifies the historical fire regime and how it shaped historical and contemporary forests.

The influence of fire on forest ecosystems in the Pacific Northwest is generally characterized in terms of its fire regime – a description of fire frequency, severity, and their variability over time and across a landscape. The infrequent, high-severity fire regime has been broadly applied to “moist” Douglas-fir forests in the western hemlock zone regime (Agee 1993, Franklin and Johnson 2012). Under an infrequent high-severity fire regime fires almost always occur under rare extreme weather events where dry, powerful, and sustained east winds result in extensive areas of high-severity or stand-replacing fire. The application of an infrequent, high-severity fire regime to moist Douglas-fir forests was influenced by extensive high-severity fires in the 19<sup>th</sup> and early 20<sup>th</sup> century in Oregon and Washington (Tepley 2010) including the 1868 fire on the ESRF (Phillips 1997). Aside from some limited evidence of at least one other fire between 1881 to 1893, it has been tacitly assumed by western science that fire has otherwise not played a significant role in stand development on the ESRF (Biosystems et al. 2003, Oregon DSL, and ODF 2011).

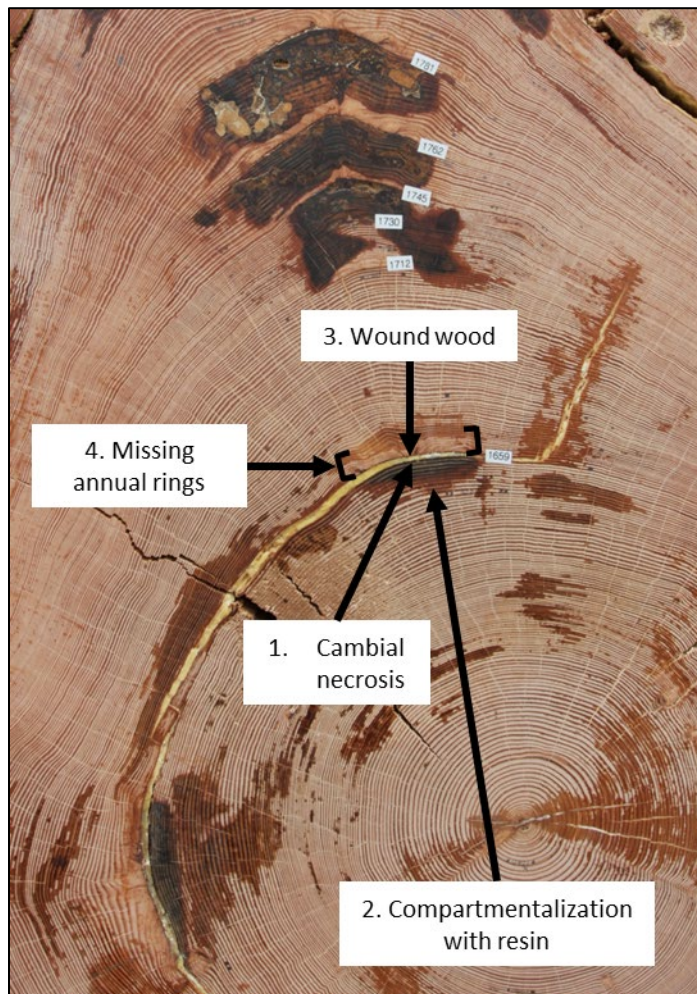
Under an infrequent high-severity fire regime, the absence of fire for centuries allows the development of mature and old-growth forests broadly across a landscape. Old-growth conditions, including large trees, canopy gaps, multi-story canopies, snags, logs, and mixed tree species composition, develop through a process of competitive exclusion of the pioneer Douglas-fir cohort (Franklin et al. 2002). Windthrow, snow and ice damage, and insect and diseases facilitate succession by killing trees, which results in snags and logs, canopy gaps, and the development of understory and mid-canopy layers. When severe drought, ignitions, and severe fire weather align, a large severe fire occurs and results in mortality of most mature trees. The post-fire landscape is largely composed of early seral shrubs, herbs, grasses, and tree seedlings with abundant snags and logs.

Ecologists are recognizing that some of the Douglas-fir region was not characterized by infrequent high-severity fire, and that relatively frequent mixed-severity fire regime was characteristic of many landscapes (Spies et al. 2018). In this regime, fire severity is variable with low (<20%), moderate (20-70%), and high (>70%) mortality of mature trees. Non-stand-replacing fire where mature fire-resistant trees survive fire is the common fire effect inside most fire perimeters. Spatial variability in fire frequency and severity creates variability in forest succession and conditions at relatively fine scales across a landscape. Many old forests have multiple shade intolerant and shade tolerant cohorts dating to past fires. The development of old-growth characteristics including canopy openings and gaps, multiple canopy layers, and snags and logs is facilitated by low- and moderate-severity fires. Variability in the frequency and severity of past fires results in several fire-mediated forest successional pathways that have distinct forest structure and composition at the old-growth stage (Tepley et al. 2013). Across a landscape this “pyrodiversity” results in high diversity of forest conditions and successional histories among forest stands (Morrison and Swanson 1990, Tepley et al. 2013, Merschel 2021).

Currently there are no published records of historical fires developed from rigorous and annually resolved dendrochronological (i.e., “tree-ring”) methods in the Oregon Coast Range. Charcoal layers in sediment cores from Triangle Lake in the central Oregon Coast Range suggest a mean interval of 220 years between fires, but this estimate may only capture relatively large



high-severity fires (Long et al. 2021). An infrequent 350-year fire return interval is estimated for most of the ESRF (LANDFIRE 2023), but this estimate is not based on direct and annually precise evidence of historical fires. To update our understanding of fire regimes, the OSU College of Forestry collaborated with the USFS PNW Research station to develop a tree ring record that characterizes the historical fire regime and forest dynamics on the ESRF and adjacent lands. Objectives of this pilot study were to quantify fire frequency, fire extent, and describe the age structure and establishment history of unmanaged stands. The combined records of fires and tree establishment data characterizes how past fires influenced forest conditions and dynamics on the ESRF.



**Figure J-1: Cambial Fire Scars.**

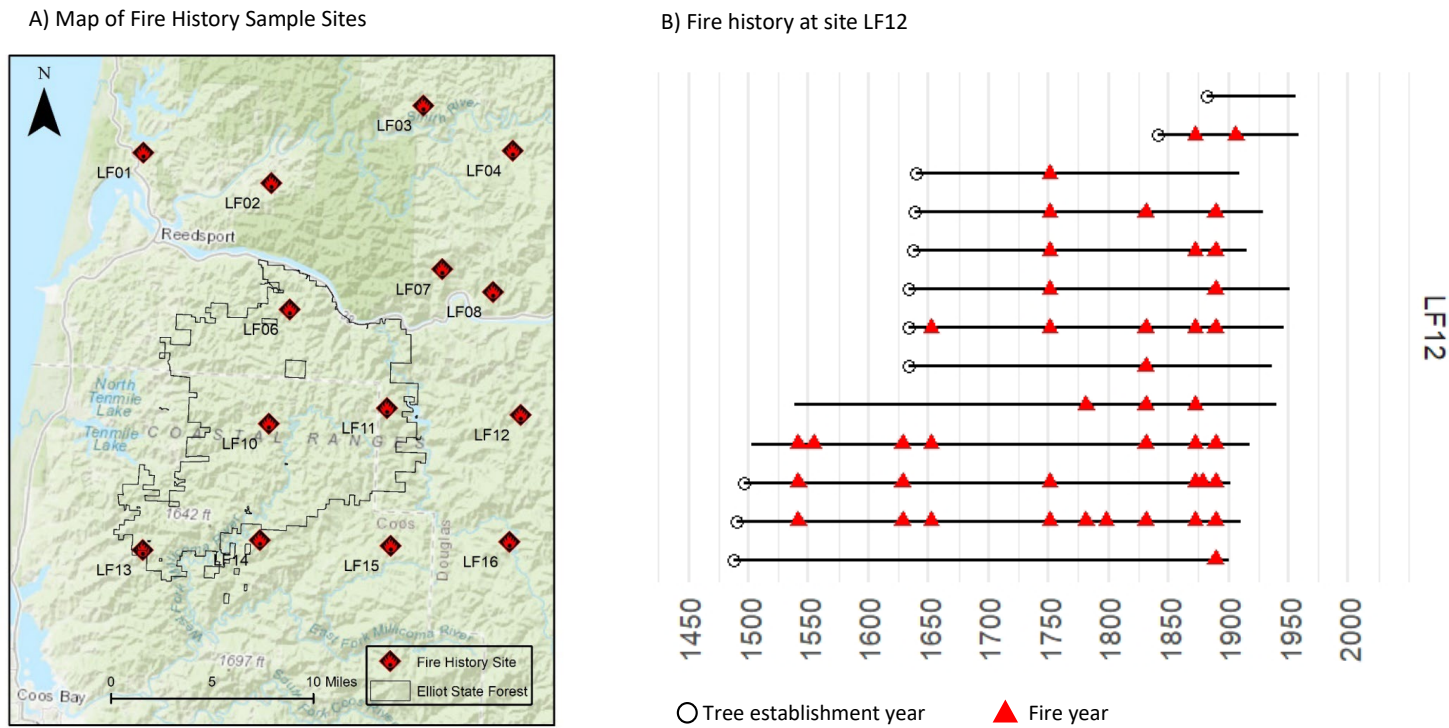
The anatomy of cambial fire scars used to reconstruct the year of fire events on the ESRF and surrounding ownerships. Cambial fire scars were identified by 1) cambial necrosis along a single boundary of cells, 2) compartmentalization of the wound with resin, 3) wound closure with “wound wood”, and 4) missing annual rings in the years following cambial necrosis. The photo highlights characteristics of a cambial fire scar formed in 1659, and displays additional cambial fire scars in 1712, 1730, 1745, and 1762 recorded on a Douglas-fir log sampled. Note that resin compartmentalization occurs on annual rings formed in the years prior to each section of cambial necrosis on the tree bole. Resin compartmentalization for the 1712 fire event was evident on another sample collected from the same log.

## Study Methodology

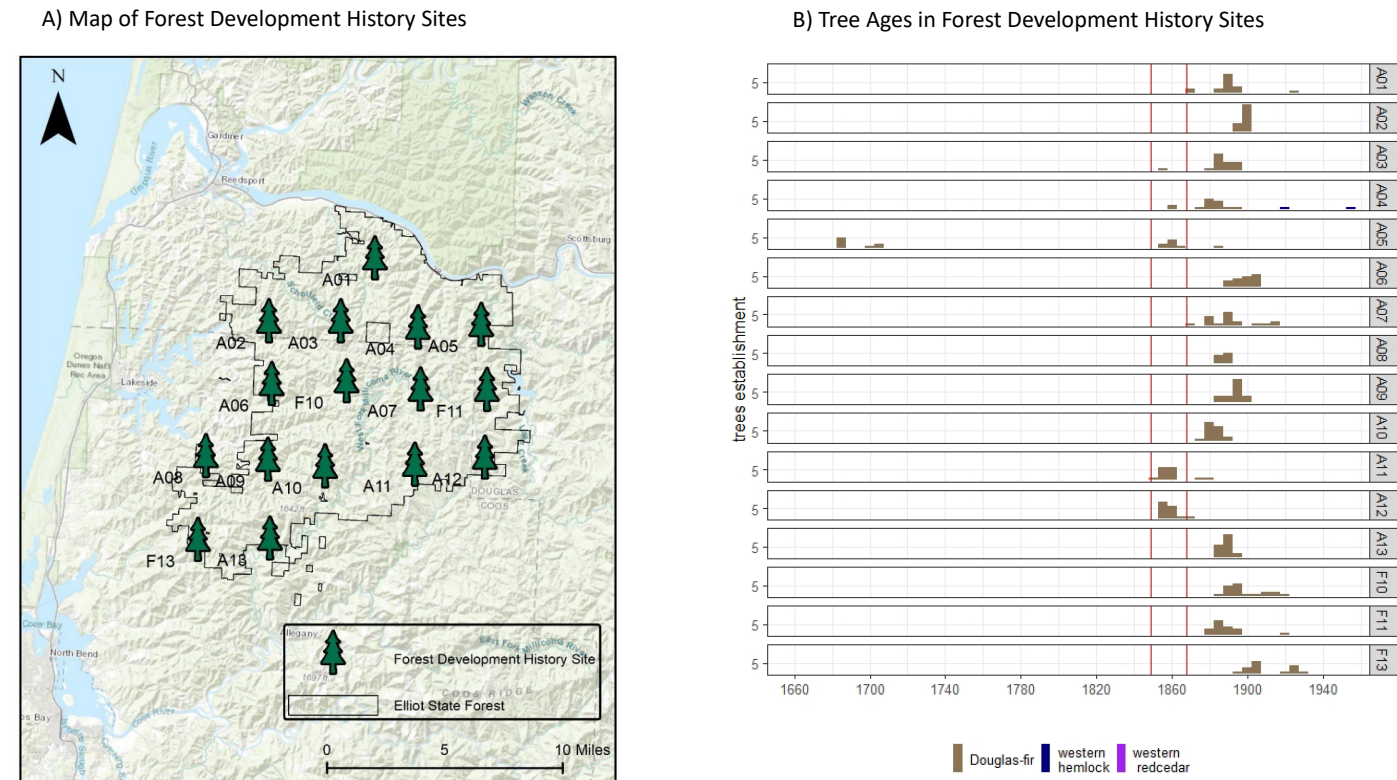
Historical fires were reconstructed from cambial fire scars. Cambial fire scars are a distinct fire caused injury to a tree bole that can be readily distinguished from other damage and disturbance processes including mechanical damage from storms or damage from biological disturbance agents (Figure J-1; Smith et al. 2016). Cross sections were collected from 15-20 fire scarred stumps and logs in 14 sample sites placed in clearcuts on the ESRF and surrounding land ownerships (Figure J-2). Fire history sampling sites were placed approximately 10 km apart, but 3 sites had to be shifted due to limited road access or to limit disturbances to marbled murrelets.

Forest development history was reconstructed by coring trees at 16 forest development history sites (Figure J-3). Forest development history sites were placed approximately 5 km apart in mature or old growth stands with no history of logging. Tree cores were collected from 20 mature trees (i.e., >100 years old) at each site along a 200 meter transect. Each transect included four inventory plots located 50 meters apart. At each inventory plot the species, distance, and bearing to the five nearest mature trees was recorded. A tree core was collected at ~50 cm height above mineral soil from all five trees in each plot.

After cross sections and tree cores were collected, they were sanded to a high polish to allow crossdating of annual rings. Crossdating is a technique that uses the relationship between climate and annual growth rings to precisely assign individual tree rings and cambial scars to their precise year of formation. The record of historical fires and tree establishment records were used to characterize how historical fires influenced forest development history on the ESRF.



**Figure J-2: Fire History Sites.** Panel A maps the locations of 14 fire history sample sites located on the ESRF and adjacent lands. Panel B describes records of historical fires collected at each site using data from site LF12. Each tree sampled at site LF12 has a timeline corresponding to the earliest and latest annual ring sampled. Black circles indicate a tree establishment year. Red triangles represent the year of historical fires that were evidenced by cambial fire scars in each sampled tree. Note that most fires are recorded on multiple trees at the sample site. Establishment dates suggest that at least 3 Douglas-fir age classes occurred at the site prior to timber harvest in the 1950s. Fires occurred multiple times per century, but there were periods without evidence of fire that lasted for several decades (e.g., 1555-1628 and 1652 to 1751).



**Figure J-3: Forest Development History Sites.** Panel A maps the locations of 16 forest development history sites where we aged 20 mature or older trees. Panel B displays the number of trees established in 5-year periods from 1660 to 1940. Red lines indicate relatively large fires in 1849 and 1868. Most unlogged forests on the ESRF were established after relatively small reburns of the 1849 and 1868 fires in the late 1800s and early 1900s.



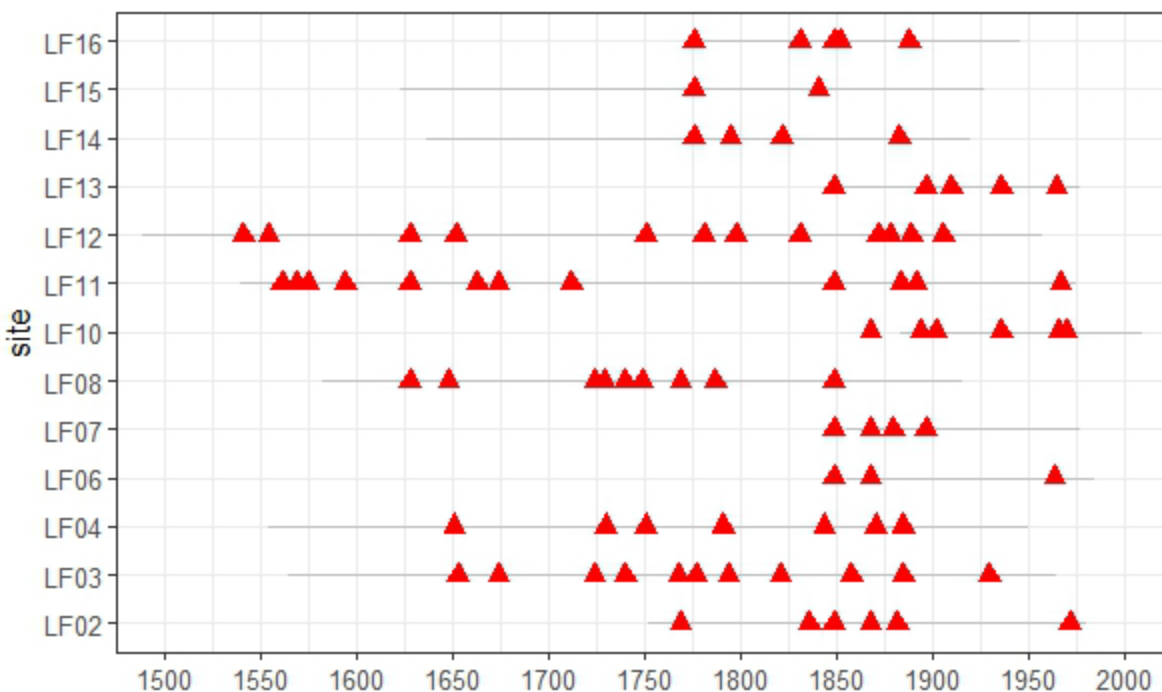
## Results

Prior to 1910, fires were frequent and occurred multiple times per century in much of the ESRF and surrounding lands. However, fire frequency was non-stationary over time, i.e. there were centuries where several fires occurred and centuries when few or no fires occurred at individual study sites. For example, there was one fire reconstructed at site LF12 from 1650-1750, but there were four fires reconstructed from 1750 -1850 (Figure J-2B). Across all fire history sites frequency was relatively high from approximately 1700-1800, low from 1800 to 1848, and then high from 1849 to 1910 following an extensive fire in 1849. Fire frequency declined in the early 20<sup>th</sup> century although there were relatively small fires reconstructed at no more than one site from 1930 to 1970. These fires may have been slash fires set after logging to reduce slash and prepare sites for planting (e.g., sites LF10 and LF13 in Figure J-2B).

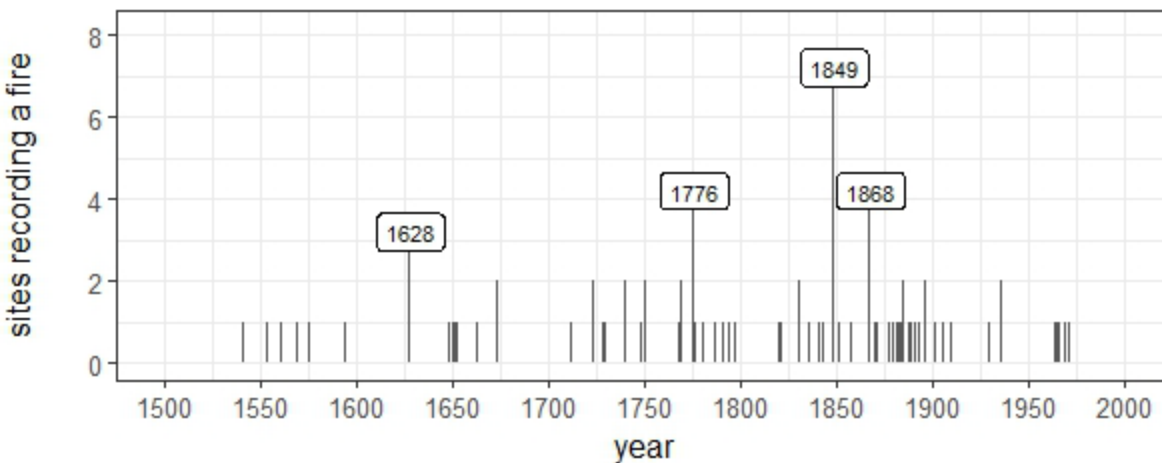
Most reconstructed fires prior to 1910 were only reconstructed at 1-2 sites, suggesting that many historical fires were relatively small (i.e. < 2500 acres). In contrast, fires in 1849 and 1868 were extensive and burned across several fire history sites, on both sides of the Umpqua River, and outside of the bounds of the study area (Figure J-4). Earlier fires in 1776 and 1628 may have been similarly extensive, but a lack of old trees at some fire history study sites limits the length of fire records in earlier centuries.

Fire severity varied spatially across fire history and forest development history sites, and most reconstructed fires included substantial evidence of low- or moderate-severity fire effects. For example, the 1849 fire was high-severity initiating early seral conditions at sites LF06, LF07, A11, and A12. In contrast, the 1849 fire burned at low- to moderate-severity at sites LF02, LF08, LF11, and A05 where Douglas-fir in different age classes survived the fire. Many of the reconstructed fires in the late 19<sup>th</sup> and early 20<sup>th</sup> century appear to be reburns of the larger and relatively severe fires in 1849 and 1868. Smaller reburns of the 1849 and 1868 fires resulted in mature forest stands that may have multiple Douglas-fir cohorts (Figure J-4B). Across forest development history sites, most mature trees were established in the decade following the last reconstructed fire at each study site.

A) Composite record of fires at Fire History sites

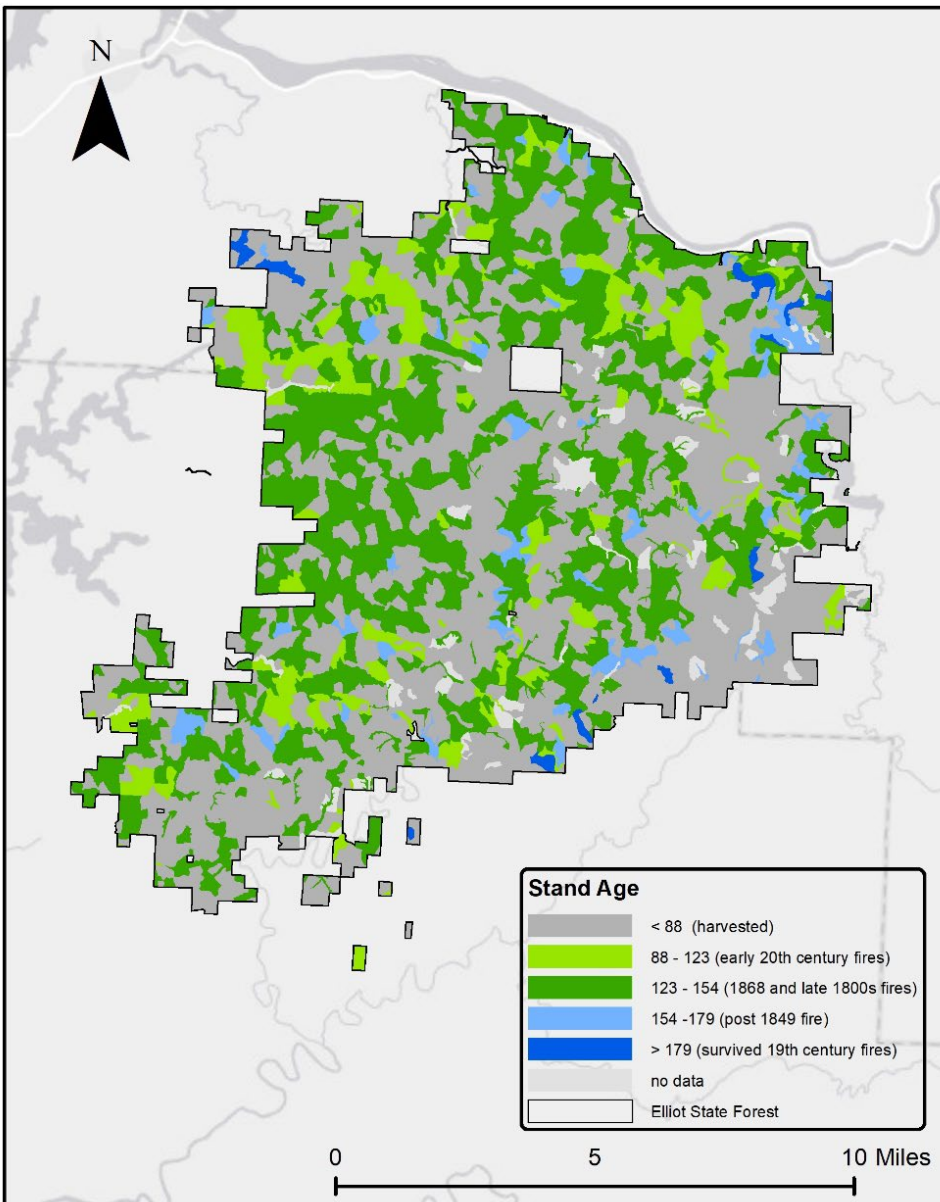


B) The number of sites recording each fire event



**Figure J-4: Composite Fire Records and Fire Extent.** Panel A reports the year of historical fires that were evidenced by fire scars at each fire history site. Red triangles indicate the years of historical fires, and grey timelines extend from the earliest to the most recent year recorded by the trees that were sectioned for fire scars. Panel B reports the number of sites that recorded a fire in each year from 1550 to 2000. Most historical fires were only recorded at 1 fire history site suggesting many fires were small with respect to the extent of the fire history sites. Relatively extensive fires burned in 1628, 1776, 1849, and 1868. Fires in 1849 1868 and smaller reburns of these fires have largely shaped age structure of unmanaged stands on the ESRF.

Forests on the ESRF that have not been harvested are a mosaic of ages created by variability in the timing, number, and severity of fires in the 19<sup>th</sup> century and early 20<sup>th</sup> century ( J-5). Old-growth stands with trees established prior to the 1849 fire are rare on the ESRF due to high-severity fires in the 19<sup>th</sup> century, and 20<sup>th</sup> century logging of old-growth stands that survived 19<sup>th</sup> century fires. The largest concentration of old-growth forest can be found in the northeast corner of the ESRF. Field observations and tree establishment data from site A05 illustrate that this old-growth is multi-aged due to multiple low- and moderate-severity fires that occurred during its development. Mature stands on the ESRF are widespread and composed of trees established after one of several severe fires in the 19<sup>th</sup> or early 20<sup>th</sup> century (age range 170-120 years). The 1849 fire was the largest reconstructed fire, but mature stands that established after the 1849 fire are relatively rare. This is likely because many young trees established after the 1849 fire were killed by the subsequent 1868 fire. The 1868 fire resulted in a broadly distributed age class that was again edited by smaller reburns in 1883, 1894, and 1902. The net effect of historical fires is that mature forests on the ESRF are different ages, and they are often composed of at least 2 age classes (e.g. a 1870s age class and a 1890s age class). This diversity in mature forest ages is the product of severe fire followed by reburns which resulted in gradual recruitment of a Douglas-fir canopy over several decades. Overall, frequent and mixed-severity fire was instrumental in shaping the development history of forests on the ESRF.



**Figure J-5: Stand ages on the ESRF.** This map displays stand ages across the ESRF using data provided by the ODF 2015 inventory of the ESRF. Mature stands on the ESRF are not all the same age. Stand age varies depending on whether the stand experienced high-severity fire in 1849 or 1868, and how it was influenced by smaller reburns of these fires in the late 19th century and early 20<sup>th</sup> century. Old-growth forests that survived fires in the 19<sup>th</sup> century and harvest in the 20<sup>th</sup> century are rare on the ESRF. The fire and establishment records collected in this study demonstrate that development of mature and old-growth forests was shaped by high-severity fire *and* low- to moderate-severity fires. \*Note: The 2015 ODF inventory cruised ½ of the stands and provided field estimates of stand age. One objective for coring stands in this study was to evaluate the accuracy of ODF stand age data. Overall ODF estimates of stand age were usually within  $\pm 10$  years of actual stand age in mature stands.



## Discussion and Implications

The key finding from the fire and forest development history pilot study on the ESRF is that forest conditions and successional dynamics were historically shaped by both frequent non-stand-replacing fires and infrequent, stand-replacing fires. In other words, relatively small and frequent mixed-severity fires were common historically, however there were occasionally extensive high-severity fires that were likely driven by rare but strong and dry east winds (Reilly et al. 2022). High-severity fires operated at coarse temporal and spatial scales because they infrequently created extensive areas of early seral conditions. Smaller mixed-severity fires created diversity in forest conditions and successional dynamics at relatively fine spatial and temporal scales. Diversity in forest conditions and successional dynamics arose from spatial variability in fire severity and temporal variability in the timing and frequency of small fires that burned in different parts of the landscape.

This pilot study expands the geography where recurrent non-stand-replacing fire shaped forest conditions and successional dynamics in Douglas-fir forests to the central Oregon Coast Range. Similar records of non-stand-replacing fires in Douglas-fir forests have been documented in the central (Morrison and Swanson 1990, Weisberg 2009, Tepley et al. 2013) and southwest Cascades (Merschel 2021). In comparison to previous study landscapes, the ESRF has a clear history of large high-severity fires in 1849 and 1868 that created extensive early successional conditions. In the late 19<sup>th</sup> and early 20<sup>th</sup> centuries, fire killed snags and logs, shrubs, herbs, grasses and seedlings and saplings were the predominant vegetation condition on the ESRF. Mature forests were rare on the ESRF during this time.

Forests developed with and were shaped by recurrent fires on the ESRF and in the central portion of the Oregon Coast Range. All fire history and forest development history sites with old-growth trees sampled had multiple Douglas-fir age classes that established after different fire events. Non-stand-replacing fires contributed to the development of old-growth structure and composition because they created snags, gaps and openings, growing space for understory and midstory trees, and growing space for shade intolerant understory species. Variation in the timing and severity of past fires likely drove diversity in successional histories and old-growth

forest structure and composition at a landscape scale (*sensu* Morrison and Swanson 1990, Tepley et al. 2013).

The key management and research implication of fire and establishment records is that historical fire regimes and forest dynamics may be emulated by varying the frequency, patch size, and intensity of tree thinning and harvest. Patterns of tree mortality are variable in mixed-severity fires, and this variability creates structural and compositional diversity at fine and coarse scales. For example, distinct postfire communities emerge across the low to high fire severity gradient after 21<sup>st</sup> century fires (Dunn et al. 2020). Species diversity is highest after moderate severity fire, shade intolerant species develop in patches of high-severity fire, and shade tolerant fire sensitive species regenerate and persist in patches of low-severity fire. Uniform thinning treatments and traditional regeneration harvests have no historical analogue, and may not provide for ecosystem functions, resilience, and biodiversity.

A largely untested assumption of western ecological science in Douglas-fir forests is that traditional burning by Indigenous peoples did not broadly contribute to fire activity, forest dynamics, and forest conditions in moist Douglas-fir forests. Variation in fire activity across the Douglas-fir region was primarily thought to be a function of aridity and lightning (Agee 1991). Therefore, relatively moist Douglas-fir forests without abundant lightning like forests on the ESRF were thought to develop old-growth characteristics over time without fire. In other words, from this view Indigenous peoples and traditional burning were not part of forest dynamics or the forest ecosystem. The frequency of fire documented in this study combined with the relatively low lightning activity in the study area directly challenges the assumption that traditional burning and Indigenous peoples did not shape the dynamics and characteristics of Douglas-fir ecosystems. It suggests an alternative hypothesis that many of the characteristics of old-growth forests are the product of recurrent fires of which many may have been intentionally prescribed by Indigenous peoples. This pilot study provides no direct knowledge of traditional burning practices including where, when, and why traditional fires were set. However, conserving and recruiting new old-growth forests may be facilitated by recognizing and restoring traditional burning and the role of relatively frequent mixed-severity fires in some

moist Douglas-fir forests. This restoration may be guided by respectful and reciprocal engagement with Indigenous peoples in the Pacific Northwest.

Non-stand-replacing “reburns” of early successional forests often shaped the development of contemporary mature forests on the ESRF. Higher windspeeds, temperatures, lower humidity, and relatively flammable fuels increase the probability of fire in early successional Douglas-fir forests (Agee and Huff 1987). Mature forests with the oldest trees established after the 1849 or 1868 fires were sampled at 15 forest development history sites. The presence of Douglas-fir in two age classes in most (9 of 15) mature stands demonstrates that reburns of early successional Douglas-fir forests were common. Further evidence of reburns in the ESRF is provided by fire histories in nine of the mature stands that recorded 1-3 reburns after the 1849 or 1868 fires. In development histories that included reburns, a few contemporary trees in the stand established immediately after the last high-severity fire in 1849 or 1868, but most contemporary trees established after smaller reburns in the late 19<sup>th</sup> or early 20<sup>th</sup> century. Trees established after the last fires on the ESRF are most abundant in most mature stands, likely because they did not experience fire in their early decades of growth. More broadly across Douglas-fir forests, there are several examples of high-severity fires driven by east winds that “primed the landscape” for reburns following the 1933 Tillamook Burn, the 1902 Yacolt Burn, and the 1987 Silver Fire (Decker 2023).

The ecological implication of historical reburns is that historically Douglas-fir ecosystems often had a prolonged early seral state and recruited canopy trees over several decades (Tepley et al. 2014). In contrast, forest management practices and many post-fire management plans aim to establish “free to grow” seedlings rapidly after contemporary stand-replacing disturbances. This truncates the early successional forest stage, creates more uniform forest canopies, and likely reduces diversity in species composition and forest structure in mature and old-growth stands that may develop after harvest and fire (Donato et al. 2011). If emulating historical forest dynamics is an objective, managers may modify post-disturbance site preparation to allow for longer persistence of earlier seral conditions where conifer recruitment is gradual, and seedlings compete with broadleaf trees and shrubs. Prescribed burning in early seral vegetation

could maintain early seral communities and could potentially emulate traditional burning practices that provide for wildlife habitat, foods, medicines, and textiles.

## **Appendix J: References Cited**

- Agee, J.K. and Huff, H.H. 1987. Fuel succession in a western hemlock/Douglas-fir forest. *Canadian Journal of Forest Research*, 17(7): 697-704. <https://doi.org/10.1139/x87-112>.
- Agee J.K. 1991. Fire history of Douglas-Fir Forest in the Pacific Northwest in Wildlife Habitat in Unmanaged Douglas-fir Forests. U.S. Department of Agriculture, Forest Service Pacific Northwest Research Station. Portland, Oregon. PNW-GTR-285.
- Agee J.K. 1993. Fire ecology of Pacific Northwest Forests. Washington, DC: Island Press. 493p.
- Biosystems, Water Work Consulting, Coos Watershed Association, Alsea Geospatial, Inc. and Karen Bahus Technical Writing. 2003. Elliott State Forest watershed analysis. Submitted to Oregon Dept. of Forestry. Biosystems, Corvallis OR.
- Decker, D. 2023. Tillamook Burn. The Oregon Encyclopedia. [https://www.oregonencyclopedia.org/articles/tillamook\\_burn/](https://www.oregonencyclopedia.org/articles/tillamook_burn/) Accessed 9-10-2023.
- Donato, D.C., Campbell, J.L, and Franklin, J.F. 2012. Multiple successional pathways and precocity in forest development: can some forests be born complex? *Journal of Vegetation Science*, 23(3):576–584.
- Dunn, C.J., Johnston, J.D., Reilly, M.J., Bailey, J.D. and Miller, R.A., 2020. How does tree regeneration respond to mixed-severity fire in the western Oregon Cascades, USA? *Ecosphere*, 11(1), p.e03003.
- Franklin, J.F. and Johnson, K.N. 2012. A Restoration Framework for Federal Forests in the Pacific Northwest. *Journal of Forestry*, 110(8), 429–439. <https://doi.org/10.5849/jof.10-006>
- Franklin, J.F., Spies, T.A., Van Pelt, R., Carey, A.B., Thornburgh, D.A., Berg, D.R., Lindenmayer, D.B., Harmon, M.E., Keeton, W.S., Shaw, D.C. and Bible, K., 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. *Forest ecology and management*, 155(1-3), pp.399-423.
- LANDFIRE, LANDFIRE: Mean Fire Return Interval, U.S. Department of Agriculture and U.S. Department of the Interior. Accessed 8 August 2023. at [https://landfire.gov/geoareamaps/LF2016/CONUS/LF2016Remap\\_CONUSEVT\\_graphic.png](https://landfire.gov/geoareamaps/LF2016/CONUS/LF2016Remap_CONUSEVT_graphic.png).



Long, C.J., Power, M.J. and Grigg, L.D. 2021. A 35,000 yr fire history from the Oregon Coast Range, USA. In: Starratt, S.W. and Rosen, M.R. (eds.) From Saline to Freshwater: The Diversity of Western Lakes in Space and Time (Vol. 536). Geological Society of America.

Merschel, A.G. 2021. Historical forest succession and disturbance dynamics in Coastal Douglas-fir forests in the southern western Cascades of Oregon. PhD Dissertation. Oregon State University, Corvallis, Oregon.

Morrison, P.H., and F.J. Swanson. 1990. Fire history and pattern in a Cascade Range landscape. USDA Forest Service General Technical Report. PNW-254. Pacific Northwest Research Station, Corvallis, Oregon.

Oregon DSL and ODF (Department of State Lands and Oregon Department of Forestry). 2011. Elliott State Forest Management Plan. <https://digital.osl.state.or.us/islandora/object/osl:88828>

Phillips, J. 1997. Caulked boots and cheese sandwiches. A forester's history of Oregon's first state forest. Self-published, Butler's Pronto Print, Coos Bay OR.

Reilly, M.J., Zuspan, A., Halofsky, J.S., Raymond, C., McEvoy, A., Dye, A.W., Donato, D.C., Kim, J.B., Potter, B.E., Walker, N., Davis, R.J., Dunn, C.J., Bell, D.M., Gregory, M.J., Johnston, J.D., Harvey, B.J., Halofsky, J.E. and Kerns, B.K. 2022. Cascadia burning: The historic, but not historically unprecedented, 2020 wildfires in the Pacific Northwest, USA. *Ecosphere*, 13(6), p.e4070.

Smith, K.T., Arbellay, E., Falk, D.A. and Sutherland, E.K. 2016. Macroanatomy and compartmentalization of recent fire scars in three North American conifers. *Canadian Journal of Forest Research*, 46(4), 535–542. <https://doi.org/10.1139/cjfr-2015-0377>

Spies, T.A., Stine, P.A., Gravenmier, R., Long, J.W., Reilly, M.J. and Mazza, R., tech. coords. 2018. Synthesis of science to inform land management within the Northwest Forest Plan area. Gen. Tech. Rep. PNW-GTR-970. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 186 p.

Tepley, A.J. 2010. Age structure, development pathways, and fire regime characterization of Douglas-fir/western hemlock forests in the Central Western Cascades of Oregon. PhD Dissertation. Oregon State University, Corvallis, Oregon.

Tepley, A.J., Swanson, F.J. and Spies, T.A. 2013. Fire-mediated pathways of stand development in Douglas-fir/western hemlock forests of the Pacific Northwest, USA. *Ecology*, 94(8), 1729–1743. <https://doi.org/10.1890/12-1506.1>

Tepley, A.J., Swanson, F.J. and Spies, T.A., 2014. Post-fire tree establishment and early cohort development in conifer forests of the western Cascades of Oregon, USA. *Ecosphere*, 5(7), pp.1-23.

Weisberg, P. J. 2009. Historical fire frequency on contrasting slope facets along the McKenzie River, western Oregon Cascades," *Western North American Naturalist*, Vol. 69: No. 2, Article 9. <https://scholarsarchive.byu.edu/wnan/vol69/iss2/9>

## Appendix K. Monitoring Indicators and Initial Target Levels in Intensive Areas

The following monitoring indicators and target levels are utilized to evaluate the efficacy of current objectives for intensive management areas at making progress toward the goals outlined in Section 6.2.

Table K-1. Monitoring indicators and initial target levels associated with individual research and land management objectives in Extensive Areas.

Relevant Objectives	Indicator	Initial Target Level	References for Target Levels
1.1	mean rotation length	>=60 years	ESRF Research Proposal
1.1	Compliance with Oregon FPA	100% compliance	Oregon FPA
1.2	Log value	>=regional baseline	Regional average log value for intensively managed forests using common practice rotation ages
1.2	Log volume	>= regional baseline	Regional average volume per acre on similar site for intensively managed forests using common practice rotation ages
1.2	Carbon storage and sequestration rates	>= regional baseline	FIA regional averages for Oregon coast range private forest lands

1.3	Mean number of partnerships with tribes to research contemporary Tribal forest management practices	>Baseline levels for the ESRF	
1.4	Number of research cooperatives or other partnerships dedicated to testing current and emerging intensive forest management approaches in the context of changing climatic conditions	>Baseline levels for the ESRF	
1.5	Slope stability	<Baseline level of slope failure related to harvest activity for the ESRF	
2.1	Volume of wood fiber to local manufacturing facilities	Projected annual and periodic harvest volumes	FMP and Biennial Forest Operations Plan
2.1	Contracted acres	≤480 acres/yr intensive regeneration	ESRF HCP
2.2	Plantations suitable for changing climate	Climate suitability measures that align with Climate Smart Forestry approaches	USFS Climate Change Resource Center resources, or similar.
2.2	Plantations at appropriate density to ensure rapid canopy closure	≥80% of units at canopy closure by year 10	



2.3	Per acre yield relative to maximum	>= modeled MAI at base age	
2.3	Herbicide applications	<=2 per rotation	FMP
2.3	Reforestation success and young stand growth	FPA stocking and free to grow standards	Oregon FPA
2.3	Detectable levels of herbicide in water	<= ESRF Baseline levels	FMP Monitoring
2.3	Animal control techniques	ODFW standards and guidelines. No use of rodenticides	ESRF HCP, FMP
2.4	Mean cover of culturally-valued plant species across intensive management areas measured at the watershed scale	>Baseline levels for the ESRF	
2.4	Mean harvest levels of culturally significant forest products and wildlife across intensive management areas measured at the watershed scale	>Baseline levels for the ESRF	
2.5	Mean recreational user satisfaction scores	>Baseline levels for the ESRF	Initial user satisfaction surveys
3.1	Species richness and diversity over variable timeframes	>Baseline levels for the ESRF	

## Appendix L. Guidelines for Management Unit-Scale Harvest Assignments in Extensive Treatment Areas to Guide the Initial Operational Planning Process on the Elliott State Research Forest

The guidelines in this section are meant to facilitate initial assignments of harvest treatments to individual management units in extensive treatment areas on the ESRF based on current conditions. As the mosaic of stand to landscape-scale conditions across extensive treatment areas changes over time, and monitoring efforts on the ESRF or peer-reviewed science provide more information about harvest treatment impacts on the desired research or resource management outcomes of extensive treatment areas described in Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.3.2 researchers and land managers working on the ESRF may wish to deviate from the criteria provided here to assign harvest treatments to individual management units. Researchers may also wish to deviate from these criteria to install nested experiments, with treatments replicated at the management unit scale, focused on questions related to variation in treatment response based on initial management unit conditions. The criteria for management unit-scale harvest treatment assignment listed below are meant to guide only the initial implementation of silvicultural activities in extensive treatment areas, on the ESRF. Adjustments to these guidelines following the initial operational planning period on the ESRF should be expected. Any such adjustments will adhere to the management direction for extensive treatment areas provided in Section 6.3.2, and all relevant conditions of the ESRF Habitat Conservation Plan.

### Overview of Initial Harvest Treatment Types in Extensive Treatment Areas

During the initial operational planning period, variable retention regeneration harvest approaches will represent the primary regeneration harvest approach utilized in extensive areas, although other regeneration harvest approaches that maintain sufficient live tree retention, as described in Objective 2.2, Sec. 6.3.2, may also be suitable for some management units. Variable density thinning is anticipated to represent the primary thinning harvest approach, although other thinning or selection harvest approaches that achieve desired density levels may also be suitable for some management units.

*Variable-retention harvesting* refers to a regeneration harvest method that includes the selective retention of forest structures, species, age classes or other components at the time of harvest to provide continuity in ecological functioning across harvest cycles while creating conditions suitable to the establishment of a new cohort of trees within the management unit. Variable retention harvests are based on the understanding that individuals or patches of live trees of various ages, dead standing trees (snags) and downed logs usually remain following natural forest disturbances such as wildfire, extreme wind events, landslides, or insect and

pathogen outbreaks. These biological legacies provide for continuity in structure, function, and composition between forest generations (Franklin et al. 2018, Franklin and Donato 2020).

Variable retention harvesting can take many forms depending on objectives for a particular management unit. A variety of forest components or combinations of components can be targeted for retention, including, but not limited to:

- large live or dead trees (snags)
- large and small logs on the forest floor
- patches of intact forest vegetation
- specific species in the overstory or understory
- specific age classes
- specific functional groups (e.g. conifers or hardwoods)

Retention can be distributed across the management unit (*dispersed retention*) or concentrated in localized patches or strips (*aggregated retention*). In addition to localized patches, retention may also be semi-aggregated as a thinned or unthinned matrix between discrete openings within the management unit. Specific goals of variable retention harvesting include sustaining forest species and processes, structural enrichment, and improving habitat connectivity in the post-harvest ecosystem. (Franklin et al. 2018.)

The initial criteria for harvest treatment assignment described below provide guidance on what stand conditions are eligible for variable retention harvests and other types of regeneration harvests with significant structural retention, and when to prioritize different retention levels or patterns based on individual site conditions. Management unit-level prescriptions developed as a part of the operational planning process will specify *what types* of forest structure and composition to retain, *where and in what spatial patterns* to retain them, and *how much* to retain within individual management units. Specific attributes of management unit-level prescriptions will be developed based on site-specific factors following analysis of spatial data layers, on-the-ground reconnaissance, and assessment of operational practicability in accordance with relevant management direction from the ESRF FMP and relevant conditions of the ESRF HCP.

*Variable density thinning* is an approach used to promote increased heterogeneity in species composition, structure, and spatial distributions of structural elements by varying the intensity of removal of trees within individual management units (Palik et al. 2021). Common elements of variable density thinning approaches include:

- Retention of patches of unharvested vegetation in “skips” within the thinned matrix
- Incorporation of gaps within the thinned matrix
- Retention of varied tree sizes and species
- Retention and/or creation of snags and logs
- Promotion or creation of culturally or ecologically important or underrepresented species

Major points of differentiation between variable retention harvesting and variable density thinning relate to their relative emphases on promoting a new cohort of tree regeneration, creating opportunities for the development of early-successional forest conditions, or enhancing the structural and compositional features associated with complex mature to late-successional forests. *Variable retention harvesting* is a regeneration harvest approach that focuses primarily on creating conditions suitable to the establishment of a new cohort, including the incorporation of large openings that promote the development of early-successional forest conditions and opportunities for the successful establishment of trees and other vegetative species that are reliant on these large openings. Fostering continuity in ecological processes across regeneration harvest cycles is the primary objective driving the retention of various structural components and/or species within variable retention harvest units, although this retention will also contribute to the development of complex, multi-aged forest structures over time.

*Variable density thinning*, in contrast, focuses primarily on creating spatial variation in tree densities across the management unit to promote increased structural complexity and vegetative species diversity over time. Variable density thinning treatments generally incorporate some objectives typical of intermediate treatments such as manipulating stand densities to foster increased residual tree growth rates, foster increased crown and branch development, promote resistance and/or resilience to disturbances such as wildfire, drought, wind, or insect outbreaks, promote the development of desired vegetative species in the understory, and/or contribute to desired spatial patterns of residual tree spacing. Creating conditions suitable to the establishment of a new cohort of tree regeneration may or may not be included as an objective within variable density thinning treatments. When tree regeneration is an objective of variable density thinning treatments in extensive treatment areas of the ESRF, the new cohort should generally contribute to fostering the development of structural and compositional features associated with complex mature to late-successional forests and/or increasing the representation of vegetative species associated with complex mature to late-successional forest structures over time.

#### Considerations for Initial Harvest Treatment Assignments to Individual Management Units

##### **Consideration 1: Maintaining Flexibility to Accommodate Emerging Research Questions and Incorporate Novel Silvicultural Practices.**

Over time, it is anticipated that changing biological, physical, social, and economic conditions, newly developed technologies, and advancements in the best available science will promote the development of new resource management concerns and associated research questions that can be addressed within the broad ESRF research platform described in Chapter 4: *Research Platform and Experimental Design*. As a fundamental, guiding principle in the development of operational plans and silvicultural prescriptions for individual management units, researchers and resource managers working on the ESRF are encouraged to remain open to the development and implementation of novel treatments that may diverge from one or



more elements of the guidance provided in Considerations 2-9, below. However, any novel experimental treatments should adhere to the following principles:

- All experimental treatments conducted in extensive treatment areas should be designed to promote outcomes and follow implementation guidelines consistent with:
  - the ESRF Research Platform and experimental design as described in Chapter 4: *Research Platform and Experimental Design*.
  - the management direction for extensive treatment areas as described in Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Sec 6.3.2, and
  - all relevant conditions of the ESRF Habitat Conservation Plan

To the extent practicable, experimental treatments, including any nested, management unit-scale studies embedded within extensive treatment areas, should adhere to core principles of experimental design. These principles may, at times, require planning processes that deviate from standard operating and decision-making procedures in conventional forest management settings. Although there are a wide range of valid experimental designs, several common considerations include:

- **Randomization in experimental treatment assignments:** The random assignment of experimental treatments, including any untreated controls, across a population of candidate management units ensures that the resulting sampling units are independent of one another. This reduces bias and is a basic requirement for the application of many commonly used statistical models.
- **Replication:** The repetition of independent applications of a given experimental treatment across multiple management units helps to increase the scope of inference (i.e., the range of conditions that we can reasonably draw inferences about based on our sample of treated management units), increase the power of statistical analyses, and increase the precision of our estimated values of any response variables of interest. Experimental treatments should generally be replicated *across* extensive treatment subwatersheds to remain consistent with the ESRF research platform.
- **Interspersion of experimental treatments:** The replicates of experimental treatments should generally be interspersed both spatially and temporally. For situations in which nested, management unit-scale experiments are implemented within extensive treatment areas, and harvesting activities or other operations must extend over multiple years, it is critical to complete full replicates of all relevant management unit-scale treatments within each year
- **Controls:** An experimental control represents a baseline condition against which all other treatments will be compared, which is essential for measuring the effect of one or more treatments on a variable of interest, particularly in situations where extensive, pre-treatment data are not available. Research principal investigators and ESRF Authority staff are encouraged to carefully evaluate whether controls are appropriate for any experimental silvicultural treatments within extensive treatment areas, what condition would represent an appropriate control, the anticipated lifetime of those controls relative to research needs, and how this might impact the ESRF Authority's

capacity to achieve outcomes consistent with the management direction for extensive treatment areas described in Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.3.2 and the broader, Triad-based research platform described in Chapter 4: *Research Platform and Experimental Design*.

The operational planning team and any project-specific research principal investigators should consult as needed to ensure that relevant experimental design considerations are incorporated within operational planning efforts focused on the design and implementation of any experimental studies nested within extensive treatment areas.

### **Consideration 2: Assessment of Treatment Needs Relative to Landscape-Scale Targets and Harvest Levels.**

To assess future treatment needs, the operational planning team should evaluate current landscape conditions and levels of provisioning of ecosystem goods and services relative to targets for extensive treatment areas as described in Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.3.2. Relevant questions include:

- Based on current conditions and anticipated stand and landscape development trajectories, are silvicultural treatments needed to foster progress towards or maintenance of extensive treatment areas within the landscape-scale target conditions associated with Objective 2.1?
- Based on past and projected future harvest levels, what range of harvest volumes and acreages during the current operational planning period will place extensive treatment areas within the target conditions associated with Objective 2.3?
- Based on current conditions and anticipated stand and landscape development trajectories, what treatments will foster progress towards increased levels of nesting, roosting, and foraging habitat for northern spotted owls as described in Objective 2.5?
- Based on current conditions and anticipated stand and landscape development trajectories, what treatments will promote the development of structural features associated with nesting habitat for marbled murrelet as described in Objective 2.6
- Based on current conditions and anticipated stand and landscape development trajectories, what treatments will foster sustained yields of culturally-valuable resources and continued opportunities for traditional practices of local tribes as described in Objective 2.8?
- Based on current conditions and projected future impacts, what treatments will foster adaptive responses to changing climatic conditions, disturbance regimes, and biological conditions consistent with Objective 2.9?

### **Consideration 3: Assessment of Economic Viability and Operational Feasibility**

The operational planning team should have sufficient operational, engineering, and economic expertise to evaluate the economic viability and operational feasibility of proposed treatments. Consultation with additional resource specialists, researchers, and practitioners should be conducted as needed, based on site-level resources conditions and potential concerns identified by the operational planning team. Development of harvest locations, levels, and prescriptions associated with individual operational plans should be primarily based on meeting short and long-term research objectives for extensive treatment areas as described in Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.3.2 while adhering to the conditions of the ESRF Habitat Conservation Plan. To achieve research objectives, it is acceptable for some treatments to fail to achieve economic viability, but a sufficient proportion of harvest units will need to be revenue positive to make sales attractive to contractors and maintain adequate levels of operational funding for the ESRF.

#### **Consideration 4: Is a regeneration harvest appropriate?**

The operational planning team should consider several factors that influence both an area's eligibility for regeneration harvest and primary experimental and silvicultural objectives when evaluating whether a regeneration harvest is appropriate for a given management unit.

- The management unit must be eligible for regeneration harvest as defined by the management direction associated with Objective 2.1 in Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.3.2, and the restrictions on eligibility of stands for extensive regeneration harvests described in Sec. 3.3.3 of the ESRF Habitat Conservation Plan to receive a regeneration harvest treatment.
- For the initial operational planning period, variable retention harvests and other multi-aged regeneration harvest methods with significant structural retention, will generally be the preferred silvicultural treatment when any the following objectives are the primary rationale for treatment:
  - Harvest treatments are being conducted to promote the successful regeneration and establishment of a new cohort of trees.
  - Harvest treatments are being conducted to assess the impacts of the spatial pattern and level of retention on a variety of responses as described in Objective 1.1 in Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.3.2.
  - Harvest treatments are being conducted to promote the development of complex, early-successional forest conditions.
  - Harvest treatments are being conducted to promote the successful regeneration of culturally, commercially, or ecologically valuable vegetative species reliant on large openings and/or high light environments for successful establishment.
  - Harvest treatments are being conducted to evaluate whether aggregating retention on unstable slopes is critical to providing attributes described in Objective 1.5.

### **Consideration 5: For regeneration harvests, what retention level is appropriate?**

Appropriate retention levels should be evaluated on a site-by-site basis. Retention levels for individual management units should ultimately be assigned based on a mix of research needs, resource management considerations, current stand attributes, and operational constraints. Economic viability and operational feasibility must also be a consideration, although it is acceptable for some treatments to be conducted at a net cost in order to achieve research objectives as outlined in the ESRF Forest Management Plan, so long as the overall self-sufficiency of the ESRF is maintained. Note that total acres of regeneration harvests with 20% retention in extensive treatment areas and average retention levels across remaining acres of regeneration harvests in extensive treatment areas must comply with the standards described in Sec. 3.3.3 of the ESRF Habitat Conservation Plan.

- In general, moderate to high retention levels (i.e., 50-80% of pre-harvest SDI[1]) may be preferable when any of the following conditions exist:
  - Increased levels of complex, mature and late-successional forest structures are needed to promote progress towards landscape-level targets.
  - A high percentage of the area in a management unit consists of disturbance-sensitive resources such as ODF-designated debris flow trigger or source areas, disturbance-sensitive cultural resources, and existing nesting, roosting, and foraging habitat within ESRF HCP-designated northern spotted owl activity centers.
  - The management unit receives documented use by sensitive wildlife species associated with patches of older forest structure with high canopy cover such as red tree voles and Pacific martens.
  - Examples of higher retention levels are needed to allow for effects-based comparisons with lower retention levels
  - The management unit falls within areas for which the ESRF Habitat Conservation Plan mandates 80% retention levels.
- In general, low retention levels (i.e., 20% of pre-harvest SDI) may be preferable when any of the following conditions exist:
  - Increased levels of complex, early-successional forest structures, broadleaf plant cover, or cultural resources associated with forest openings are needed to promote progress towards landscape-level targets.
  - Regeneration of vegetative species with low to moderate shade tolerance is desired to achieve research or resource management objectives.
  - Examples of lower retention levels are needed to allow for effects-based comparisons with higher retention levels.
- Deviations from the general guidelines for assignment of retention levels listed under Consideration 5 may be appropriate in a variety of conditions, so long as these deviations adhere to all relevant management direction in the ESRF Forest Management Plan and all relevant conditions of the ESRF Habitat Conservation Plan. Examples of



situations in which deviations from the general guidelines for assignment of retention levels listed under Consideration 5 include, but are not limited to:

- Periods in which increases or decreases in volume removals are needed to promote long-term outcomes consistent with the 50% fiber production requirement described in Objective 2.3 of Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.3.2.
- Situations in which current site conditions or equipment and technologies available through local contractors impose operational constraints that may necessitate higher or lower retention levels to maintain operational feasibility and operator safety.

**Consideration 6: For variable retention harvests, what spatial pattern of retention is appropriate?**

- Appropriate retention patterns should be evaluated on a site-by-site basis. Retention patterns for individual management units should ultimately be assigned based on a mix of research needs, resource management considerations, current stand attributes and operational constraints. Economic viability and operational feasibility must also be a consideration, although it is acceptable for some treatments to be conducted at a net cost in order to achieve research objectives as outlined in the ESRF Forest Management Plan, so long as doing so does not compromise the overall financial self-sufficiency of the ESRF. When consistent with research objectives, utilize aggregated retention under any of the following conditions:
  - Aggregates can be placed to reduce harvest impacts on sensitive ecological, cultural, or archeological resources that are present within the management unit and likely to be degraded or reduced in longevity by soil disturbance or reduced canopy cover.
  - Patches containing topographic, geological, or infrastructure features that restrict or prevent the use of areas around them for yarding and skidding corridors are present within the management unit.
  - Residual trees on sites with high wind exposure and/or high susceptibility to top snap-out and windthrow as indicated by pre-harvest H:D ratios of dominant and codominant trees.
  - Residual stand densities at higher retention levels will limit the successful regeneration of desired vegetative species if dispersed retention is utilized.
  - Situations in which large openings are desired to create conditions favorable to the establishment or persistence of highly shade intolerant vegetation and other organisms that benefit from open, high light microclimates.
- When consistent with research objectives, utilize primarily dispersed retention under any of the following conditions:
  - Pre-harvest conditions and planned retention levels will result in residual stand densities that promote a high probability of successful regeneration and

- establishment of desired vegetative species in a dispersed retention environment.
- Site-specific operational constraints do not inhibit equipment access to significant portions of the management unit.
- Preharvest tree and site conditions do not suggest a high risk of extensive top snap-out and windthrow in residual trees, and when operating in areas where windthrow would not represent a significant safety or transportation issue.
- Retention is desired across a majority of the management unit to moderate physical or biological stressors on regeneration.
- When consistent with research objectives, allow for mixtures of dispersed and aggregated retention within individual management units.
- Utilized gap-based or patch-based regeneration harvest methods with an aggregated retention matrix between openings at the highest levels of retention, including all 80% retention harvests.
  - Gap or patch opening sizes and retention within openings should be sufficient to promote complex, early-successional forest structure.
  - Aggregated retention areas may be subject to thinning or other intermediate treatments as part of the management unit harvest operation.

#### **Consideration 7: When are variable density thinning, uniform thinning, or other density management treatments appropriate?**

Variable density thinning, uniform thinning, and other density management treatments may be utilized to promote a variety of outcomes consistent with the research and resource management objectives for extensive treatment areas. The operational planning team should consider several factors when determining whether thinning treatments are appropriate for a given management unit.

- Management units that meet any of the following conditions are generally higher priorities for thinning during the current operational planning cycle:
  - Reductions in relative density are needed to increase resistance and resilience to drought, insects, windthrow, wildfire, extreme climate events, or other disturbances based on the best available scientific information.
  - The current stand structure is generally characterized by a dense, uniform canopy with limited variability in tree sizes or diversity of vegetative species and increased levels of complex, mature and late-successional forest structures are needed to promote progress towards landscape-level targets.
  - The stand includes patches of existing understory and/or midstory trees that are at risk of high-levels of suppression-related mortality due to increasing overstory densities.

- Sufficient time would elapse before the next planned regeneration harvest to allow the management unit to develop the desired outcomes of the thinning treatment.
  - Density reductions are desired to promote the accelerated development of large-diameter live trees or to slow crown recession to foster the development of large-diameter branches and larger crown sizes in management units where current tree conditions suggest a good release potential and current stand development trajectories are likely to contribute to rapid declines in individual tree growth and crown size that would limit future release potential.
- Otherwise, the stand is generally a lower priority for thinning during the current operational planning cycle.

### **Consideration 8: What residual density or range of residual densities is appropriate for thinning treatments?**

Appropriate residual densities and placements of features such as skips and gaps within thinned units should be evaluated on a site-by-site basis. Thinning prescriptions for individual management units should ultimately be assigned based on a mix of research needs, resource management considerations, current stand attributes, and operational constraints. Economic viability and operational feasibility must also be a consideration, although it is acceptable for some treatments to be conducted at a net cost in order to achieve research objectives as outlined in the ESRF Forest Management Plan, so long as doing so does not compromise the overall financial self-sufficiency of the ESRF.

- Variable density thinning treatments that incorporate skips and gaps within a thinned matrix are preferable when research and/or resource management objectives call for increasing structural complexity, promoting increased vegetative species diversity, and fostering the accelerated development of complex mature to late-successional structural characteristics.
- Higher residual densities ( $\geq 35\%$  of  $SDI_{max}$ ) are generally appropriate in areas where site conditions suggest an increased risk of windthrow or top snapout, increased potential for landslides, or the presence of high-value resources that are likely to be degraded by lower canopy cover.
- Lower residual densities ( $< 35\%$  of  $SDI_{max}$ ) are generally appropriate in areas where site conditions suggest an increased risk of significant drought stress, promoting understory development or vertical recruitment of understory to midstory trees is desired, promoting the rapid development of large-diameter trees with larger crowns is desired, or promoting the development of culturally or ecologically valuable understory species is desired.
- Thinning prescriptions should consider the long-term productivity of the stand as well as the need for volume removals to promote long-term outcomes consistent with the 50%

fiber production requirement described in Objective 2.3 of Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.3.2.

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[1] Where aggregate retention or patch cutting is used, the percentage of area retained or percentage of area planned for removal in patch cuts will be treated as equivalent to the percentage of pre-harvest SDI retained in aggregates or removed in patch cuts unless preliminary stand exam data suggest significant spatial variability in stand density across the management unit. In cases where significant spatial variability in stand density exists, remotely-sensed data or cruise data may be used to generate area-weighted estimates of pre-harvest SDI encompassed within planned aggregates or patch cut locations.



## Appendix M. Monitoring Indicators and Initial Target Levels in Extensive Areas

The following monitoring indicators and target levels are utilized to evaluate the efficacy of current objectives for extensive management areas at making progress toward the goals outlined in Chapter 6: *Silviculture, Harvest Systems, and Operations Planning*, Section 6.3.

Table M-1. Monitoring indicators and initial target levels associated with individual research and land management objectives in Extensive Areas.

Relevant Objectives	Indicator	Initial Target Level	References for Target Levels
2.1	Mean percentage of extensive areas within a subwatershed that meet complex, early-successional habitat definition.	10-30%	Wimberly et al. 2000, Reilly et al. 2021
2.1	Mean percentage of Extensive areas within a subwatershed that meet complex mature, and late-successional habitat definition.	25-50%	Wimberly et al. 2000
2.1	Mean return intervals for harvest treatments designed to promote early-successional habitat conditions across a majority of the management unit.	≥ 100 years	ESRF Research Proposal and ESRF HCP <u>Note:</u> neither source specifies this as a minimum rotation age and both suggest it should be flexible
2.1	Mean tree regeneration diversity in harvested units measured 6-years post-harvest	> Baseline levels for extensive management areas	FMP management direction/Oregon FPA
2.1	Mean tree regeneration densities in areas treated with regeneration harvests, measured 6-years post-harvest	Targets to be set in operational plans based on ongoing research needs	FMP management direction/Oregon FPA
2.1	Diversity of native vegetative species in treated management units,	≥ Diversity of native vegetative species prior to herbicide application	FMP management direction

	measured 2 years after herbicide application		
2.1	Cover of native vegetative species in treated management units, measured 2 years after herbicide application	≥ Cover of native vegetative species prior to herbicide application	FMP management direction
2.1	Mean canopy cover of broadleaf trees and shrubs in extensive management areas, measured at the subwatershed scale	≥ 10%	Betts et al. (2010, 2011), Ellis et al. (2012), and Kroll et al. (2012)
2.2	Mean retention in harvest areas outside of NSO activity center home ranges and MAMU designated occupied habitat, measured as % of pre-harvest relative density.	20% - 80%	ESRF Research Proposal and ESRF HCP
2.2	Mean, per-acre snag volumes		
2.2	Mean, per-acre CWD volumes		
2.3	Rolling, ten-year average harvest volume across all extensive management areas, including both salvage and green tree harvests	= approximately 50% of harvest volumes across all Intensive treatment areas for the same time period	ESRF Research Proposal
2.3	Annually contracted acres of commercial harvests across all Extensive management areas and intensive management areas combined	≤ 800 ac in yrs 1-5 ≤ 700 ac in yrs 6-15 ≤ 800 ac in yrs 16-20	ESRF HCP
2.3	Average log quality in year 21 and beyond	>Average log quality in years 1-20	
2.3	# of reported workplace injuries		
2.3	Treatment costs/unit volume/year in year 21 and beyond	< corresponding costs in years 1-20	

2.4	Mean # jobs/yr in local forestry-related workforce beginning in year 1 of treatment implementation	> mean # jobs/yr in local forestry-related workforce in 2011-2020	
2.4	Mean % of female and minority workers in local forestry-related workforce	> Mean % of female and minority workers in local forestry-related workforce from 2011-2020	
2.5	Follow NSO monitoring requirements of the ESRF HCP		
2.6	Follow MAMU monitoring requirements of the ESRF HCP		
2.7	Mean acres of landslides/year across all extensive management areas measured from year 1-20		
2.8	Mean number of visits from local tribal members/yr	>Baseline levels for the ESRF	
2.8	Mean cover of culturally-valued plant species across extensive management areas measured at the watershed scale	>Baseline levels for the ESRF	
2.8	Mean biomass of culturally-valued plant species across extensive management areas measured at the watershed scale	>Baseline levels for the ESRF	
2.9	Mean tree species diversity in extensive management areas, measured at the watershed scale	>Baseline levels for the ESRF	
2.9	Mean proportion of overstory BA represented by fire resistant conifers and sprouting hardwoods	>Baseline levels for the ESRF	
2.9	Mean cover of understory vegetative species with adaptations to regenerate	>Baseline levels for the ESRF	

	after fire such as seedbanking and sprouting strategies		
2.9	% of extensive management areas burned in simulated fires under 97 <sup>th</sup> percentile fire weather conditions	< Baseline levels for the ESRF	
2.9	% of extensive management areas with relative densities < 55% of SDImax	< baseline levels for the ESRF	
2.10	# recreational visits/year	≥Baseline levels for the ESRF	
2.10	Mean recreational user satisfaction scores	≥Baseline levels for the ESRF	

### Appendix M: References Cited

Reilly, M.J., Halofsky, J.E., Krawchuk, M.A., Donato, D.C., Hessburg, P.F., Johnston, J.D., Merschel, A.G., Swanson, M.E., Halofsky, J.S., and Spies, T.A. 2021. Fire ecology and management in Pacific Northwest forests. In: Greenberg, C.H., and Collins, B. Eds. Fire ecology and management: Past, present, and future of US forested ecosystems. New York: Springer. p. 393-435

Wimberly, M.C., Spies, T.A., Long, C.J. and Whitlock, C. 2000. Simulating historical variability in the amount of old forests in the Oregon Coast Range. Conservation Biology 14(1): 167-180.



## Appendix N. Restoration Experiment for Plantations in Conservation Research Watersheds: Decision Guidelines for Treatment Implementation

### Decision Guidelines for Treatment Implementation

Natural conditions influence the ecosystem development at smaller spatial scales, and are integrated into decision-making about timing and location of management actions under the reserve restoration experimental design. Conditions that are reflected in treatment specifics include:

- Aspect:
  - North facing portions of the stand are prime locations to consider higher densities; fewer but larger gaps, tree species composition reflective of old-growth stands.
  - South facing portions of the stand are prime locations to consider:
    - lower densities, more gaps, tree species composition – shifted towards more drought tolerant species, possibly sprouting species that can regenerate quickly after disturbances.
    - patches that are bordered by conditions that can act as burn boundaries (i.e., ridges, roads, wet spots, areas dominated by hardwoods) that may lend themselves for repeated Indigenous Knowledge-driven burns should be opened up in a gap and burned as soon as possible.
- Slope position:
  - Bottom of the slope (but outside riparian buffer)
    - Leave more trees for broader riparian area protection, to have gradual transition to buffer.
    - Emphasize diversity of trees, consider characteristics of litter and wood that may enter the stream.
    - Not necessary to consider wind stability in tree selection.
  - Top of slope
    - Leave trees set up for windthrow (high height/diameter ratio).
    - Leave “stable” trees (low height:diameter ratio) that can withstand wind.
  - If the ridge can provide a corridor to facilitate species movements to different sub-watersheds (focus on movement towards “north?”), leave islands should be elongated (towards the ridge) and located near or attached to leave islands on the adjacent sub-watershed to provide travel corridors.

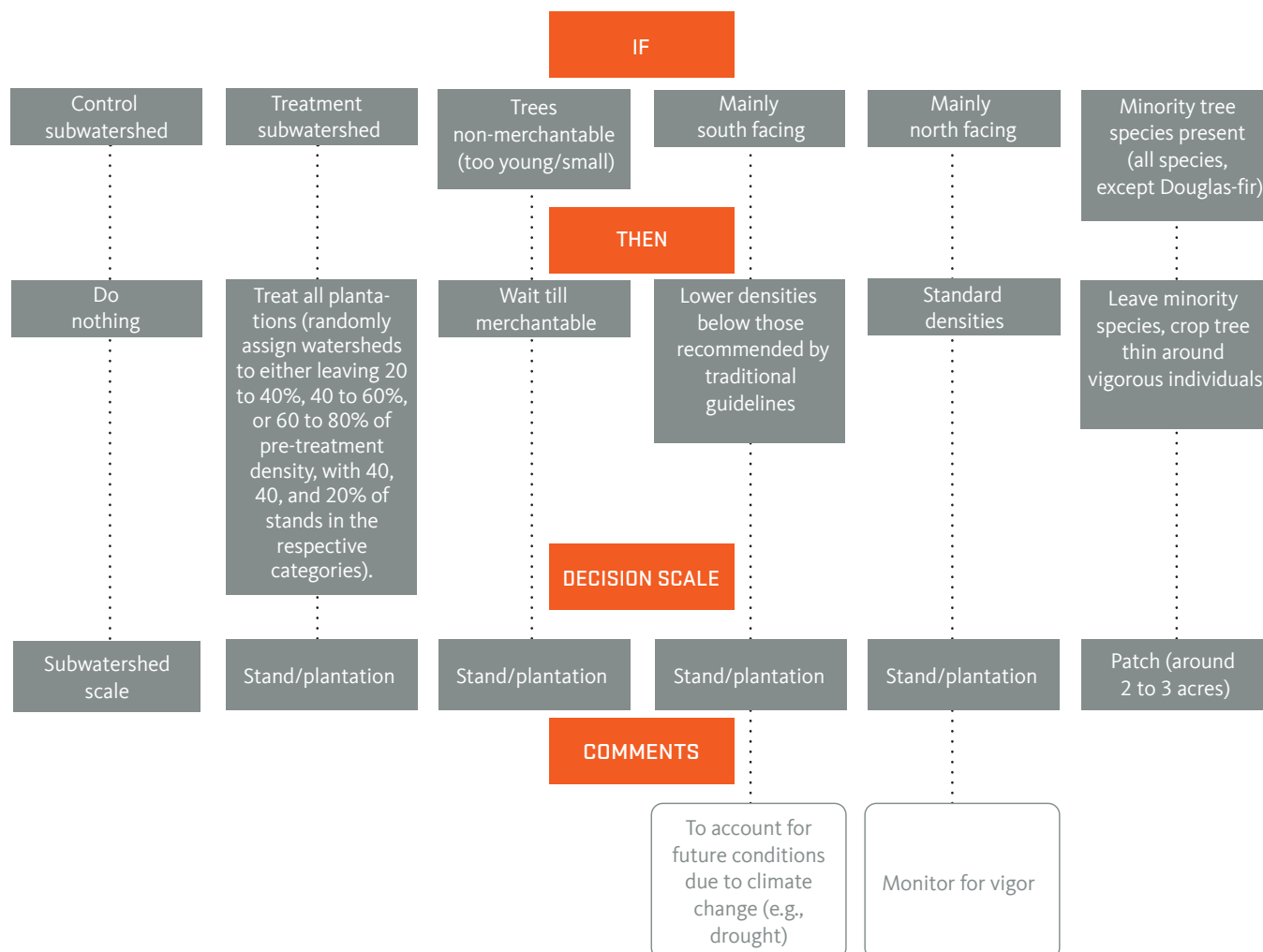
### Treatment Assignments to Subwatersheds

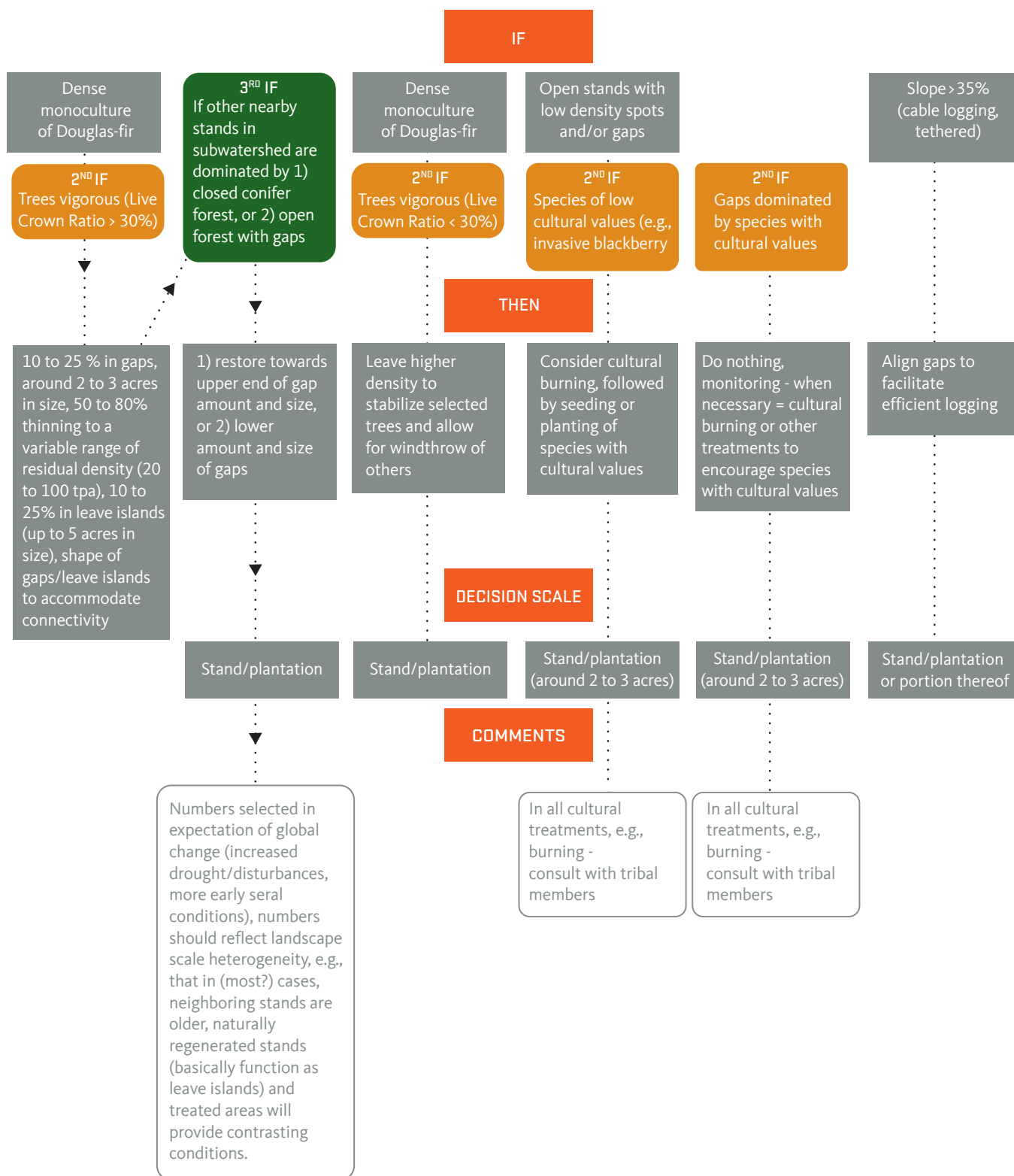
1. The treatment assignment will be stratified assignments to address Goal
3. Subwatersheds will be sorted within the CRW based on:

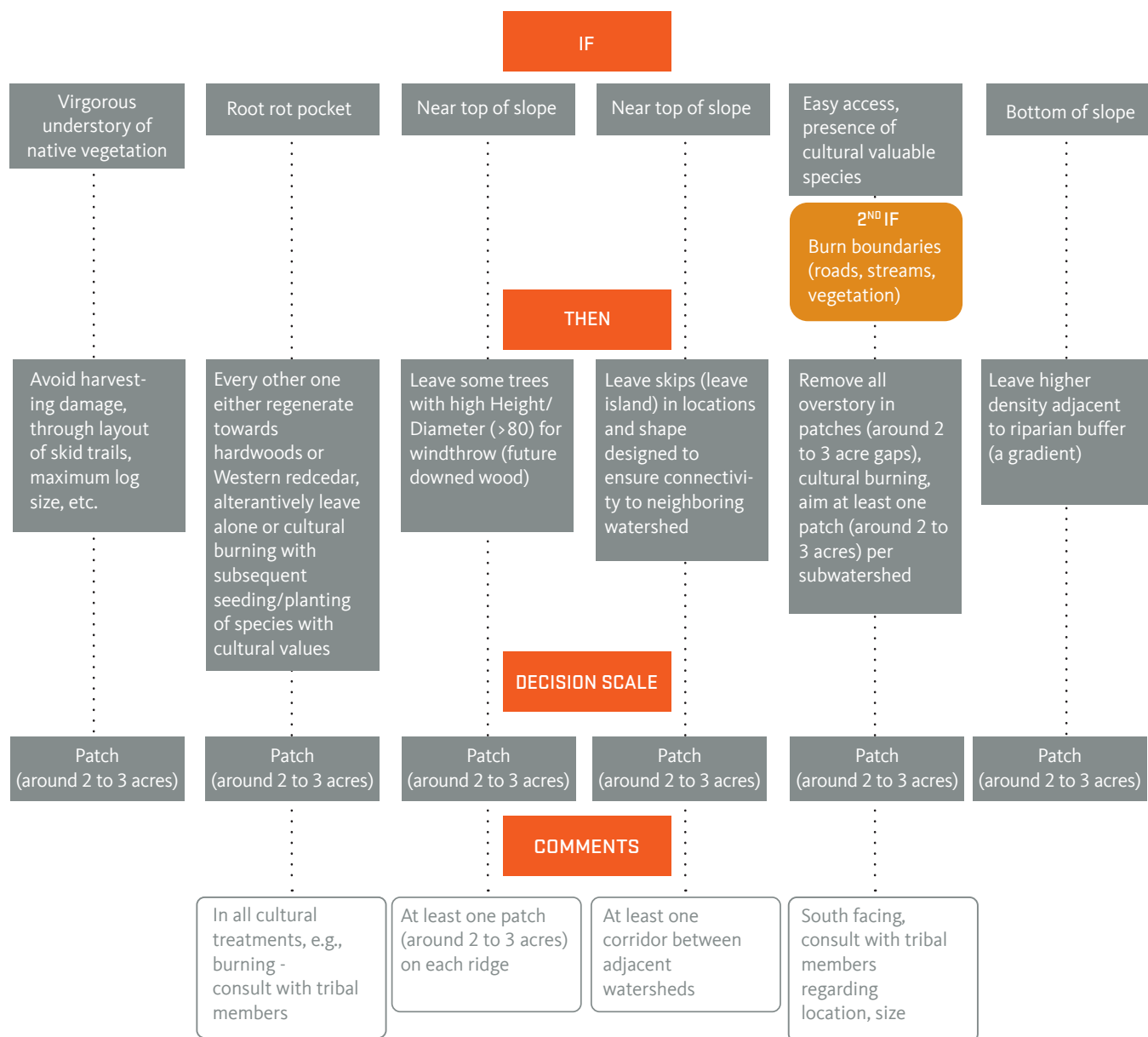
- a. Proportion of subwatershed in plantations into thirds (low, medium, high). Note that the high- and low-proportion comparison will give the most information.
  - b. Mainly north versus mainly south facing slopes. Aim for both north and south facing sub-watersheds in each proportion group, if possible.
2. Depending on the outcome of Step 1, i.e., the numbers of subwatersheds in regards to proportions (a) and aspect (b), we may have to modify the exact cutoffs.
3. Within each proportion/aspect group, we will randomly assign up to 80% and at least 20% of the subwatersheds to be treated or act as a control, respectively.
4. After assignment, we will investigate biases (e.g., elevation, distance from coast, site index). Depending on the amount of bias (e.g., if most or all control treatments are lower elevation), we will either re-randomize or use the current assignment and the biased variable as a covariate in the analysis.

### Decision Support Tree for CRW Restoration Experiment Treatment Assignment

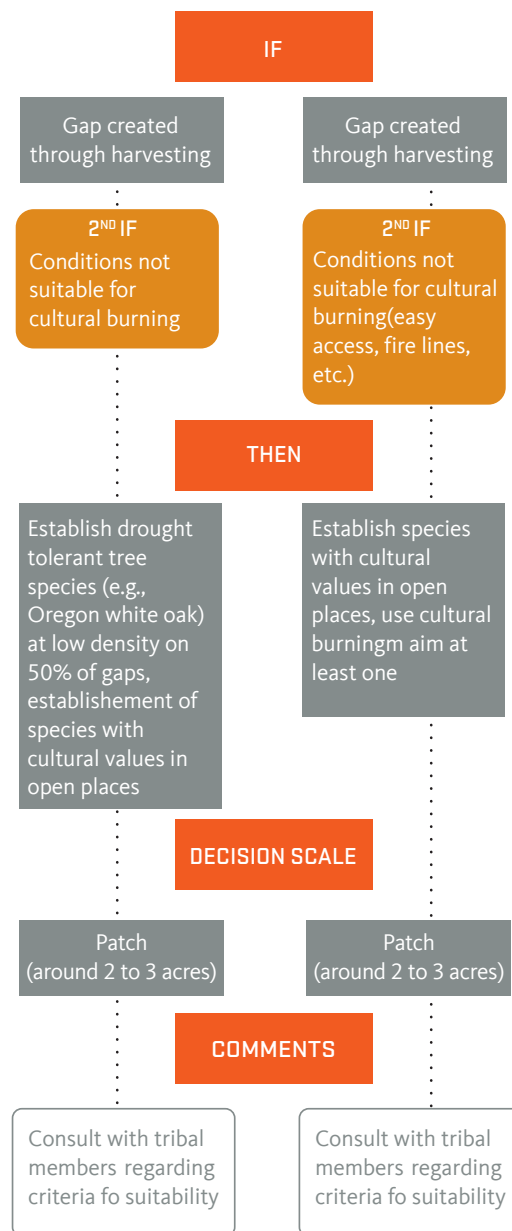
**Figure N-1.** Decision support tree highlighting how selected forest conditions (IF) influence management decisions (THEN) for the CRW Restoration Experiment Treatment Assignment. As indicated, criteria are based on information at various DECISION SCALES, from patches to stands/plantations to subwatersheds. COMMENTS describe additional concerns and considerations.











## Appendix O. Steep Slopes and ESRF Landslide Inventory

Throughout the Oregon Coast Range, steep slopes (e.g., >65%) are prominent features of the landscape and strongly influence associated aquatic and terrestrial ecosystems. They are sources of shallow, translational landslides and to some level, deep-seated landslides such as earthflows. Shallow translational landslides are typically constrained to the soil mantle within the forest rooting zone, generally less than 10 feet deep and more often less than 3 feet in thickness. These landslides are typically initiated by intense rainfall and/or rapid snowmelt, particularly during relatively wet periods. Shallow landslides can be important sources of large wood and sediment that are critical for the creation of productive fish habitat (Bigelow et al. 2007). The channels from which landslides originate provide habitat for a suite of native amphibians, insects, birds, bats and other organisms, and they function as a corridor for energy, carbon, and nutrient flux within the watershed (Wipfli and Gregovich 2002, Vascik et al. 2021). Deep-seated landslides occur much less frequently than shallow landslides but can have major impacts when they occur – when active, deep-seated landslides are agents of sediment transport through evacuation of smaller, nested failures and/or through the encroachment of toe-adjacent streams that consequently entrain landslide debris. While deep-seated landslides appear to serve as a slower source of wood and sediment than shallow landslides, they can be crucial in creating and maintaining landscape heterogeneity and aquatic and riparian habitat (Beeson et al. 2018, May et al. 2013).

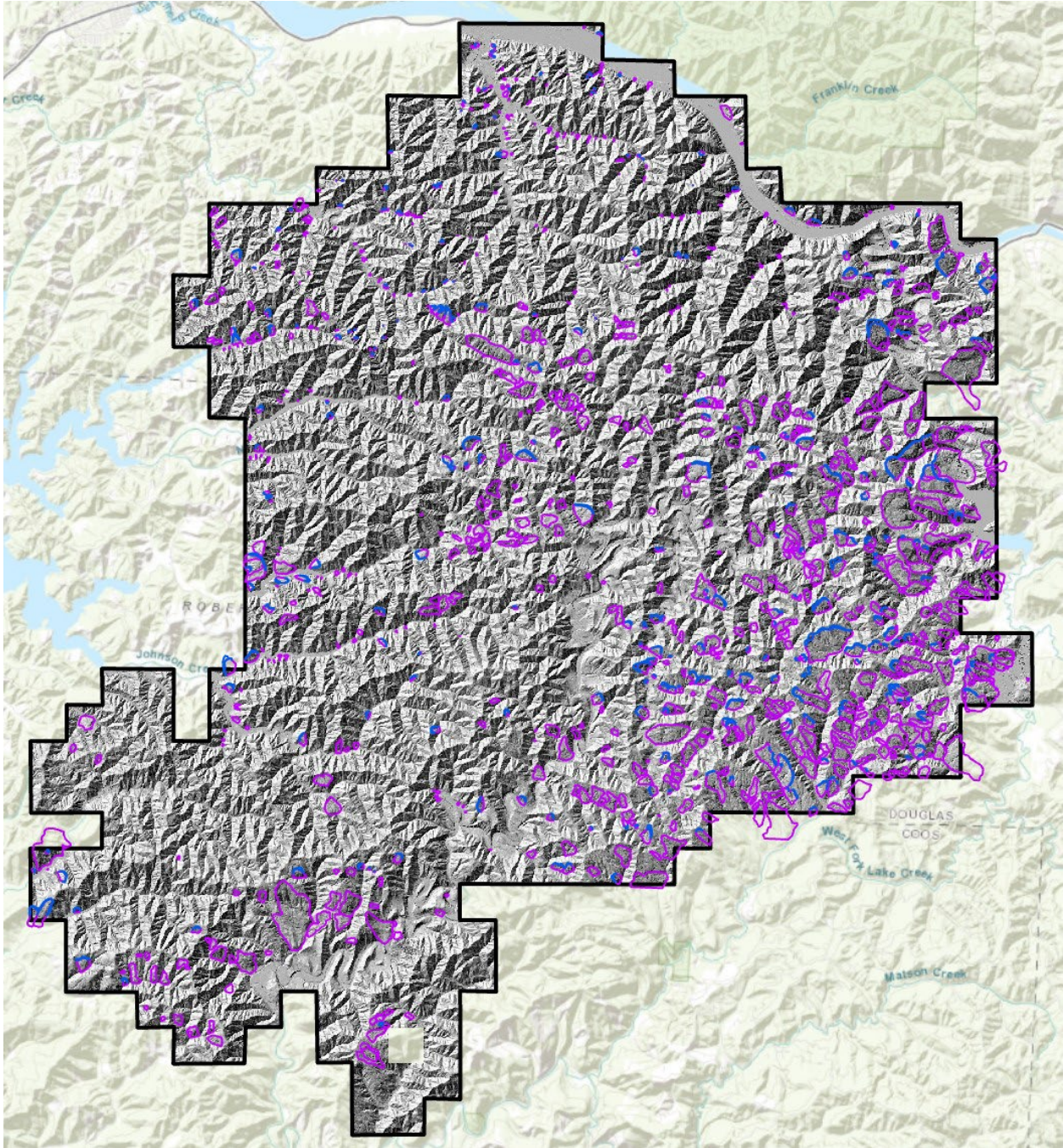
Steep slopes present challenges for land managers, particularly through altered hydrological conditions due to removal of trees, which can increase the frequency of shallow landslides and potentially amplify the seasonal movements of active, deep-seated features (Roering et al. 2003). In particular, roads can exert a strong influence on the frequency of shallow landslides and associated debris flows (Swanson and Dyrness 1975), often through adverse changes in groundwater and surface flow patterns.

Research on the ESRF will explore the effects of a suite of management options on the stability of steep slopes over representative timeframes to capture the importance of extreme events (i.e. rain and snow events), as well as constrain how the ecological consequences of any subsequent landslides fits within the lifecycle of aquatic ecosystems. There are important opportunities to better understand the feedbacks, evolution and lifecycle of steep slopes and the streams that confine them. We will explore the key processes leading to the production and delivery of large trees and sediment/nutrient pulses to the aquatic systems and evaluate whether they occur more quickly in steep landscapes. This research will address multiple questions relevant to land management and conservation, including understanding implications for the retention of carbon, nutrients and biota in headwater ecosystems and quantifying the role of large wood in sorting sediments and creating functional habitat on steep landscapes. This process is generally understood but lacks long-term empirical data that would constrain the importance of significant events (i.e. rain, snow) versus baseline conditions. Studies will seek to provide knowledge of short and long-term impacts of headwater stream retention and

headwater stream failure in the form of landslides and associated wood recruitment and sediment yields.

As a starting point, we have developed an initial landslide inventory of the ESRF using mapping protocols developed by DOGAMI. Approximately 1,350 landslides were mapped and assigned inferred mechanisms, volumes, and mapping confidence levels. As shown, many of the features in the eastern portion of the ESRF are large, deep-seated landslides typically prone to intermittent movements and dormancy, likely associated with geologic controls from the Elkton Formation. The western portion of the ESRF is primarily in Tyee, and has numerous mapped debris fans as well as numerous deep-seated bedrock landslide features. There is undermapping of shallow landslide features as these are often resolution-limited and their signatures brief on the landscape. However, uneroded downstream fans are a reasonable proxy for relatively frequent upstream shallow landslide activity.





**Figure O-1.** Landslides inventoried from the 2021 bare earth LiDAR hillshade. Purple polygons represent landslide deposits and debris flow fans. Blue polygons represent headscarp flanks (i.e. daylighted landslide scars). Over 1350 landslides were mapped.

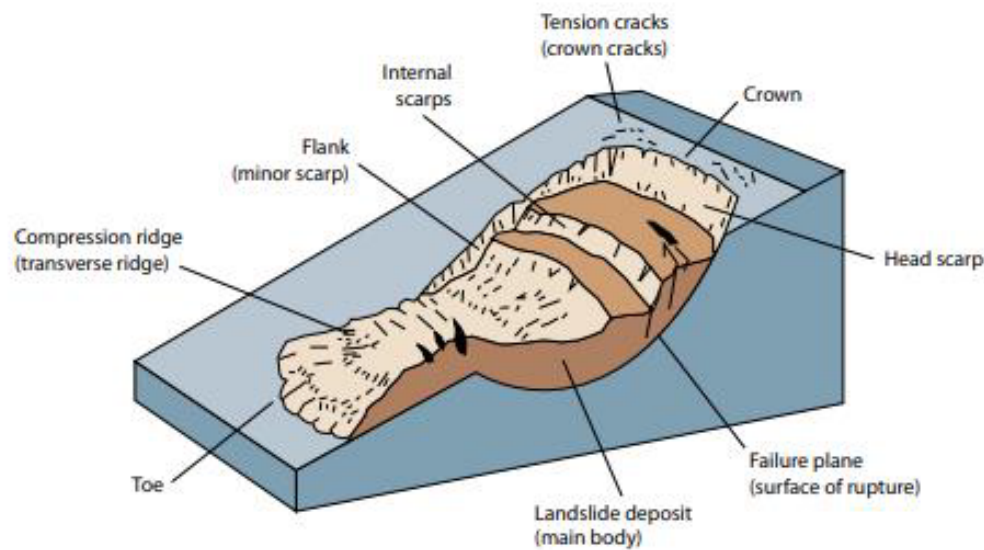
### ***Landslide Mapping Protocols***



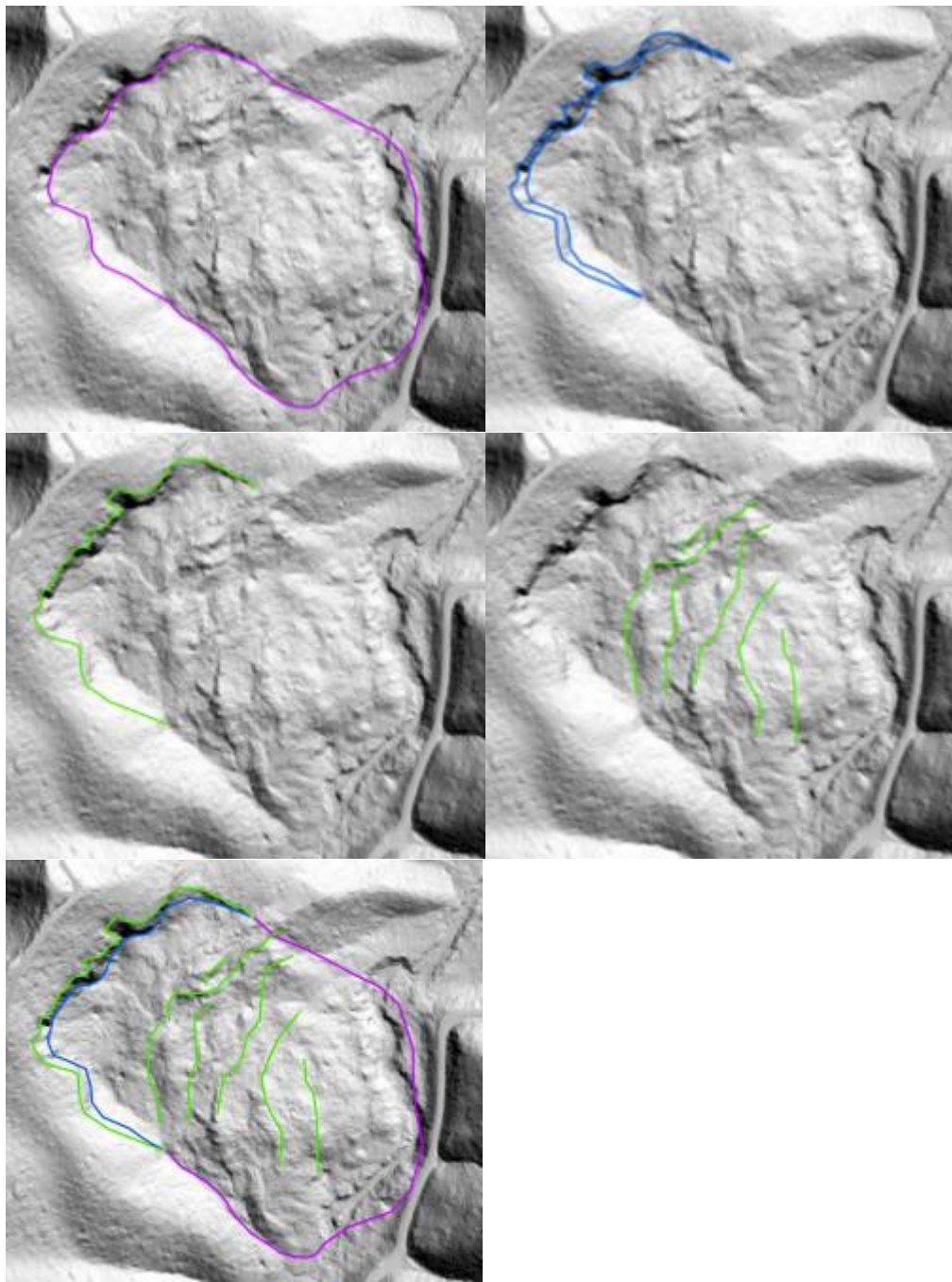
Three shapefiles were created to map the landslides in the Elliott State Research Forest (ESRF) using a template provided by the Oregon Department of Geology and Mineral Industries (DOGAMI). The shapefiles associated with each landslide are linked, and each shapefile has an attribute table with many fields of metadata that can be filled out. Table O-1 lists the three shapefiles and includes a brief overview of their purpose in this inventory. Figure O-1 is a graphic of the different features that are commonly observed in a classic landslide, and Figure O-2 is an example of a mapped landslide in this inventory highlighting these different features.

**Table O-1:** Overview of the three shapefiles used to map landslides for this inventory

Deposits	This is a polygon shapefile that outlines the material that has moved during the landslide.
Scarp_Flanks	This is a polygon shapefile that outlines the head scarp and flanks of the landslide, which are the areas of exposed ground above and on the sides of the slide where the material has moved away from. This polygon will trace the top of the deposit shapefile in part but will never overlap it.
Scarps	This is a polyline shapefile that traces the top of each scarp/flank, and any internal scarps that can be observed.



**Figure O-2:** Typical landslide features used in mapping process (credit: Burns and Madin 2009).



**Figure O-3:** Images a. – e. are screenshots of a landslide within the inventory that have distinct features. Image a. includes the outline of the deposit, image b. includes the outline of the head scarp and side flanks, image c. includes the tracing of the tip of the head scarp/flanks, image d. includes the mapping of internal scarps, and image e. is a screenshot of what the landslide looks like in the inventory after all the features have been mapped.

## Attribute Tables

Tables O-2 to O-4 list the fields in the attribute tables associated with each shapefile that are filled out during the completion of this inventory, as well as a quick description of each field including field units. The fields that were left empty are listed below each table. More information about each field, including the fields that were left blank, can be found in Appendix A of Burns and Madin’s landslide mapping protocol (2009).

**Table O-2:** Name and description of field that were filled out for the Deposit shapefile.

OBJECTID	Unique number automatically assigned to each new polygon, polyline, or point added to a shape file.
SHAPE	Automatic designation of each new feature as a polygon, polyline, or point.
SHAPE_Length	Automatic calculation of the perimeter of each new feature. Units: feet.
SHAPE_Area	Automatic calculation of the area of each new feature. Units: square feet.
UNIQUE_ID	Unique name assigned to each landslide used to link landslide features between shapefiles. i.e. the unique ID of a landslide deposit will match the unique ID of the scarp/flank polygon for the same landslide, and any scarp polylines for the same landslide.
TYPE_MOVE	Type of movement, see figure O-3.
MOVE_CLASS	Movement classification, see figure O-4.
CONFIDANCE	Confidence of landslide identification, see figure O-5.

SLOPE	Average mean slope of landslide calculated using the zonal statistics tool in ArcGIS.
FAIL_DEPTH	Estimated depth of failure calculated using the relationship $\text{Depth} = \text{Volume}/\text{Area}$ . Units: feet.
AREA	Area of landslide deposit calculated by simply copying the value calculated in the SHAPE_Area field. Units: feet.
VOLUME	Estimated volume of the landslide deposit using a relationship between volume and area proposed in Guzzetti et al. (2009). Units: cubic feet.
Global_ID	Code automatically assigned to each new polygon, polyline, or point describing its location.

Attribute columns included in the DOGAMI template that were not filled out in this inventory: MOVE\_CODE, AGE, DATE\_MOVE, NAME, GEOL, FAN\_HEIGHT, HS\_HEIGHT, DEEP\_SHAL, HS\_IS1, IS1-IS2, IS2-IS3, IS3-IS4, HD\_AVE, DIRECT, QUADNAME.

**Table O-3:** Name and description of field that were filled out for the Scarp\_Flank shapefile.

OBJECTID	Unique number automatically assigned to each new polygon, polyline, or point added to a shape file.
SHAPE	Automatic designation of each new feature as a polygon, polyline, or point.
UNIQUE_ID	Unique name assigned to each landslide used to link landslide features between shapefiles.
SHAPE_Length	Automatic calculation of the perimeter of each new feature. Units: feet.
SHAPE_Area	Automatic calculation of the area of each new feature. Units: square feet.



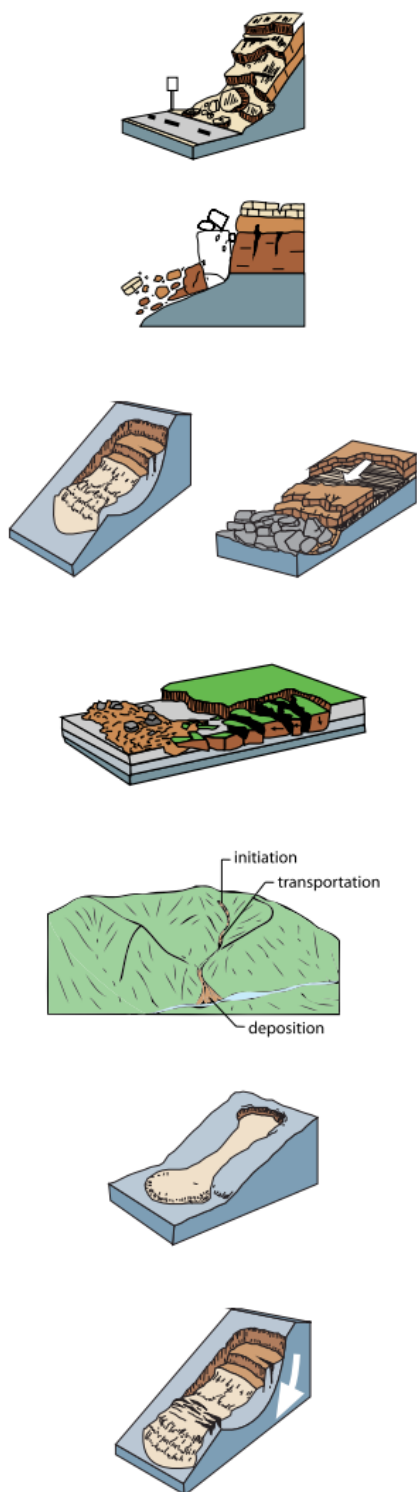
Global_ID	Code automatically assigned to each new polygon, polyline, or point describing its location.
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Attribute columns included in the DOGAMI template that were not filled out in this inventory: CONFIDENCE, AGE, HS\_HEIGHT, FAIL\_DEPTH, DEEP\_SHAL, QUADNAME.

**Table O-4:** Name and description of field that were filled out for the Scarp shapefile.

OBJECTID	Unique number automatically assigned to each new polygon, polyline, or point added to a shape file.
SHAPE	Automatic designation of each new feature as a polygon, polyline, or point.
UNIQUE_ID	Unique name assigned to each landslide used to link landslide features between shapefiles.
SHAPE_Length	Automatic calculation of the perimeter of each new feature. Units: feet.
Global_ID	Code automatically assigned to each new polygon, polyline, or point describing its location.

All attribute columns included in the DOGAMI template were filled out in this inventory.



**Falls** are near-vertical, rapid movements of masses of materials, such as rocks or boulders. The rock debris sometimes accumulates as talus at the base of a cliff.

**Topples** are distinguished by forward rotation about some pivotal point, below or low in the mass.

**Slides** are downslope movement of soil or rock on a surface of rupture (failure plane or shear-zone).

- **Rotational** slides move along a surface of rupture that is curved and concave.
- **Translational** slides displace along a planar or undulating surface of rupture, sliding out over the original ground surface.

**Spreads** are commonly triggered by earthquakes, which can cause liquefaction of an underlying layer and extension and subsidence of commonly cohesive materials overlying liquefied layers.

**Channelized Debris Flows** commonly start on a steep, concave slope as a small slide or earth flow into a channel. As this mixture of landslide debris and water flows down the channel, it picks up more debris, water, and speed, and deposits in a fan at the outlet of the channel.

**Earth Flows** commonly have a characteristic “hourglass” shape. The slope material liquefies and runs out, forming a bowl or depression at the head.

**Complex** landslides are combinations of two or more types. A common complex landslide is a slump-earth flow, which usually exhibit slump features in the upper region and earth flow features near the toe.

**Figure O-4:** Overview of different landslide movements (credit: Burns and Madin 2009).

Type of Movement	Type of Material		
	Rock	Debris	Soil
Fall	RF rock fall	DF debris fall	EF earth fall
Topple	RT rock topple	DT debris topple	ET earth topple
Slide-rotational	RS-R rock slide-rotational	DS-R debris slide-rotational	ES-R earth slide-rotational
Slide-translational	RS-T rock slide-translational	DS-T debris slide-translational	ES-T earth slide-translational
Lateral spread	RSP rock spread	DSP debris spread	ESP earth spread
Flow	RFL rock flow	DFL debris flow	EFL earth flow
Complex	C complex or combinations of two or more types (for example, ES-R + EFL)		

**Figure O-5:** Image of a table included in Burns and Madin (2009) listing different landslide movements. The first column are the movement types used to fill out the TYPE\_MOVE attribute field, and the next three columns were used to fill out the MOVE\_CLASS attribute field.

Landslide Feature	Points	Confidence	Total Points
Head scarp	0-10	High	> 30
Flanks	0-10	Moderate	11–29
Toe	0-10	Low	≤ 10
Internal scarps, sag ponds or closed depressions, compression ridges, etc.	0-10 *		

\*Applied only once so that total points do not exceed 40.

**Figure O-6:** Image of a table in Burns and Madin (2009) used to assist assigning a confidence to each landslide identification.

## Other Datasets

Four additional datasets were included in this inventory and were clipped to the extent of the ESRF. Table O-5 lists these datasets and includes a brief description of each.

**Table O-5:** Overview of additional datasets included in the inventory.

Deposits_SLIDO	Deposits within the ESRF that were mapped by DOGAMI in their Statewide Landslide Information Database for Oregon (SLIDO).
Scarp_Flanks_SLIDO	Scarp/flank polygons within the ESRF that were mapped by DOGAMI in SLIDO.
Scarps_SLIDO	Scarp polylines within the ESRF that were mapped by DOGAMI in SLIDO.
Historic_Landslide_Points_SLIDO	Compilation of points indicating the centers of known landslides that DOGAMI has compiled from multiple sources and added to SLIDO, trimmed to the ESRF boundary.
Index_LS_Studies	Compilation of points indicating the centers landslides that have detailed and publicly available studies, trimmed to the ESRF boundary.

## Appendix O: References Cited

Beeson, H.W., Flitcroft, R.L., Fonstad, M.A. and Roering, J.J. 2018. Deep-seated landslides drive variability in valley width and increase connectivity of salmon habitat in the Oregon Coast Range. JAWRA Journal of the American Water Resources Association, 54(6), pp.1325-1340.

Bigelow, P.E., Benda, L.E., Miller, D.J. and Burnett, K.M. 2007. On debris flows, river networks, and the spatial structure of channel morphology. Forest Science, 53(2), pp.220-238.

May, C., Roering, J., Eaton, L.S. and Burnett, K.M. 2013. Controls on valley width in mountainous landscapes: The role of landsliding and implications for salmonid habitat. Geology, 41(4), 503-506.

Swanson, F.J. and Dyrness, C.T. 1975. Impact of clear-cutting and road construction on soil erosion by landslides in the western Cascade Range, Oregon. Geology, 3(7), 393-396.



Vascik, B.A., Booth, A.M., Buma, B. and Berti, M. 2021. Estimated amounts and rates of carbon mobilized by landsliding in old-growth temperate forests of SE Alaska. *Journal of Geophysical Research: Biogeosciences*, 126(11), e2021JG006321.

Wipfli, M.S. and Gregovich, D.P. 2002. Export of invertebrates and detritus from fishless headwater streams in southeastern Alaska: implications for downstream salmonid production. *Freshwater Biology*, 47(5), 957-969.

## Appendix P. Carbon and Climate Change Research at the Elliott State Research Forest

The spatial and temporal scope of research on the ESRF make it an ideal location for investigating a broad range of science questions relating to Coast Range forests, forest management, carbon and climate change. This appendix builds on the research outlined in the ESRF Research Proposal by briefly describing the issues and details around three key research questions. This is by no means a complete list. Numerous other related topics and potential study designs could be described and accommodated under the Triad and nested research umbrella.

*Melissa Lucash, Terrestrial Ecosystems Ecology and Landscapes Lab, University of Oregon*  
*Neil Williams, Terrestrial Ecosystems Ecology and Landscapes Lab, University of Oregon*

**Research Question 1: How does the spatial distribution of timber harvesting influence total forest carbon storage and long-term carbon sequestration rates at sub-watershed (meso) scales?** Empirical and simulation-based studies indicate that disturbance (e.g., harvesting) intensity is a primary control on forest carbon storage at stand and landscape scales. The spatial distribution of harvesting activities *for a given volume of harvest removals* may also influence forest carbon storage and sequestration for biological (e.g., shading, edge effects) and logistical (e.g., road layout, harvesting disturbance) reasons but has received less study. This research gap is particularly acute for carbon assessment at larger spatial scales – scales that are operationally significant for timber harvest planning and terrestrial carbon accounting. The Triad design at the ESRF provides a rare opportunity to evaluate the large-scale effects, on forest carbon sequestration and storage (live/dead vegetation and soils), of spatial distribution in timber harvesting stemming from differences in the proportional allocation of different silvicultural systems across the landscape. Simulation modeling and field sampling both have a role to play in this work. *Relevance:* this work contributes to an understanding of how climate change mitigation objectives might be achieved and balanced with other objectives on public forestland and large private and industrial timberlands.

**Research Question 2: In what ways might the combined effect of climate change and disturbance alter forest structure and composition in the Oregon Coast Range?** Douglas-fir-dominated forests of the Oregon Coast Range are less likely to be exposed to severe disturbances associated with climatic change, and are potentially more resistant to this change, than certain other Pacific Northwest forest types. Unprecedented drought and heat effects coupled with pest and pathogen outbreaks pose a risk to the natural resource value of these forests. Ongoing and prior research is being conducted to quantify the effects of a range of global change phenomena on Coast Range forests and species. Much of this work necessarily focuses on individual stressors. However, in reality, many stressors will occur simultaneously or in sequence with potential compounding effects. Simulation modeling can be used to capture

many of these integrative effects on forest dynamics and ecosystem service provision and will be conducted on the ESRF. *Relevance:* Improving our understanding of potential climate change effects on Coast Range forests is fundamental to all elements of forest management (passive or active) for a wide range of ecosystem services.

**Research Question 3: What does adaptive silviculture for climate change in coastal Douglas-fir forests look like now, in the near-term (~ 2030 – 2050) and over the longer term (~ 2070 – 2100), and under what circumstances do climate adaptive strategies also confer climate change mitigation benefits?** Adaptive silviculture for climate change (ASCC) provides a framework for collaborative development and implementation of strategies designed to reduce climate and disturbance risks over varying timescales. Existing manipulative and observational studies in west-side forests have yielded information to inform the development of ASCC strategies that include changes in stand density, species (or planting stock seed zones) and inter/intra-stand spatial dynamics, and the ESRF presents an opportunity to synthesize and integrate lessons learnt into novel silvicultural approaches to manage changing and uncertain future conditions. Also of interest are the environmental conditions (e.g., press and pulse disturbances) under which ASCC strategies may provide net carbon storage benefits relative to a conventional silvicultural baseline. *Relevance:* ASCC can provide tangible benefits for better understanding ecosystem service supply. Further, lessons learnt from its implementation on the ESRF will integrate west-side forests into an emerging network of silvicultural demonstration sites throughout North America.

## Appendix Q. Forest Adaptation Strategies, Approaches, and Tactics

This appendix describes broad options of *resistance*, *resilience*, and *transition* for adapting forests to climate change, then a process for downscaling from this conceptual basis to stand and site-scale strategies, approaches, and tactical actions (Millar et al. 2007; Swanston et al. 2016). This information is meant to outline the types of strategies and approaches available to ESRF researchers and managers when planning adaptive forest operations and research within the context of climate change and is not a prescriptive list.

Resistance actions improve ecosystem defenses against anticipated changes or directly defend the ecosystem against disturbance to maintain relatively unchanged conditions. This option may be effective in the short term (mid-century or sooner) but supporting persistence of the existing ecosystem will likely require greater resources and effort over the long term as climate changes intensify. Resistance actions may also be most effective in ecosystems (or portions of them) with low vulnerability to climate change impacts. As an ecosystem persists into an unsuitable climate, the risk of the ecosystem undergoing irreversible change (such as through a severe disturbance) increases over time.

Resilience actions enhance the ability of the ecosystem to bounce back from disturbance and tolerate changing environmental conditions, albeit with sometimes fluctuating populations. Resilience actions may be most effective in systems that can already tolerate a wide range of environmental conditions and disturbance. Like the resistance option, this option may be most effective in the short term and may be subject to increasing risk over time. Resilience is effective until the degree of change exceeds the ability of an ecosystem to cope, resulting in transition to another state.

Transition actions intentionally anticipate and accommodate change to help ecosystems adapt to fundamental changes and shift to new conditions. Whereas resistance and resilience actions foster persistence of the current ecosystem, transition actions intentionally facilitate transformation of the current ecosystem into a different ecosystem with clearly different characteristics. Transition actions may be appropriate in ecosystems assessed as being highly vulnerable across a range of plausible future climates, where resistance and resilience actions are judged as being unable to maintain key ecosystem attributes and functions. Transition actions are typically designed for long-term effectiveness and are often phased into broader management plans that predominantly have a shorter-term focus on resilience actions.

These options of *resistance*, *resilience*, and *transition* serve as the broadest level in a continuum of adaptation responses to climate change. Figure Q-1 (below) provides examples of forest climate change adaptation strategies and their relationships to this range of adaptation responses.



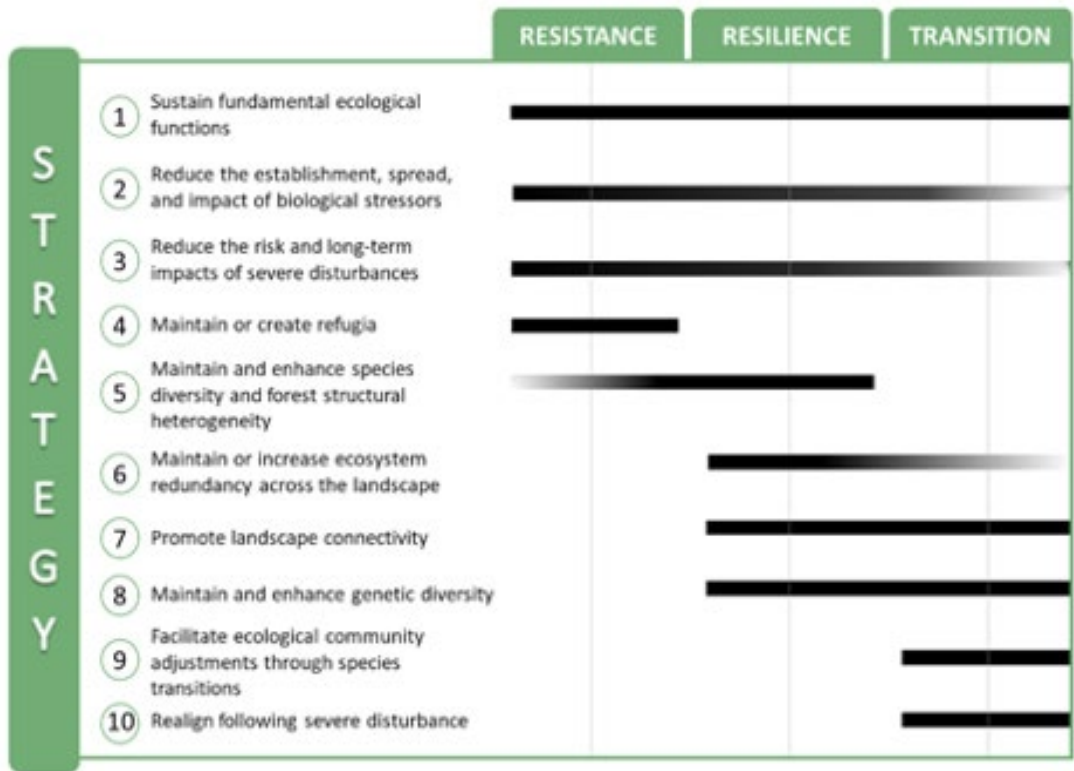


Figure Q-1. Climate change adaptation strategies work to achieve three broad adaptation options: **resistance**, **resilience**, and **transition**. Strategies may be used to achieve one or more options. A solid line indicates a strong relationship between an option and a strategy, whereas fading indicates that the strategy relates to that option under some circumstances. A strategy may work under multiple options but implementation is likely to be achieved through very different approaches and tactics (Swanston et al. 2020).

Within the conceptual framework of *resistance*, *resilience* and *transition*, a series of progressively more detailed and focused adaptation *strategies*, *approaches* and *tactics* can be nested underneath (Figure Q-2.)

In this context, a **strategy** is a broad adaptation response that is applicable across a variety of resources and sites, hydrologic and ecological conditions, and overarching management goals.

An **approach** is a more detailed adaptation response specific to a resource issue, site condition, and management objectives.

**Tactics** are the most specific adaptation response, providing prescriptive direction about what actions can be applied on the ground, and how, where, and when.

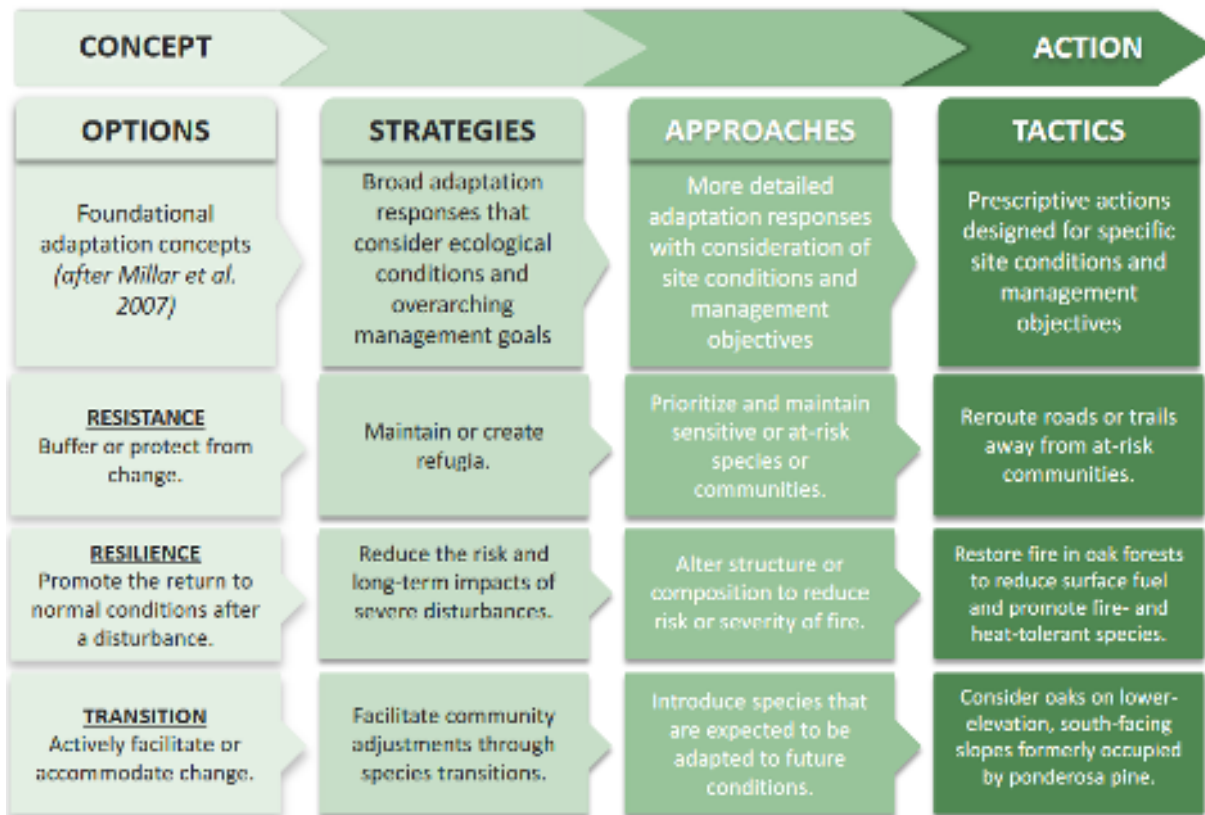


Figure Q-2. A continuum of adaptation actions to address needs at appropriate scales and levels of management (top row) and examples of each level of action (lower row) (Swanston et al. 2020).

Adaptive strategy and tactic lists or “menus” have been designed to help managers move from broad ideas to specific actions. The lists are intended to move discussion from the range of options available to selection of best options and how to apply them in specific areas. Not all strategies will be applicable or relevant in all situations. Some strategies cannot be applied at the same time as other strategies. What makes sense for one stand or subwatershed may not make sense in others, even within the same larger planning area (ASCC website 2022).

The following “menu” of actions to help forests adapt to climate change was developed by Swanston et al. (2016). Managers select actions best suited to their specific management goals and objectives, informed by location-specific factors, science information and manager expertise. Managers are also encouraged to consider additional actionable tactics appropriate for their goals, opportunities and constraints.

**Strategy 1: Sustain fundamental ecological functions**

*Strategy 1 Approaches:*

- Reduce impacts to soils and nutrient cycling
- Examples:

- Alter the timing of forest operations to reduce potential impacts on water, soils, and residual trees, especially in areas that rely on particular conditions for operations that may be affected by a changing climate (e.g., dry conditions).
  - Modify forest operations techniques and equipment to minimize soil compaction, rutting, or other impacts on water, soils, and residual trees.
  - Retain coarse woody debris to maintain moisture, soil quality, and nutrient cycling.
  - Restore native herbaceous groundcover following management activities in order to retain soil moisture and reduce erosion.
- Maintain or restore hydrology.
  - Upgrade culvert size and clean culverts regularly to accommodate changes in peak flow and thus reduce damage to infrastructure and the environment during heavy rain events.
  - Decommission or temporarily close roads to reduce erosion and sedimentation and to restore permeability and soil hydrology.
- Maintain or restore riparian areas
  - Restoring or promoting a diversity of tree and plant species to increase stream shading, provide a source of woody debris, stabilize the soil, and provide habitat and connectivity for wildlife
  - Creating buffers along riparian areas with reduced or no harvest based on the landform, hydrology, and vegetation of the riparian zone in addition to any recommended buffer distance
  - Reconnecting floodplains to rivers and restoring natural floodplain conditions and associated native habitats (e.g., bottomland forest, wetlands, and wet prairie and other grasslands) in order to restore fluvial processes
- Reduce competition for moisture, nutrients, and light
  - Using herbicide or mechanical thinning to prevent the encroachment of woody competitors and invasive species, especially after disturbance
  - Thinning forest stands to remove crowded, damaged, or stressed trees in order to reduce competition for light, nutrients, and water
  - Using prescribed fire to maintain growing space for fire-tolerant species or to increase nutrient turnover
- Restore or maintain fire in fire-adapted ecosystems
  - Using prescribed fire to reduce ladder fuels, invasive species, and understory competition
  - Shifting prescribed burn seasons to align with projected seasonal precipitation changes, thereby reducing the risk of unintended wildfire conditions.

**Strategy 2: *Reduce the impact of biological stressors***

- Maintain or improve the ability of forests to resist pests and pathogens

- Thinning to reduce the density of a pest's host species in order to discourage infestation, based on the knowledge that species are especially susceptible to pests and pathogens at particular stocking levels
  - Creating a diverse mix of forest or community types, age classes, and stand structures to reduce the availability of host species for pests and pathogens
  - Using impact models and monitoring data to anticipate the arrival of pests and pathogens and prioritize management actions
- Prevent the introduction and establishment of invasive plant species and remove existing invasive species
  - Increasing monitoring for known or potential invasive species to ensure early detection, especially at trailheads, along roads, and along other pathways known for infestation
  - Eradicating existing populations or seed sources (e.g., upstream) of invasive plants through physical or chemical treatments
  - Maintaining closed-canopy conditions to reduce the ability of light-loving invasive species to enter the understory
  - Educating personnel and the public on identification and eradication of current and potential invasive species.
- Manage herbivory to promote regeneration of desired species
  - Installing physical barriers to prevent herbivory of seedlings
  - Promoting abundant regeneration of multiple species in order to supply more browse than herbivores are expected to consume
  - Using tree tops from forest harvest or plantings of nonpalatable tree species as locations for “hiding” desirable species from herbivores to reduce browse pressure
  - Partnering with state wildlife agencies to monitor herbivore populations

**Strategy 3: *Reduce the risk and long-term impacts of severe disturbances***

- Alter forest structure or composition to reduce risk or severity of wildfire
  - Using prescribed fire and thinning to reduce surface fuels, increase height to live crown, decrease crown closure, and create a more open forest structure that is expected to be less vulnerable to severe wildfire
  - Promoting fire-resistant species, such as hardwoods, in buffer zones between more flammable conifers to slow the movement of wildfires
  - Physically removing dead or dying trees or other vegetation to reduce surface and ladder fuels, while minimizing exposure to invasive plants, pests, or pathogens.
- Establish fuel breaks to slow the spread of catastrophic fire
  - Establishing fuel breaks along roads, power lines, and other existing features in order to reduce the spread of wildfire while minimizing additional fragmentation



- Alter forest structure to reduce severity or extent of wind and ice damage
  - Retaining trees at the edge of a clearcut or surrounding desirable residual trees to help protect trees that have not been previously exposed to wind
  - Conducting forest harvest over multiple entries in order to gradually increase the resistance of residual trees to wind
  - Using directional felling, cut-to-length logging, and other harvest techniques that minimize damage to residual trees
  - Creating canopy gaps that have an orientation and shape informed by the prevailing winds in order to reduce the risk of windthrow.
- Promptly revegetate sites after disturbance
  - Planting species expected to be adapted to future conditions and resistant to insect pests or present pathogens
  - Creating suitable physical conditions for natural regeneration through site preparation
  - Monitoring areas of natural regeneration on a more frequent basis, and prioritizing planting or seeding where natural regeneration is slow to succeed

**Strategy 4: *Maintain or create refugia***

- Prioritize and maintain unique sites
  - Identifying and managing cooler and wetter locations that are expected to be more resistant to changes in climate as refugia for maintaining native plant communities into the future
  - Identifying and protecting a network of sheltered mountain slopes, valleys, or forests with continuous shading canopy
  - Protecting areas that have been generally undisturbed by humans, such as those within old-growth forest, in order to preserve a reference condition or legacy.
- Prioritize and maintain sensitive or at-risk species or communities
  - Using impact models and monitoring data to identify and prioritize management of species expected to decline under future conditions
  - Retaining individuals of a priority species across many diverse sites representing various environmental conditions or within differing forest types
  - Monitoring regeneration to detect migration of plant populations or communities to adjacent areas.

**Strategy 5: *Maintain and enhance species and structural diversity***

- Promote diverse age classes
  - Emulating aspects of disturbances through forest management techniques such as variable-density treatments or irregular return intervals in order to encourage the development of multiple age cohorts
  - Focusing salvage operations on creating desired residual stand structures following disturbance

- Using site scarification, planting, or other techniques to support adequate regeneration
  - Maintaining a variety of age classes of a given forest type across a larger landscape.
- Maintain and restore diversity of native species
  - Using silvicultural treatments to promote and enhance diverse regeneration of native species
  - Transitioning plantations to more complex systems by underplanting or promoting regeneration of a variety of native species expected to do well under future conditions
  - Planting desired native species within an area that is otherwise expected to regenerate naturally in order to add diversity
  - Planting species with diverse timing of phenological events (e.g., flowering, fruiting, leaf out, leaf drop) to provide necessary resources over a longer timeframe to forest-dependent wildlife species.
- Retain biological legacies
  - Retaining the oldest and largest trees with good vigor during forest management activities
  - Retaining survivors of pest or disease outbreaks, droughts, windthrow events, or other disturbances during salvage operations
  - Retaining individual trees of a variety of uncommon species to maintain their presence on the landscape.
- Establish reserves to maintain ecosystem diversity
  - Identifying areas with high diversity or other desirable attributes that can be set aside as a reserve on an existing ownership
  - Setting a minimum requirement for percentage of land in reserve
  - Prioritizing areas where riparian corridors connect core areas to other reserves and habitats
  - Providing a large reserve based on a species' known optimum conditions in order to preserve a species.

**Strategy 6: *Increase ecosystem redundancy across the landscape***

- Manage habitats over a range of sites and conditions
  - Restoring or increasing a community type on a variety of soil types and across a range of topographic positions
  - Implementing a variety of forest management activities or silvicultural prescriptions across multiple stands or areas with similar starting conditions in order to diversify forest conditions and evaluate different management approaches
  - Coordinating with partners to manage an at-risk species or community existing on a variety of suitable sites.

- Expand the boundaries of reserves to increase diversity
  - Restoring or conserving land directly adjacent to established reserves
  - Developing a network of reserves with adjacent landowners with shared conservation goals
  - Designating buffer zones of low-intensity management around core reserve areas and between different land uses.

**Strategy 7: *Promote landscape connectivity***

- Reduce landscape fragmentation
  - Using geospatial information to identify new and existing migration corridors
  - Restoring native vegetation and vegetation structure in degraded areas within the forested matrix
  - Establishing or expanding reserves adjacent to other forest blocks to form a connective network of a few large reserves, many small reserves along a climatic gradient, or a combination of large and small reserves close to each other
- Maintain and create habitat corridors through reforestation or restoration
  - Establishing or restoring forest cover along rivers or ridges to build on natural linear features that connect larger forests
  - Working with partners on the landscape to identify high-priority sites to protect for landscape-scale corridors or habitat.

**Strategy 8: *Maintain and enhance genetic diversity***

- Use seeds, germplasm, and other genetic material from across a greater geographic range
  - Using mapping programs to match seeds collected from a known origin to planting sites based on climatic information
  - Planting seedlings germinated from seeds collected from various locations throughout a species' native range
- Favor existing genotypes that are better adapted to future conditions
  - Planting stock from seeds collected from local trees that exhibit drought tolerance, pest resistance, or other desirable qualities
  - Retaining some survivors of a die-back event, such as drought-induced mortality or pathogenic blight, rather than salvage harvesting all trees in an affected area
  - Creating and monitoring areas of natural regeneration in order to identify and promote well-adapted phenotypes

**Strategy 9: *Facilitate community adjustments through species transitions.***

- Favor or restore native species that are expected to be adapted to future conditions
  - Underplanting a variety of native species on a site to increase overall species richness and provide more options for future management

- Favoring or establishing more drought- and heat-tolerant species on narrow ridge tops, south-facing slopes with shallow soils, or other sites that are expected to become warmer and drier
- Establish or encourage new mixes of native species
  - Planting or seeding a mixture of native species currently found in the area that are not typically grown together but may be a suitable combination under future conditions
- Guide changes in species composition at early stages of stand development
  - Preventing and removing undesired species, including invasive nonnative or aggressive native species, in order to reduce competition for moisture, nutrients, and light
  - Planting or seeding sufficient stocks of desired species before undesirable species have the chance to establish or compete
  - Performing timber stand improvement to favor and promote the growth of desirable growing stock
- Protect future-adapted seedlings and saplings
  - Using tree tops from forest harvest or plantings of nonpalatable tree species as locations for “hiding” desirable species from herbivores to reduce browse pressure
  - Preventing and removing undesired species, including invasive nonnative or aggressive native species, in order to reduce competition for moisture, nutrients, and light
  - Restricting recreation or management activities that may have the potential to damage regeneration
- Disfavor species that are distinctly maladapted
  - Protecting healthy legacy trees that fail to regenerate while deemphasizing their importance in the mix of species being promoted for regeneration.
- Manage for species and genotypes with wide moisture and temperature tolerances
  - Favoring species that are currently present that have wide ecological amplitude and can persist under a wide variety of climate and site conditions
  - Planting or otherwise promoting species that have a large geographic range, occupy a diversity of site conditions, and are projected to have increases in suitable habitat and productivity
  - Identifying and promoting species that currently occupy a variety of site conditions and landscape positions
- Introduce species that are expected to be adapted to future conditions



- Planting drought-tolerant species on sites within the current range that are expected to become drier and that have not been historically occupied by those species

**Strategy 10: *Realign ecosystems after disturbance***

- Promptly revegetate sites after disturbance
  - Planting a variety of future-adapted species during revegetation efforts to ensure diverse regeneration and provide options for future management
  - Monitoring areas of natural regeneration on a more frequent basis, and prioritizing planting or seeding where natural regeneration is slow to succeed
- Allow for areas of natural regeneration to test for future-adapted species
  - Monitoring naturally revegetated areas for changes in species composition, productivity, and other factors
  - Controlling competition from undesirable tree species and invasive species to enhance regeneration of desired tree species
  - Removing small-diameter residual trees to reduce competition, increase sunlight, and improve seed germination potential
- Realign significantly disrupted ecosystems to meet expected future conditions
  - Planting species expected to be better adapted to future conditions, especially where natural regeneration in forests affected by disturbance is widely failing

**Appendix Q References Cited**

Millar, C.I., Stephenson, N.L. and Stephens, S.L. 2007. Climate change and forests of the future: managing in the face of uncertainty. *Ecological Applications*, 17(8), pp.2145-2151.

Swanston, C.W.; Janowiak, M.K.; Brandt, L.A.; Butler, P.R.; Handler, S.D.; Shannon, P.D.; Derby Lewis, A.; Hall, K.; Fahey, R.T.; Scott, L.; Kerber, A.; Miesbauer, J.W.; Darling, L.; Parker, L. and St. Pierre, M. 2016. Forest adaptation resources: Climate change tools and approaches for land managers, 2nd ed. Gen. Tech. Rep. NRS-GTR-87-2. Newtown Square, PA: U.S. Dept of Agriculture, Forest Service, Northern Research Station. 161 p. <https://doi.org/10.2737/NRS-GTR-87-2>

Swanston, C.W.; Brandt, L.A.; Butler-Leopold, P.R.; Hall, K.R.; Handler, S.D.; Janowiak, M.K.; Merriam, K.; Meyer, M.; Molinari, N.; Schmitt, K.M.; Shannon, P.D.; Smith, J.B.; Wuenschel, A.; Ostoja, S.M. 2020. Adaptation strategies and approaches for California forest ecosystems. USDA California Climate Hub Technical Report CACH-2020-1. Davis, CA: U.S. Dept. of Agriculture, Climate Hubs. 65 p.

## Appendix R. Marbled Murrelet Power Analysis

To aid in study design, a power analysis was implemented using data simulations to detect treatment effects on murrelet nest success as a function of potential sampling scenarios. The power analysis presented here uses previously recorded data on daily probabilities of murrelet nest survival to evaluate power under various study designs. Overall, the power analysis indicated that effects of management treatments will need to reduce the odds of daily nest survival by at least 50% (i.e., a very strong effect size) in order to have a power of > 0.5 to detect significant treatment effects, given the proposed sampling design. For this reason, it is imperative to monitor additional indicators of murrelet habitat and productivity, in addition to nest success. Simulation assumptions and results are presented below.

### Simulation Assumptions

- There are 67 days from egg laying to fledging
  - 29 incubation days followed by 38 rearing days
- At least 1 nest can be found in each treatment and control site each year it is sampled
- Nest initiation and fledge/fail dates can be accurately assessed
- Effects of harvest treatment on daily survival do not vary by year
- Random site-level effects do not vary by year
- There are no random year effects on daily survival probability
- Nests in control sites will have similar daily survival probabilities to those we recorded in central Oregon as part of the Oregon marbled murrelet Project
  - $P(\text{surviving 1 day}) = 0.9811676$
  - $P(\text{fledging}) = (0.9811676)^{67} = 0.28$

### Variables in Simulations

- There are either 20 or 50 total sites (half treatment, half control)
- Baseline daily survival probabilities were slightly different between treatment and control sites to account for non-random sampling
  - Control sites
    - $P(\text{surviving 1 day}) = 0.981$
    - $P(\text{fledging}) = 0.28$
  - Treatment sites
    - $P(\text{surviving 1 day}) = 0.976$
    - $P(\text{fledging}) = 0.20$
- SD for random site effects = 0.2
  - Adds variability such that  $P(\text{Control nest fledging})$  ranges from ~0.13-0.45
- Three effect sizes for change in odds of daily success as a function of treatment
  - 10% reduction in odds
    - Fledging rate reduced from 0.28 to 0.24
  - 25% reduction in odds
    - Fledging rate reduced from 0.28 to 0.18
  - 50% reduction in odds

- Fledging rate reduced from 0.28 to 0.08
- 100 simulations per scenario

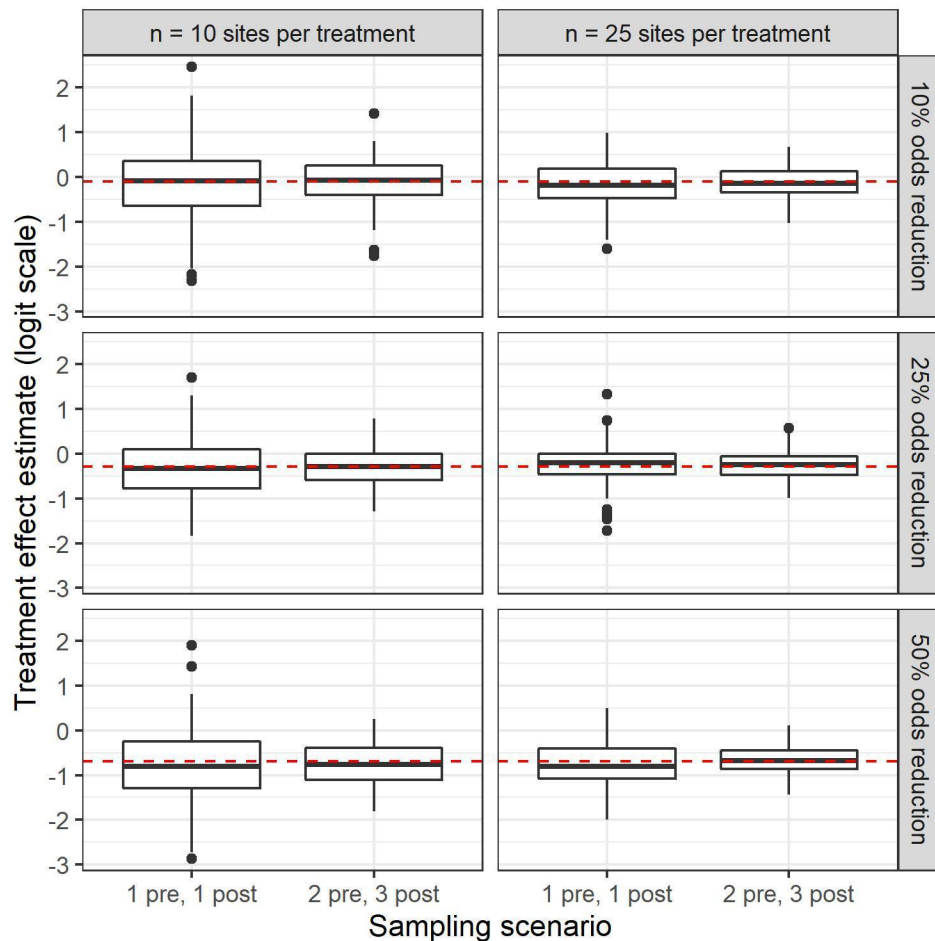


Figure R-1. The distribution of treatment effect estimates under all simulated scenarios. Regardless of the number of sites, treatment effect, or sampling scenario, parameter estimates were relatively unbiased (true value indicated by the red dashed line). Precision of those estimates was better with 25 sites per treatment relative to 10 sites per treatment. Precision was also improved when sites were sampled more times before and after treatment.

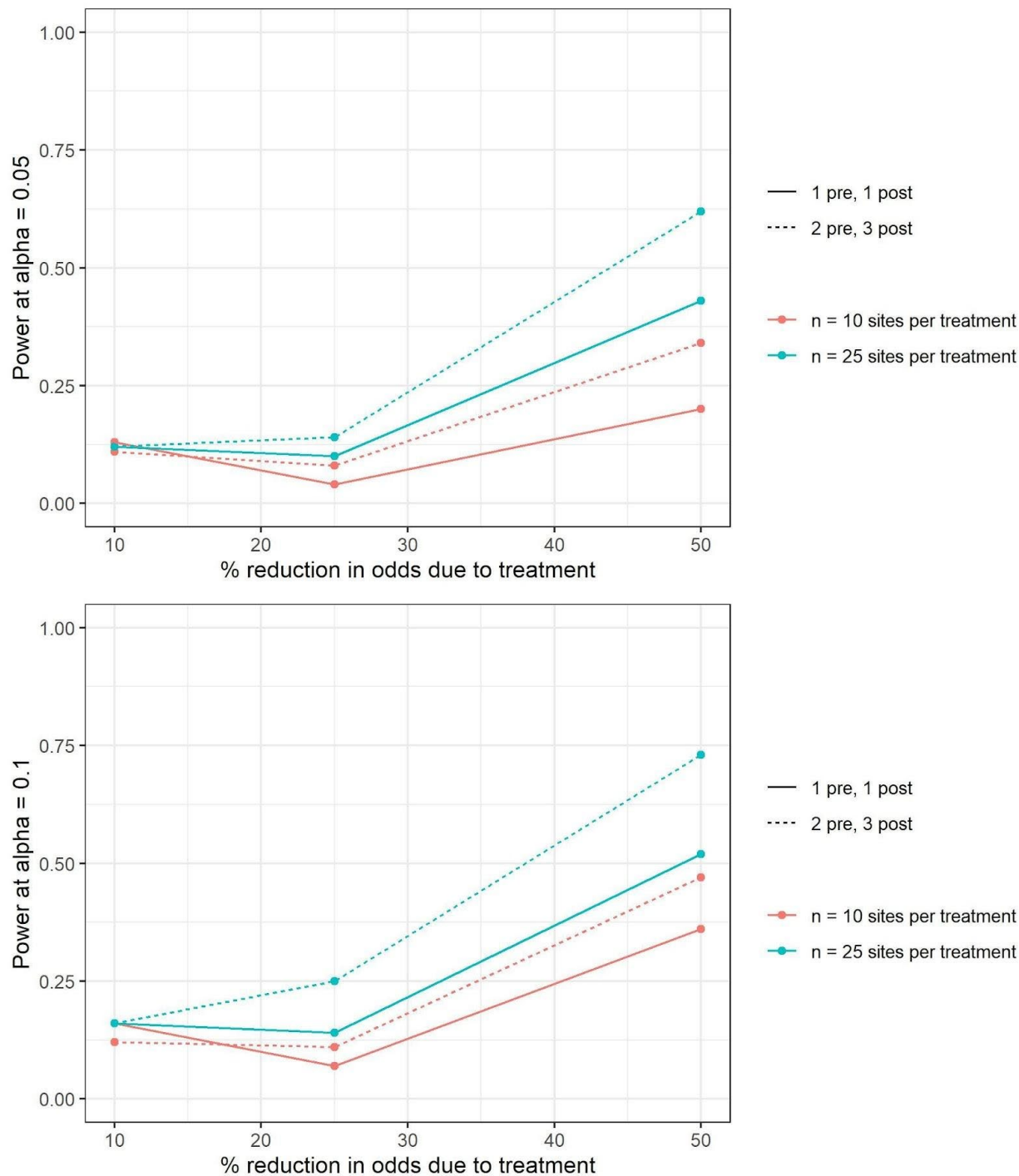


Figure R-2. Power to detect treatment effects based on number of sampling sites, sampling scenario, and % reduction in odds due to treatment for alpha = 0.05 (top) and alpha = 0.1. Power was calculated as the proportion of the time the null hypothesis (no treatment effect) was rejected out of 100 simulations.



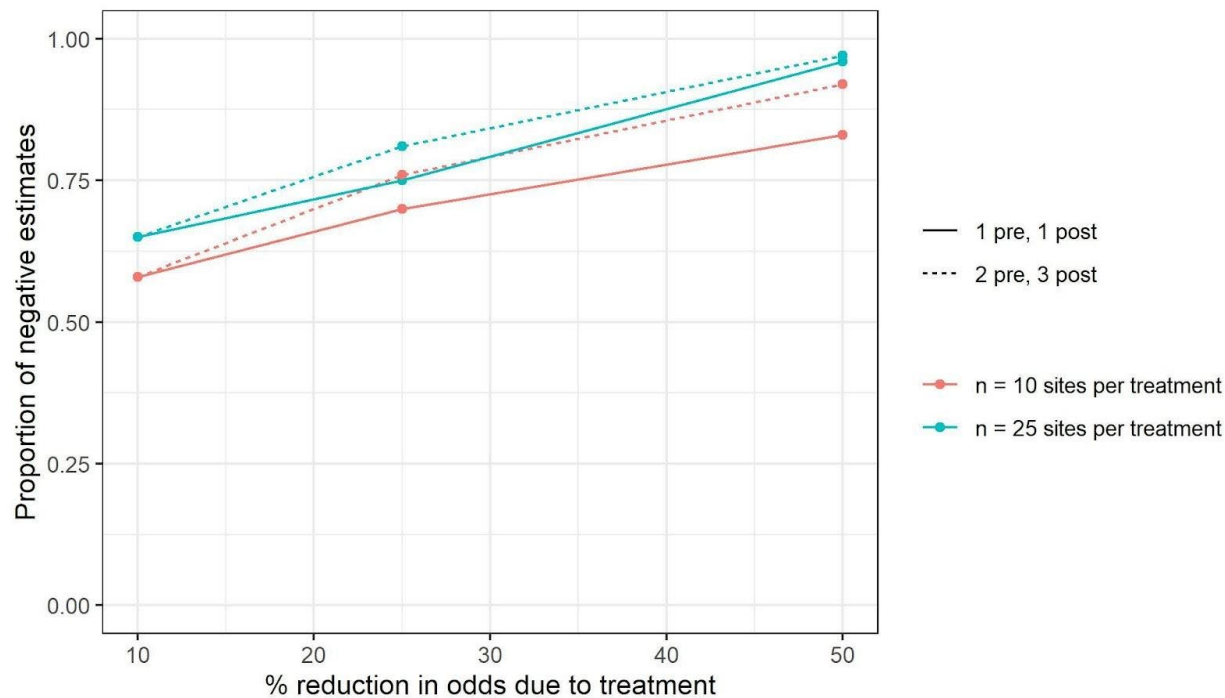


Figure R-3. The proportion of estimates that were negative (as they should be) based on number of sampling sites, sampling scenario, and % reduction in odds due to treatment. These proportions are based on 100 simulations per point on the figure.

## Appendix S: Modeling timber harvest induced edge effects on marbled murrelet (*Brachyramphus marmoratus*) habitat under a prospective timber harvest scenario on the Elliott State Research Forest

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### **Introduction**

The marbled murrelet (*Brachyramphus marmoratus*; hereafter murrelet or MAMU) is a small diving seabird that lives and breeds along the North American Pacific coast from the Aleutian Islands south to central California. The species is listed as threatened under the federal Endangered Species Act from the Canadian border south along the Washington, Oregon, and California coasts, and is listed as endangered under the Oregon Endangered Species Act.

Throughout its range the murrelet forages for small fish and invertebrates in shallow, near-shore waters. In Alaska murrelet may breed on coastal cliffs or talus slopes, but south of Alaska murrelet nest almost exclusively in mature and late-successional coniferous coastal forests up to 80 kilometers inland from their marine foraging habitat (Hamer and Nelson, 1995). During the breeding season murrelet molt into a mottled-brown plumage for camouflage in their forest nesting grounds. The female lays a single egg in a depression formed in moss, lichens, or litter that accumulate on large or deformed (mistletoe) platforms within the tree canopy (Hamer, 1995; Burger, 2002; McShane et al., 2004; Nelson et al., 2006). Murrelet do not build nests, and instead select a stable, flat nesting platform of sufficient width to support the egg and developing chick, generally  $\geq 10$  cm in diameter (Evans Mack et al., 2003). Thus, murrelet nest locations are physically limited to forests old enough to develop such features, typically at least 100 years of age with large, well-developed canopy structures (Hamer et al., 2021). Murrelet breeding pairs share and alternate incubation and foraging activities over 24-hour cycles. Once the egg hatches both parents make multiple trips each day between their marine foraging grounds and the nest site, bringing food for the growing nestling. At the end of the breeding cycle the young bird fledges and finds its way to marine foraging areas alone. Although adults are well camouflaged and are fast flyers, eggs and young are susceptible to predation at the nest location by both avian and mammalian predators.

Commercial harvest of late-successional forests over the past century has directly removed and fragmented large areas of murrelet breeding habitat throughout the coastal region of the Pacific Northwest (Valente et al., 2023; Betts et al., 2020; Nelson, 2020; Raphael et al., 2018). Moreover, contemporary forestry practices on commercial forests throughout the region maintain non-habitat conditions by harvesting forests at rotation cycles that preclude the development of older forests and canopy structures required by marbled murrelet as breeding habitat. Where older forest does occur or is allowed to develop, timber harvest adjacent to such forest may degrade existing murrelet nesting habitat and reduce nesting success (Malt and Lank, 2007). Habitat degradation may be directly attributable to habitat loss caused by windthrow along forest edges, or by microclimate effects that, for example, may create unfavorable conditions at existing nest sites or diminish the growth of mosses and lichens necessary for the development of suitable nest sites. Harvested forest edges may also be a proximal cause of increased nest predation by making nest locations and adult flights to and from the nest site more visible to predators; moreover, the early seral habitat that develops in recently harvested areas may be attractive to predators by increasing the availability of forage and prey.

## *Objective*

Management plans for the Elliott State Research Forest (ESRF) require both the protection of MAMU habitat and the harvest of timber in fulfillment of research and financial objectives. Measures for the protection of MAMU are embodied in ESRF planning documents, including the ESRF Research Proposal (OSU, 2021), the ESRF Forest Management Plan (FMP), and the ESRF Habitat Conservation Plan (HCP), while the ability to harvest timber on the ESRF without potentially violating “take” provisions of the federal Endangered Species Act requires issuance of an Incidental Take Permit by federal regulators. The goal of the modeling methodology described here is to provide a quantitative means of evaluating changes in the quantity and quality of MAMU habitat available over the duration of the Permit term such that terms of an Incidental Take Permit can be monitored and enforced. We intend that this methodology provide relevant information to decision-makers and regulators during planning and implementation of ESRF forest operations, including:

- The quantification of the effects of timber harvest, including edge effects, on MAMU habitat as measured against baseline conditions
- The quantitative comparison of the effects of alternative management scenarios on MAMU habitat through time
- Provide a quantifiable, spatially-aware, and scalable means of predicting the effects of prospective management operations on MAMU habitat during biennial planning, with the expectation that unacceptable adverse effects will be avoided, moderated, or mitigated during the planning process
- Provide a quantifiable, spatially-aware, and scalable means of monitoring the effects of management operations to MAMU habitat over the duration of the HCP for purposes of compliance with terms of the HCP and Incidental Take Permit

## *Analytical Framework*

### Edge Effects

Empirical evidence suggests that timber harvest is associated with decreased MAMU nesting success, primarily as a result of increased predation in nesting habitat adjacent to recently harvested areas (Nelson and Hamer, 1995; Raphael et.al. 2002; Malt and Lank, 2007). Edge effects attributable to timber harvest may also be a function of time since harvest and the seral state of the disturbed forest creating an edge (Malt and Lank 2009). In this analysis we assume that the diminution of MAMU habitat value associated with harvested forest edge is a function of both distance from a disturbed forest edge and time since disturbance. Following the analysis of WDNR (2019c), we employ “inner” and “outer” Edge Effect Evaluation Zones (EEEZs) and classify the severity of edge effect with respect to time since harvest as hard edge (zero to 20 years post harvest), soft edge (21 to 40 years post harvest), and no edge (more than 40 years post harvest). The outer EEEZ is defined as the outer 50-meter strip immediately interior to the exterior boundary of affected habitat, and the inner EEEZ is a 50-meter strip immediately interior to the outer EEEZ (Figure S-1). For purposes of spatial analysis in a GIS, the outer EEEZ of any potentially affected habitat may be represented as a 50-meter buffer around a harvest area (or forest age class), and the inner EEEZ as a 50-meter buffer around the outer EEEZ (Figure S-2).

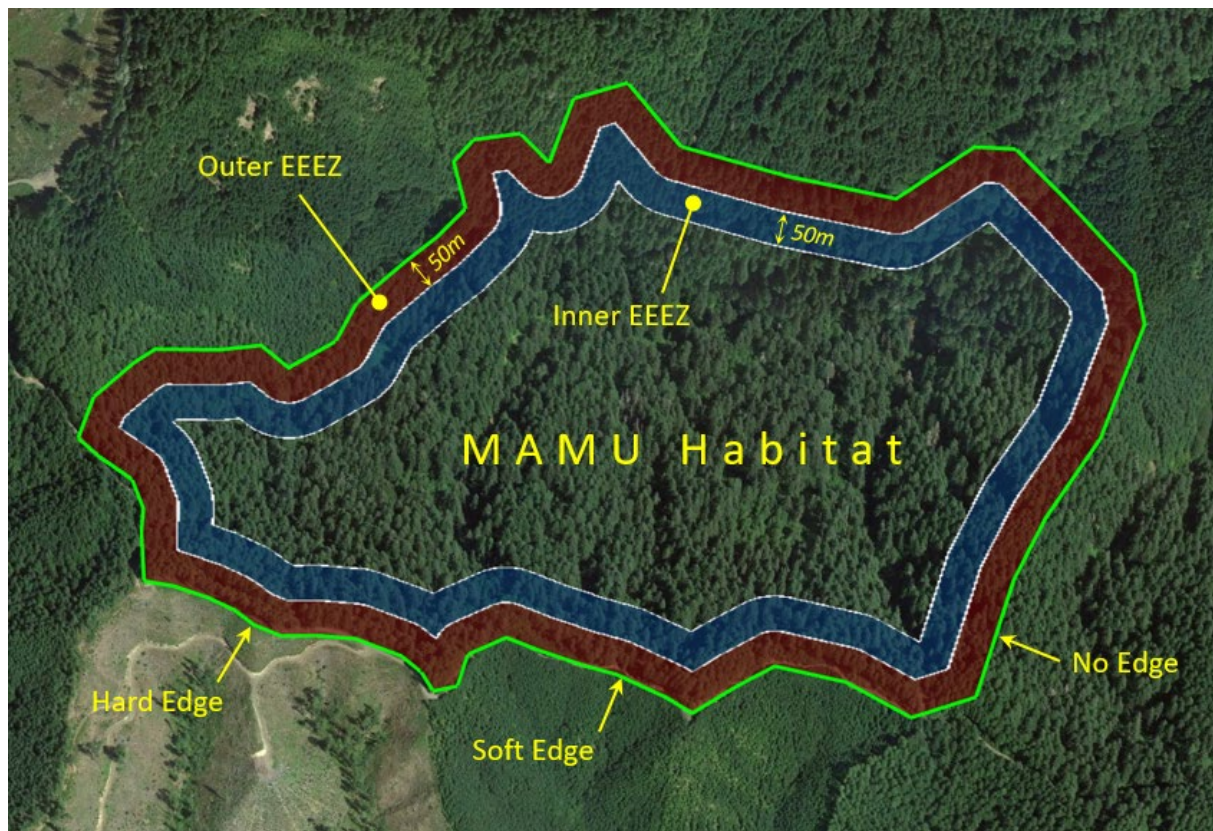


Figure S-1. Edge effects (i.e. diminution of habitat) to an area of MAMU habitat (bounded by green) caused by disturbance in adjacent stands. Effects evaluated with respect to the diminution of MAMU habitat within the outer 50m EEEZ, and the diminution of habitat within the inner 50m EEEZ. Edges are classified as hard edge (0 to 20 years post disturbance), soft edge (21 to 40 years post disturbance, and no edge (more than 40 years post disturbance). Image: Google Earth



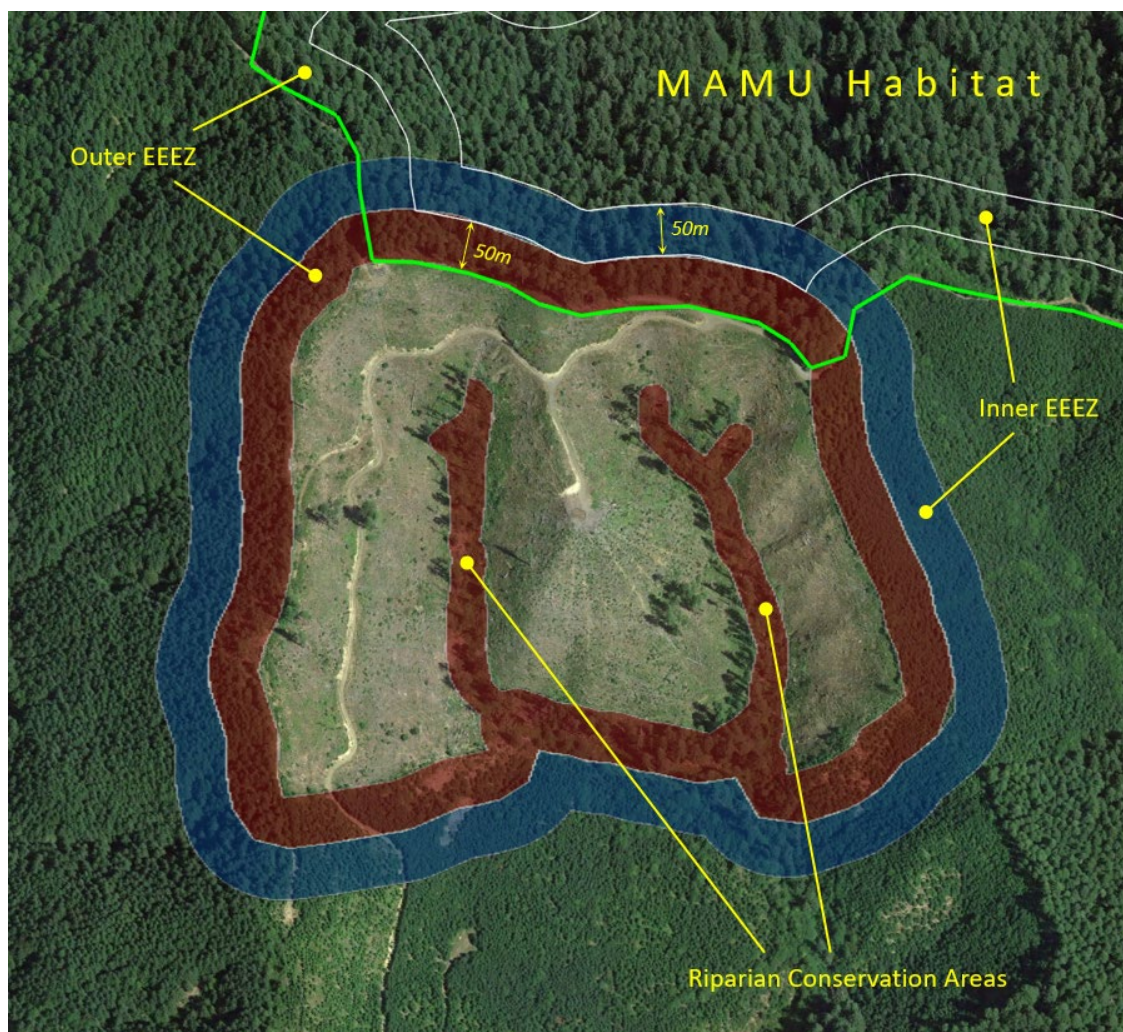


Figure S-2. The EEEZs within the perimeter of MAMU habitat are coincident with concentric 50-meter “buffers” around a timber harvest area, and for purposes of analysis we specify EEEZs as buffers around the harvest area rather than as EEEZs within MAMU habitat. Inner and outer EEEZs are nevertheless identified with respect to interior MAMU habitat, not the harvest area; thus, the outer EEEZ is adjacent to the harvest area boundary. Within ArcMap the outer EEEZ is created as a 50-meter buffer around the harvest area, and the inner EEEZ is created as a 50-meter buffer around the outer EEEZ. Riparian Conservation Areas (RCAs) that project into the interior of the harvest unit are included in the geometry of the outer EEEZ, and are subject to the same Habitat Diminution Factor as the outer EEEZ. Image: Google Earth

## Unit of Analysis

We use a generalized habitat suitability index (HSI) to quantify the relative quality of MAMU breeding habitat on a scale of zero to 1, with zero being non-habitat and 1 being the best possible habitat. Stand age is the primary stand attribute used for harvest scheduling and for tracking forest status throughout the permit term; hence, we employ a quantitative model of HSI as a function of stand age for estimating the HSI values of delineated stands at decadal mileposts through the duration of the term of the HCP. As we employ it here, HSI is conceptually similar to the P-stage model used by the Washington State Department of Natural Resources (WDNR) in their 2019 amendment to the 1997 State Trust Lands HCP (WDNR 2019), but is modeled here as a single continuous exponential function with respect to stand age, rather than as separate step functions for Douglas-fir forests and for western hemlock forests (Figure S-3).

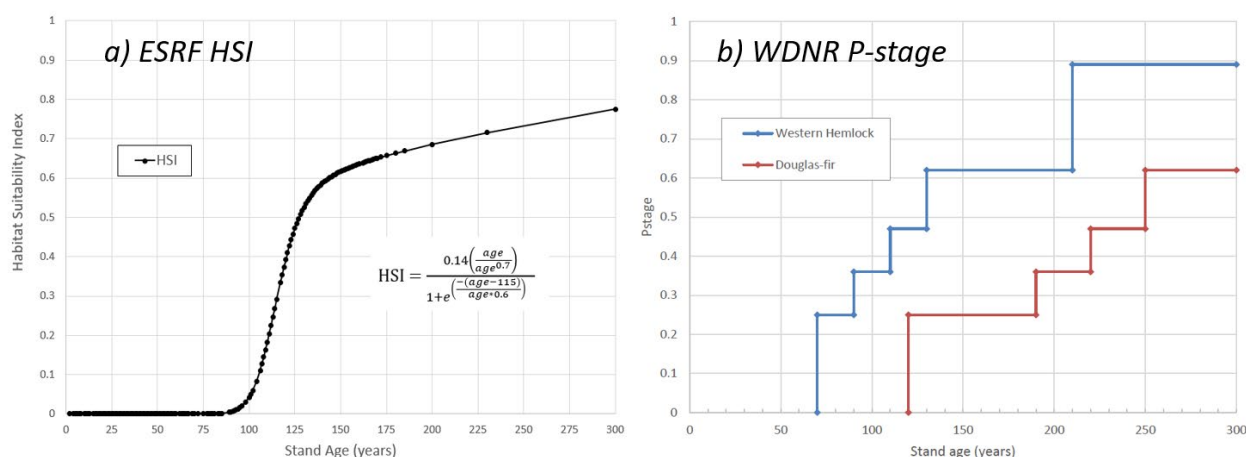


Figure S-3. HSI-age function as employed on the ESRF for all forest types (a) and P-stage step functions for Douglas-fir and for western hemlock forests as employed by WDNR (b). The HSI-age function is a generalized habitat model based on a conservative assessment of empirical and observational data by OSU and USFWS scientists. (P-stage graphics source: Figure E-1, WDNR 2019b)

The ESRF HSI-age function is a generalization developed by OSU and USFWS scientists during consultation on the ESRF HCP, and is based on a conservative assessment of empirical and observational data. Stand age is strongly associated with the presence of habitat attributes necessary for MAMU occupancy (e.g. large, moss-covered limbs used by MAMU as nesting platforms; Hamer et al., 2021). We thus assume that even-age stands too young to produce these attributes have negligible value as MAMU breeding habitat, notwithstanding older residual trees that may be present. As stands age they are subject to localized mortality and/or damage caused by suppression, mistletoe, insects, disease, ice, snow, and wind, creating gaps in the forest canopy and features in the remaining live trees such as large or swollen branches, multiple tops, and mistletoe brooms that, over time, can develop into suitable MAMU nesting platforms. Observational data from the ESRF provide evidence that some stands become suitable for MAMU occupancy at around 100 years of age. Using MAMU survey data from the ESRF, Betts and Yang (2023, unpublished data) found a strong association between probability of MAMU occupancy and stand age. Based on the Betts and Yang data we assume that HSI values increase sharply at stand ages greater than 100 years, but that the rate of increase in HSI decreases at approximately 150 years of age (Figure S-3a).

Although the HSI-age function is a simplified, deterministic construct, it nevertheless provides a consistent, conservative theoretical model through which changes in habitat quantity and quality attributable to changes in forest condition, such as stand age and spatial patterns of timber harvest, may be assessed.

As discussed above, HSI is a function of stand age. The stand age of each stand on the ESRF can be determined at each decadal milepost throughout the permit term given an initial stand age (i.e. stand age in year 2024), harvest schedule, and the arithmetic progression of stand age through time. Given stand age, corresponding HSI values can be calculated according to the HSI-age function (Figure S-3a); however, this does not take into account the size of a stand or total amount of habitat available. In order to quantify the *aggregate* value of MAMU habitat across a geographic area of interest at a given point in time we employ the construct of *HSI-weighted acres* (HSI-acres). HSI-acres is the product of the HSI value of a subject stand and the area, in acres, of the subject stand. The aggregate habitat value for an area of interest at a given point in time is the sum of HSI-acres of all stands within the area of interest. Our primary area of interest for this analysis is the entire ESRF, but any subset of stands within the ESRF could be specified as the area of interest and evaluated accordingly.

A fundamental assumption of this analysis is that the aggregate habitat value of a subject stand can be expressed as the product of stand area and HSI value. Thus, for any given stand of a given area there is a simple, linear relationship between HSI value and aggregate habitat value expressed in terms of HSI-acres. For example, the aggregate habitat value of a 100-acre stand with an HSI value 0.6 is twice the aggregate habitat value of a 100-acre stand with an HSI value of 0.3; alternatively, a 100-acre stand with an HSI value of 0.3 has the same aggregate habitat value as a 50-acre stand with an HSI value of 0.6. Another fundamental assumption of this analysis is that – with the exception of edge effects, which are calculated separately – the HSI value of individual stands are independent of one another. Thus, the aggregate habitat value of a set of stands can be expressed as the simple arithmetic sum of the HSI-acre values of member stands.

## **Methodology**

This analysis has two specific modeling objectives:

- Create base rasters of HSI values at decadal mileposts (e.g. year 2034, 2044, 2054, etc.) throughout the permit term under an assumed harvest scenario, including initial forest condition (year 2024)
- Adjust the HSI base rasters for harvest-induced edge effects, including continuing edge effects from harvest that occurred prior to year 2024.

By comparing differences between base rasters and edge-effect-adjusted rasters (hence: *net HSI rasters*), harvest-induced edge effects can be quantified and evaluated spatially and temporally.

We used a combination of GIS software (ArcGIS Desktop) and Excel spreadsheets to model the spatial distribution, quality, and quantity of MAMU breeding habitat on the ESRF at decadal milepost for the expected 80-year duration of the ESRF HCP. “Decadal milepost” (hence, DM) refers to modeled habitat conditions at the end each decade of the Permit term, not the flux in habitat condition that occurs during the decade. The analysis begins with initial condition at the beginning of year 2024, and evaluates conditions at the end of each decade in years 2034, 2044, and so-on, to the anticipated end of the permit term in year 2104.

Primary model output is in the form of 3-foot resolution HSI rasters covering the area of the ESRF. There are two key rasters produced for each DM: 1) a base raster comprising HSI values for all stands and, 2) a net HSI raster derived from the base raster that is adjusted to account for habitat diminution attributable to harvest-induced edge effects. Data contained within the rasters may be further processed to show spatial and temporal differences in modeled MAMU habitat, and to show projected habitat diminution attributable to edge effects. A workflow diagram shows the relationships between inputs, parameters, and processes used to create these rasters (Figure S-4).

Primary model inputs and parameters are:

- Spatial data
  - Spatially explicit stand definitions
  - Stand ages
  - Stand allocations
- Spatially and temporally explicit harvest scenario
  - Harvest parameters and assumptions for each harvest category
- Direct-effect and edge-effect parameters for each harvest category
  - Habitat Diminution Factors

These inputs and parameters are described in turn below, followed by a description of the processes used to create the output rasters.

#### *Spatial data: Stand Allocations and Attributes*

The primary inputs to the model are spatial data containing ESRF stand definitions, allocations, and attributes in the form of a GIS shapefile. The GIS shapefile is used to integrate many other stand attributes that are necessary for this analysis, including stand allocations (Figure S-5), stand age, stand area, and unique stand identification numbers to facilitate transfer of data between the GIS shapefile and an Excel spreadsheet, where most calculations and logical functions are performed.

The ESRF GIS shapefile<sup>1</sup> used in this analysis comprises 5,735 individual polygons. The original stand definitions used in this file come from Oregon Department of Forestry (ODF) 2016 GIS inventory data for the Elliott State Forest, and comprises 1,968 polygons over the same geographic area as the ESRF GIS shapefile. Many of the original 2016 ODF stands have been split or modified during the ESRF planning process as a result of the imposition of Riparian Conservation Area (RCA) boundaries, watershed boundaries, and other allocation requirements. Additionally, many stand boundaries and stand ages have been revised based on newly acquired lidar vegetation height data and satellite imagery.

The harvest classes and stand allocations used for this analysis are based on a June 2023 revision of land allocations by the Oregon Department of State Lands (Figure S-5 & Table S-1). Apart from the Triad research watersheds, which are unchanged, these allocations and harvest classes differ from those described in the ESRF research proposal (OSU 2021) in many locations. In addition, the 787-acre Hakki Ridge parcel is included in this analysis, whereas it was not included in original ESRF research proposal.

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<sup>1</sup> Filename: *DSL\_Allocations\_August\_2023\_Take6\_rev1*, available from OSU upon request.



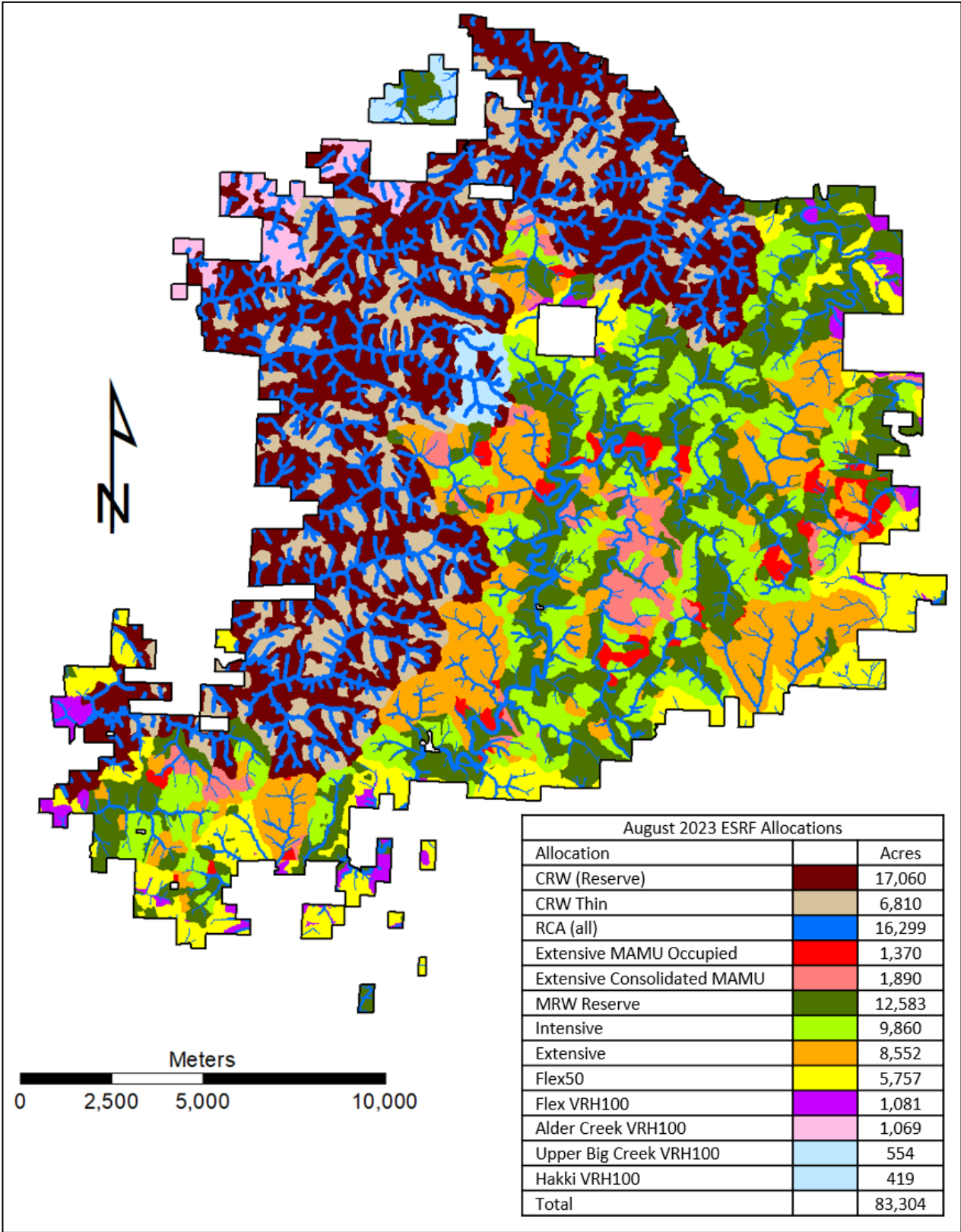


Figure S-4. ESRF Allocations, as revised June, 2023.

Table S-1. Summary of Land Allocations on the ESRF, September 2023

Allocation	Total Allocated Acres	HCP Silviculture Category	Allocation Notes
CRW Reserve	17,060	Reserve	Does not include CRW RCA or CRW Thin
CRW Thin	6,810	Restoration Thin	Candidate stands for restoration thinning
CRW RCA	9,568	Limited Thin in stands <=65	Riparian Conservation Areas within the CRW
Triad Extensive MAMU Occupied	1,370	MAMU Experiment	"MAMU Experiment" Extensive allocations considered to be MAMU occupied as defined by the HCP
Triad Extensive Consolidated MAMU	1,890	Extensive	Triad research watershed stands allocated to extensive within the MAMU Consolidated habitat layer but that are not considered occupied as defined by the HCP
Triad Intensive	9,860	Even-age Intensive	Intensive even-age management within Triad research watersheds
Triad Extensive <u>not</u> Consolidated MAMU	8,552	Extensive	Triad research watershed stands allocated to extensive that are not within the MAMU Consolidated habitat layer
Triad Reserve	10,058	Reserve	Reserve stands within Triad watersheds
MRW Reserve (non-Triad, includes Hakki)	2,525	Reserve	Reserve stands outside of Triad watersheds, excluding CRW reserve
MRW RCA (Triad Watersheds)	5,141	Limited Thin in stands <=65	Riparian Conservation Areas within Triad watersheds
MRW RCA (Non-Triad )	1,590	Limited Thin in stands <=65	Riparian Conservation Areas outside of Triad watersheds, excluding CRW RCAs
Flex 50	5,757	Flexible	Stands <= 65 years as-of year 2020 located in MRW non-Triad watersheds. Generally open silvicultural options, with minimum rotation age of 50 years
Flex VRH100	1,081	Flexible Variable Retention	Stands > 65 years as-of year 2020 located in MRW non-Triad watersheds. Generally open silvicultural options, with average rotation age of 100 years and minimum retention of 20%
Alder Creek VRH100	1,069	"Replacement" Extensive	Stands <= 65 years as-of year 2020 located in the Alder Creek area. Intended to replace Extensive Consolidated MAMU acres in Triad watersheds that are removed from harvest base due MAMU presence.
Upper Big Creek VRH100	554	Flexible Variable Retention	Stands <= 65 years as-of year 2020 located in the Upper Big Creek area.
Hakki Ridge VRH100	419	Flexible Variable Retention	Stands <= 65 years as-of year 2020 located in the Hakki Ridge parcel.
Total	83,304		

### *Harvest Scenario – August 2023*

The harvest base used for this analysis includes all harvest base acres less than or equal to 65 years of age as-of year 2020 (LTE65), and the greatest number of harvest base acres greater than 65 years of age as-of year 2020 (GT65) that could be harvested given a 3,400-acre cap on the total number of GT65 acres that may be harvested during the permit term. The harvest schedule imposed upon the harvest base is primarily determined by the year that each stand achieves a target age (e.g. rotation age) rather than, for example, a schedule based on the optimization of an objective function, such as the maximization of volume production or revenue. For both existing and future stands on the ESRF, the year that a subject stand achieves a target age is determined by its 2020 inventory age; thus, the existing age class distribution of the forest, in combination with the harvest base land allocations, largely determines the harvest schedule. The existing age-class structure of the ESRF is the primary reason harvest acres vary between decades under the harvest scenario employed here (Table S-3c).

By design some allocation classes specified in the HCP have a large amount of flexibility in how they may be implemented. For example, the Flex 50 class was intended to make possible a wide variety of potential silvicultural prescriptions under terms of the HCP; however, it would not be possible to model all potential instances of how this class might be implemented. Because there was no average retention or average rotation length specified in the HCP for the Flex 50 class, it was modeled here at the lowest possible retention (0%) and rotation age (50 years) as a way to capture the assumed “worst case” effects to MAMU habitat under terms of the HCP. As with the Flex 50 class there are a wide range of silvicultural options under the variable retention harvest classes, which includes the extensive allocations in the Triad watersheds. However, based on language in the HCP and in the Research Proposal we infer a commitment to an average retention of 50% and rotation length of 100 years for all variable retention harvest classes other than the Extensive MAMU Occupied class, which is 80% retention, and model them accordingly.

#### Conditional Harvest Acres

Survey and manage requirements for Triad Extensive allocations that are within the Consolidated MAMU habitat layer (ConMAMU) complicate harvest scheduling because harvest in these allocations is conditional based on the results of MAMU occupancy surveys, which have yet to be performed. The Alder Creek variable retention harvest allocation was created by the Department of State Lands (DSL) as a way to mitigate potential reductions in Triad harvest base acres in the event that Triad Extensive harvest base stands are found to be occupied by MAMU. Because the Alder Creek allocation is restricted to LTE65 forests, and has relatively low volume per acre compared to the GT65 Triad Extensive allocations, DSL applied a factor of 1.5 in calculating “replacement” volume from the Alder Creek allocation. Thus, according to the DSL formula, the 1,069 acres of the Alder Creek allocation are the equivalent to 712 acres of Triad Extensive. For purposes of analysis we assume that 712 acres of Triad Extensive will be found to be MAMU occupied, and that the entirety of the Alder Creek allocation will be placed in the harvest base as volume replacement acres.

With 712 acres of GT65 forest removed from the harvest base in the Triad watersheds this creates space under the 3,400-acre GT65 harvest cap for the harvest of GT65 forest from the Flex VRH100 allocation. Thus, 712 acres of GT65 forest were scheduled for harvest in the Flex VRH100 allocation under the harvest scenario described here.

### Harvest Scheduling Parameters

Primary harvest scheduling parameters, including harvest base acres, rotation age, and retention, are displayed in Table S-2, and an outline of harvest scheduling specifications for each allocation follows the table.

Table S-2. Harvest Schedule Parameters

Allocation	Total Allocated Acres	HCP Silviculture	Modeled Silviculture	Modeled Harvest Base Acres	Modeled Rotation Age	Modeled Average Retention	Thin?
CRW Reserve	17,060	Reserve	Reserve	0	NA	100%	No
CRW Thin	6,810	Restoration Thin	Restoration Thin	5,621	NA	100%	Yes
CRW RCA	9,568	Limited thin in stands <=65	Reserve	0	NA	100%	No
Extensive MAMU Occupied	1,370	MAMU Experiment	MAMU Experiment	1,370	NA	80%	No
Extensive Consolidated MAMU	1,890	Extensive	Variable Retention	1,178	100 years	50%	Yes
Intensive	9,860	Even-age Intensive	Even-Age Intensive	9,860	60 years	0%	No
Extensive not Con. MAMU	8,552	Extensive	Variable Retention	8,550	100 years	50%	Yes
MRW Reserve (Triad Watersheds)	10,058	Reserve	Reserve	0	NA	100%	No
MRW Reserve (non-Triad)	2,525	Reserve	Reserve	0	NA	100%	No
MRW RCA (Triad Watersheds)	5,141	Limited Thin in stands <=65	Reserve	0	NA	100%	No
MRW RCA (Non-Triad )	1,590	Limited Thin in stands <=65	Reserve	0	NA	100%	No
Flex 50	5,757	Flexible	Even-Age Intensive	5,757	50 years	0%	No
Flex VRH100	1,081	Flexible Variable Retention	Variable Retention	962	100 years	50%	Yes
Alder Creek VRH100	1,069	"Replacement" Extensive	Variable Retention	1,069	100 years	50%	Yes
Upper Big Creek VRH100	554	Flexible Variable Retention	Variable Retention	554	100 years	50%	Yes
Hakki Ridge VRH100	419	Flexible Variable Retention	Variable Retention	419	100 years	50%	Yes
Total	83,304			35,340			



- 1) CRW Reserve
  - a. No scheduled harvest
- 2) CRW Thin
  - a. There are a total of 7,614 acres of stands  $\leq 65$  years of age in the (revised) CRW. Of these, 804 acres were identified as being either too young to commercially thin or already meeting CRW objectives (e.g. heterogeneous stand structure). The balance of 6,810 acres were assumed to be candidate stands for restoration thinning. 1,189 acres were set aside as restoration experiment controls, leaving 5,621 acres in the CRW thin category.
  - b. The 5,621 acres of prospective restoration thinning in the CRW was scheduled to occur over the first two decades of implementation (approximately 280 acres per year)
- 3) CRW RCA
  - a. No scheduled harvest
- 4) Extensive MAMU Occupied (“MAMU experiment”)
  - a. All Extensive MAMU Occupied stands are located in Triad (Full) Research Watersheds
  - b. Harvest 500 acres of surveyed MAMU-occupied habitat in the first decade. Subsequent acres harvested are contingent on results of harvest in the first 500 acres, but this harvest scenario assumes the “worst case” that all available acres will be harvested. Subsequent harvests are scheduled for third and fifth decade, which allows time for interpretation of the results from previous harvests
  - c. Retention = 80%
  - d. No commercial thinning scheduled
- 5) Extensive Consolidated MAMU
  - a. These are GT65 “survey and manage” stands currently classified as unoccupied
  - b. All Extensive Consolidated MAMU stands are located in Triad (Full) Research Watersheds
  - c. These stands may only be harvested if they are determined to be unoccupied. For purposes of analysis 712 acres in this class are assumed to be occupied, resulting in 1,069 acres of “replacement volume” being added to the harvest base from the AC\_VRH100 (Alder Creek) allocation. We assume that the remaining 1,178 acres in this class will be found unoccupied and will be available for harvest.
  - d. The 712 acres presumed occupied within Extensive Consolidated MAMU frees up GT65 harvest cap acres for harvest in the Flex VRH100 category
  - e. Regen harvest age = 100 years.
  - f. Retention = 50% (assumed average retention over permit term)
  - g. Nearly all of the 1,178 acres in this class are  $>100$  years, and thus are “backlog” harvest acres
    - i. Backlog harvest was partitioned across the first four decades
    - ii. Decadal harvest areas were spatially clustered to avoid creating small, isolated harvest areas.
  - h. No commercial thin in existing stands
  - i. Silvicultural thin stands that were regeneration-harvested after year 2023 at 40 years of age

- 6) Intensive (Triad Research Watersheds)
  - a. All Intensive stands are located in Triad (Full) Research Watersheds
  - b. Even-age, intensive management
  - c. No retention
  - d. Regen harvest age = 60 years
  - e. Schedule harvest for the year a subject stand reaches 60 years of age
  - f. Schedule backlog stands for harvest in first year of implementation (2024)
  - g. Commercial thinning is not currently programmed under the FMP, and was not scheduled for this analysis
- 7) Extensive not Consolidated MAMU
  - a. All Extensive not Consolidated MAMU stands are located in Triad (Full) Research Watersheds
  - b. Regen harvest age = 100 years
  - c. Retention = 50% (assumed average retention over permit term)
  - d. Schedule for regen harvest for the year a subject stand reaches 100 years of age
  - e. Schedule backlog stands for harvest in first year of implementation (2024)
  - f. Commercial thin existing stands at 50 years of age (“maintenance thin”)
    - i. Existing stands >60 years of age as-of 2024 are not thinned
    - ii. Existing stands >50 years and ≤60 years thinned in first decade
  - g. Commercial thin stands regen harvested after year 2023 at 40 years of age (“silvicultural thin”)
- 8) MRW Reserve (Triad and non-Triad watersheds)
  - a. No scheduled harvest
- 9) MRW RCA (Triad and non-Triad watersheds)
  - a. No scheduled harvest
- 10) Flex 50
  - a. Located in “Partial” MRW Watersheds
  - b. Even-age, intensive management
  - c. No retention
  - d. Regen harvest age = 50 years
  - e. Schedule harvest for the year a given stand reaches 50 years of age
  - f. Schedule backlog stands for harvest in first year of implementation (2024)
  - g. Commercial thinning is not currently programmed under the FMP, and was not scheduled for this analysis

11) Flex VRH100

- a. Located outside of MRW Triad Research Watersheds
- b. 692 acres of this allocation are within the Consolidated MAMU layer, and would be subject to MAMU survey prior to harvest.
- c. Most stands in this allocation are >65 years of age as-of year 2020 and would be constrained by the forest-wide 3,400-acre cap on the harvest of GT65 stands.
- d. 711 acres of GT65 stands in this allocation were scheduled for harvest; this assumes constraints elsewhere in the forest (e.g.; MAMU detections) will allow harvest of these acres without exceeding the forest-wide harvest cap, and that scheduled acres are not found to be MAMU-occupied.
- e. Regen harvest age = 100 years
- f. Retention = 50% (assumed average retention over permit term)
- g. Commercial thin stands regen harvested after year 2023 at 40 years of age (“silvicultural thin”)

12) Alder Creek VRH100

- a. This allocation is intended to provide “volume replacement” for Extensive allocations within MRW Full Research Watersheds found to be MAMU occupied. Replacement acres were calculated at a ratio of 1.5:1
  - i. Assume 712 acres of Extensive Consolidated MAMU allocation are found to be MAMU occupied, and that 1,069 acres of this allocation are shifted to harvest base
- b. All stands in this allocation are <=65 years of age as-of year 2020
- c. Regen harvest age = 100 years.
- d. Retention = 50% (assumed average retention over permit term)
- e. Commercial thin existing stands at 50 years of age (“maintenance thin”)
- f. Commercial thin stands regen harvested after year 2023 at 40 years of age (“silvicultural thin”)

13) Upper Big Creek VRH100

- a. All stands in this allocation are <=65 years of age as-of year 2020
- b. Regen harvest age = 100 years
- c. Retention = 50% (assumed average retention over permit term)
- d. Commercial thin existing stands at 50 years of age (“maintenance thin”)

14) Hakki Ridge VRH 100

- a. All stands in this allocation are <=65 years of age as-of year 2020
- b. Regen harvest age = 100 years
- c. Retention = 50% (assumed average retention over permit term)
- d. Commercial thin existing stands at 50 years of age (“maintenance thin”)

Table S-3. MAMU HSI analysis harvest scenario: Decadal harvest in acres.

(a) Regeneration Harvest								
	2024-2033	2034-2043	2044-2053	2054-2063	2064-2073	2074-2083	2084-2093	2094-2103
Intensive	1,314.0	2,492.3	2,177.3	1,961.5	1,708.9	206.5	1,314.0	2,492.3
Flex50	3,249.1	861.3	390.7	877.8	377.9	3,249.1	861.3	390.7
Extensive	146.1	0.0	59.7	385.2	1,334.1	2,634.4	1,427.8	1,477.5
Extensive ConMAMU	286.3	312.6	268.9	310.0	0.0	0.0	0.0	0.0
Extensive MAMU experiment	518.8	0.0	431.7	0.0	419.0	0.0	0.0	0.0
UBC_VRH100	0.0	0.0	0.0	0.0	164.5	293.6	69.9	8.9
AC_VRH100	0.0	0.0	0.0	44.0	24.9	871.9	106.1	0.0
Flex_VRH100	1.7	323.0	570.7	4.5	0.0	52.5	9.0	0.0
Hakki_VRH100	0.0	0.0	0.0	0.0	101.0	179.4	138.3	0.0
All CRW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
All RCA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
All Reserve	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(b) Thinning								
	2024-2033	2034-2043	2044-2053	2054-2063	2064-2073	2074-2083	2084-2093	2094-2103
Intensive	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flex50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Extensive	3,968.4	1,427.8	1,388.1	1,014.9	306.3	0.0	59.7	385.2
Extensive ConMAMU	0.0	0.0	0.0	0.0	286.3	312.6	268.9	310.0
Extensive MAMU experiment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UBC_VRH100	458.1	69.9	8.9	17.6	0.0	0.0	0.0	0.0
AC_VRH100	896.8	106.1	0.0	0.0	21.8	0.0	0.0	44.0
Flex_VRH100	52.5	9.0	0.0	25.1	0.0	266.8	414.4	4.5
Hakki_VRH100	280.4	138.3	0.0	0.0	0.0	0.0	0.0	0.0
CRW Thin	2,771.7	2,849.8	0.0	0.0	0.0	0.0	0.0	0.0
All RCA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
All Reserve	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(c) Summary: Harvest by Silvicultural Class								
	2024-2033	2034-2043	2044-2053	2054-2063	2064-2073	2074-2083	2084-2093	2094-2103
Total Intensive Regen	4,563.1	3,353.6	2,568.0	2,839.3	2,086.7	3,455.6	2,175.4	2,883.0
Total Extensive/VRH Regen	952.9	635.6	1,331.1	743.7	2,043.5	4,031.8	1,751.1	1,486.5
<b>Subtotal Regen Harvest</b>	<b>5,516.0</b>	<b>3,989.2</b>	<b>3,899.1</b>	<b>3,583.0</b>	<b>4,130.2</b>	<b>7,487.4</b>	<b>3,926.4</b>	<b>4,369.5</b>
Total Thinning	8,427.9	4,600.9	1,397.1	1,057.6	614.4	579.5	743.0	743.7
<b>Total Decadal Harvest</b>	<b>13,943.9<sup>2</sup></b>	<b>8,590.2</b>	<b>5,296.2</b>	<b>4,640.6</b>	<b>4,744.5</b>	<b>8,066.9</b>	<b>4,669.5</b>	<b>5,113.1</b>

<sup>2</sup> This would exceed the annual harvest cap. To stay within the annual harvest cap some of these acres could be re-scheduled for later decades.



### *Direct effects and edge effects: Habitat Diminution Factors*

Habitat Diminution Factor (HDF) is a coefficient we employ to quantify the degree to which harvest reduces the value of MAMU nesting habitat, either directly to the area being harvested, or to habitat in the inner and outer EEZs adjacent to the harvest area. HDF is conceptually the same as the “discount multiplier” described by WDNR (2019c); however, we employ HDFs at temporally discrete stand scales rather than temporally averaged landscape scales. HDF values were specified in cooperation with USFWS biologists during consultation on the ESRF HCP.

#### Edge Effects

We specified HDF values for five primary silvicultural classes proposed for the ESRF (Table S-4). We defined hard edge, soft edge, no edge, and inner and outer EEZs as had been defined by WDNR (WDNR 2019c). For Intensive and Flex 50 allocations (intensive, even-age management) we employed the same edge-effect discount multiplier values used by WDNR for managed forests (WDNR 2019c, Table S-2 and Table S-3). HDFs for extensive management and for thinning on the ESRF were determined based on the specified values for intensive management, descriptions of extensive silvicultural prescriptions proposed by OSU for the ESRF, and synthesis of available scientific information. Because retention could vary between 20% and 80% in extensive allocations during implementation we assumed an average retention of 50% for all extensive allocations over the permit term, with the exception of the Extensive MAMU Occupied experiment allocation, which specifies 80% retention. We assumed that retention in variable retention harvest units would not be preferentially distributed to provide buffers adjacent to occupied habitat. In determining HDFs for CRW restoration thinning and for extensive thinning we assumed that during implementation an average of at least 60% canopy closure<sup>3</sup> would be maintained within 50 meters of any occupied or potentially occupied MAMU habitat.

Table S-4. Edge-effect Habitat Diminution Factors (HDF)		
Allocation	Edge Effect HDF	
	Inner EEZ	Outer EEZ
Intensive (hard)	0.42	0.83
Intensive (soft)	0.2	0.4
Extensive MAMU experiment (hard)	0.1	0.17
Extensive MAMU experiment (soft)	0.0	0.1
Extensive Medium Retention (hard)	0.37	0.73
Extensive Medium Retention (soft)	0.18	0.35
Extensive Maintenance Thin (hard)	0.0	0.2
Extensive Maintenance Thin (soft)	0.0	0.0
CRW Thin (hard)	0.0	0.2
CRW Thin (soft)	0.0	0.0

<sup>3</sup> We distinguish between canopy closure, which measures the proportion of the total sky hemisphere visible from a point 1.5m above the forest floor, and canopy cover, which is the vertical projection of forest canopy across a specified area of forest floor (Jennings, Brown, and Sheil. 1999).

Direct Effects

Because some stands with non-zero HSI values are allocated for harvest we estimated HDF values that would be associated with the direct effects of harvest, independent of edge effects (Table S-5). We assume that there is no habitat value following intensive harvest, and we assume that thinning will have no effect on habitat value because thinning is not expected to occur in stands with non-zero HSI values. Of relevance are HDF values for extensive allocations. As modeled here, when harvest to a stand with a non-zero HSI value occurs habitat value is reduced according to the appropriate HDF value (Table S-5). As modeled, this diminution of habitat does not recover with age, as is the case with modeled edge effects; this was a “worst-case” assumption that we may be able to relax when more information becomes available on the effects of partial harvest in occupied stands. Although the direct effects of harvest on habitat are not modeled to recover with time since harvest, the diminished HSI value of affected habitat does increase according to the HSI-age function (Figure S-3a).

Table S-5. Direct-effect Habitat Diminution Factors (HDF)	
Allocation	Direct HDF
Intensive	1.0
Extensive MAMUx (80% retention)	0.2
Extensive Medium Retention	0.88
Thin, all classes	0.0

June 2023 Allocation Revisions

Consultations between OSU and USFWS biologists to determine the HDFs specified in Table S-4 and Table S-5 occurred prior to the June 2023 allocation revisions. These revisions resulted in specification of the Flex 50 allocation, and in the specification of variable retention harvest allocations outside of the Triad research watersheds (Figure S-5) that may be conceptually different from Triad Extensive allocations described in the Research Proposal (OSU 2021). We assume that all variable retention harvest systems outside of the Triad research watersheds (Alder Creek VRH100, Big Creek VRH100, Flex VRH100, and Hakki VRH100) fit the parameters for Extensive medium retention harvest and thinning (Table S-4, Table S-5) and, as noted above, we assume that Flex 50 allocations will be intensively managed as even-age forests on 50-year harvest rotation cycles.

*Creation of Base Rasters and Net Rasters*

The sequential process we used for the creation of base rasters and net HSI rasters is represented in a workflow diagram (Figure S-4); the numbered procedural outline below corresponds to numbers in the workflow diagram.

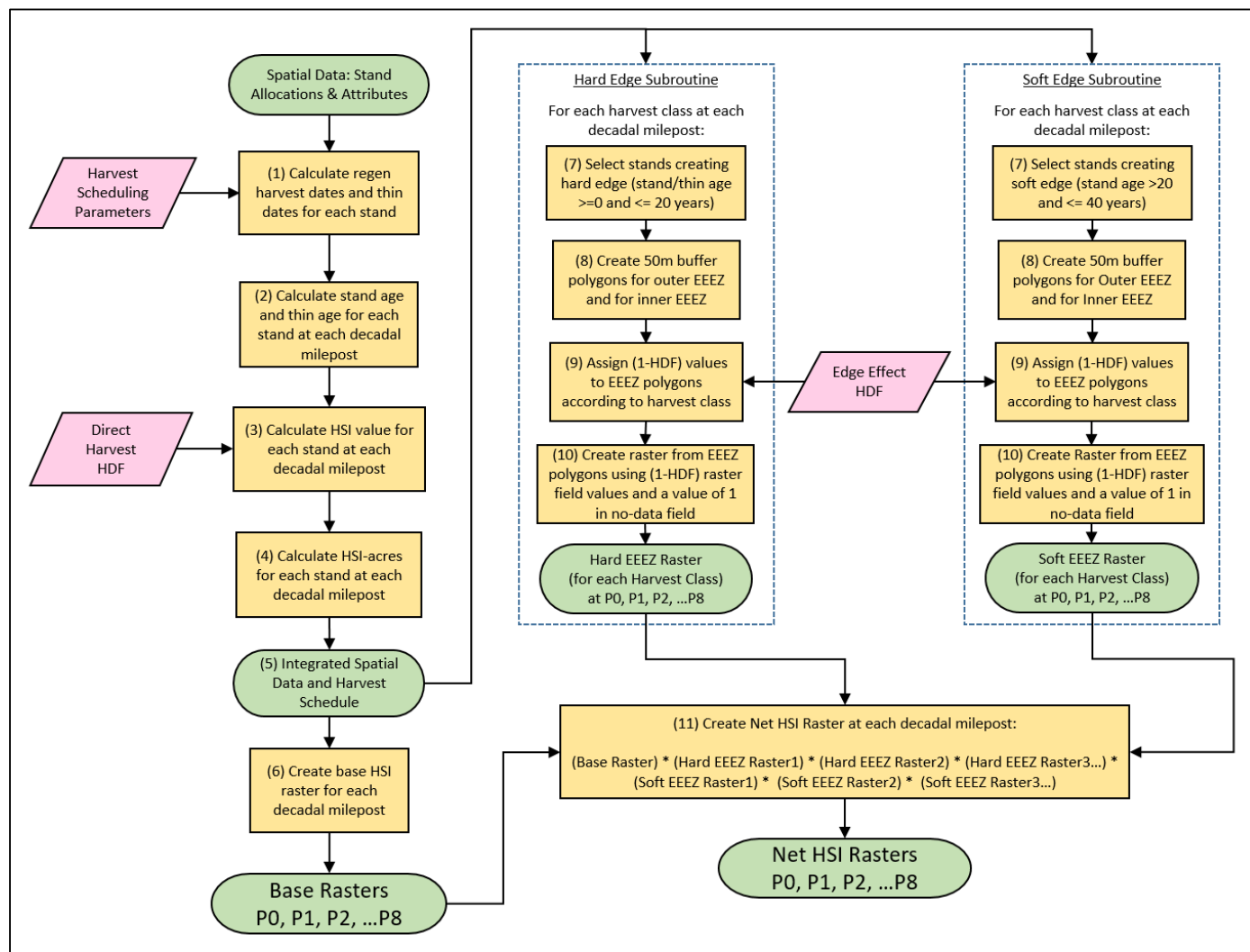


Figure S-5. Workflow diagram for creating base rasters and net HSI rasters. Base rasters are 3-foot resolution rasters containing unadjusted HSI values for the ESRF at each decadal milepost. Net HSI rasters are derived from the base rasters, and represent HSI values net of edge effects at each decadal milepost.

### Base Rasters

- 1) Specify harvest dates for each stand polygon:
  - a. Add attribute fields to the spatial stand file (i.e. allocation file) to facilitate integration of harvest schedule with spatial stand data. These fields are: *Regeneration year 1*, *Regeneration year 2*, *Maintenance Thin year*, *Silvicultural Thin year*, and *CRW Thin year*. Attribute fields for *Stand Age*, *Thin Age*, *HSI Value*, and *HSI-acres* for each DM are also added
  - b. Export spatial stand file, including all attributes, to an Excel spreadsheet.
    - i. Note that each stand must have a unique identification number to facilitate transfer of data back to ArcMap at a later stage of this process
  - c. Based on the harvest schedule parameters, for each allocation/harvest class and initial stand age calculate regeneration harvest dates and thin dates for each stand
    - i. Assign value of 9999 where no harvest is scheduled
- 2) Calculate stand age and thin age at each DM based on regeneration/thin year(s) for each stand
  - a. Extensive and VRH harvest classes use the age of the retained stand for stand age
- 3) Calculate the HSI value for each stand at each DM based on stand age
  - a. Adjust stand HSI for direct-effects according to Table S-5
    - i. HDF values represent the fraction by which habitat is reduced. The fraction of habitat that remains is:  $(1 - HDF)$
    - ii. For all variable retention harvest allocations, including Triad extensive, post-harvest HSI is based on retained stand age, and the HDF applies to all decades post-harvest
- 4) Calculate HSI-acres for each stand at each DM
  - a.  $HSI\text{-acres} = \text{stand area (acres)} * \text{stand HSI}$
  - b. HSI-acres may be summed across any area of interest
    - i. This step should produce the same HSI-acres calculated from base rasters, and serves as a check for error.
    - ii. HSI-acres values do not include edge effects
- 5) Transfer attribute values calculated in the Excel worksheet back to the respective spatial/GIS stand file attributes
  - a. Create a “Join” in ArcMap between spatial stand file and Excel file using the unique stand identifier (i.e. “SID\_011”)
  - b. Write Excel values to the spatial stand file
- 6) Create base HSI raster for each DM
  - a. 3-foot raster resolution
  - b. Validate this process by comparing the sum of HSI-acres for an area of interest (AOI) from the stand file with the value of *[mean base raster pixel value for AOI \* AOI acres]*

### Net HSI Rasters

A set of EEEZ rasters containing  $[1 - HDF]$  values for each harvest class (Table S-4) at each DM is created. Each set of rasters will include a subset of rasters derived from stands creating hard edge, and a subset of rasters derived from stands creating soft edge. The following description applies to creating hard edge rasters; the procedure for soft edge rasters is identical, with the exception that the age parameters for soft edge are for stands >20 years and ≤40 years.



For each harvest class at each DM, including initial condition:

- 7) Select stands with stand age of  $\leq 20$  years of age at the subject DM. For thin harvest classes (e.g. CRW thin, extensive thin) select stands based on thin age
- 8) Create buffer polygons representing outer and inner EEEZs:
  - a. Create a 50-meter buffer around the selected polygons. This defines the outer EEEZ (See Figures S-1 and S-2)
  - b. Create a 50-meter buffer around the 50-meter buffer polygon. This defines the inner EEEZ (See Figures S-1 and S-2))
- 9) Assign [1-HDF] values to EEEZ polygons
  - a. Create a blank rectangular polygon “mask” that covers the entire ESRF
  - b. For each harvest class create a spatial union of the mask polygon, inner EEEZ polygons, and outer EEEZ polygons
  - c. Assign [1-HDF] values to the inner and outer EEEZ features according to Table S-4
  - d. Assign a value of 1 to areas not within the EEEZ polygons
    - i. In the step 11 (below) this allows areas not within EEEZs of a subject harvest class to pass through the edge raster calculation at full HSI value
- 10) Using the parameterized EEEZ union polygons created in step 9, create a 3-foot resolution raster for each harvest class at each DM
  - a. For each DM there will be a separate hard edge raster for each harvest class.

---Repeat Steps 7 through 10 for stands creating soft edge---

- 11) Create the Net HSI Raster at each DM
  - a. The Net HSI Raster is the Base Raster net of edge effects, and is the product of the base raster and all soft and hard EEEZ rasters for a subject DM (Figure S-6)

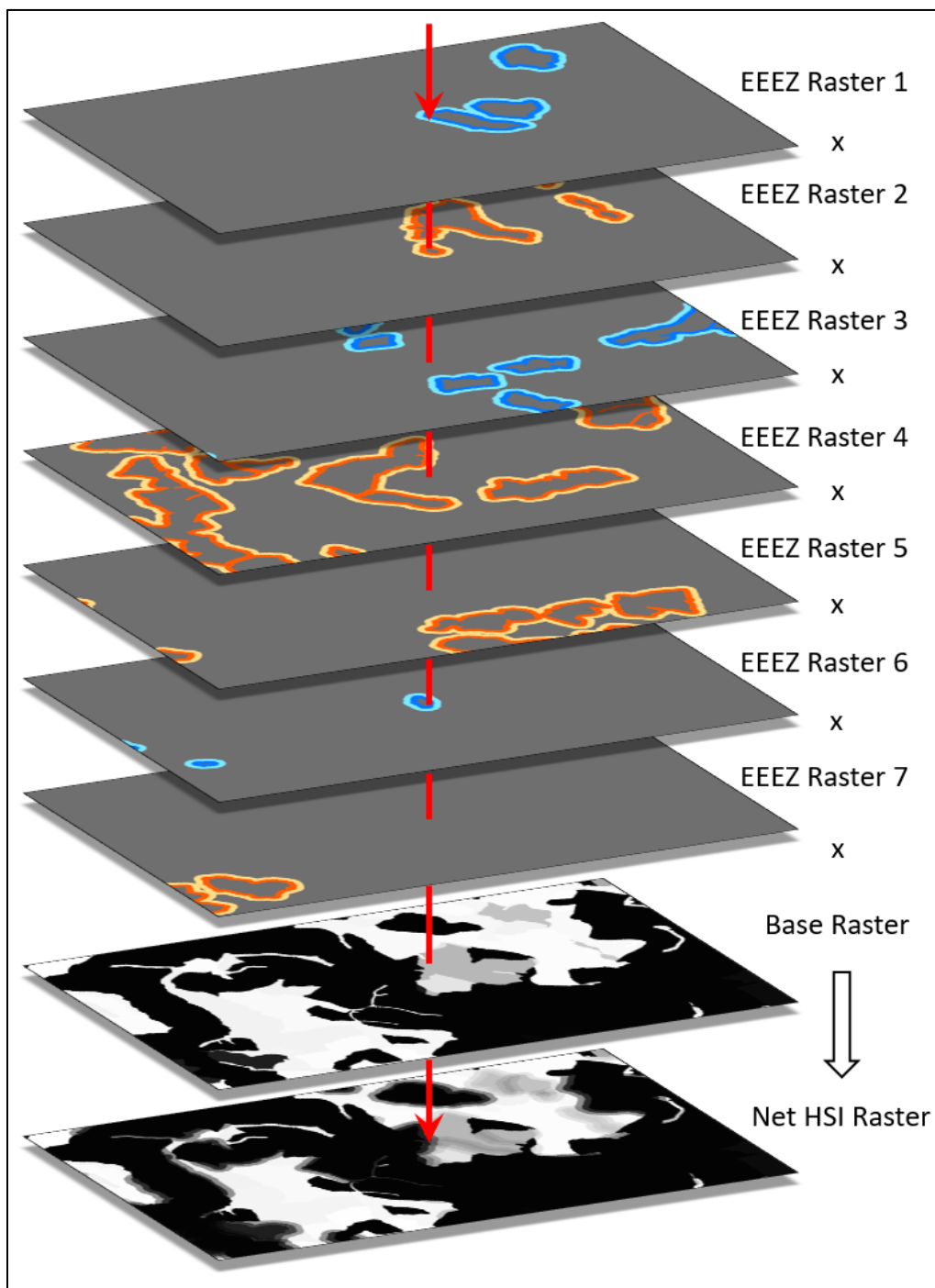


Figure S-6. Calculation of the Net HSI raster was performed using the ArcMap Raster Calculator tool, which performs logical and mathematical functions on spatially coincident pixels of multiple rasters. The EEEZ rasters contain inner and outer EEEZ habitat diminution data for each harvest class; the pixels in the grey area of the EEEZ rasters have a value of 1, and the EEEZ pixels (colored bands in grey field) have values that represent HDF values from Table S-4 (pixel values =  $(1-HDF)$ ). When all EEEZ rasters are multiplied together with the base raster, a new raster with pixel values net of edge effects is created – the Net HSI raster.

Results and Discussion

Compilation of Edge Effects and Direct Effects

Edge Effects

Base HSI-acres and HSI-acres net of edge effects for the entire ESRF are summarized for each DM (Table S-6, Figure S-7). Percent edge diminution is calculated as the difference between *Net HSI-acres* and *Base HSI-acres*, expressed as a percent of *Base HSI-acres*.

Table S-6. ESRF forest-wide MAMU habitat: mean raster values and HSI-acres at DMs from beginning (2024) to end (2104) of HCP term. Base values are net of direct harvest effects (Table S-5), but do not include edge effects. Net HSI raster values are net of both direct harvest effects <i>and</i> edge effects, as are net HSI-acres (Table S-4). Percent edge diminution is the difference between <i>Net HSI-acres</i> and <i>Base HSI-acres</i> , expressed as a percent of <i>Base HSI-acres</i>					
Year	Base Raster Mean HSI	Base HSI-Acres	Net HSI Raster Mean HSI	Net HSI-acres	Edge Diminution (%)
2024	0.26206	21,831	0.24314	20,255	7.2%
2034	0.28369	23,633	0.26452	22,035	6.8%
2044	0.29190	24,316	0.26919	22,424	7.8%
2054	0.30040	25,024	0.27899	23,241	7.1%
2064	0.30873	25,718	0.28738	23,940	6.9%
2074	0.32235	26,853	0.29985	24,978	7.0%
2084	0.34555	28,785	0.31479	26,223	8.9%
2094	0.37991	31,648	0.34445	28,694	9.3%
2104	0.41529	34,596	0.37885	31,560	8.8%

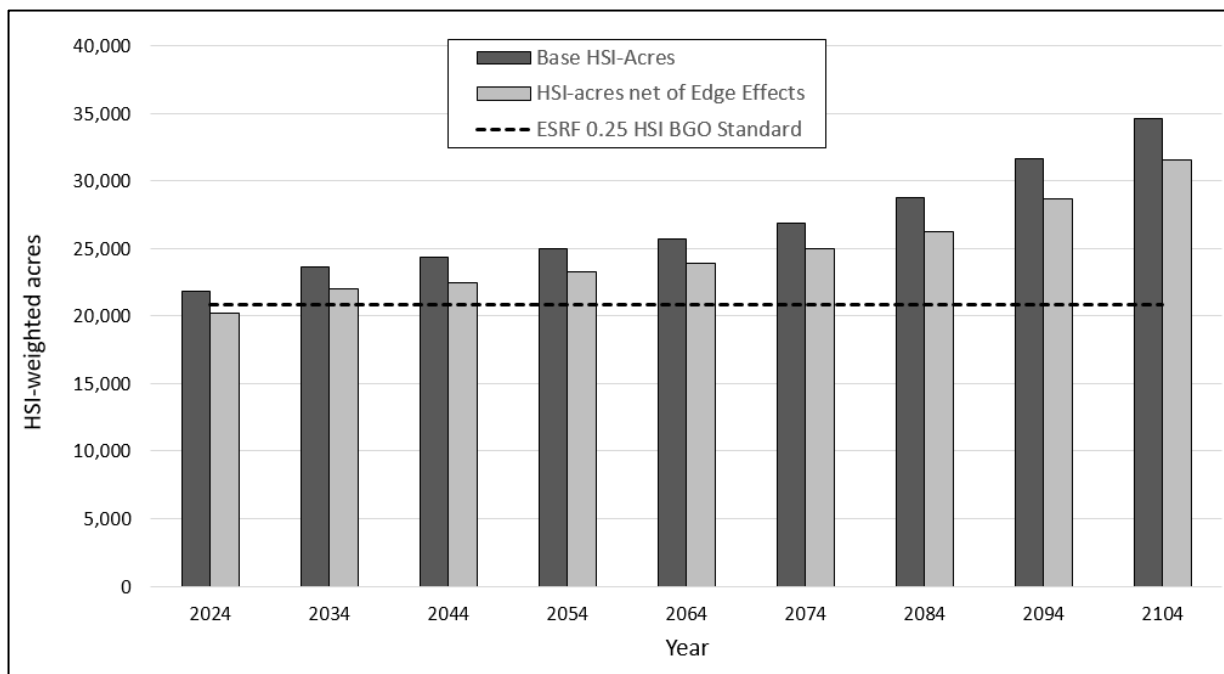


Figure S-7. MAMU HSI-acres for the ESRF at DMs from beginning (DM 2024) to end (DM 2104) of the HCP term. *Base HSI-acres* values are net of direct harvest effects (Table S-5), but do not include edge effects. *HSI-acres net of edge effects* are net of both direct harvest effects and edge effects (Table S-4). At the scale of the ESRF as a whole and for all DMs, neither base HSI-acres nor HSI-acres net of edge effects decreased in value with respect to earlier DMs. The HCP Biological Goals and Objectives (BGO) standard requiring a mean net HSI value of 0.25 for the ESRF is the equivalent of 20,816 HSI-acres, shown here as a dashed horizontal line.

### Direct Effects

Base raster values are net of the diminution of habitat directly attributable to the harvest or partial harvest of habitat with non-zero HSI values; thus, HSI values net of edge effects and percent edge diminution are also net of direct effects. To calculate what direct effects would be over the permit term we summed all scheduled harvest acres by allocation over the permit term. We then summed the *initial* state (year 2024) HSI-acres for each allocation and multiplied this value times the appropriate HDF value for each harvest class (Table S-7). The baseline for estimating direct effects is thus the HSI value of harvested stands at the beginning of the HCP permit term, not the HSI value of stands at the time of harvest.



Table S-7. Direct Harvest Effects. Direct harvest effects represent the direct reduction in habitat value of a harvested area, and do not include offsite effects, such as edge effects. The baseline for estimating direct effects is the HSI value of harvested stands at the beginning of the HCP permit term (year 2024).						
	Total Acres	Acres Scheduled for Harvest	Total HSI-Acres (year 2024)	HSI-Acres Scheduled for Harvest	Direct Effect HDF	Direct Effect (HSI-Acres)
Intensive	9,860.8	9,860.8	0.0	0.0	1	0.0
Flex50	5,757.0	5,757.0	0.0	0.0	1	0.0
Extensive (Not ConMAMU)	8,551.6	8,551.6	77.9	77.9	0.88	68.6
Upper Big Creek VRH100	554.5	554.5	0.0	0.0	0.88	0.0
Alder Creek VRH100	1,068.8	1,068.8	0.0	0.0	0.88	0.0
Hakki Ridge VRH100	418.7	418.7	0.0	0.0	0.88	0.0
Flex VRH100	1,081.2	986.6	452.0	402.0	0.88	353.8
Extensive ConMAMU	1,889.6	1,177.8	998.9	629.4	0.88	553.9
Extensive MAMU experiment	1,370.0	1,370.0	688.5	688.5	0.2	137.7
CRW Thin	6,810.0	5,621.5	0.0	0.0	0	0.0
CRW No Thin	17,059.8	0.0	8,553.5	0.0	0	0.0
CRW RCA	9,568.6	0.0	3,484.8	0.0	0	0.0
MRW Reserve	12,304.6	0.0	5,569.5	0.0	0	0.0
MRW RCA	6,640.2	0.0	1,842.1	0.0	0	0.0
Hakki Reserve	278.3	0.0	145.8	0.0	0	0.0
Hakki RCA	90.4	0.0	20.7	0.0	0	0.0
ESRF Total	83,304.1	35,367.3	21,833.6	1,797.8		1,113.9

### ESRF Subunits

Edge effects for subunits of the ESRF can be derived by evaluating raster statistics within zones of interest. Such zones could be the Triad research watersheds, the conservation research watersheds (CRW), individual watersheds or sets of watersheds, or any other spatial delineation. We evaluated edge effects separately for the Triad research watersheds (Triad), the CRW, and the Multiple Objectives Zone (MOZ); together these three zones comprise the entire ESRF (Figure S-8). We also evaluated as a single zone the combined Triad and MOZ, which together comprise the primary harvest base lands of the ESRF.

### Habitat Trends

As might be expected, the relative fraction of net HSI-acres attributable to the CRW increases through the permit term while the relative fraction of net HSI-acres attributable to the Triad and to the MOZ declines (Figure S-9; Table S-8). This is in alignment with OSU’s planning strategy of creating a large contiguous area with a conservation research emphasis – the Conservation Research Watersheds – where new fragmentation is avoided and existing fragmentation attributable to pre-existing plantation forestry is remediated, and an area with a research emphasis on active forest management – the Management Research Watersheds (OSU, 2021).

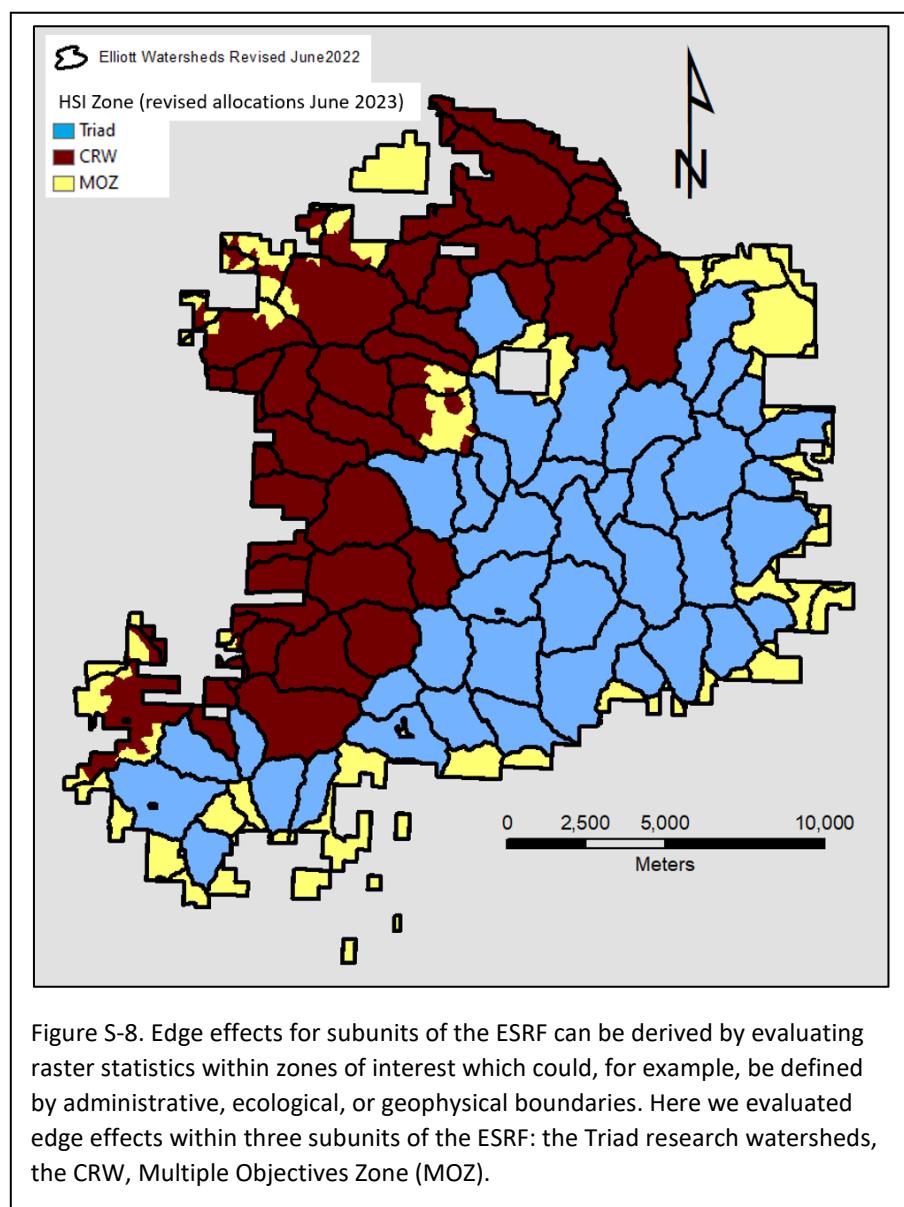
Considering the ESRF as a whole, habitat value net of edge effects increases from 20,255 HSI-acres in year 2024 to 31,560 HSI-acres in year 2104, with no DM showing a decrease in HSI-acres from prior years (Figure

S-7; Table S-6). This overall increase in net HSI value across the forest, as well as the disproportionate increase in the HSI value of the CRW, is apparent in Figure S-11.

When considering HSI trends for the three subunits of the ESRF, all showed an increase in both base and edge-adjusted HSI values between the beginning of the permit term and the end of term, with the CRW and Triad zones showing no periodic declines in HSI values throughout the permit term (Figure S-10a and S-10b). When evaluating the combined Triad and MOZ subunits there is no decline in base HSI value through the permit term; however, net HSI value declines slightly in years 2044 and 2054 (Figure S-10d, Table S-9).

Evaluated by itself, the MOZ showed periodic declines in both base HSI values and net HSI values (Figure S-10c; Table S-9) and a general suppression of net HSI values compared to the Triad watersheds. This suppression in net HSI values in the MOZ is at least in part attributable to the short-rotation Flex 50 allocation. The MOZ includes all 5,757 acres of the Flex 50 allocation, which was modeled assuming the “worst case” of 50-year rotation even-age intensive management. At a 50-year rotation, harvest units in

this allocation would be in an edge state for 40 years out of the 50-year harvest cycle, with 20 years in hard edge and 20 years in soft edge. If actual management instead employed longer harvest cycles – for example, 100 years instead of 50 years – habitat diminution attributable to edge effects from this harvest class would be reduced by approximately 50%.



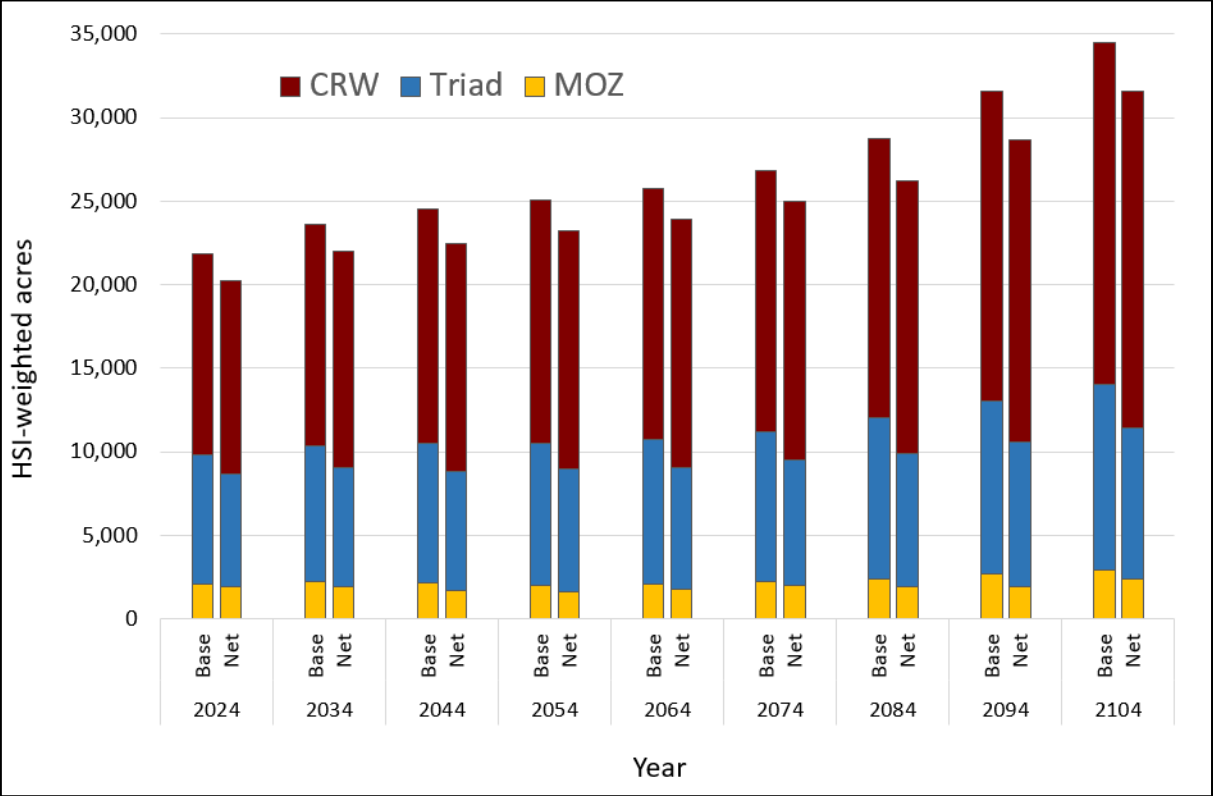


Figure S-9. Base and edge-adjusted HSI-acres for the ESRF, partitioned by Triad research watersheds, the CRW, and the MOZ. The Triad and MOZ categories together comprise the primary harvest-base allocations on the ESRF and are evaluated together (Table S-9 and Figure S-10d).

Table S-8. Percent of total net HSI-acres by DM. The relative proportion of net HSI-acres in the CRW increases through the permit term, whereas it declines in the two active forest management zones (Triad and MOZ).

DM (Year)	Triad	CRW	MOZ	Total
2024	33%	57%	9%	100%
2034	32%	59%	9%	100%
2044	32%	61%	8%	100%
2054	31%	61%	7%	100%
2064	31%	62%	7%	100%
2074	30%	62%	8%	100%
2084	30%	62%	7%	100%
2094	30%	63%	7%	100%
2104	29%	64%	7%	100%

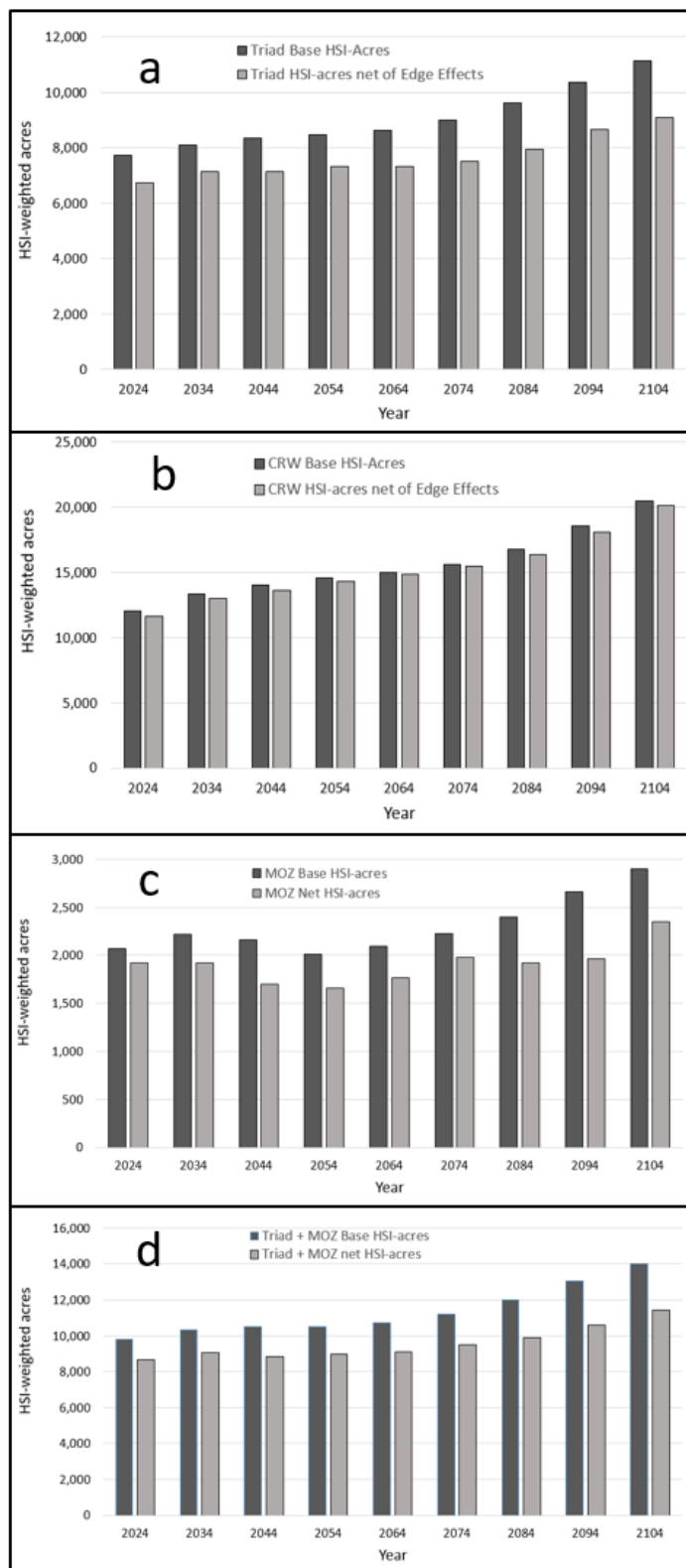


Table S-9. Tabular data that accompanies Figure S-10.

Decadal Milepost (year)	Base HSI-Acres	HSI-acres net of Edge Effects	Edge Diminution (%)
<b>Triad Research Watersheds (36,871 acres)</b>			
2024	7,726	6,750	13%
2034	8,102	7,134	12%
2044	8,363	7,140	15%
2054	8,484	7,314	14%
2064	8,622	7,324	15%
2074	8,988	7,520	16%
2084	9,607	7,960	17%
2094	10,380	8,649	17%
2104	11,141	9,082	18%
<b>CRW (33,438 acres)</b>			
2024	12,038	11,587	4%
2034	13,311	12,981	2%
2044	14,046	13,582	3%
2054	14,551	14,269	2%
2064	15,004	14,855	1%
2074	15,616	15,480	1%
2084	16,738	16,339	2%
2094	18,555	18,080	3%
2104	20,491	20,125	2%
<b>MOZ (12,995 acres)</b>			
2024	2,066	1,918	7%
2034	2,219	1,920	13%
2044	2,160	1,702	21%
2054	2,013	1,658	18%
2064	2,094	1,761	16%
2074	2,223	1,978	11%
2084	2,397	1,924	20%
2094	2,657	1,964	26%
2104	2,897	2,353	19%
<b>Triad + MOZ (49,866 acres)</b>			
2024	9,793	8,668	11%
2034	10,322	9,054	12%
2044	10,523	8,843	16%
2054	10,497	8,972	15%
2064	10,716	9,085	15%
2074	11,211	9,499	15%
2084	12,004	9,884	18%
2094	13,037	10,614	19%
2104	14,038	11,435	19%

Figure S-10. Base HSI-acres and HSI-acres net of edge effects for the Triad Research Watersheds (a), the CRW (b), and the MOZ (c); these three zones comprise the entire ESRF. Combined, the Triad Research Watersheds and the MOZ (d) comprise the primary harvest-base allocations for the ESRF.





Figure S-11. Map of Net HSI values across the across the ESRF at DMs throughout the permit term, including initial condition (year 2024). Net HSI values symbolized in the decadal maps shown here correspond to the decadal HSI values displayed in Table S-6.

## Monitoring and Adaptive Management

Objective 2.3 of the HCP specifies two quantifiable objectives related to HSI: 1) Maintain an area-weighted mean marbled murrelet Habitat Suitability Index (HSI) value of 0.25 across the permit area (net of all edge effects) and, 2) limit reduction of marbled murrelet habitat attributable to harvest-related edge effects to 7.2 percent of total permit area HSI-weighted acres throughout the permit term. Attaining these objectives while also achieving other goals and objectives for the ESRF will require ongoing monitoring of forest condition in terms of HSI, and will require the evaluation of prospective harvesting scenarios as part of the biennial planning process to ensure that planned harvests achieve HCP objectives.

Current forest condition is very close to the quantitative objectives described above, both in terms of mean net HSI and in terms of legacy edge effects from previous harvests (Figure S-7 and Figure S-12). The intent of Objective 2.3 is to ensure that forest condition, as quantified by HSI, does not drop below conditions that existed at the beginning of the permit term. As modeled, forest-wide mean net HSI is 0.243 at the beginning of the permit term, rises to a value of 0.265 by the end of the first decade of implementation (year 2034), and is projected to increase every decade thereafter (Table S-6). HSI projections are based on worst-case assumptions, so it seems likely that with appropriate monitoring and adaptive measures during biennial planning and implementation the mean net HSI standard for the forest can be achieved. This does not preclude applying different standards at smaller scales of analysis however, such as maintaining a minimum standard for areas of concern outside of the CRW.

The 7.2% maximum diminution of MAMU habitat attributable to harvest-related edge effects may be a more difficult standard to achieve than the mean net HSI standard. As modeled, edge diminution is projected to be very close to the 7.2% standard during the first 5 decades of the permit term, but exceeds the standard in the final three decades (Figure S-12). This increase is attributable to a convergence of scheduled regeneration harvests beginning in the fifth decade (Table S-3), and is exacerbated by the modeled 50-year rotation in the Flex 50 allocation, which contributes to peaks in harvest-related edge diminution in the MOZ (Figure S-12).

There are several adaptive measures available to planners that would allow the forest to remain within the edge diminution standard. Such adaptive measures could include: strategically removing lands from the harvest base that produce the most edge effects; strategically reallocating lands to reduce fragmentation; strategically employ variable retention silviculture (rather than even-age silviculture); where variable retention silviculture is employed spatially configure retention so as to reduce edge effects; increase the length of harvest rotation cycles; place no-harvest buffers adjacent to affected habitat. All of these measures require a means to identify areas where harvest-related edge effects can be expected to occur.

Given prospective harvest schedules developed during the planning process, an edge raster can be created of potential future HSI values given implementation of the prospective harvest schedule. When this raster is subtracted from another raster of existing or baseline conditions, a new raster showing changes in HSI values is produced (Figure S-13). This raster map can be used to inform decisions about applying adaptive measures that moderate harvest-related edge effects.

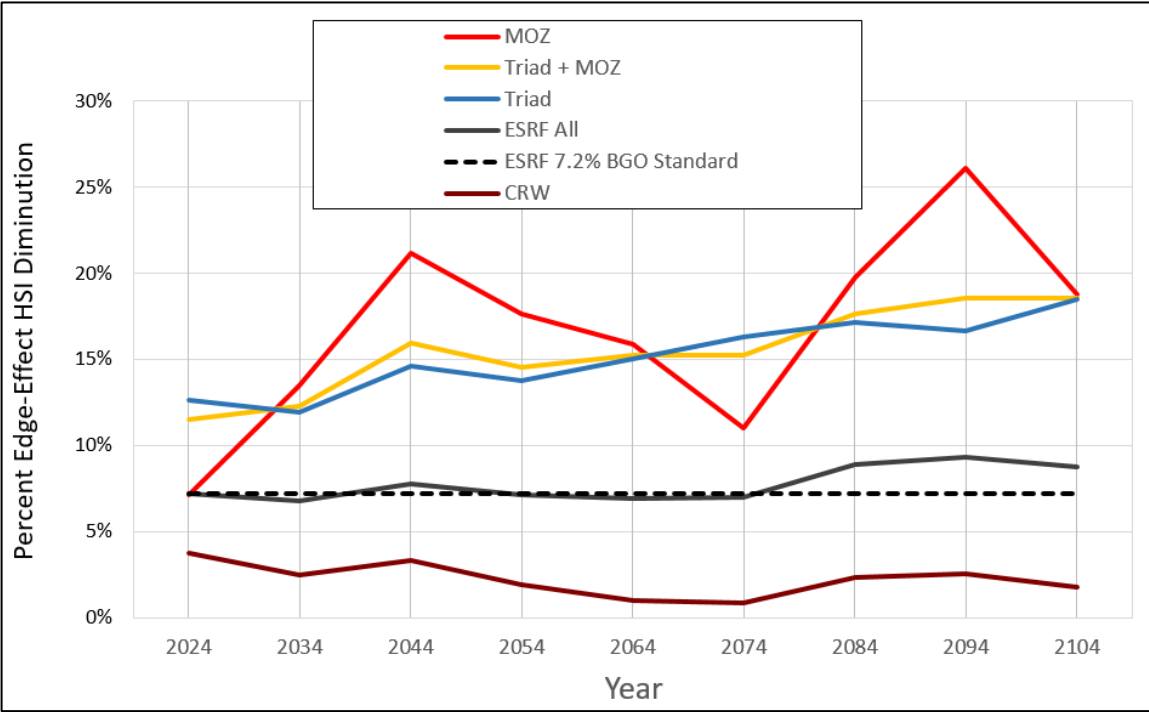
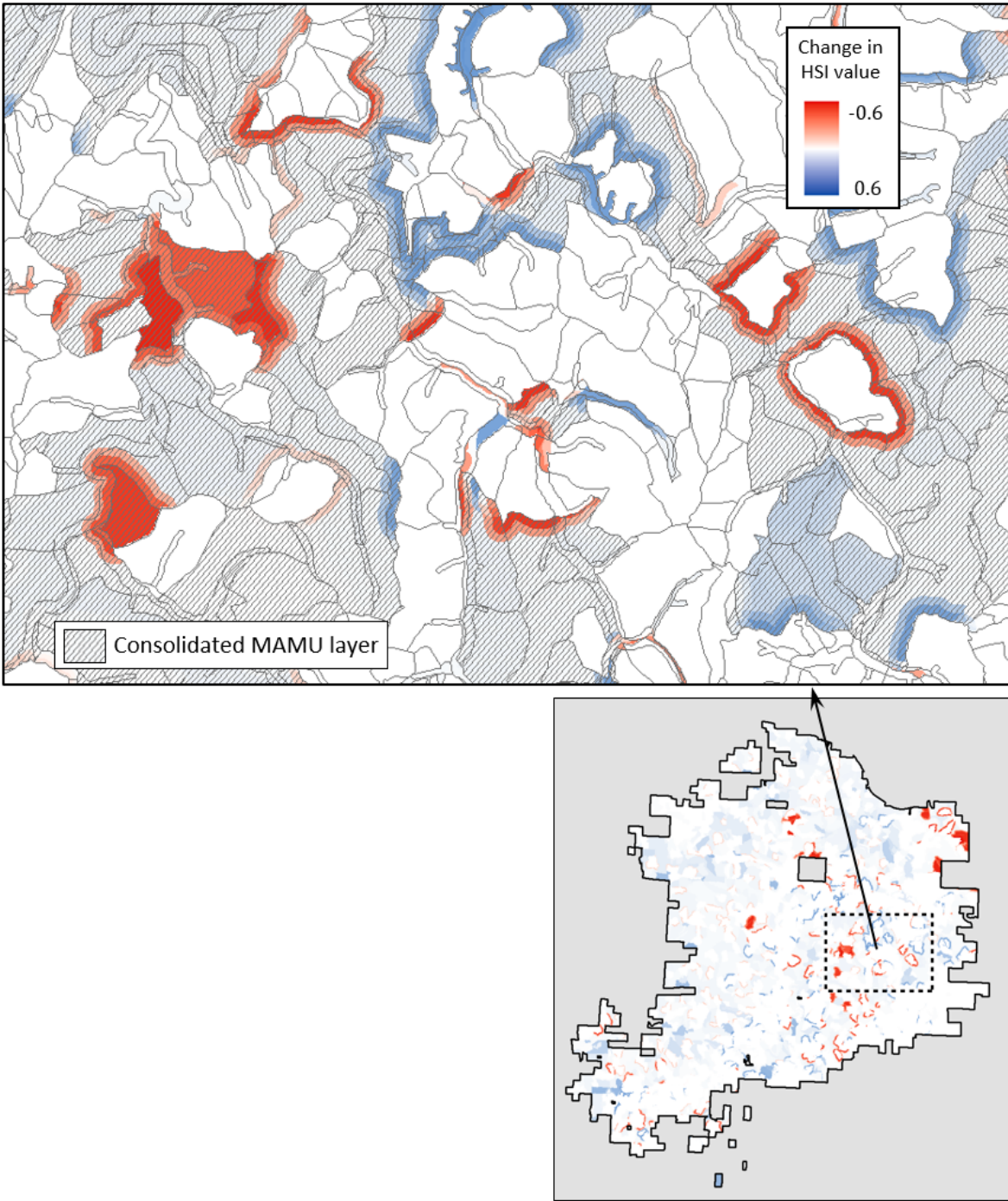


Figure S-12. Percent of habitat diminution attributable to harvest-related edge effects, by management zone. Harvest-related edge effects are relatively low in the CRW, where the only programmed harvest activity is restoration thinning. In contrast, harvest-related edge effects are higher in areas with more scheduled harvest, such as the MOZ and Triad watersheds. As modeled, the ESRF as a whole remains very close to the 7.2% standard through the first 5 decades of the permit term but is projected to exceed the standard in the final 3 decades.





## Appendix S: References Cited

- Betts, M. G., Northrup, J. M., Bailey Guerrero, J. A., Adrean, L. J., Nelson, S. K., Fisher, J. L., Gerber, B. D., Garcia-Heras, M.-S., Yang, Z., Roby, D.D., & Rivers, J. W. (2020). Squeezed by a habitat split: Warm ocean conditions and old-forest loss interact to reduce long-term occupancy of a threatened seabird. *Conservation Letters*, 13, e12745.
- Burger, A. E. 2002. Conservation assessment of Marbled Murrelets in British Columbia: a review of the biology, populations, habitat associations, and conservation. Technical Report Series No. 387, Canadian Wildlife Service, Pacific and Yukon Region, Delta, British Columbia, Canada.
- Evans Mack, D., W. P. Ritchie, S. K. Nelson, E. Kuo-Harrison, P. Harrison, and T. E. Hamer. 2003. Methods for surveying Marbled Murrelets in forests: a revised protocol for land management and research. Technical Publication Number 2. Pacific Seabird Group, Corvallis, Oregon, USA. [online] URL: [https://pacificseabirdgroup.org/wp-content/uploads/2016/06/PSG\\_TechPub2\\_MAMU\\_ISP.pdf](https://pacificseabirdgroup.org/wp-content/uploads/2016/06/PSG_TechPub2_MAMU_ISP.pdf)
- Hamer, T. E., K. Nelson, J. Jones, and J. Verschuyt. 2021. Marbled Murrelet nest site selection at three fine spatial scales. *Avian Conservation and Ecology* 16(2):4. <https://doi.org/10.5751/ACE-01883-160204>
- Hamer, T. E. 1995. Inland habitat associations of Marbled Murrelets in Western Washington. Pages 163-175 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, and J. F. Piatt, editors. *Ecology and conservation of the Marbled Murrelet*. U.S. Forest Service General Technical Report PSW-GTR-152. Pacific Southwest Research Station Albany, California, USA. <https://doi.org/10.5962/bhl.title.23948>
- Hamer, T.E. and Nelson, S.K., 1995. Characteristics of marbled murrelet nest trees and nesting stands. *Ecology and Conservation of the Marbled Murrelet*. USDA Forest Service General Technical Report PSW-GTR-152. Pacific Southwest Research Station, Albany, CA, pp.69-82.
- Jennings, S.B., Brown, N.D. and Sheil, D., 1999. Assessing forest canopies and understorey illumination: canopy closure, canopy cover and other measures. *Forestry*, 72(1), pp.59-74.
- Malt, J. and Lank, D., 2007. Temporal dynamics of edge effects on nest predation risk for the marbled murrelet. *Biological Conservation*, 140(1-2), pp.160-173.
- Malt, J.M. and Lank, D.B., 2009. Marbled murrelet nest predation risk in managed forest landscapes: dynamic fragmentation effects at multiple scales. *Ecological Applications*, 19(5), pp.1274-1287.
- McShane, C., T. Hamer, H. Carter, G. Swartzman, V. Friesen, D. Ainley, R. Tressler, K. Nelson, A. Burger, L. Spear, T. Mohagen, R. Martin, L. Henkel, K. Prindle, C. Strong, and J. Keany. 2004. Evaluation report for the 5-year status review of the Marbled Murrelet in Washington, Oregon and California. Prepared for the U.S. Fish and Wildlife Service, Region 1, Portland, Oregon. EDAW Inc., Seattle, Washington, USA.
- Nelson, S.K. and Hamer, T.E., 1995. Nest success and the effects of predation on Marbled Murrelets. *Ecology and Conservation of the Marbled Murrelet*. USDA Forest Service General Technical Report PSW-GTR-152. Pacific Southwest Research Station, Albany, CA, pp.89-98.

- Nelson, S. K., M. H. Huff, S. L. Miller, and M. G. Raphael. 2006. Marbled Murrelet biology: habitat relations and populations. Pages 9-30 in M. H. Huff, M. G. Raphael, S. L. Miller, S. K. Nelson, and J. Baldwin, editors. Northwest forest plan—the first 10 years (1994-2003): status and trends of populations and nesting habitat for the Marbled Murrelet. General Technical Report PNW-GTR-650. U.S. Forest Service, Pacific Northwest Research Station, Portland, Oregon, USA. <https://doi.org/10.2737/pnw-gtr-650>
- Nelson, S. K. (2020). Marbled Murrelet (*Brachyramphus marmoratus*), version 1.0. In A. F. Poole & F. B. Gill (Eds.), *Birds of the world*. Cornell Lab of Ornithology. Available online at: <https://doi.org/10.2173/bow.marmur.01>
- OSU (Oregon State University), 2021. *Proposal: Elliott State Research Forest*. Oregon State University College of Forestry, Corvallis, Oregon. 125pp.
- Raphael, M.G., Mack, D.E., Marzluff, J.M. and Luginbuhl, J.M., 2002. Effects of forest fragmentation on populations of the marbled murrelet. *Studies in Avian Biology*, 25, pp.221-235.
- Raphael, M. G., Falxa, G. A., & Burger, A. E. (2018). Marbled Murrelet. In T. A. Spies, P. A. Stine, R. Gravenmier, J. W. Long, & M. J. Reilly (Technical Coordinators), *Synthesis of science to inform land management within the Northwest Forest Plan area*. General Technical Report PNW-GTR-966 (Vol. 1, pp. 301–350). U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.
- Valente, J. J, Rivers, J. W., Yang, Z., Nelson, S. K., Northrup, J. M., Roby, D. D., Meyer, C. B., & Betts, M. G. (2023). Fragmentation effects on an endangered species across a gradient from the interior to edge of its range. *Conservation Biology*, e14091. <https://doi.org/10.1111/cobi.14091>
- WDNR (Washington State Department of Natural Resources). 2019a. *Final State trust lands Habitat Conservation Plan amendment: marbled murrelet long-term conservation strategy*. Washington State Department of Natural Resources, Forest Resources Division, Olympia, Washington. 286pp.
- WDNR. 2019b. Appendix E: Estimating the location and quality of marbled murrelet habitat | Focus Paper #3. Published in: *Long term conservation strategy for the marbled murrelet. Final Environmental Impact Statement*, September 2019. Washing State Department of Natural Resources. Available online at: <https://www.dnr.wa.gov/long-term-conservation-strategy-marbled-murrelet>
- WDNR. 2019c. Appendix H: Potential impacts and mitigation | Focus Paper # 5. Published in: *Long term conservation strategy for the marbled murrelet. Final Environmental Impact Statement*, September 2019. Washing State Department of Natural Resources. Available online at: <https://www.dnr.wa.gov/long-term-conservation-strategy-marbled-murrelet>

## Appendix T. List of Fish, Amphibian, Reptile, Mammal and Bird Species Observed or Potentially Present on the Elliott State Research Forest

Fish, amphibian, reptile, mammal and bird species that have been observed or are potentially present in the ESRF are listed in Table T-1. Some species are known to be present. Others are considered likely to be present based on their known ranges and use of forested habitats. The list is based on a similar list from Oregon DSL and ODF (2011) with status updates found in USFWS (2022), ODFW (2021) and Oregon Biodiversity Information Center (ORBIC, 2019). Four bird species were provisionally added based on biodiversity monitoring conducted in 2022-23.

This list should not be considered definitive. It will continue to be updated as information regarding status and other details is further verified and additional monitoring information regarding species occurrence on the ESRF becomes available.

**Table T-1. Species observed or potentially present on the ESRF**

Common Name	Scientific Name	Status 2011	Status 2023
<b>FISH</b>			
Oregon Coast Coho Salmon	<i>Oncorhynchus kisutch</i>	FT, OCS, SSV	FT, OCS, SSV, ORBIC 1
Chum Salmon	<i>Oncorhynchus keta</i>	OCS	OCS, SC, ORBIC 2
Fall chinook salmon	<i>Oncorhynchus tshawytscha</i>	SSV, OCS	OCS
Winter steelhead	<i>Oncorhynchus mykiss</i>	FSOC, SSV, OCS	FSOC ORBIC 1
Coastal cutthroat trout	<i>Oncorhynchus clarki</i>	FSOC, OCS	FSOC, OCS, ORBIC 2
Millicoma longnose dace	<i>Rhinichthys cataractae</i> spp.	FSOC, SSV, OCS	SS, FSOC, OCS, ORBIC 1
Umpqua dace	<i>Rhinichthys evermanni</i>		
Speckled dace	<i>Rhinichthys osculus</i>		
Largescale sucker	<i>Catostomus macrocheilus</i>		
Threespine stickleback	<i>Gasterosteus aculeatus</i>		
Redside shiner	<i>Richardsonius balteatus</i>		
Pacific lamprey	<i>Lampetra tridentata</i>	SSV, FSOC, OCS	SSV, OCS, FSOC, ORBIC 2
[Western] River lamprey	<i>Lampetra ayresi</i>	FSOC	SS, FSOC, OCS, ORBIC 3
Western brook lamprey	<i>Lampetra richardsoni</i>	SSV, OCS	SS, FSOC, OCS, ORBIC 4
Coastrange sculpin	<i>Cottus aleuticus</i>		

Prickly sculpin	<i>Cottus asper</i>		
Reticulate sculpin	<i>Cottus perplexus</i>		
Riffle sculpin	<i>Cottus gulosus</i>		
Brown bullhead	<i>Ictalurus nebulosus</i>		
Umpqua chub	<i>Oregonichthys kalawatseti</i>	FSOC, SSC, OCS	FSOC, SSC, SC, OCS, ORBIC 1
Largemouth bass	<i>Micropterus salmoides</i>	NON	
Smallmouth bass	<i>Micropterus dolomieu</i>	NON	
Black crappie	<i>Pomoxis nigromaculatus</i>	NON?	
Bluegill	<i>Lepomis macrochirus</i>	NON?	
<b>AMPHIBIANS and REPTILES</b>			
Coastal tailed frog	<i>Ascaphus truei</i>	SS	SS, OCS, ORBIC 4
[Northern] Red-legged frog	<i>Rana aurora aurora</i>		SS, OCS, ORBIC 4
Foothill yellow-legged frog	<i>Rana boylei</i>		FSOC, SSC, OCS, ORBIC 2
Pacific tree frog	<i>Pseudacris regilla</i>		
Southern torrent salamander	<i>Rhyacotriton variegates</i>	SS	SS, OCS, ORBIC 4
Pacific giant salamander	<i>Dicamptodon tenebro</i>		
Long-toed salamander	<i>Ambystoma macrodactylum</i>		
Dunn's salamander	<i>Plethodon dunni</i>		
Western red-backed salamander	<i>Plethodon vehiculum</i>		
Northwestern salamander	<i>Ambystoma gracile</i>		
Clouded salamander	<i>Aneides ferreus</i>		SS, OCS, ORBIC 4
Ensatina salamander	<i>Ensatina eschscholtzii</i>		
Rough-skinned newt	<i>Taricha granulosa</i>		
Western toad	<i>Bufo boreas</i>		SS, OCS, ORBIC 4
Bullfrog	<i>Rana catesbeiana</i>	NON	
Northwestern pond turtle	<i>Clemmys marmorata</i>	SSC, FSOC, OCS	FSOC, OCS, SC, ORBIC 2
Northern alligator lizard	<i>Gerrhontus coeruleus</i>		
Western skink	<i>Eumeces skiltonianus</i>		
Rubber boa	<i>Charina bottae</i>		
Northwestern garter snake	<i>Thamnophis ordinoides</i>		
Common garter snake	<i>Thamnophis sirtalis</i>		
Sharptail snake	<i>Contia tenuis</i>		
Common kingsnake	<i>Lampropeltis getula</i>		
*Western pond turtle	<i>Actinemys marmorata marmorata</i>		FC
<b>MAMMALS</b>			
Mountain lion	<i>Felis concolor</i>	SG	



Bobcat	<i>Felis Rufus</i>		
Roosevelt elk	<i>Cervus elaphus roosevelti</i>	SG	
Black-tailed mule deer	<i>Odocoileus hemionus columbianus</i>	SG	
Coyote	<i>Canis latrans</i>		
Gray fox	<i>Urocyon cinereoargenteus</i>		
Black bear	<i>Ursus americanus</i>	SG	
Fisher	<i>Pekania pennanti</i>	FC, SSC	PT, FC, SSC, OCS, ORBIC 2
Raccoon	<i>Procyon lotor</i>		
River otter	<i>Lutra canadensis</i>		
American beaver	<i>Castor canadensis</i>		
Porcupine	<i>Erethizon dorsatum</i>		ORBIC 3
Snowshoe hare	<i>Lepus americanus</i>		
Brush rabbit	<i>Sylvilagus bachmani</i>		
Mountain beaver	<i>Aplodontia rufa</i>		
Coastal (Humboldt) marten	<i>Martes caurina humboldtensis</i>	FT, SSV, OCS	FT, SS, OCS, ORBIC 1
Long-tailed weasel	<i>Mustela frenata</i>		
Mink	<i>Mustela vison</i>		
Spotted skunk	<i>Spilogale gracilis</i>		
Striped skunk	<i>Mephitis mephitis</i>		
Trowbridge's shrew	<i>Sorex trowbridgii</i>		
Fog shrew	<i>Sorex sonomae</i>		
Vagrant shrew	<i>Sorex vagrans</i>		
Pacific shrew	<i>Sorex pacificus</i>		
Pacific marsh shrew	<i>Sorex bendirii</i>		
Shrew-mole	<i>Neurotrichus gibbsii</i>		
Townsend's mole	<i>Scapanus townsendii</i>		
Coast mole	<i>Scapanus orarius</i>		
California myotis	<i>Myotis californicus</i>	SSV, OCS	SS, OCS, ORBIC 4
Long-eared myotis	<i>Myotis evotis</i>	FSOC	ORBIC 4
Little brown myotis	<i>Myotis lucifugus</i>		ORBIC 4
Yuma myotis	<i>Myotis yumanensis</i>	FSOC	ORBIC 4
Long-legged myotis	<i>Myotis volans</i>	SSV, FSOC, OCS	SS, OCS, ORBIC 4
Fringed myotis	<i>Myotis thysanodes</i>	SSV, FSOC, OCS	SS, OCS, ORBIC 2
Big brown bat	<i>Eptesicus fuscus</i>		
Hoary bat	<i>Lasiurus cinereus</i>	SSV, OCS	SS, OCS, ORBIC 3
Silver-haired bat	<i>Lasionycteris noctivagans</i>	SSV, FSOC, OCS	SS, OCS, ORBIC 4
Townsend's big-eared bat	<i>Corynorhinus townsendii</i>	SSC, FSOC, OCS	SSC, OCS, ORBIC 2
Townsend's chipmunk	<i>Tamias townsendii</i>		
Western gray squirrel	<i>Sciurus griseus</i>	SG	OCS, ORBIC 4
Douglas' squirrel	<i>Tamiasciurus douglasii</i>		
Northern flying squirrel	<i>Glaucomys sabrinus</i>		
California ground squirrel	<i>Spermophilus beecheyi</i>		

Dusky-footed woodrat	<i>Neotoma fuscipes</i>		
Bushy-tailed woodrat	<i>Neotoma cinerea</i>		
Ringtail	<i>Bassariscus astutus</i>		SS, OCS, ORBIC 4
Deer mouse	<i>Peromyscus maniculatus</i>		
White-footed vole	<i>Phenacomys albipes</i>	FSOC	
Western red-backed vole	<i>Clethrionomys californicus</i>		
Red tree vole	<i>Arborimus longicaudus</i>	SSV, FSOC, OCS	SS, FC, OCS, ORBIC 4
Long-tailed vole	<i>Microtus longicaudus</i>		
Creeping vole	<i>Microtus oregoni</i>		
Townsend's vole	<i>Microtus townsendii</i>		
Muskrat	<i>Ondatra zibethicus</i>		
Pacific jumping mouse	<i>Zapus trinotatus</i>		
Nutria	<i>Myocastor coypus</i>	NON	
Virginia opossum	<i>Didelphis virginiana</i>	NON	
<b>BIRDS</b>			
Marbled murrelet	<i>Brachyramphus marmoratus</i>	FT, ST, OCS	FT, SE, CH, OCS, ORBIC 2
Northern spotted owl	<i>Strix occidentalis</i>	FT, ST, OCS	FT, ST, CH, OCS, ORBIC 1
Green heron	<i>Butorides virescens</i>	NTMB	
Great blue heron	<i>Ardea herodias</i>		
Wood duck	<i>Aix sponsa</i>	SG, NTMB	
Harlequin duck	<i>Histrionicus histrionicus</i>	SG, FSOC	SS, OCS, ORBIC 2
Hooded merganser	<i>Lophodytes cucullatus</i>	SG, NTMB	
Common merganser	<i>Mergus merganser</i>	SG	
Turkey vulture	<i>Cathartes aura</i>	NTMB	
Osprey	<i>Pandion haliaetus</i>	NTMB	
Bald eagle	<i>Haliaeetus leucocephalus</i>	ST, OCS	Fed ESA delisted ORBIC 4
Northern goshawk	<i>Accipiter gentiles</i>	SSV, FSOC	
Sharp-shinned hawk	<i>Accipiter striatus</i>	NTMB	
Cooper's hawk	<i>Accipiter cooperii</i>	NTMB	
Red-tailed hawk	<i>Buteo jamaicensis</i>	NTMB	
American kestrel	<i>Falco sparverius</i>	NTMB	
Peregrine falcon	<i>Falco peregrinus</i>	NTMB, SSV, OCS	Fed ESA delisted
Mountain quail	<i>Oreortyx pictus</i>	SG, FSOC	OCS, ORBIC 4
Blue grouse	<i>Dendragapus obscurus</i>	SG	
Ruffed grouse	<i>Bonasa umbellus</i>	SG	
Killdeer	<i>Charadrius vociferus</i>	NTMB	
American dipper	<i>Cinclus mexicanus</i>		
Rock dove	<i>Columba livia</i>	NON, SG	
Mourning dove	<i>Zenaida macroura</i>	SG, NTMB	
Band-tailed pigeon	<i>Patagioenas fasciata</i>	SG, FSOC, NTMB, OCS	ORBIC 4
Western screech-owl	<i>Otus kennicottii</i>		

Great horned owl	<i>Bubo virginianus</i>		
Northern pygmy-owl	<i>Glaucidium gnoma</i>		
Barred owl	<i>Strix varia</i>		
Northern saw-whet owl	<i>Aegolius acadicus</i>		
Common nighthawk	<i>Chordeiles minor</i>	NTMB	OCS, SC, ORBIC 4
Vaux's swift	<i>Chaetura vauxi</i>	NTMB	
Anna's hummingbird	<i>Calypte anna</i>	NTMB	
Rufous hummingbird	<i>Selasphorus rufus</i>	NTMB	
Belted kingfisher	<i>Ceryle alcyon</i>	NTMB	
Red-breasted sapsucker	<i>Sphyrapicus ruber</i>	NTMB	
Downy woodpecker	<i>Picoides pubescens</i>		
Hairy woodpecker	<i>Picoides villosus</i>		
Northern flicker	<i>Colaptes auratus</i>		
Pileated woodpecker	<i>Dryocopus pileatus</i>		OCS, ORBIC 4
Olive-sided flycatcher	<i>Contopus cooperi</i>	SSV, FSOC, NTMB, OCS	SS, SC, OCS, ORBIC 4
Hammond's flycatcher	<i>Empidonax hammondii</i>	NTMB	
Little Willow flycatcher	<i>Empidonax trailii brewsteri</i>	SSV, FSOC, NTMB	OCS, ORBIC 4
Pacific-slope flycatcher	<i>Empidonax difficilis</i>	NTMB	
Western wood-pewee	<i>Contopus sordidulus</i>	NTMB	
Purple martin	<i>Progne subis</i>	SSC, FSOC, NTMB	SSC, OCS, ORBIC 2
Tree swallow	<i>Tachycineta bicolor</i>	NTMB	
Violet-green swallow	<i>Tachycineta thalassina</i>	NTMB	
Cliff swallow	<i>Petrochelidon pyrrhonota</i>	NTMB	
Barn swallow	<i>Hirundo rustica</i>	NTMB	
Gray jay	<i>Perisoreus canadensis</i>		
Western scrub jay	<i>Aphelocoma californica</i>		
Steller's jay	<i>Cyanocitta stelleri</i>		
Canada jay*	<i>Perisoreus canadensis</i>		
American crow	<i>Corvus brachyrhynchos</i>		
Common raven	<i>Corvus corax</i>		
Black-capped chickadee	<i>Poecile atricapillus</i>		
Chestnut-backed chickadee	<i>Poecile rufescens</i>		
Red-breasted nuthatch	<i>Sitta canadensis</i>		
White-breasted nuthatch	<i>Sitta carolinensis</i>		
Brown creeper	<i>Certhia americana</i>		
House wren	<i>Troglodytes aedon</i>		
Winter wren	<i>Troglodytes troglodytes</i>		
Bewick's wren*	<i>Thryomanes bewickii</i>		
Pacific wren*	<i>Troglodytes pacificus</i>		
Golden-crowned kinglet	<i>Regulus satrapa</i>		ORBIC 4
Western bluebird	<i>Sialia mexicana</i>	SSV, NTMB	SS, OCS, ORBIC 4
Townsend's solitaire	<i>Myadestes townsendi</i>	NTMB	
Swainson's thrush	<i>Catharus ustulatus</i>	NTMB	
Hermit thrush	<i>Catharus guttatus</i>	NTMB	

Varied thrush	<i>Ixoreus naevius</i>		
American robin	<i>Turdus migratorius</i>	NTMB	
Wrentit	<i>Chamaea fasciata</i>		
Cedar waxwing	<i>Bombycilla cedrorum</i>	NTMB	
Warbling vireo	<i>Vireo gilvus</i>	NTMB	
Cassin's vireo	<i>Vireo cassinii</i>	NTMB	
Hutton's vireo	<i>Vireo huttoni</i>		
Orange-crowned warbler	<i>Vermivora celata</i>	NTMB	
Nashville warbler	<i>Vermivora ruficapilla</i>	NTMB	
Yellow warbler	<i>Dendroica petechia</i>	NTMB	
Yellow-rumped warbler	<i>Dendroica coronata</i>	NTMB	
Black-throated gray warbler	<i>Dendroica nigrescens</i>	NTMB	
Townsend's warbler	<i>Dendroica townsendi</i>	NTMB	
Hermit warbler	<i>Dendroica occidentalis</i>	NTMB	
MacGillivray's warbler	<i>Oporornis tolmiei</i>	NTMB	
Wilson's warbler	<i>Wilsonia pusilla</i>	NTMB	
Common yellowthroat	<i>Geothlypis trichas</i>	NTMB	
Western tanager	<i>Piranga ludoviciana</i>	NTMB	
Black-headed grosbeak	<i>Pheucticus melanocephalus</i>	NTMB	
Evening grosbeak	<i>Coccothraustes vespertina</i>		
Lazuli bunting	<i>Passerina amoena</i>	NTMB	
Spotted towhee	<i>Pipilo erythrophthalmus</i>		
Chipping sparrow	<i>Spizella passerina</i>	NTMB	OCS, ORBIC 4
Fox sparrow	<i>Passerella iliaca</i>		
Song sparrow	<i>Melospiza melodia</i>		
White-crowned sparrow	<i>Zonotrichia leucophrys</i>	NTMB	
Golden-crowned sparrow*	<i>Zonotrichia atricapilla</i>		
Dark-eyed junco	<i>Junco hyemalis</i>		
Red-winged blackbird	<i>Agelaius phoeniceus</i>	NTMB	
Brown-headed cowbird	<i>Molothrus ater</i>	NTMB	
Northern oriole	<i>Icterus galbula</i>	NTMB	
Purple finch	<i>Carpodacus purpureus</i>		
American goldfinch	<i>Carduelis tristis</i>	NTMB	
Pine siskin	<i>Carduelis pinus</i>		
Red crossbill	<i>Loxia curvirostra</i>		
House sparrow	<i>Passer domesticus</i>	NON	
European starling	<i>Sturnus vulgaris</i>	NON	

\*Species added to list based on 2022 ESRF biodiversity surveying, subject to additional verification.

## Key to Status

- FC - Federal candidate species
- FE - Federal endangered species
- FSOC - Federal species of concern
- FT - Federal threatened species



NON - Non-native species; introduced  
NTMB - Neotropical migratory bird  
OCS - Strategy Species identified in Oregon Conservation Strategy  
SE - State endangered species  
SG - State game species  
SS - State Sensitive  
SSC - State sensitive species: critical status  
SSV - State sensitive species: vulnerable status  
ST - State threatened species

### **Key and definitions for 2022 federal USFWS list**

E - Endangered  
T - Threatened  
CH - Critical Habitat has been designated for this species  
PE - Proposed Endangered  
PT - Proposed Threatened  
PCH - Critical Habitat has been proposed for this species

Listed Species: An endangered species is one that is *in danger of extinction* throughout all or a significant portion of its range. A threatened species is one that is *likely to become endangered* in the foreseeable future.

Proposed Species: Taxa for which the Fish and Wildlife Service or National Marine Fisheries Service has published a proposal to list as endangered or threatened in the Federal Register.

Candidate Species: Taxa for which the Fish and Wildlife Service has sufficient biological information to support a proposal to list as endangered or threatened.

Delisted Species: A species that has been removed from the Federal list of endangered and threatened wildlife and plants.

Species of Concern: Taxa whose conservation status is of concern to the U.S. Fish and Wildlife Service (many previously known as Category 2 candidates), but for which further information is still needed. Such species receive no legal protection and use of the term does not necessarily imply that a species will eventually be proposed for listing.

### **Oregon Biodiversity Information Center (ORBIC) status rankings**

1 = Critically Imperiled. At high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors.

2 = Imperiled. At high risk of extinction due to very restricted range, very few populations, steep declines, or other factors, often with 6-20 occurrences.

3 = Vulnerable. At moderate risk of extinction due to a restricted range, relatively few populations, recent and widespread declines, or other factors, often with 21-100 occurrences.

4 = Apparently Secure. Uncommon but not rare; some cause for long-term concern due to declines or other factors, often with more than 100 occurrences.

5 = Secure. Demonstrably common, widespread and abundant

## **Appendix T: References Cited**

ODFW (Oregon Department of Fish and Wildlife). 2021. List of sensitive species.  
[https://www.dfw.state.or.us/wildlife/diversity/species/docs/Sensitive\\_Species\\_List.pdf](https://www.dfw.state.or.us/wildlife/diversity/species/docs/Sensitive_Species_List.pdf)

Oregon Biodiversity Information Center. 2019. Rare, threatened and endangered species of Oregon. Institute for Natural Resources, Portland State University, Portland, Oregon. 133 pp.

Oregon DSL and ODF (Oregon Department of State Lands and Oregon Department of Forestry) 2011. Elliott State Forest Management Plan.  
[http://www.orwww.org/Elliott\\_Forest/References/Agency/ODF/Decker\\_et\\_al\\_20111100.pdf](http://www.orwww.org/Elliott_Forest/References/Agency/ODF/Decker_et_al_20111100.pdf)

USFWS (United States Fish and Wildlife Service). 2022. Federally listed, proposed, candidate, delisted species and species of concern under the jurisdiction of the US Fish and Wildlife Service which may occur within Oregon. USFWS Portland Office. <https://www.fws.gov/media/oregonspeciesstatelistpdf>

# Appendix U: Biodiversity Monitoring Report for the Elliott State Research Forest

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## Summary

This report describes the biodiversity project conducted around the H.J. Andrews Experimental Forest located on the western slope of the Oregon Cascade Range during 2017-2019 and a pilot season of the biodiversity project conducted at the Elliott State Research Forest in 2022. The objective of the H.J. Andrews Experimental Forest biodiversity project was to conduct a survey of as many taxonomic groups as possible in an efficient manner using emerging methods in ecology to investigate the relationships and consequences of timber harvest on forest biodiversity and species conservation. To that end, we collected data on mammals, songbirds, invertebrates, fungi, and plants across 96 sites and used equipment such as camera trap and genetic techniques such as shotgun sequencing and DNA metabarcoding to estimate species presence. We took a multiscale approach to analyzing these data and investigated community-level responses to site-specific environmental variables and quantified single-species responses to site-specific environmental variables. These environmental variables included elevation, old growth structural index, time since logging, canopy height, distance to features (e.g., streams or roads), and those derived from remotely-sensed imagery (e.g., Landsat8, LiDAR).

Through the H. J. Andrews Experimental Forest biodiversity project, we collected 380 pitfall trap samples, 248 malaise trap samples, and 480 soil core samples and conducted 96 vegetation surveys, 1,446 songbird surveys, and more than 12 months of camera trapping at all sites. We identified 1735 fungal operational taxonomic units (OTUs) from soil cores, 342 invertebrate OTUs from pitfall traps, 891 invertebrate OTUs from malaise traps, 61 bird species from songbird surveys, and 29 mammal species from camera traps. By investigating the community level response to site-specific environmental variables, we identified two environmental gradients along which communities of multiple taxa consistently responded: a temperature-elevation gradient and a time since disturbance-forest structure complexity gradient. Using these two gradients, we quantified single-species responses and demonstrated that we were able to identify specialist and generalist species along those gradients. Moreover, we demonstrated the utility of joint species distribution models for mapping areas of high species richness and conservation planning through the calculation of indices such as irreplaceability.

The methods used in the H. J. Andrews Experimental Forest biodiversity project are easily transferrable to other study areas and study systems, in part because taxonomic expertise is not required to identify species from genetic methods. Advances in techniques such as passive bioacoustics recording also enable broader applications of these biodiversity surveys across large spatial and temporal extents. During the summer of 2022, PhD student Margaret Hallerud led a similar effort at the Elliott State Research Forest as a pilot study. During this effort, Hallerud deployed pitfall traps, blue vane traps, camera traps, and an ultrasonic recorder to sample invertebrates, bats, and mammals at 56 sites. Malaise traps ( $n = 25$ ) and passive acoustic recorders ( $n = 20$ ) were deployed at a subset of those sites to sample flying invertebrates, songbirds, owls, and murrelets. Samples are currently being processed and species presence data should be available within the next year.



## Introduction

Historically in the Pacific Northwest forests, a suite of old growth forest specialists faced substantial habitat decline due to logging in the 20th century. This decline of habitat prompted antagonism between extractive land use and endangered species conservation that ultimately resulted in the 1994 Northwest Forest Plan. Despite protection of remaining old forests on federal land, timber continues to dominate land use in the Pacific Northwest, where > 4 billion board feet are harvested annually, producing ~\$7 billion in revenue, and supporting >43,000 jobs (Simmons et al. 2016). Balancing wood production and conservation is an ongoing challenge because numerous species remain or have become imperiled since the 1994 Northwest Forest Plan (e.g., northern spotted owl, *Strix occidentalis caurina*; marbled murrelet, *Brachyramphus marmoratus*; red tree vole, *Arborimus longicaudus*; Humboldt marten, *Martes americana humboldtensis*). These and possibly other species may depend on old growth forests or may be negatively affected by the homogenous, even-aged Douglas fir (*Pseudotsuga menziesii*) plantations, which are favored by timber harvest and forest management (Lindenmayer et al. 2012 XX).

Forests support the majority (about 70%) of terrestrial biodiversity (International Union for Conservation of Nature 2017), and forest loss and degradation are primary global drivers of biodiversity decline (Betts et al. 2017). We, however, have limited knowledge concerning the precise relationship that most species have with forest loss and degradation, besides those that have been extensively studied due to their status under the Endangered Species Act. In one of the only studies on other taxa during the USDA Forest Service's Old-Growth Wildlife Habitat Research Program (OGWHRP; Ruggiero et al. 1991), Carey (1989) summarized that 9 species (Olympic salamander, Oregon slender salamander, spotted owl, Vaux's swift, tailed frog, Pacific giant salamander, red crossbills, pine siskins, and northern flying squirrels) and 2 groups (*Myotis* bats and cavity-nesting birds) were strongly tied to old-growth forests. Still, most diversity's response to forest age and structure remains a mystery. Given that biodiversity is strongly associated with ecosystem processes (Brockerhoff et al. 2017) and services (Ricketts et al. 2016), it is essential to develop management practices that ameliorate the growing biodiversity crisis.

Until recently, it was difficult to survey biodiversity across multiple taxonomic groups simultaneously. Surveying multiple taxonomic groups was expensive, labor intensive, and required expertise in each field if using traditional methods (e.g., morphological identification, call identification). Since surveying multiple taxa was demanding, many researchers used indicator, umbrella, or charismatic species for biodiversity monitoring and management. These methods, however, have drawn wide criticism because many co-occurring species are limited by ecological factors that are not relevant to the focal species (Andelman and Fagan 2000, Roberge and Angelstam 2004).

Advances in technology now allow us to survey multiple taxonomic groups simultaneously in extreme detail across broad spatial and temporal extents (Tosa et al. 2021). These advances, including new electronic sensors such as camera traps (Steenweg et al. 2017) and acoustic recorders (Rempel et al. 2005, Sueur et al. 2009), genetic methods such as DNA metabarcoding (Ji et al. 2013) have enabled researchers to create robust "next-generation natural

history” datasets. These impressive datasets can then leverage aircraft- and satellite based remote sensing, which have also improved dramatically, to quantify relationships of biodiversity to environmental factors and predict biodiversity (Gillespie et al. 2008, Bush et al. 2017, Barsoum et al. 2019). These results can then be utilized for conservation and management.

Here, we use next-generation natural history (Tosa et al. 2021) and some traditional methods to implement a biodiversity inventory of multiple taxonomic groups (i.e., plants, fungi, invertebrates, songbirds, and mammals) across gradients of elevation and disturbance on federal forests in the Oregon Cascades. This comprehensive survey will allow us to quantify the relationships of single species and communities with these gradients. Moreover, quantifying these relationships will allow us to predict biodiversity using remotely sensed data and inform conservation at the landscape scale.

## Study Area

This study was conducted in the McKenzie River Ranger District of the Willamette National Forest in the Blue River watershed and the H. J. Andrews Experimental Forest (HJA), a Long Term Ecological Research station (6,400 ha) located on the western slope of the Cascade Mountain Range near Blue River, Oregon (Figure U-1). Elevations range from 410 m to 1,630 m. The maritime climate consists of warm, dry summers and mild, wet winters. The maritime climate consists of warm, dry summers and mild, wet winters. Mean monthly temperatures range from 1°C in January to 18°C in July. Precipitation falls primarily as rain, is concentrated from November through March, and averages 230 cm at lower elevations and 355 cm at higher elevations (Greenland 1993, Swanson and Jones 2002).

Lower elevation forests are dominated by Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), and western red cedar (*Thuja plicata*). Upper elevation forests are dominated by noble fir (*Abies procera*), Pacific silver fir (*Abies amabilis*), Douglas-fir, and western hemlock. The understory is variable and ranged from open to dense shrubs. Common shrubs included Oregon grape (*Mahonia aquifolium*), salal (*Gaultheria shallon*), sword fern (*Polystichum munitum*), vine maple (*Acer circinatum*), Pacific rhododendron (*Rhododendron macrophyllum*), huckleberry (*Vaccinium* spp.), and blackberry and salmonberry (*Rubus* spp.).

Before timber cutting in 1950, 65% of the HJA was covered in old-growth forest. Approximately 30% of the HJA was clear cut or shelterwood cut to create plantation forests varying in tree composition, stocking level, and age. In 1980, the HJA became a charter member of the Long Term Ecological Research network and no logging has occurred since 1985. The Willamette National Forest immediately surrounding the HJA has a similar logging history, but logging continues to occur. Currently, the HJA consists of a higher percentage of old-growth forest than the surrounding Willamette National Forest (approximately 58% in the HJA vs. 37% in the study area) (Davis et al. In Press). Wildfires are the primary disturbance type, followed by windthrow, landslides, root rot infections, and lateral stream channel erosion. Mean fire return interval of partial or complete stand-replacing fires for this area is 166 years and ranges from 20 years to 400 years (Teensma 1987, Morrison and Swanson 1990).

## Methods

We conducted biodiversity surveys at 96 sites, stratified by elevation and time since disturbance. Sites were also stratified between inside and outside the HJA to capture landscape-scale differences between the long-term ecological research site where no logging has occurred since 1989 and neighboring sites within a landscape context of continued active management. At each site, we surveyed for vegetation, fungi, invertebrates, songbirds, and mammals (Figure U-2). To quantify fungal and invertebrate diversity, we used genetic methods.

### *Vegetation Surveys*

We conducted vegetation sampling at each of the sites outside the HJA according to protocols developed by Kim et al. (2022). Briefly, at each site, we measured vegetation at 500 m<sup>2</sup> subplots (12.6 m radius). Measurements included size of trees (diameter at breast height), vertical structure, ground cover, woody species cover, fern cover, and size and class of coarse woody debris.

### *Fungal Surveys*

We collected 5 soil cores (15 cm length x 1.3 cm radius) at each site: 4 samples were taken 10 m from site center in each of the cardinal directions and 1 at site center. Once collected, samples were stored at -20C until DNA extraction. We extracted DNA from soil samples using the FastDNA SPIN Kit for Soil (MP Biomedicals, USA), amplified the ITS1 region from resultant DNA (White et al. 1990, Blaailid et al. 2013), and used DNA metabarcoding to identify operational taxonomic units (OTUs). We sequenced barcode regions of DNA (PE, 150 bp insert size) using the Illumina HiSeq 3000 at the Center for Quantitative Life Sciences at Oregon State University. We assigned taxonomic information to OTUs, when possible, based on the UNITE database (<https://unite.ut.ee/>).

### *Invertebrate Surveys*

We collected flying and crawling invertebrate samples using at least 1 Malaise trap and 8 pitfall traps at each site during July and August 2018. Malaise traps were placed at site center. At 32 of the sites, we placed a second malaise trap set 40 m apart. Pitfall traps were placed 10 m and 20 m from site center in each cardinal direction. Each pitfall trap consisted of two 16 oz plastic cups (10.0 cm diameter opening, 6.0 cm bottom, 12 cm height). Each malaise trap and pitfall trap was deployed for 7 days. Malaise traps consisted of 100% ethanol and pitfall traps consisted of 150 ml of a 50:50 mixture of propylene glycol and DI water. Pitfall trap samples were pooled at the 10 m and 20 m distances. All samples were transferred to fresh 100% ethanol to store at room temperature until DNA extraction. Prior to DNA extraction, we air-dried and weighed the biomass of all pitfall trap samples to quantify the invertebrate productivity of a site.

We extracted DNA non-destructively by soaking invertebrate samples in 5X lysis buffer (for 50 ml of lysis buffer: 2 ml Tris HCl [1M], 1 ml NaCl [5M], 10 ml SDS [10%], 150 ul CaCl<sub>2</sub> [1M], 34.225 ml H<sub>2</sub>O) while shaking and incubating at 56C for 60 hours following a protocol described in Ji et al. (2020). For malaise trap samples, we followed the SPIKEPIPE protocol from Ji et al. (2020) and added a known quantity of invertebrate DNA (not found in the study area) (i.e., internal standard DNA) to help calibrate sequencing data in the downstream bioinformatics pipeline. We shotgun sequenced malaise trap samples (PE 150, 350 bp insert size)

to a mean depth of 29.0 million read pairs (range 21–47) on an Illumina NovaSeq 6000 at Novogene (Beijing, China). We used a custom bioinformatics pipeline to filter reads, assemble sequences, and assigned taxonomic information to OTUs based on the GBIF database (<https://www.gbif.org/tools/sequence-id> accessed 3 Aug 2021). For pitfall traps, we DNA metabarcode samples at NatureMetrics (UK) and amplified the COI region using LerayXT primers (Wangensteen et al. 2018). We sequenced barcode regions of DNA using the Illumina MiSeq and used a custom bioinformatics pipeline to filter reads and assign taxonomic information to OTUs based on the NCBI Genbank database.

#### *Songbird Surveys*

We conducted point count surveys on 3 occasions from 14 May to 9 July in 2018 and from 18 May to 5 July in 2019, corresponding to the arrival and breeding period of the majority of the bird species in the region. Point count surveys followed previously established protocols for long term monitoring of songbirds within the HJA (Frey et al. 2016, Kim et al. 2022). Surveys were conducted during favorable weather conditions between 05:15 and 10:30. Birds heard or seen within a 100 m radius were recorded. Surveys were conducted using the same protocol to ensure data from inside the HJA and outside the HJA could be combined for analysis. Thus, for songbird data analysis, we were able to survey 241 sites ( $n_{HJA} = 184$ ,  $n_{WNF} = 57$ ) in collaboration with concomitant efforts led by Hankyu Kim.

#### *Mammal Surveys*

We conducted mammal surveys using remote trail cameras located at the center of each site. Cameras inside the HJA were set in June 2017 and cameras outside the HJA were set in June 2018. Cameras were baited with a can of sardines or cat food, a fresh dead mouse (*Mus musculus*), and a carnivore scent lure and were placed 1.5 – 2 m away from bait. Cameras were visited monthly when accessible, and we replaced baits at this time. We identified species in photos and imbedded tag information in images from camera taps using Picasa 3.9.141 (Google, Inc., 2013) or DigiKam 6.1.0 (KDE, 2019). We extracted metadata information from photos using the *exifr* package (Dunnington and Harvey 2021) in Program R (R Development Core Team 2014).

#### *Environmental covariates*

We extracted environmental covariates at the site level related to vegetation, forest structure, topography, and anthropogenic features including number of years since disturbance, old-growth structural index (range: 0 to  $\infty$ ), elevation (m), canopy height (m), Normalized Difference Vegetation Index (NDVI), Normalized Difference Moisture Index (NDMI), Normalized Burn Ratio (NBR), average annual minimum and maximum temperatures ( $^{\circ}\text{C}$ ), amount of precipitation (inches), distance to roads (m), and distance to stream (m). We also included variables such as year or season in which the data were collected, management organization (binary WNF = 0, HJA = 1), and whether the site had previously been harvested in the last 100 years (no harvest = 0, harvest = 1). We log transformed values for number of years since disturbance, distance to road, and distance to stream because the most extreme changes



occur immediately after a disturbance and distance to variables spanned multiple orders of magnitude.

No single LiDAR acquisition covered our entire study region. Therefore, we derived measures of forest canopy height and cover from data collected during 6 LiDAR acquisitions from 2008 to 2016 that overlapped portions of our study area: H. J. Andrews Experimental Forest (2008), Willamette Valley (2009), Blue River (2011), Lane County (2014), McKenzie River (2016), and Willamette-Sweet Home (2016) acquisitions (downloaded from <ftp://lidar.engr.oregonstate.edu>; February 2020). Seasonal timing of LiDAR acquisitions varied from June to October, coinciding with the snow-free portion of the growing season. Acquisition details of flights varied (e.g., duration = 2-60 days; minimum flightline overlap = 50% - 100%; maximum scan angle = 14 – 15, sensors included Leica ALS50 Phase II, ALS60 Phase II, ALS70 HP and ALS80), resulting in pulse densities ranging from 8 to 18 pulses m<sup>-2</sup>. Initial exploration of LiDAR metrics indicated good agreement (coefficient of determination > 0.9) between acquisitions (where overlap was available) for the metrics used in this study: 95<sup>th</sup> percentile height, cover based on point-cloud density, and cover based on canopy height models. Data delivered by the vendor for each acquisition included (1) 1-m rasters of elevation at the ground surface, (2) 1-m rasters of the elevation of the highest hit (i.e., top of canopy), and (3) x, y, z coordinates of individual classified laser returns (.las or .laz files). All data were reprojected to UTM 10N prior to analysis using the *sp* (Pebesma and Bivand 2005) and *raster* (Hijmans 2022) packages in Program R.

#### *Community analysis and non-metric multi-dimensional scaling (NMDS)*

We constructed community matrices for each taxonomic group and tapping method. Each row in the community matrix represented a site in a particular session or year and each column represented a species or operational taxonomic unit (OTU). For the response variable in these community matrices, we used the number of reads for genetically derived biodiversity metrics for each session, the mean counts of detections across 3 surveys in a single year for songbird surveys, and a standardized count of detections per month for mammal surveys. We fit species accumulation curves for each taxonomic group using the *accumcomp* function in the *BiodiversityR* package (Kindt and Coe 2005) to compare species richness metrics across previously logged sites and sites with no logging history within 100 years. Species accumulation curves allow for comparisons between groups with differing numbers of samples.

To ensure convergence of community analysis models, we analyzed a subset of species that were present at more than 5% of sites or present at more than 5 sites. We relativized species or OTU abundances by annual species maxima. This relativization accounts for differences in abundances due to the year effect and differences in behavior (e.g., flocking vs. solitary). We used non-metric multidimensional scaling (NMDS) ordinations using the *metaMDS* function (distance = bray, k = 3, maxit = 999, trymax = 500) in the *vegan* package (Oksanen et al. 2020) in Program R. To further understand differences in communities, we calculated correlations of ordination axes with environmental variables and species trait variables using the *envfit* function (perm = 9999).

### *Single species response curves*

Using the main environmental variables with most explanatory power identified by community analyses, we fit local regressions to single species to quantify the strength of response by these species to these variables. The main variables identified by community analysis were a temperature-elevation gradient and a disturbance gradient, so we used elevation and old-growth structural index as the independent variables. We used locally estimated scatterplot smoothing (LOESS) to visualize these response curves.

### *Joint species distribution modeling (JSDM) and site irreplaceability*

We used joint species distribution models to interpolate distributions of arthropod species (collected with malaise traps) across our study area. We used the *sjSDM* package (Pichler and Hartig 2021) in Program R, which includes the option to apply a deep neural network (DNN) to account for complex, non-linear effects of environmental covariates and can account for spatial autocorrelation (‘spatial niches’). We modeled presence-absence data with a multivariate normal distribution (probit link) in the *sjSDM* framework and calculated species occurrence probabilities as a function of a 3-layer DNN on the environmental covariates, spatial coordinates, and a species covariance matrix given as:

$$Z_{ij} = \beta_{0j} + DNN(X_{in}) + X_{s_i}\beta_{s_j} + MVN(0, \Sigma_{ij})$$

$$Y_{ij} = 1(Z_{ij} > 0),$$

in which  $Z_{ij}$  is the occurrence probability of species  $j$  at sampling site  $i$ ;  $Y_{ij}$  is the observed presence of species  $j$  at site  $i$ ;  $X_{in}$  is the value of environmental covariate  $n$  in sampling site  $i$ ;  $X_{s_i}\beta_{s_j}$  is the spatial term, which includes the individual and interaction terms of two Universal Transverse Mercator variables ( $X_{s_i}$  is the coordinate variable for sampling site  $i$ , and  $\beta_{s_j}$  the coefficient of the coordinate variable for species  $j$ );  $MVN$  is the multivariate normal error representing the species correlation matrix. Only species present at greater than 6 sites were included in the *sjSDM* model.

We tested the accuracy of the predicted distributions by holding out 25% of our dataset and using it as test data ( $n = 30$ ). We tuned 9 hyperparameters of the *sjSDM* model with 5-fold cross-validation on training data (75% of our dataset,  $n = 91$ ). The 9 hyperparameters consisted of the weighting between lasso and ridge regularization parameters ( $\alpha_{e,s,b}$ ) and their strength ( $\lambda_{e,s,b}$ ) for each of the environmental, spatial, and species covariance components, the dropout rate, the hidden structure for the DNN, and the learning rate of the model. We restricted predictions of species distributions to a 1-km buffered convex hull around all sample sites, edited manually to avoid suburban areas in the southern extreme of the study area to prevent over-extrapolation (Norberg et al., 2019). From each species distribution map, we created a binary species distribution map by applying a 0.5 threshold on the occurrence probability values and summed these to create a species richness map.

We calculated the site irreplaceability (following Pollock et al. 2020), a key metric in systematic conservation planning (Kukkala and Moilanen 2013), from JSDM-interpolated species distribution maps. Site irreplaceability ranks each site by its importance to the “efficient

achievement of conservation objectives” relative to the population of sites within the surveyed region (Kukkala and Moilanen 2013). Sites with higher irreplaceability are then typically selected in more conservation solutions whereas sites with lower irreplaceability are selected in fewer solutions because they have many substitutes. We calculated the Baisero et al. (2022) site irreplaceability index ( $\beta$ ) per pixel across the study area as the combined probability that a site is irreplaceable for at least one OTU. High irreplaceability sites typically house many species with small ranges and/or with large ranges of which we wish to conserve a large fraction.

## Results

During our biodiversity surveys, we collected 380 pitfall trap samples, 248 malaise trap samples, and 480 soil core samples and conducted 96 vegetation surveys, 1,446 songbird surveys, and more than 12 months of camera trapping at all sites. We identified 1735 fungal OTUs from soil cores, 342 invertebrate OTUs from pitfall traps, 891 invertebrate OTUs from malaise traps, 61 bird species from songbird surveys, and 29 mammal species from camera traps (Table U-1).

### *Community analysis and non-metric multidimensional scaling*

Species accumulation curves revealed that previously logged areas were generally more species rich across all taxa surveyed, regardless of season (Figure U-3). Bird and mammal species accumulation curves revealed a plateauing effect of species richness whereas invertebrate and fungal species richness continued to increase with the addition of more sites.

NMDS analyses recommended 3 axes solutions for invertebrate, bird, and mammal communities (Figure U-4). Axis 1 in all ordinations was highly correlated with an elevation-temperature gradient and axis 2 in all ordinations was correlated with a disturbance gradient (both years since disturbance and old growth structural index). For malaise trap, pitfall trap, and mammal communities, axis 1 was also correlated with whether sites were located inside or outside of the HJA. For bird communities, axis 2 was correlated with whether sites were located inside or outside of the HJA. NMDS ordinations revealed that malaise trap communities changed by month whereas pitfall trap communities remained similar across months (Figure U-5).

### *Single species response curves*

We identified a number of species with strong relationships with elevation and old growth structural index (Figure U-6). Single species responses ranged from strong negative relationships, strong positive relationships, quadratic relationships, and no relationships with elevation and old growth structural index. Species with strong negative relationships with elevation (i.e., low elevation specialists) included the Pacific wren, Hammond’s flycatcher, and black-throated grey warbler (Figure U-6A). Species with strong positive relationships with elevation (i.e., high elevation specialists) included the golden-crowned kinglet, hermit thrush, red-breasted nuthatch, and dark-eyed junco (Figure U-6C). Species with a quadratic relationship with elevation (i.e., mid-elevation specialists) included the varied thrush, pacific-slope flycatcher, and brown creeper (Figure U-6B).

Species with strong positive relationships with old growth structural index (i.e., old-growth specialists) included the Pacific wren, pacific-slope flycatcher, and brown creeper

(Figure U-6E). Species with strong negative relationships with old growth structural index (i.e., young forest specialists) included dark-eyed junco and MacGillivray’s warbler (Figure U-6G). Only one species had a quadratic relationship with old growth structural index (i.e., mature forest specialist): the red-breasted nuthatch (Figure U-6F).

*Joint species distribution models*

Malaise trap samples were sequenced to a mean depth of 29.0 million read-pairs 150 bp (median 28.9 M, range 20.8 – 47.1 M). For JSDMs, we only analyzed samples collected in July 2018. After model tuning via 5-fold cross-validation in sjSDM, the 9 hyperparameter values were:  $\alpha_e = 0.2$ ,  $\lambda_e = 0.6$ ,  $\alpha_s = 0.5$ ,  $\lambda_s = 0.25$ ,  $\alpha_b = 1$ ,  $\lambda_b = 0.1$ , hidden layer of [50, 50, 10], dropout = 0.2, and learning rate = 0.002. The final model achieved median and mean explanatory AUC values of 0.83 and 0.82, respectively (range: 0.62 – 0.98). The final model achieved lower median and mean predictive AUC values of 0.68 and 0.66, respectively (range: 0 – 1).

From the sjSDM models, we were able to achieve a predictive AUC > 0.7 for 87 species. From these maps, we were able to visualize species richness, site irreplaceability, and community composition (Figure U-7). We emphasize here that these are not estimates of true community species richness, irreplaceability, or composition but serve as an illustration of potential uses of having large numbers of fine-scale species distribution maps.

With the 87 species we were able to achieve high predictive power, we predicted greater species richness for areas without recent logging, especially within the northeast section of the HJA, Carpenter Mountain, on west-facing slopes, and in the southern section of the study area (Figure U-7A). Site irreplaceability did not follow species richness, with the most irreplaceable sites generally located at lower elevations, along valleys in proximity to streams, in areas of plantations, in the northeast and in the southern sections of the study area.

**Tables**

**Table U-1.** Taxa identified through biodiversity surveys

<b>Taxon</b>	<b>Method</b>	<b>Number of Samples</b>	<b>Number of Species</b>	<b>Number of Genera</b>	<b>Number of Families</b>	<b>Number of Orders</b>	<b>Number of Classes</b>	<b>Number of Phyla</b>
Fungus	Soil core	480	1735	281	172	90	36	10
Plant	Survey	96	processing	data				
Invertebrate	Pitfall	380	342	158	114	27	8	4
	trap							
Invertebrate	Malaise	248	891	450	167	18	2	1
	trap							
Songbird	Survey	1,446	61	51	25	9	1	1
Mammal	Camera	> 12	29	28	16	5	1	1
	trap	months						



## Lesson Learned

The work done at the HJA served as a proof-of-concept study in which we learned substantial lessons from data collection through analysis to inform future efforts such as biodiversity surveys at the Elliott State Research Forest. The Elliott State Research Forest (36,000 ha) is approximately double the area of what was surveyed for this biodiversity study and roughly 5-fold larger than the HJA, similar vegetation types, elevation gradients, and disturbance history. After completing the sample collection and initial data analysis phases of the project, there are lessons we have learned and changes we would make to our protocols.

First, we emphasize the importance of being able to quantify detection probability of individual species. Without quantification of detection probability, we lack the ability to account for whether a species was present and detected, a species was present and not detected, or a species was not present. This may have significant consequences for modeling species distributions. We were not able to quantify detection probabilities of the majority of species detected in the malaise traps since we were logistically limited by the number of malaise traps we had. We were, however, able to quantify some detection probabilities at some of the sites at which we deployed 2 malaise traps in a single session and the 2 samples for each pitfall trap session. In the future, we recommend keeping the 8 pitfall trap samples separate and setting at least 2 malaise traps per site to get more representative detection probabilities.

Second, we highlight the value of repeated sampling. In particular, invertebrate communities can change rapidly throughout the season due to phenological differences between species. This was especially true for species detected in the malaise traps to the point where it was not appropriate to combine data from samples collected in July with samples collected in August. If the goal is to quantify the full biodiversity of a site, it would be wise to collect samples at multiple sessions and to collect samples from all sites within as short of a time frame as possible. Otherwise, differences detected may only be reflective of the phenology of invertebrates instead of differences between environmental site characteristics.

Along these lines, we recommend long-term monitoring of these taxa. For our study, we mostly collected our samples during the summer of 2018. During 2018 – 2019, western Oregon experienced an extreme drought (USDM 2022). In Lane County, drought severity was greatest during August 2018 – February 2019, but abnormally dry conditions began as early as January 2018 and moderate drought conditions began as early as June 2018. These conditions have been shown to be correlated with irruptions in wasp populations (Akre and Reed 1981, Dejean et al. 2011), and wasps were observed to be more abundant on the landscape (W. Gerth, personal communication). Thus, it would be prudent to resample at least a subset of sites on a regular basis to characterize the interannual variation in biodiversity.

Third, we recommend surveying amphibians and reptiles at these sites. Given logistical constraints, we were unable to survey for these taxa, but amphibians and reptiles are important components of the terrestrial temperate rainforest, especially in the Pacific Northwest. Since current best methods for surveying for amphibians and reptiles consist of physical searches of sites, this would require collaboration with taxa specific experts. Moreover, these surveys could

further be expanded to survey aquatic species by analyzing environmental DNA in water samples or to canopy biota by analyzing environmental DNA in rainwater throughfall.

These biodiversity surveys generate an enormous amount of data. As such, it is prudent to have a plan for data management and archiving in addition to a plan for long-term sample storage. Many of the methods that we utilized allow for the preservation of samples so they can be examined in the future. This allows for verification of species presence and allows for the possibility of reanalysis of samples in the future, especially with improved technology.

## Appendix U: References Cited

- Akre, R. D., and H. C. Reed. 1981. Population Cycles of Yellowjackets (Hymenoptera: Vespinae) in the Pacific Northwest 1. *Environmental Entomology* 10:267–274.
- Andelman, S. J., and W. F. Fagan. 2000. Umbrellas and flagships: Efficient conservation surrogates or expensive mistakes? *Proceedings of the National Academy of Sciences* 97:5954.
- Baisero, D., R. Schuster, and A. J. Plumptre. 2022. Redefining and mapping global irreplaceability. *Conservation Biology* 36.  
<<https://onlinelibrary.wiley.com/doi/10.1111/cobi.13806>>. Accessed 12 Oct 2022.
- Barsoum, N., C. Bruce, J. Forster, Y.-Q. Ji, and D. W. Yu. 2019. The devil is in the detail: metabarcoding of arthropods provides a sensitive measure of biodiversity response to forest stand composition compared with surrogate measures of biodiversity. *Ecological Indicators* 101:313–323.
- Betts, M. G., C. Wolf, W. J. Ripple, B. Phalan, K. A. Millers, A. Duarte, S. H. M. Butchart, and T. Levi. 2017. Global forest loss disproportionately erodes biodiversity in intact landscapes. *Nature* 547:441–444.
- Blaalid, R., S. Kumar, R. H. Nilsson, K. Abarenkov, P. M. Kirk, and H. Kauserud. 2013. ITS1 versus ITS2 as DNA metabarcodes for fungi. *Molecular Ecology Resources* 13:218–224.
- Brockerhoff, E. G., L. Barbaro, B. Castagneyrol, D. I. Forrester, B. Gardiner, J. R. González-Olabarria, P. O. Lyver, N. Meurisse, A. Oxbrough, H. Taki, I. D. Thompson, F. van der Plas, and H. Jactel. 2017. Forest biodiversity, ecosystem functioning and the provision of ecosystem services. *Biodiversity and Conservation* 26:3005–3035.
- Bush, A., R. Sollmann, A. Wilting, K. Bohmann, B. Cole, H. Balzter, C. Martius, A. Zlinszky, S. Calvignac-Spencer, C. A. Cobbold, T. P. Dawson, B. C. Emerson, S. Ferrier, M. T. P. Gilbert, M. Herold, L. Jones, F. H. Leendertz, L. Matthews, J. D. A. Millington, J. R. Olson, O. Ovaskainen, D. Raffaelli, R. Reeve, M.-O. Rödel, T. W. Rodgers, S. Snape, I. Visseren-Hamakers, A. P. Vogler, P. C. L. White, M. J. Wooster, and D. W. Yu. 2017. Connecting Earth observation to high-throughput biodiversity data. *Nature Ecology & Evolution* 1:0176.
- Carey, A. B. 1989. Wildlife associated with old-growth forests in the Pacific Northwest. *Natural Areas Journal* 9:151–162.
- Davis, R. J., D. M. Bell, M. J. Gregory, Z. Yang, A. N. Gray, S. P. Healey, and A. E. Stratton. In Press. Northwest Forest Plan - the first 25 years: status and trends of late successional and old-growth forests. General Technical Report, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon.

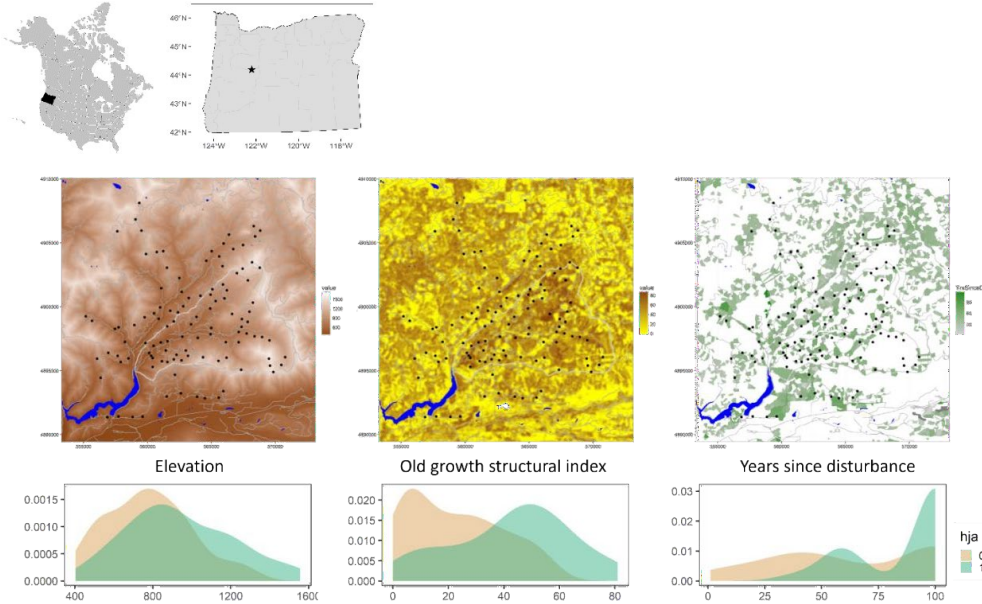
- Dejean, A., R. Céréghino, J. M. Carpenter, B. Corbara, B. Hérault, V. Rossi, M. Leponce, J. Orivel, and D. Bonal. 2011. Climate Change Impact on Neotropical Social Wasps. *PLOS ONE* 6:e27004.
- Dunnington, D., and P. Harvey. 2021. exifr: EXIF Image Data in R. R package. <<https://CRAN.R-project.org/package=exifr>>.
- Frey, S. J. K., A. S. Hadley, and M. G. Betts. 2016. Microclimate predicts within-season distribution dynamics of montane forest birds. *Diversity and Distributions* 22:944–959.
- Gillespie, T. W., G. M. Foody, D. Rocchini, A. P. Giorgi, and S. Saatchi. 2008. Measuring and modelling biodiversity from space. *Progress in Physical Geography: Earth and Environment* 32:203–221.
- Greenland, D. 1993. The climate of the HJ Andrews Experimental Forest, Oregon, and its regional synthesis. USDA Forest Service. Pacific Northwest Research Station 92–0221.
- Hijmans, R. J. 2022. raster: Geographic Data Analysis and Modeling. R package. <<https://CRAN.R-project.org/package=raster>>.
- International Union for Conservation of Nature. 2017. IUCN 2017 Annual Report. <<https://portals.iucn.org/library/sites/library/files/documents/2018-007-En.pdf>>.
- Ji, Y., L. Ashton, S. M. Pedley, D. P. Edwards, Y. Tang, A. Nakamura, R. Kitching, P. M. Dolman, P. Woodcock, F. A. Edwards, T. H. Larsen, W. W. Hsu, S. Benedick, K. C. Hamer, D. S. Wilcove, C. Bruce, X. Wang, T. Levi, M. Lott, B. C. Emerson, and D. W. Yu. 2013. Reliable, verifiable and efficient monitoring of biodiversity via metabarcoding. M. Holyoak, editor. *Ecology Letters* 16:1245–1257.
- Ji, Y., T. Huotari, T. Roslin, N. M. Schmidt, J. Wang, D. W. Yu, and O. Ovaskainen. 2020. SPIKEPIPE: A metagenomic pipeline for the accurate quantification of eukaryotic species occurrences and intraspecific abundance change using DNA barcodes or mitogenomes. *Molecular Ecology Resources* 20:256–267.
- Kim, H., B. C. McComb, S. J. K. Frey, D. M. Bell, and M. G. Betts. 2022. Forest microclimate and composition mediate long-term trends of breeding bird populations. *Global Change Biology* 28:6180–6193.
- Kindt, R., and R. Coe. 2005. Tree diversity analysis: a manual and software for common statistical methods for ecological and biodiversity studies. World Agroforestry Centre, Nairobi, Kenya. <<http://www.worldagroforestry.org/output/tree-diversity-analysis>>.
- Kukkala, A. S., and A. Moilanen. 2013. Core concepts of spatial prioritisation in systematic conservation planning. *Biological Reviews* 88:443–464.
- Morrison, P. H., and F. J. Swanson. 1990. Fire history and pattern in a Cascade Range landscape. General Technical Report, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon.
- Oksanen, J., F. Guillaume Blanchet, M. Friendly, R. Kindt, P. Legendre, D. McGlinn, P. R. Minchin, R. B. O'Hara, G. L. Simpson, P. Solymos, M. H. H. Stevens, E. Szoecs, and H. Wagner. 2020. vegan: Community Ecology Package. R package. <<https://CRAN.R-project.org/package=vegan>>.
- Pebesma, E. J., and R. S. Bivand. 2005. Classes and methods for spatial data in {R}. *R News* 5:9–13.
- Pichler, M., and F. Hartig. 2021. A new joint species distribution model for faster and more accurate inference of species associations from big community data. *Methods in Ecology and Evolution* 12:2159–2173.

- Pollock, L. J., L. M. J. O'Connor, K. Mokany, D. F. Rosauer, M. V. Talluto, and W. Thuiller. 2020. Protecting Biodiversity (in All Its Complexity): New Models and Methods. *Trends in Ecology & Evolution* 35:1119–1128.
- R Development Core Team. 2014. R. A language and environment for statistical computing, R Foundation for Statistical Computing, Vienna, Austria.
- Rempel, R. S., K. A. Hobson, George Holborn, S. L. van Wilgenburg, and Julie Elliott. 2005. Bioacoustic monitoring of forest songbirds: interpreter variability and effects of configuration and digital processing methods in the laboratory. *Journal of Field Ornithology* 76:1–11.
- Ricketts, T. H., K. B. Watson, I. Koh, A. M. Ellis, C. C. Nicholson, S. Posner, L. L. Richardson, and L. J. Senter. 2016. Disaggregating the evidence linking biodiversity and ecosystem services. *Nature Communications* 7:13106.
- Roberge, J.-M., and P. Angelstam. 2004. Usefulness of the umbrella species concept as a conservation tool. *Conservation Biology* 18:76–85.
- Ruggiero, L. F., L. C. Jones, and K. B. Aubry. 1991. Plant and animal habitat associations in Douglas-fir forests of the Pacific Northwest: an overview. *Wildlife and Vegetation of Unmanaged Douglas-fir Forests*, General Technical Report, USDA Forest Service, Portland, Oregon.
- Simmons, E. A., M. G. Scudder, T. A. Morgan, E. C. Berg, and G. A. Christensen. 2016. Oregon's forest products industry and timber harvest 2013 with trends through 2014. Gen. Tech. Rep. PNW-GTR-942. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station. 58 p. 942.
- Steenweg, R., M. Hebblewhite, R. Kays, J. Ahumada, J. T. Fisher, C. Burton, S. E. Townsend, C. Carbone, J. M. Rowcliffe, J. Whittington, J. Brodie, J. A. Royle, A. Switalski, A. P. Clevenger, N. Heim, and L. N. Rich. 2017. Scaling-up camera traps: monitoring the planet's biodiversity with networks of remote sensors. *Frontiers in Ecology and the Environment* 15:26–34.
- Sueur, J., S. Pavoine, O. Hamerlynck, and S. Duvail. 2009. Rapid acoustic survey for biodiversity appraisal. *PLOS ONE* 3:e4065.
- Swanson, F. J., and J. A. Jones. 2002. Geomorphology and hydrology of the HJ Andrews experimental forest, Blue River, Oregon. *Field guide to geologic processes in Cascadia* 36:289–313.
- Teensma, P. D. A. 1987. Fire history and fire regimes of the central western cascades of Oregon. University of Oregon, Eugene, Oregon.
- Tosa, M. I., E. H. Dziedzic, C. L. Appel, J. Urbina, A. Massey, J. Ruprecht, C. E. Eriksson, J. E. Dolliver, D. B. Lesmeister, M. G. Betts, C. A. Peres, and T. Levi. 2021. The Rapid Rise of Next-Generation Natural History. *Frontiers in Ecology and Evolution* 9:698131.
- USDM. 2022. U.S. Drought Monitor. National Drought Mitigation Center at the University of Nebraska-Lincoln, U.S. Department of Agriculture, and National Oceanic and Atmospheric Administration, Lincoln, Nebraska, USA. <<https://droughtmonitor.unl.edu/>>. Accessed 1 Feb 2022.
- Wangensteen, O. S., C. Palacín, M. Guardiola, and X. Turon. 2018. DNA metabarcoding of littoral hard-bottom communities: high diversity and database gaps revealed by two molecular markers. X. Pochon, editor. *PeerJ* 6:e4705.
- White, T. J., T. Bruns, S. Lee, and J. Taylor. 1990. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. Pages 315–322 in M. A. Innis, D. H. Gelfand, J.

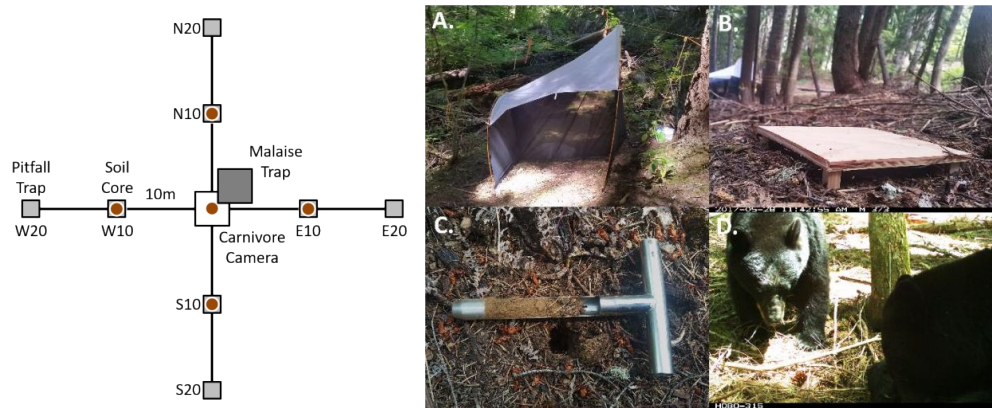


J. Sninsky, and Thomas J. White, editors. PCR protocols: a guide to methods and applications. Academic Press, St. Louis.

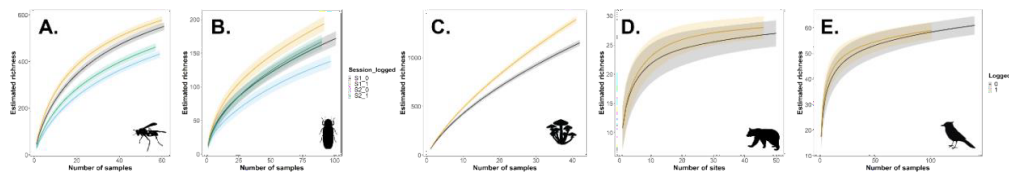
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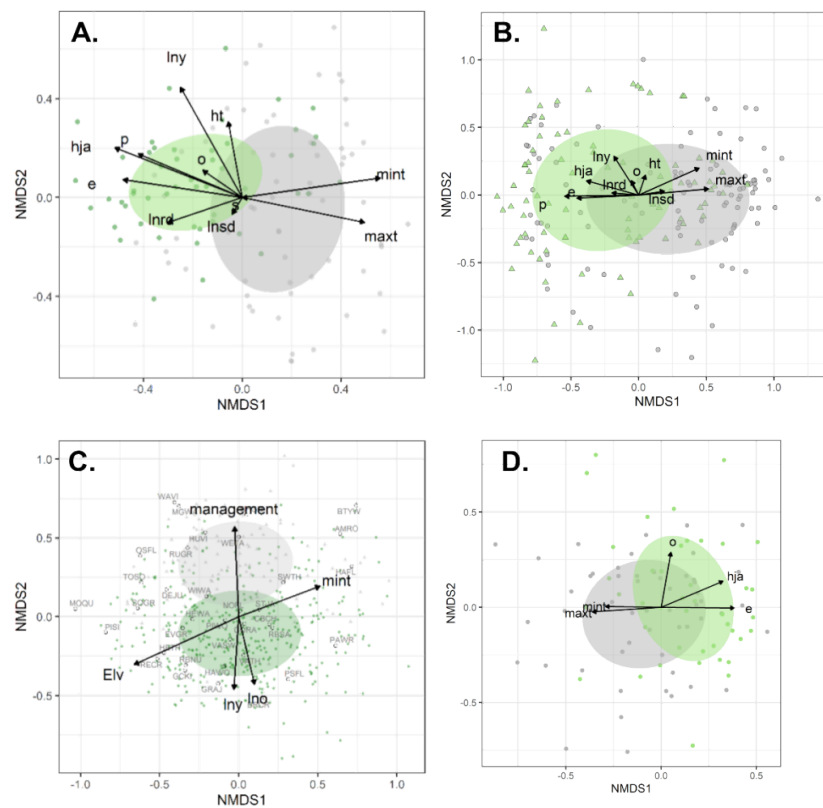
**Figure U-1.** Study area within the Willamette National Forest in the Cascade Range of Oregon, USA. Density plots of elevation, old growth structural index, and years since disturbance for sites inside the HJA (green) and the greater WNF (brown) shown separately.



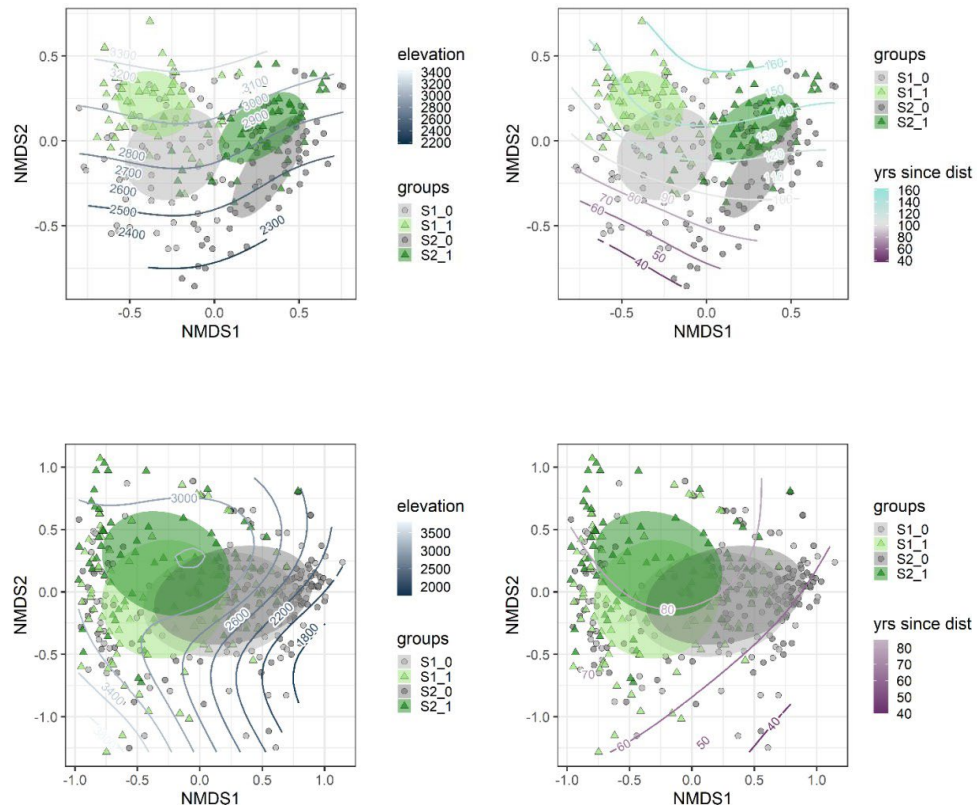
**Figure U-2.** Instrumentation deployed at each site to collect biodiversity data on vegetation, fungus, invertebrates, songbirds, and mammals.



**Figure U-3.** Species accumulation curves for (A) malaise traps, (B) pitfall traps, (C) fungus, (D) mammals, and (E) songbirds. Curves were fit for sites that were previously logged (yellow) and sites that were not logged within the last 100 years (black). For malaise and pitfall traps, curves were fit to month (July or August 2018) of sample collection to account for invertebrate phenology.

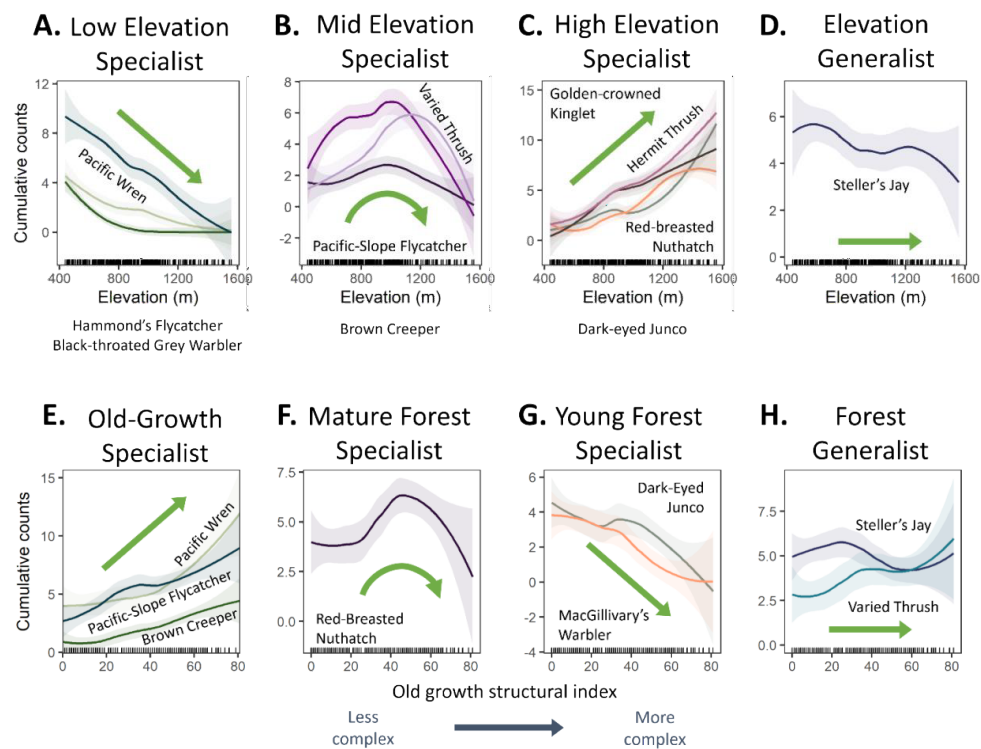


**Figure U-4.** Community analysis of (A) flying invertebrates, (B) crawling invertebrates, (C) birds, and (D) mammals using non-metric multidimensional scaling (NMDS).

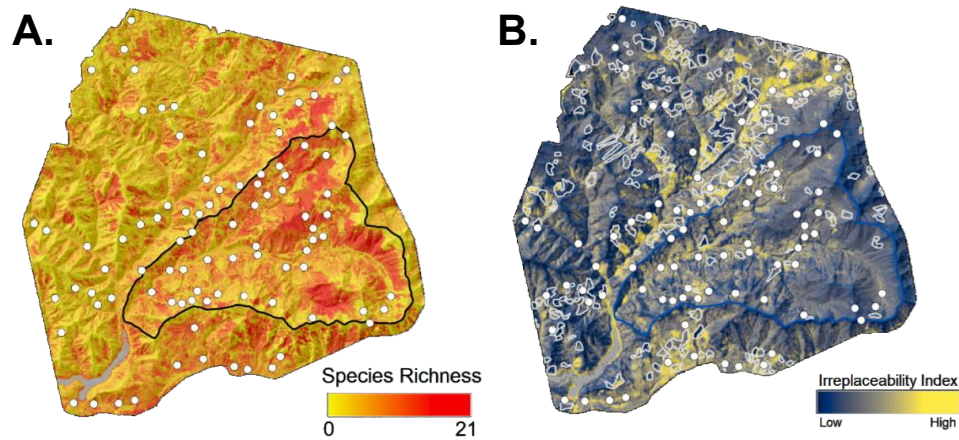


**Figure U-5.** Community analysis of flying invertebrates from malaise traps (top panels) and pitfall traps (bottom panels) during July (lighter ellipses) and August (darker ellipses) 2018. Contours represent elevation (left panels) and years since disturbance (right panels).





**Figure U-6.** Single species songbird response curves in response to elevation (top row) and old growth structural index (bottom row). Ticks along the x-axis represent distribution of sites.



**Figure U-7.** Predicted (A) species richness and (B) irreplaceability from joint species distribution models from sjSDM.

## **Elliott State Research Forest Pilot study summary**

We conducted biodiversity surveys at 56 sites within the Elliott State Research Forest between June and September of 2022 (Figure U-8) as part of a pilot study. At each site, we set 8 pitfall traps, 2 blue vane traps, 1 camera trap on a game trail, 1 camera trap baited for carnivores, and 1 ultrasonic recorder (Song Meter Mini Acoustic Recorder, Wildlife Acoustics, Inc., Maynard, MA) (Figure U-9). At 25 of these sites, we deployed 2 malaise traps and at 20 of these sites, we deployed 1 passive acoustic recorder (Song Meter Mini Bat Ultrasonic Recorder, Wildlife Acoustics Inc., Maynard, MA). Sites were selected to fit within the Northern Spotted Owl Monitoring Program run by the USDA Forest Service. Within the Northern Spotted Owl Monitoring Program survey design, we stratified sites based on 4 categories of stand age: 0 – 15 years, 16 – 30 years, 31 – 80 years, 81 – 200 years (Figure U-10). Based on lessons learned at the HJA, we increased the number of detectors per site such as deploying 2 malaise traps at each site and processing all 8 pitfall traps separately instead of pooling samples together.

### *Passive acoustic recorders*

Passive acoustic recorders were programmed to record according to the same schedule as the Northern Spotted Owl Monitoring Program. Recorders were set continuously for 4 weeks. The program is as follows: starting 1 hour before sunset and recording until 3 hours sunset, starting again 2 hours before sunrise and recording until 2 hours after sunrise, and 10 minutes on the hour each hour in between.

### *Samples and processing*

To date, we have collected over 600 insect samples, 30,000 camera trap photos, 8,800 acoustic recordings, and 100,000 ultrasonic recordings. Insect samples will be processed using the DNA extraction protocol used for insect samples at the H. J. Andrews Experimental Forest. We will then identify species using DNA metabarcoding and LerayXT primers. Camera trap photos will be tagged in DigiKam. Passive acoustic recordings will be analyzed using the convolutional neural network developed by the Lesmeister Lab at the USDA Forest Service Pacific Northwest Research Station. Finally, ultrasonic recordings will be analyzed for bat detections and Humboldt flying squirrel using the Kaleidoscope Pro Analysis software. By deploying passive acoustic recorders and ultrasonic recorders, we will be able to survey for ESA listed species such as the Northern Spotted Owl and the marbled murrelet (*Brachyramphus marmoratus*), bats, and Humboldt flying squirrels that we were not able to survey for at the HJA using traditional methods.

Figures

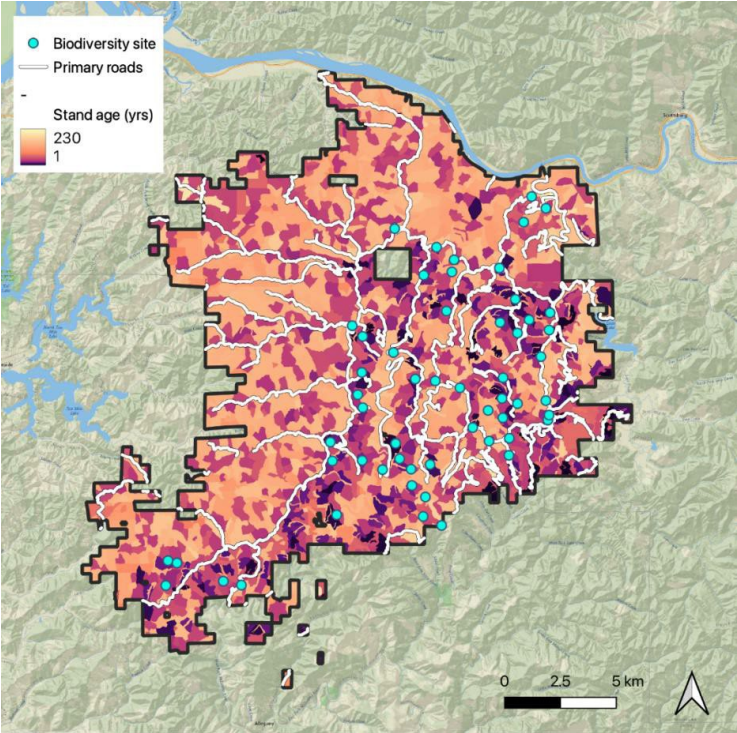


Figure U-8. Map of the Elliott State Research Forest and biodiversity survey site locations.

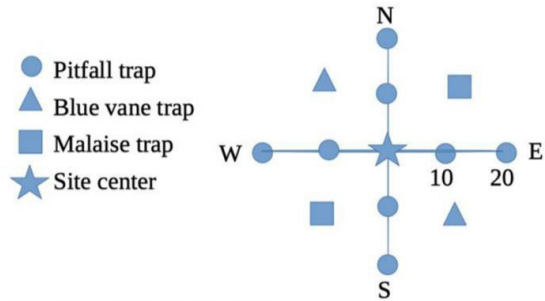
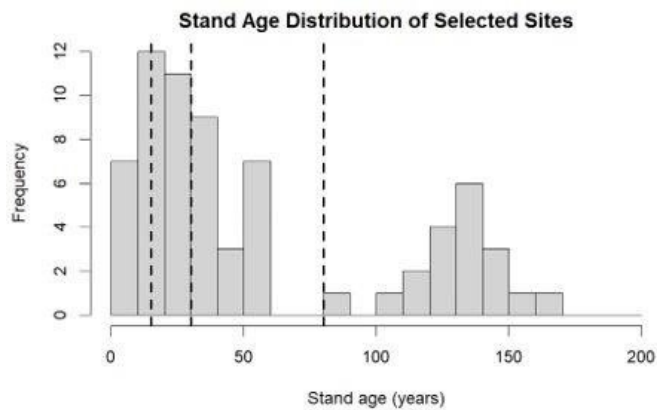


Figure U-9. Schematic of instrumentation deployment at each site for biodiversity surveys.





**Figure U-10.** Distribution of sites along stand age gradient in years. Sites were stratified in 4 categories: 0 – 15 years, 16 – 30 years, 31 – 80 years, 81 – 200 years.

# Appendix V: Report to the Elliott State Research Forest: Biodiversity Surveys 2022

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## 1. Introduction

Forests support the majority of terrestrial biodiversity, and forest loss and degradation are primary global drivers of biodiversity decline (Betts et al. 2017). The United Nations Convention on Biological Diversity and subsequent Strategic Plan for Biodiversity were significant attempts to address this crisis, but consensus is emerging that the overall objective – halting biodiversity loss by 2020 – has failed (Mehrabi, Ellis, & Ramankutty 2018, Díaz et al. 2019). Given that biodiversity is strongly associated with ecosystem processes (Brokeroff et al. 2017) and services (Nelson et al. 2014, Ricketts et al. 2016), it will be essential to develop management practices that ameliorate the biodiversity crisis under a changing climate.

Central to the challenge of conserving global biodiversity is an increasingly demanding human population with escalating rates of consumption (Tilman & Clark 2014). The provision and use of forest products is no exception, with current roundwood production equal to 3.7 billion m<sup>3</sup>/year and projected growth in wood demand of 30% by 2050 (Kok et al. 2018). Forests remain of high economic value to humanity, worth over \$US 600 billion annually (Rametsteiner & Whiteman 2014), but wood production potentially threatens other critical values including forest biodiversity and carbon stocks, which are both in rapid decline (Butchart et al. 2010).

To meet the world's wood demand, foresters have often adapted the agricultural model of increasing production through intensive, high-input management practices aimed at increased tree growth and management efficiency by simplifying and homogenizing stand structure (Puettmann, Coates, & Messier 2008). This has been successful at boosting yields – in some cases as much as 40-fold [25- 40 m<sup>3</sup>/ha/year vs. 1-2 m<sup>3</sup>/ha/year in unmanaged natural forests (Wagner et al. 2005)]. Indeed, plantation forest area has increased by over 105 million ha since 1990, with an average annual increase of 3.6 million ha, and planted forests now account for 7 percent of the world's forests and 33% of roundwood production (Food and Agriculture Organization of the United Nations 2015).

Closing the wood production 'yield gap' through plantations has two important implications for biodiversity and carbon conservation. First, high-yielding plantations create the potential to reduce harvesting pressure on natural, unmanaged forests (Edwards et al. 2014) and to free up forest land for conservation, provided that appropriate conservation policies are implemented for native forests. Second, however, plantations themselves may have relatively low conservation value (Swanson et al. 2011, Betts et al. 2013). For this and other reasons, researchers and land managers have proposed and developed various local versions of 'ecological forestry' or extensive management techniques Puettmann et al. 2015, Franklin, Johnson, & Johnson 2018). These techniques typically aim to emulate natural disturbance regimes and vegetation structure, often relying on retention of trees and downed wood and longer harvest rotations (Lindenmayer et al. 2012, Root & Betts 2016). However, compared to management of homogeneous plantations, profits and yields of extensive forestry approaches are often substantially lower, in part because of the added complexity of management operations (Newton & Cole 2015, Kormann et al. 2021).

### The Triad Approach

Attempts to reconcile conservation, production, and other objectives have prompted a proposed compromise approach involving forest management in three distinct zones. This 'Triad' zoning divides landscapes into discrete units that emphasize reserves, extensive management, or intensive management (Seymour & Hunter 1992). Reserve areas are managed for biodiversity

conservation, which often means little or no intervention. Extensive (or “ecological”) forestry operations are typically characterized by partial retention, minimal use of external inputs, more time between harvests, and reliance on natural tree regeneration (Franklin & Donato 2020). Practices in the intensive zone can include planting of native or exotic tree species, use of herbicide to control competing vegetation, thinning, and fertilization (Paquette & Messier 2010). Triad provides a framework for assessing the implications for biodiversity and ecosystem services of these approaches. The Triad approach is grounded in the idea that producing wood from intensively managed forests can permit more land to be freed up for conservation (Côté et al. 2010, Tittler, Messier, & Goodman 2016).

Our research seeks to test the hypothesis that multiple objectives can be better achieved via a forest management zoning approach (i.e., Triad) at the landscape scale. We seek to test a range of scenarios with differing proportions of (1) extensive (ecological) forestry, (2) intensive forestry and (3) reserves to determine a suite of policy options to produce timber, sequester carbon (both ecosystem services) and maintain native biodiversity. To do this, we are initiating the most comprehensive biodiversity sampling to date across gradients in management intensity and forest age. We will then use these data to parameterize spatial forest management models that test scenarios with differing proportions of management under different scenarios of climate. Although forest management models have been used previously to examine Triad scenarios (Tittler, Messier, & Fall 2012), none of these models have been parameterized with empirical biodiversity and carbon data, so ours will be the first to do so. Our work will serve as an important first step in a long-term experiment that will test the Triad approach at the Elliott State Forest (Oregon). Here we report on the objectives and preliminary results of our pilot study in the summer of 2022, which will inform an intensive research effort beginning April 24, 2023.

## 1.1 Objectives

Our pilot study was designed to collect and analyze preliminary high-throughput biodiversity data in advance of a USDA funded initiative seeking to balance biodiversity and timber production. As such, our objectives for the summer 2022 field season included.

1. Collect baseline biodiversity data across stand ages and landscape variables within priority management watersheds that will receive experimental forest management treatments.
2. Develop and test methods for landscape-scale biodiversity sampling, sample preparation, molecular methods, and use of camera traps and bioacoustics for multi-taxa surveys.

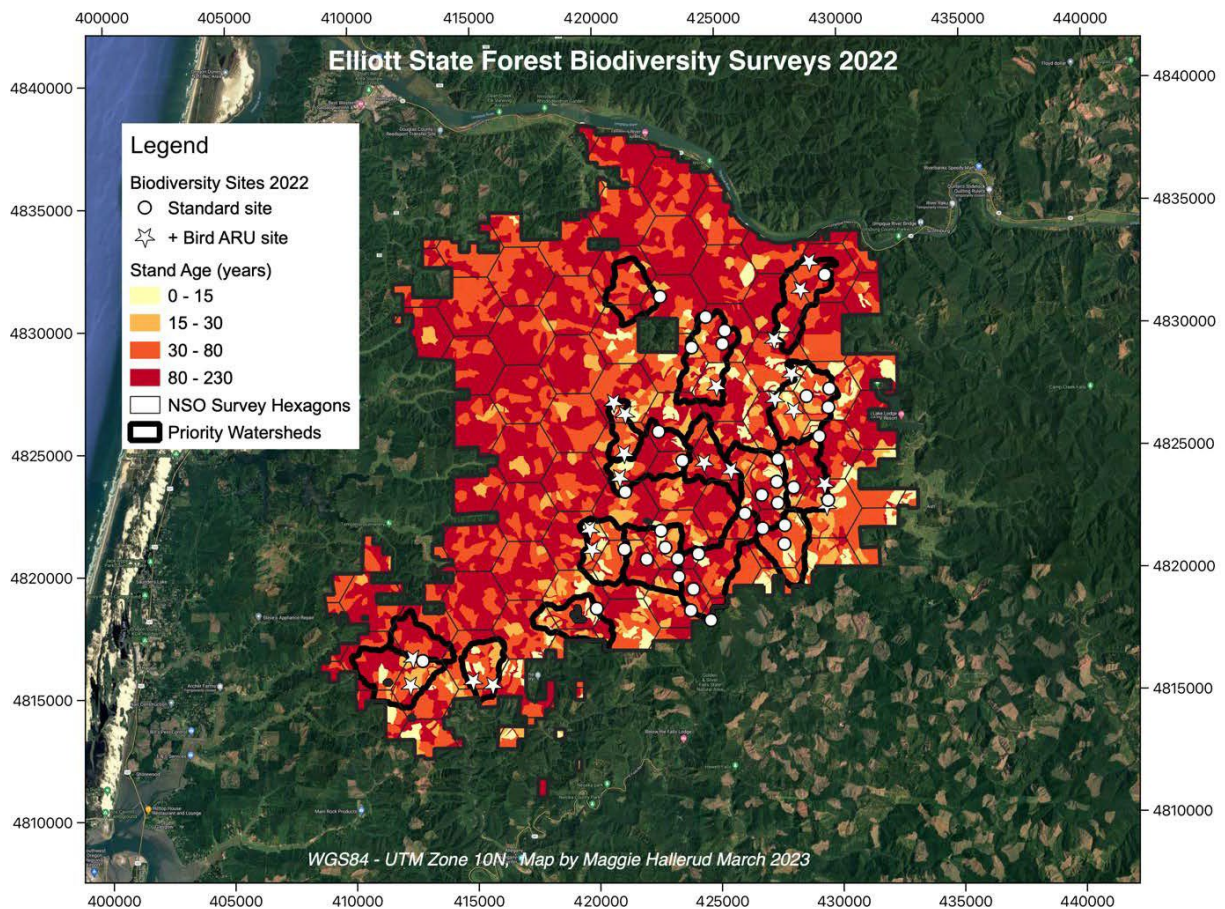


## 1.2 Study Design

We designed this study by stratifying sites across stand ages using the northern spotted owl sampling grid as a template. Survey sites were restricted to priority watersheds selected for early implementation forestry treatments in the TRIAD management zone (Elliott State Research Forest Proposal, Section 4). We used the hexagonal sampling grid from the northern spotted owl survey design (USFWS 2012) to remain consistent with rangewide spotted owl monitoring while also ensuring spatial coverage and spatial independence of sites. Each hexagon is 5 km<sup>2</sup> and survey points in each hexagonal grid are a minimum of 800 meters apart.

From the northern spotted owl survey points, we identified accessible points (i.e., those within 300 meters of a road) and classified these into 4 stand age groups based on available GIS data: early seral (0-14 years), early- to mid-seral (15-29 years), mid- to late-seral (30-80 years), and mature forest (>80 years). Given a goal of 68 survey sites (~4 per priority watershed), we aimed to randomly stratify survey locations within each age class and planned TRIAD treatment (intensive, extensive, intensive reserve, and riparian). Early seral stands are limited on the ESRF and underrepresented in our surveys. Our final design included 11 stands in the early seral class, 19 stands in the early-mid seral class, 19 stands in the mid-late seral class, and 19 stands in the mature forest class. Remaining accessible sites were considered as backup sites.

We surveyed 56 biodiversity sites within 16 priority watersheds (*Figure V-1*). Sites were adjusted in the field to avoid edge effects and to ensure reasonable accessibility. When possible, sites were moved less than 300 meters away from the original survey point and towards the centroid of the stand. If sites needed to be adjusted more than 300 meters or the designated stand was deemed unsuitable due to feasibility concerns (i.e., safety or time required to access) or stand characteristics (e.g., the stand was too small to avoid edge effects) then the site was moved to the nearest stand of the same age class. In rare instances, a site had to be dropped because it was inaccessible and no sites within the area were suitable replacements. Site centers were placed a minimum of 50 meters from roads.



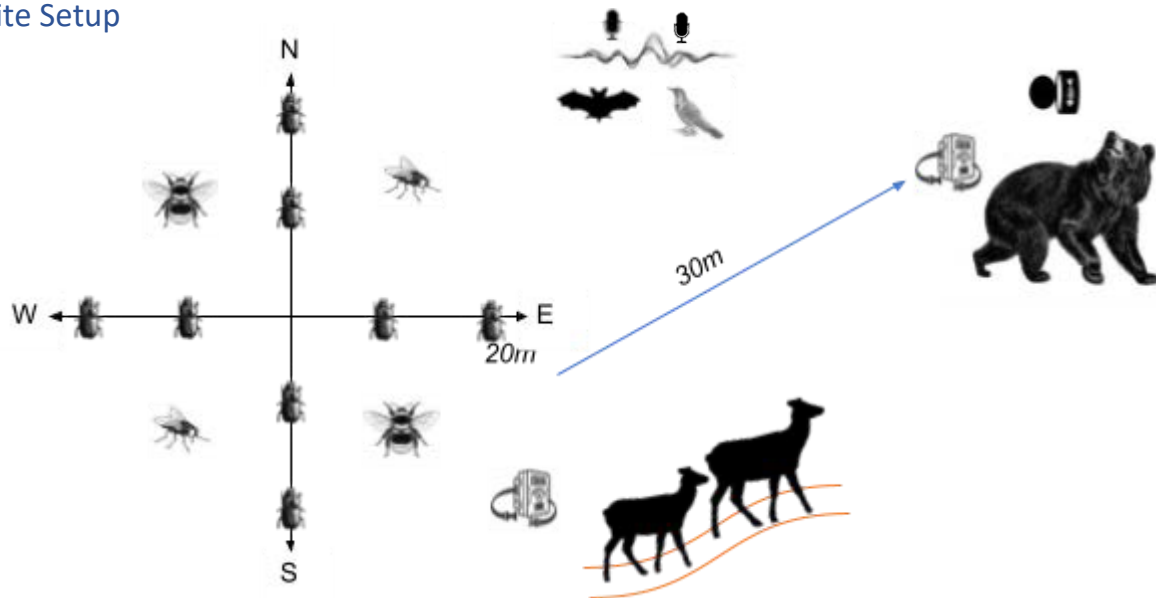
**Figure V-1.** We surveyed 56 biodiversity sites during the 2023 field season, including 21 sites with songbird acoustic recorders.

## 2. Survey Methods

The bulk of our biodiversity survey effort is targeted towards terrestrial arthropods because these animals are incredibly speciose, have a wide diversity of morphological and life history traits, and can be locally adapted as well as highly sensitive to environmental variation. Terrestrial arthropods were targeted via 3 types of invertebrate trapping which separately target crawling arthropods, flying insects, and insect pollinators. Vertebrates were monitored via remote camera-traps targeting mid-large sized mammals, bioacoustics recorders targeting songbirds, and ultrasonic recorders targeting bats.

Our methods largely follow Marie Tosa’s work on the H.J. Andrews Experimental Forest, with additions of blue vane traps for surveying insect pollinators, an additional camera-trap set on trails to survey animals that are not attracted to bait (e.g., elk, deer, cougars), bat bioacoustics, and tree coring to measure stand age; the substitution of songbird point counts for songbird bioacoustics; and the exclusion of soil fungi coring (which we will be adding back to 2023 surveys). We will also be analyzing our invertebrate data slightly differently, using metabarcoding rather than shotgun sequencing, as well as beginning to develop a reference specimen collection that we can link back to reference DNA sequences.

## Site Setup



**Figure V-2.** Schematic of device placement at each biodiversity site: 8 pitfall traps capture crawling invertebrates, 2 blue vane traps capture pollinators, 2 malaise traps capture flying insects, a trail camera and baited camera record activity of medium and large mammals, and acoustic and ultrasonic recorders record bat and bird activity.

### 2.1 Invertebrate Trapping

We set 8 pitfall traps to capture crawling arthropods, 2 blue vane traps to capture pollinators, and 2 malaise traps to capture flying insects at each site. We placed pitfall traps 10 and 20 meters from site center in each cardinal direction, blue vane traps at ~10 meters from site center in the southeast and northwest quadrants, and malaise traps at ~10 meters from site center in the northeast and southwest quadrants (*Figure V-2*). All traps were filled with a 200 mL of propylene glycol-water mixture to hold captured invertebrates. We collected samples after 7 days and transferred to 100% ethanol for DNA preservation and storage. We only set malaise traps at 25 sites because the shipment didn't arrive until July.

We cleaned samples of dirt and debris and extracted DNA non-destructively following the protocol described in Ji et al. (2020). We followed the SPIKEPIPE protocol from Ji et al. (2020) and added a known quantity of invertebrate DNA (from a species not found in the study area) to help calibrate sequencing data in the downstream bioinformatics pipeline. We will identify operational taxonomic units within each sample via metabarcoding using Leray et al. (2013) primers that amplify a short, highly variable region of the cytochrome c oxidase 1 (COI) gene (i.e., the gene used as the 'Barcode of Life' in animals; Ratnasingham & Hebert 2007). The Leray et al. (2013) primers are among the most effective primer sets for metabarcoding terrestrial arthropods (Elbrecht et al. 2019).

In addition to metabarcoding bulk samples, we manually sorted a subset of samples to morphospecies for rough estimates of abundance per taxonomic order. Individual specimens of unique morphospecies are being identified for a subset of taxa, including beetles (Coleoptera), bees and wasps (Hymenoptera), butterflies and moths (Lepidoptera), millipedes (Diplopoda), centipedes (Chilopoda), crickets and grasshoppers (Orthoptera), and damselflies and dragonflies (Odonata). Morphospecies are being identified based on their physical characteristics, and when possible linked to known species via online web searches. In the future, we hope to confirm species identity by cross-referencing our specimens with the Oregon

State Arthropod Collection (<https://osac.oregonstate.edu>). Each unique morphospecies will be individually DNA barcoded, which will serve two purposes: 1) development of a reference genetic database linked back to a physical specimen collection, and 2) discovery of novel species and cryptic diversity (e.g., Srivathsan et al. 2019; Srivathsan et al. 2021). If individual DNA barcoding proves efficient and effective, species discovery as well as collecting abundance information for a subset of taxa will be more tractable.

We are still actively working on sorting samples to morphospecies, however once this is completed samples will be sent for DNA sequencing. Analysis of DNA sequences will include identification of genetically documented species using the GenBank reference database (Clark et al. 2016) and assignment to operational taxonomic units (OTUs) for sequences missing from GenBank.

## 2.2 Bat Bioacoustics

To record bat activity, we set ultrasonic recording units (Song Meter Mini Bat, Wildlife Acoustics, Maynard, MA) for 1 week at each site. To test whether any species present on the ESRF were missed in the forested stand surveys, we also set three ultrasonic recording units on streams (areas of high bat activity). We scheduled recorders to record 15 minutes before sunset to 15 minutes after sunrise following the bioacoustic protocol of the North American Bat Monitoring Program (Rodriguez et al. 2019). We set recorders in forest openings, when available, since bats are more likely to use these areas for foraging. To maximize detection area, we placed recorders in prominent topographic positions and areas with dense vegetation were avoided when possible, and set recorders ~2 meters off the ground on trees or shrubs with small boles (<30 cm) and at a ~30-45 degree angle off of the tree to minimize sound interference by the tree. We placed recorders a minimum of 50 meters from the nearest road to avoid bias or disturbance due to the road.

## 2.3 Camera-Trapping

We set two camera-traps at each site: one baited camera and one trail camera. We used two camera-traps per site because the different set types capture activity of different species: trail cameras target large-bodied mammals such as ungulates and large carnivores, while baited cameras target mesocarnivores and other smaller animals. Bait and scent lure are effective at increasing detection probabilities for elusive species while not overriding animal movement or habitat use patterns (Stewart et al. 2019; Holinda et al. 2020), though some studies suggest that prey species may avoid sites with scent lure (Rocha et al. 2016; Fidino et al. 2020). We used Browning DarkOps HD Max Plus cameras (Prometheus Outdoors, Birmingham, AL) at all sites to minimize potential bias created by variable camera brands (Driessen et al. 2017). DarkOps cameras are a no-glow variety that minimize altering animal behavior by using infrared flashes outside of the visual range of the majority of mammals; like most mainstream trail cameras, they are triggered by motion and heat (Apps & McNutt 2018). We set cameras in June-August when sites were initially visited for invertebrate trapping, and retrieved cameras in September and early October. Following Kays et al. (2020), we ensured that each camera was active for a minimum of 30 days. We rebaited cameras and checked batteries after a week when sites were revisited to check invertebrate traps.

We set baited cameras to maximize potential marten and fisher detections following standardized protocols (Moriarty et al. 2019): bait (canned cat food) and skunk-based scent lure is set ~0.5 m off the ground and camera and bait are set ~2-5 meters apart, with the camera approximately north-facing to avoid excessive sun exposure. We set cameras to take a burst of 3 photos per trigger with a delay of 10 seconds between triggers; these settings maximize



identifiability of animals while minimizing data management. While this protocol is intended to maximize detection probabilities of the most rare and elusive species (coastal martens and Pacific fishers), these methods are also effective for more common small carnivores and other mammals attracted to bait (e.g., flying squirrels and other rodents). When possible, we placed baited cameras in dense cover to maximize detection probabilities for smaller animals that may avoid open areas, in topographically prominent areas to maximize the scent plume, and a minimum of 30 meters from any other device at the site to minimize site disturbance by animals attracted to the bait.

We set trail cameras on the heaviest used trail encountered at the site, with a preference for heavily used trails nearer to the site center. Trail camera settings were the same as baited cameras, except that we changed the minimum delay between photo bursts to 1 second to avoid missing any animals passing through. If a trail camera showed very low animal activity upon the first revisit, we moved the camera to a new trail to avoid missing data due to poor trail selection. We moved cameras to new trails at two sites.

## 2.4 Songbird Bioacoustics

We placed acoustic recording units (Song Meter Mini, Wildlife Acoustics, Maynard, MA) at 20 sites representing 10 northern spotted owl survey unit hexagons in early to mid-July. We selected sites that represent different stand age classes within each hexagon and an even distribution of stand ages across all acoustic sites. We followed acoustic recorder settings and placement in the draft protocol for passive acoustic surveying of northern spotted owls (USFWS 2021). Specifically, recorders were scheduled to record 1 hour before to 3 hours after sunset, 2 hours before to 2 hours after sunrise, and 10 minutes for every other hour between these times. This schedule aligns with peaks in songbird and owl calling activity. Recorder settings were optimized for recording in the 0-16 kHz frequencies, with a sample rate of 32 kHz and gain of 18 dB. By following this recording protocol and spatial survey design, our bioacoustics data will be compatible with broader-scale datasets collected by the PNW Bioacoustics Lab as well as rangewide passive acoustic surveys for federally threatened northern spotted owls.

To maximize detection area and minimize background noise, we placed recorders in prominent topographic positions and in areas with less dense vegetation when possible. When present, we placed recorders a minimum of 100 meters from the nearest road to avoid vehicle disturbance. We placed recorders ~2 meters off the ground on trees or shrubs with small boles (<30 cm) and set at a ~30-45 degree angle off of the tree to minimize interference due to the tree. We set recorders at the beginning of the field season (early - mid July) and batteries were replenished when a site was revisited for invertebrate trapping 1 week after setting. In general, fresh batteries in recorders lasted ~3 weeks.

We classified audio recordings to species using a convolutional neural network model built by the PNW Bioacoustic Lab to identify audio signatures of 37 focal species found in Pacific Northwest forests (Ruff et al. 2022). Of the classes the model is able to identify, 34 species are present on and around the ESRF including the northern saw-whet owl, great horned owl, northern pygmy owl, barred owl, western screech owl, northern spotted owl, common raven, Steller's jay, Canada jay, Canada goose, sooty grouse, mountain quail, band-tailed pigeon, mourning dove, marbled murrelet, common nighthawk, hermit thrush, Swainson's thrush, olive-sided flycatcher, wrentit, varied thrush, Townsend's solitaire, Clark's nutcracker, spotted towhee, chickadees (non-specific), nuthatches (non-specific), American robin, northern flicker, downy woodpecker, pileated woodpecker, sapsuckers (non-specific), wolf howls, Douglas squirrel, and chipmunks (non-specific). Nuisance sounds classifiable by the model include dog

barks, insect buzzes, frog chorus, human speech, gunshots, and machinery. The 3 species the model is able to identify that are not present on the ESRF include American pika, flammulated owl, and common poorwill.

## 2.5 Vegetation surveys

We conducted vegetation surveys in September. For each site, we collected data on understory cover, coarse woody debris, and cored three trees per site for non-mature sites (<80 years old) to confirm stand age. We visually estimated cover for common understory species at 8 1.8-meter radius plots located 10 and 20 meters in each cardinal direction from site center (i.e., at the same location as pitfall traps). We measured coarse woody debris diameter, length, and type (e.g., stump, log, snag) along 20-meter long and 3 meter wide transects in each cardinal direction. For each woody debris piece, we also classified to decay class following Sollins (1982), where a decay class of 1 represents freshly fallen wood and a decay class of 5 represents nearly fully decayed wood. Total volume of coarse woody debris was calculated per site and per decay class and size class (10-20, 20-50, 50-100, and 100+ cm diameter) per class. We cored the three nearest trees of the dominant age class with a preference for Douglas fir. Species, DBH, and distance and direction from site center were recorded for each cored tree. Dendrochronology of cores was performed in Andrew Merschel's lab. Landscape photos showing forest type and structure were also taken at each site.

## 2.6 Survey Context for Species of Conservation Concern

### 2.6.1 Northern Spotted Owl

The northern spotted owl (*Strix occidentalis caurina*) is listed as federally and state threatened. Prior work has established that mature on the ESRF comprises nesting habitat for northern spotted owls. By following the study design and field protocol of the northern spotted owl monitoring program, our songbird bioacoustics protocol is optimized towards northern spotted owl detection and monitoring. Passive acoustic recorders are highly effective for monitoring federally threatened northern spotted owls and barred owls (*Strix varia*) with weekly per-station detection probabilities of 0.27 and 0.72, respectively (Duchac et al. 2020). This translates to 0.85 and 0.99 detection probabilities for 2 stations per 3-week period, roughly the criteria our surveys achieved. Recent research also demonstrates the effectiveness of passive acoustic monitoring for estimating pair status of northern spotted owls (Appel et al. 2023).

### 2.6.2 Marbled Murrelet

The marbled murrelet (*Brachyramphus marmoratus*) is federally threatened and state endangered. Traditional visual surveys for marbled murrelets confirmed presence of the species on the ESRF in 2013 and played a large role in selling the land to Oregon State University rather than privately. While methods are still being developed for passive acoustic monitoring of marbled murrelets throughout the Pacific Northwest (Lesmeister et al. 2022), early research suggests that acoustics are a promising means to improve efficiency and detection probabilities in marbled murrelet surveys (Borker et al. 2015). Interpreting marbled murrelet calls is an active area of research, as some of these detections are likely at stands under flight paths rather than stands that are actively used by murrelets. The implications of using a bioacoustics study design optimized for northern spotted owls to monitor marbled murrelets are also not well understood.

### 2.6.3 Coastal Marten & Pacific Fisher

The coastal or Humboldt marten (*Martes caurina humboldtensis*) is listed as a federally threatened Distinct Population Segment and the species (*M. caurina*, which includes populations in the Cascades and Blue Mountains) is listed as sensitive under the Oregon State

Conservation Strategy. Related Pacific fishers are listed as sensitive under the Oregon Conservation Strategy and a federal species of concern which have been repeatedly petitioned for listing under the Endangered Species Act. The ESRF has been long assumed to host a population of coastal martens due to relatively extensive mature forest as well as proximity to the known marten population on the Oregon Dunes National Recreation Area. Because the ESRF hasn't previously been extensively surveyed, whether Pacific fishers could occupy the forest is also uncertain. Our baited camera-trap methods are known to be effective for detecting both marten and fisher (*Figure V-3*), however our detection probabilities will be lower than dedicated surveys which usually include two baited stations per site as well as much longer survey durations.



*Figure V-3. Coastal marten (left) and Pacific fisher (right) at baited camera stations -- photos not taken on the ESRF. (Fisher photo credit: Brent Barry)*

#### 2.6.4 Franklin's Bumblebee & Western Bumblebee

Federally threatened Franklin's bumblebee and declining western bumblebee are both species that we may miss in our surveys. While we are surveying for pollinators, survey effort is low compared to true pollinator studies and most of our sites are not in typical pollinator habitat (roadsides or very young <5 year old stands). We could still possibly detect these species in blue vane traps or malaise traps. If this happens, care will need to be taken to avoid capturing species of conservation concern since our invertebrate trapping methods are extractive and would remove individuals from the population. An alternative, non-extractive method for monitoring threatened pollinators would be hand-netting.

#### 2.6.5 State Sensitive Bats

Fringed myotis, California myotis, hoary bat, long-legged myotis, silver-haired bat, and Townsend's big-eared bat are state sensitive species that occur in the Coast Range. Our ultrasonic recorders should be able to detect calls from all of these species.

#### 2.6.6 Other Sensitive Species

Other species of conservation concern that we could detect at our camera-traps include the gray wolf (federally endangered in Oregon) and wolverine (*Gulo gulo*, state sensitive). While the ESRF is not currently occupied by either species (as far as we know), dispersing wolves and wolverines would both be attracted to baited camera-trap stations, as well as would use game trails where they could be detected by trail cameras. Gray wolves are known to avoid trail cameras, however their howls would also be detectable by our songbird acoustic recorders.

Given their association with mesic mature forests, red tree voles are likely present across much of the ESRF. The red tree vole is a state sensitive and federal candidate species for listing

under the Endangered Species Act and is the only species of conservation concern that our biodiversity survey methods would be highly unlikely to detect. Best practice for red tree vole survey consists of targeted tree climbing surveys to search for nests and other red tree vole sign (Marks-Fife 2022).

## 2.7 Data Summary

For each survey method, we identified species (or OTUs - in the case of invertebrates) We identified bat calls using automated software Kaleidoscope Pro (Wildlife Acoustics, Maynard, MA), songbird calls using automated software PNW-Cnet (see section 2.3 for details), camera-trap photos using manual sorting of each trigger event, and we will identify invertebrates to OTU using DNA metabarcoding (see *2.1 Invertebrate Trapping* for details). Species richness (i.e., alpha diversity) was summarized per method, site, and age class.

Species detections per method were summarized by total species activity, species activity per stand age class, naïve occupancy per species, and species detectability. We calculated species activity as the total number of detections per unit survey effort, with camera-trap detections split into hourly survey periods and songbird and bat recorder detections were split into daily survey periods to increase independence between detections at a site. Naïve occupancy is the proportion of sites where a species is detected and reflects the minimum occupancy of the species in the surveyed areas. Naïve occupancy does not account for variable species detection probabilities or survey effort, but it can provide a rough idea of how widespread the species is on the ESRF. We estimated species detectability (not to be confused with detection probability calculated in formal occupancy) in two ways: 1) the proportion of survey periods detected at sites where the species was detected, and 2) latency to detection calculated as the number of days until a species was detected at each site. Detectability metrics inform the per-site survey duration needed to detect each species. We also report survey effort per method.

## 2.8 Field Schedule & Field Crew

Surveys began at the start of July and ended in early September. Biodiversity surveys were completed by a 4-person crew, including 1 crew lead (Hallerud). The crew generally worked 10-12 hour days Monday - Thursday, often camping near sites during site set weeks. The crew was based out of Corvallis and usually drove to the ESRF at 6 am Monday mornings and back from ESRF early afternoon on Thursdays. The crew lead scouted sites, finished processing samples, prepared equipment, entered data, and planned the site schedule for the upcoming week on weekends.



Week	Dates	Task
1	June 19 - 22	Crew training.
2	June 26 - 29	Week off - COVID-19 outbreak in crew.
3	July 3 - 8	Set 8 biodiversity sites, including 4 songbird sites.
4	July 10 - 15	Collected invertebrate samples and bat recorders, checked cameras and songbird recorders at 8 biodiversity sites.
5	July 18 - 21	Set 12 biodiversity sites, including 12 songbird sites.
6	July 25 - 28	Collected invertebrate samples and bat recorders, checked cameras and songbird recorders at 12 biodiversity sites.
7	August 1 - 4	Set 12 biodiversity sites, including 4 songbird sites.
8	August 8 - 11	Collected invertebrate samples and bat recorders, checked cameras and songbird recorders at 12 biodiversity sites.
9	August 15 - 18	Set 12 biodiversity sites.
10	August 22 - 25	Collected invertebrate samples and bat recorders, checked cameras and songbird recorders at 12 biodiversity sites.
11	Aug 29 - 1 Sep	Set 12 biodiversity sites.
12	Sep 5 - 8	Collected invertebrate samples and bat recorders, checked cameras and songbird recorders at 12 biodiversity sites.
13	Sep 12 - 15	Vegetation surveys and retrieving cameras and songbird recorders.
14	Sep 19 - 22	Vegetation surveys and retrieving cameras and songbird recorders.
15	Sep 26 - 30	Vegetation surveys and retrieving cameras and songbird recorders.

## 3. Preliminary Results

### 3.1 Summary

Survey Method	Number of Species Detected				
	Early Seral 0 - 15 yrs	Early-Mid Seral 16 - 29 yrs	Mid-Late Seral 30 - 79 yrs	Mature Forest ≥80 years	Total
Acoustic recorders**	19	22	21	20	25
Ultrasonic recorders	13	14	12	14	14
Baited cameras*	23	23	26	18	36
Trail cameras*	17	20	20	19	30
Pitfall traps	Data processing in progress				-
Malaise traps	Data processing in progress				-
Blue vane traps	Data processing in progress				-
Vegetation surveys	28	24	21	22	34
<b>TOTAL</b>	<b>83</b>	<b>80</b>	<b>75</b>	<b>72</b>	<b>104</b>

\* Domestic species and humans not counted in species tallies.

\*\*Only species with > 20 total detections counted, to account for model error.

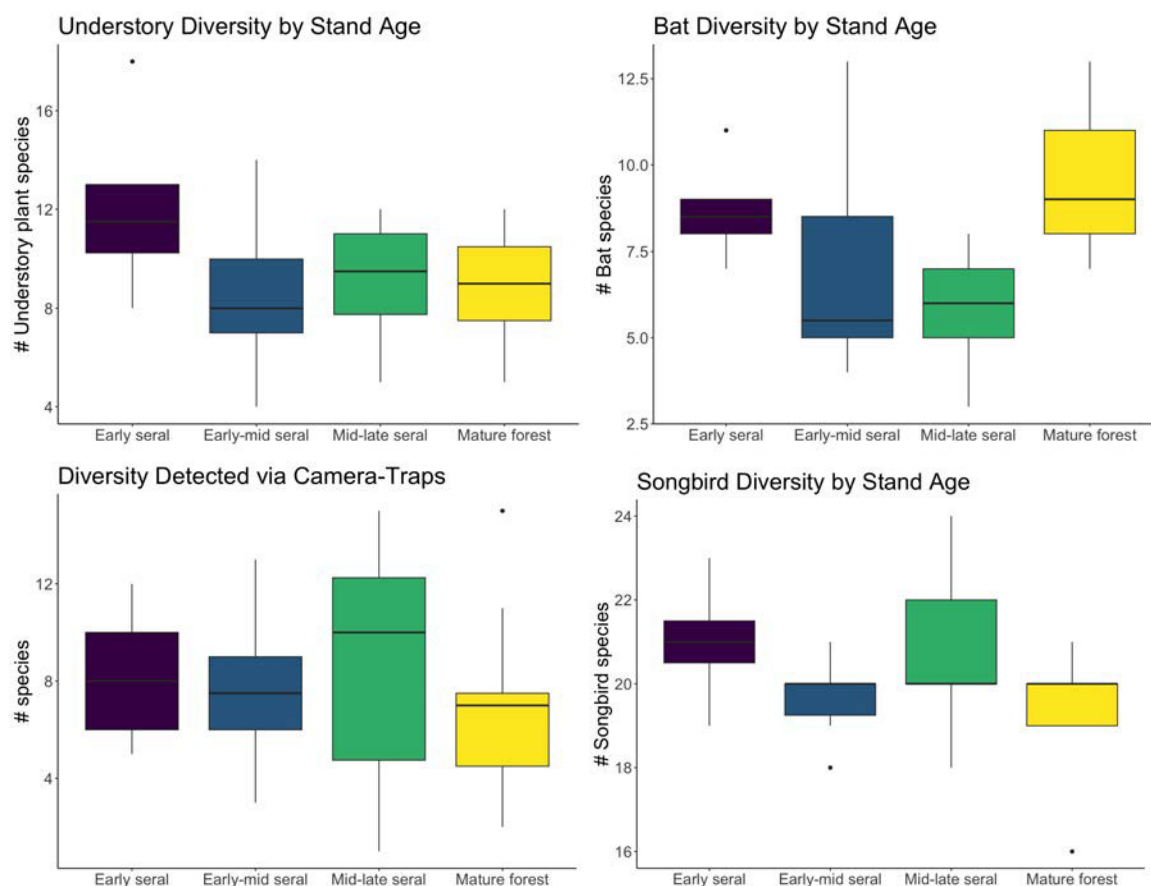


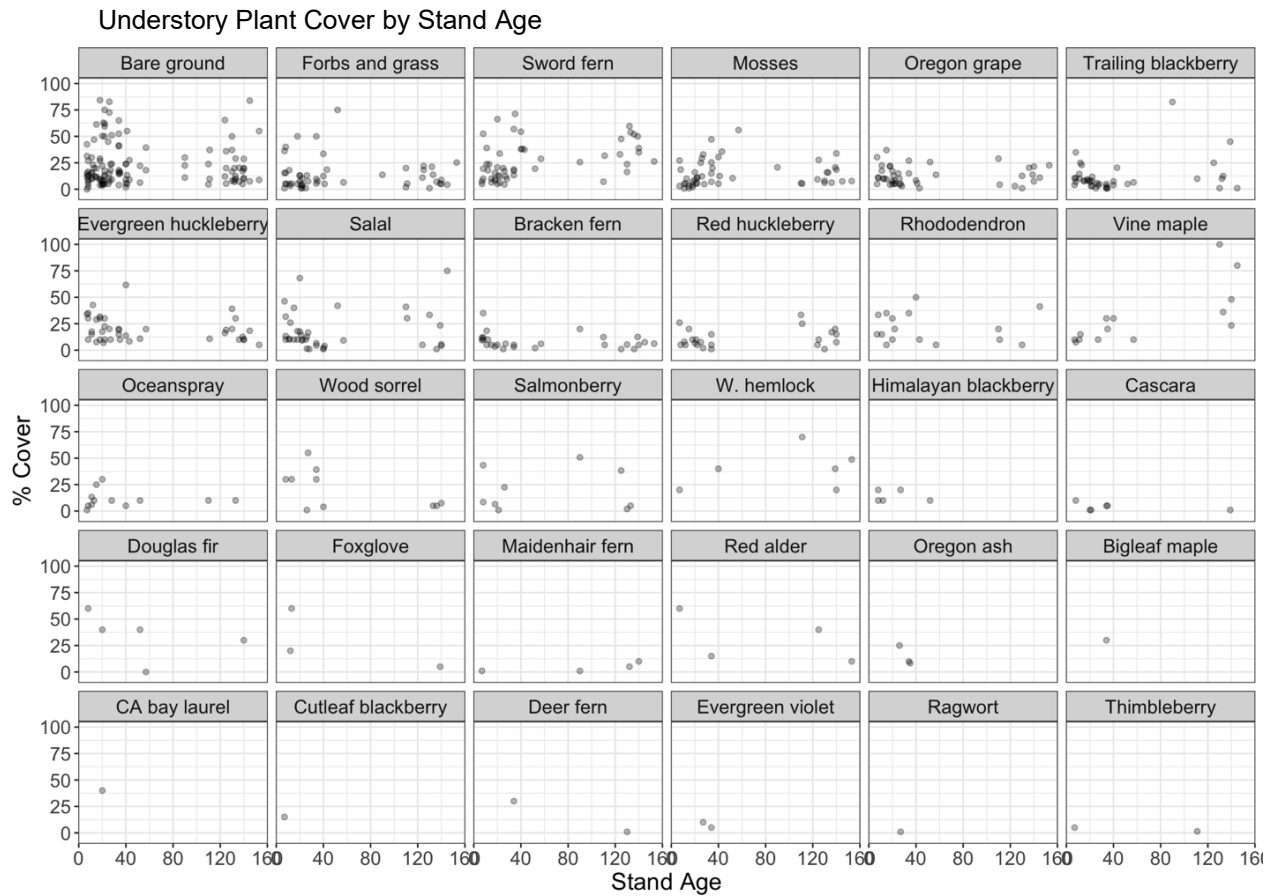
Figure V-4. Summary of per-site species richness by stand age class and survey method.

### 3.2 Vegetation Surveys

Understory cover across the ESRF was largely dominated by bare ground, sword fern (*Polystichum munitum*), mosses, Oregon grape (*Mahonia aquifolium*), trailing blackberry (*Rubus ursinus*), evergreen huckleberry (*Vaccinium ovatum*), salal (*Gaultheria shallon*), bracken fern (*Pteridium aquilinum*), and red huckleberry (*Vaccinium parvifolia*) (Figure V-5). While understory cover between stand age classes was largely similar, differences included higher berry-producing plant and invasive species (primarily Himalayan blackberry *Rubus bifrons* and common foxglove *Digitalis purpurea*) cover in early seral stands and highest bare ground cover in early-mid seral stands (Figure V-6). *Differences in understory cover have not yet been statistically tested.*

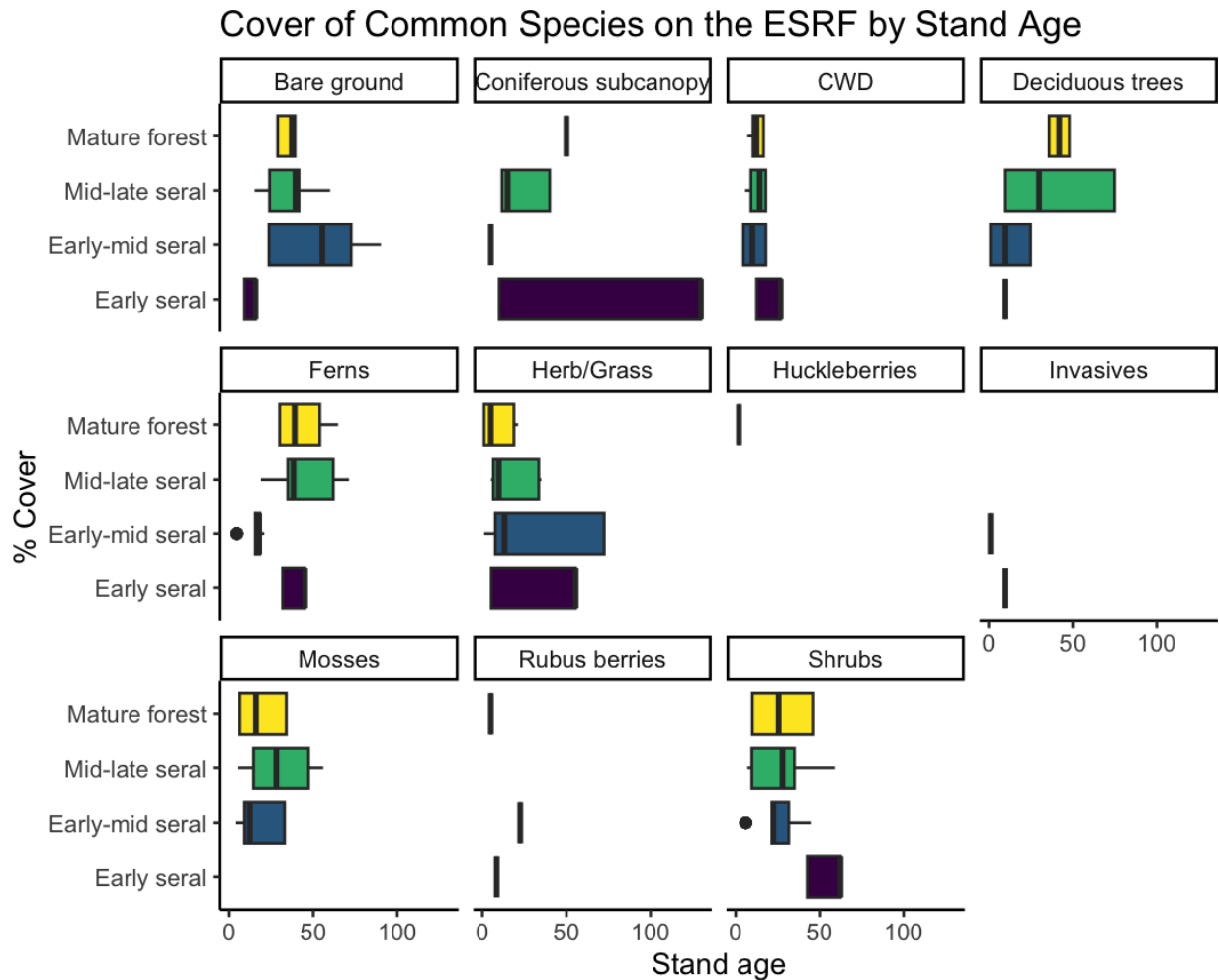
We measured relatively large amounts of coarse woody debris per site (mean: 142 m<sup>3</sup> based on 80 meters of transects per site), however, important habitat features including large (>100 cm diameter) items and snags appear to be limited on the ESRF (Figure V-7). Based on field observation, available woody debris seems to be largely due to logging activity or deadfall (which seemed to be most common in early-mid seral stands). There are no obvious differences in coarse woody debris availability between stand age classes (Figure V-7). *Differences in coarse woody debris volume have not yet been statistically tested.*

Unique stand types were qualitatively observable in the field (see site photos at the bottom of this section), however few quantitative differences in understory cover and coarse woody debris availability were observed between stand age classes based on raw data summaries. We suspect that including overstory data in data in the future will help to distinguish vegetation communities.

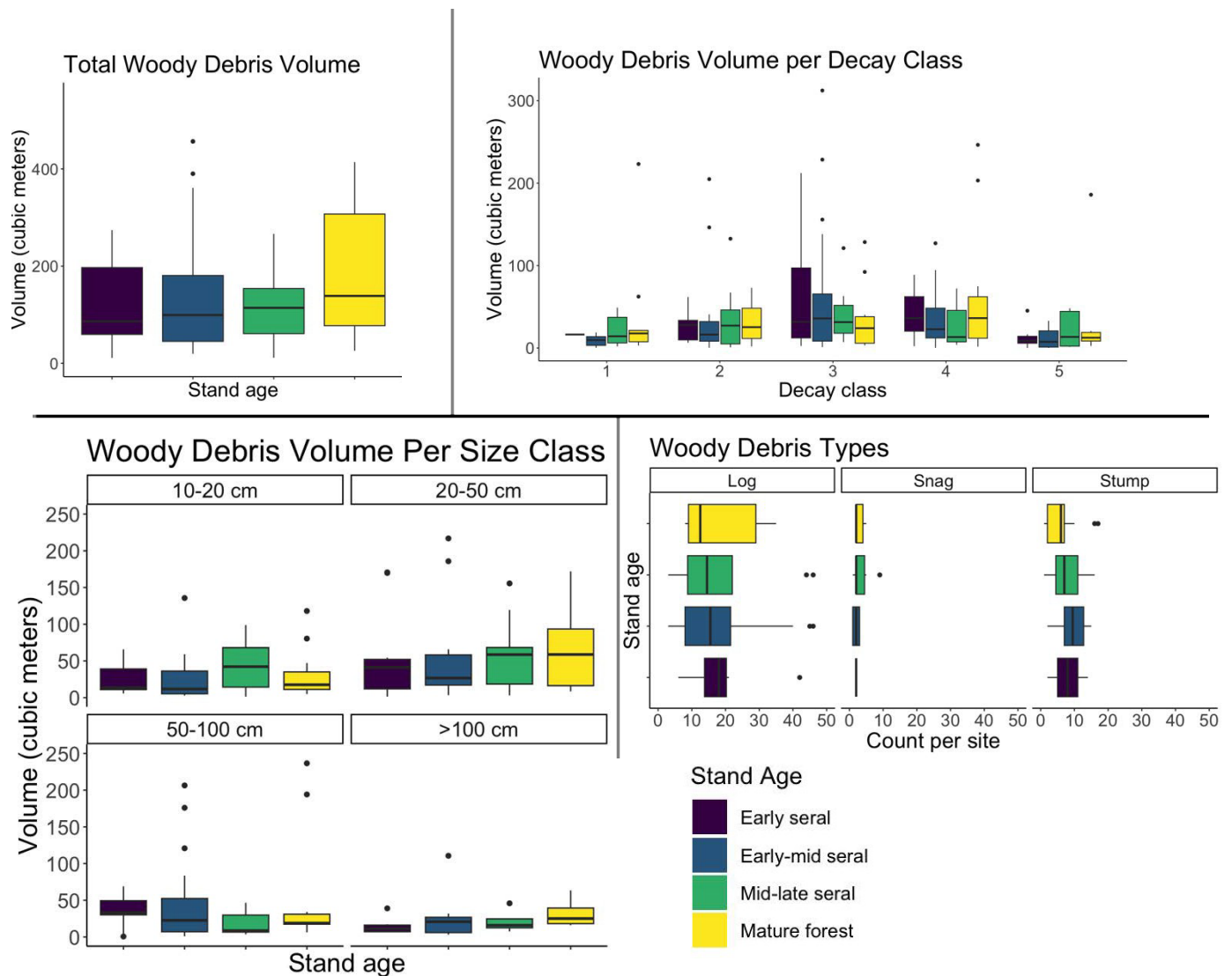


**Figure V-5.** Mean understory cover per site by stand age. Classes are ordered (top to bottom and left to right) by the number of sites each class is present at. Percent cover per site was calculated as the mean species cover across plots.





**Figure V-6.** Understory plantcover of major groups by stand age. Mean cover was taken across plots per site. Cover may be >100% because overlapping cover was considered. Invasive plant species included (in order of occurrence from most common to least) Himalayan blackberry (*Rubus bifrons*), common foxglove (*Digitalis purpurea*), tansy ragwort (*Jacobaea vulgaris*), and coyote brush (*Baccharis pilularis*).



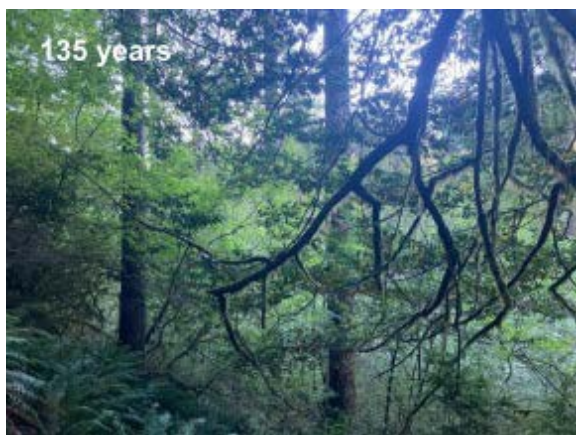
**Figure V-7.** Summary of coarse woody debris survey per site by stand age class. All logs, stumps, and snags >10 cm diameter or width were measured along 80 meters of transects per site, and volume was calculated per site. Top left: Total coarse woody debris volume per site. Top right: Coarse woody debris volume per decay class, with decay class 1 reflecting freshly fallen branches and decay class 5 reflecting nearly fully decayed material (i.e., wood that has turned powdery). Bottom left: Coarse woody debris volume per size class. Size classes were arbitrarily defined. Bottom right: Per-site counts of coarse woody debris types.

### Site photos (page 1)





### Site Photos (page 2)





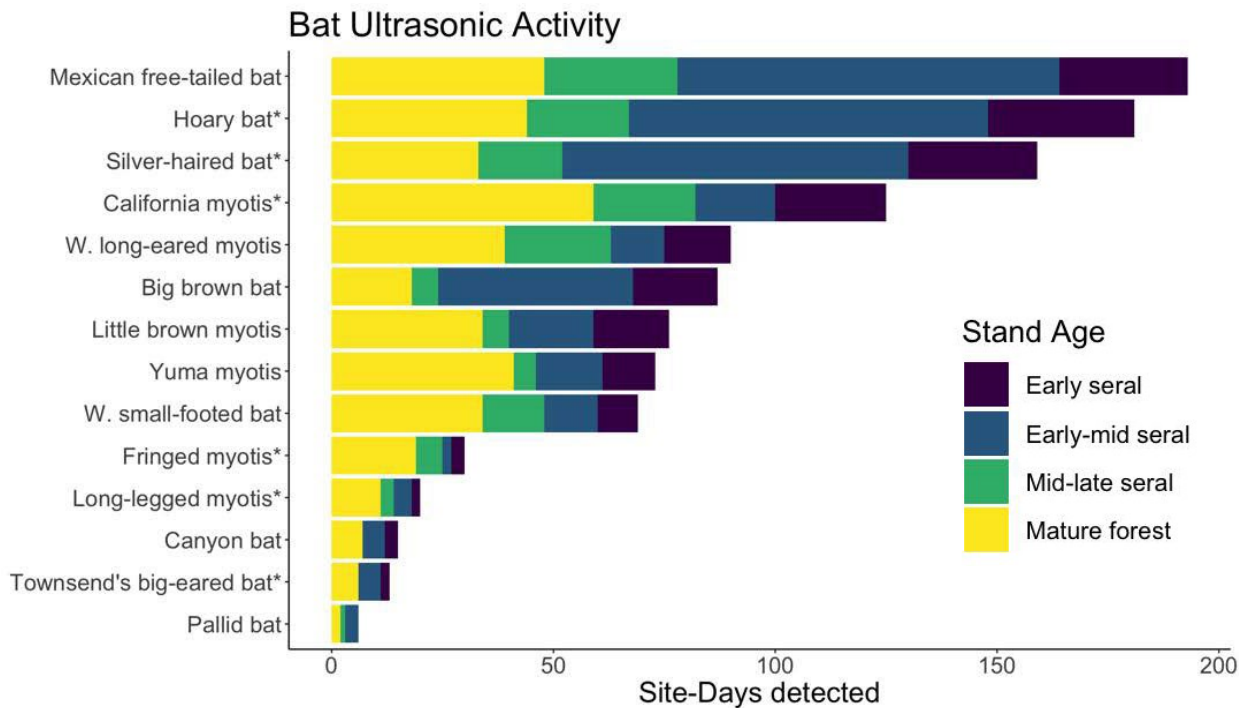
### 3.3 Bat Bioacoustics

We have processed bat ultrasonic data for 40 of 59 sites. From these 40 sites, a total of 30,285 total bat recordings ranging from 3-15 seconds in duration were collected between July 3 and August 25. The number of bat recordings per site was highly variable and ranged from 24 to 8,584.

We manually verified 9497 records (31.7%) which demonstrated high levels of classification sensitivity for all bat species but lower levels of specificity for bat calls. >99% manual verifications matched auto-identification for bats, but 8% of records classified as 'NoID' had bats present. Results should be regarded with caution because the initial set of manually verified calls were the easiest identified bat calls, so our current accuracy may be overestimated.

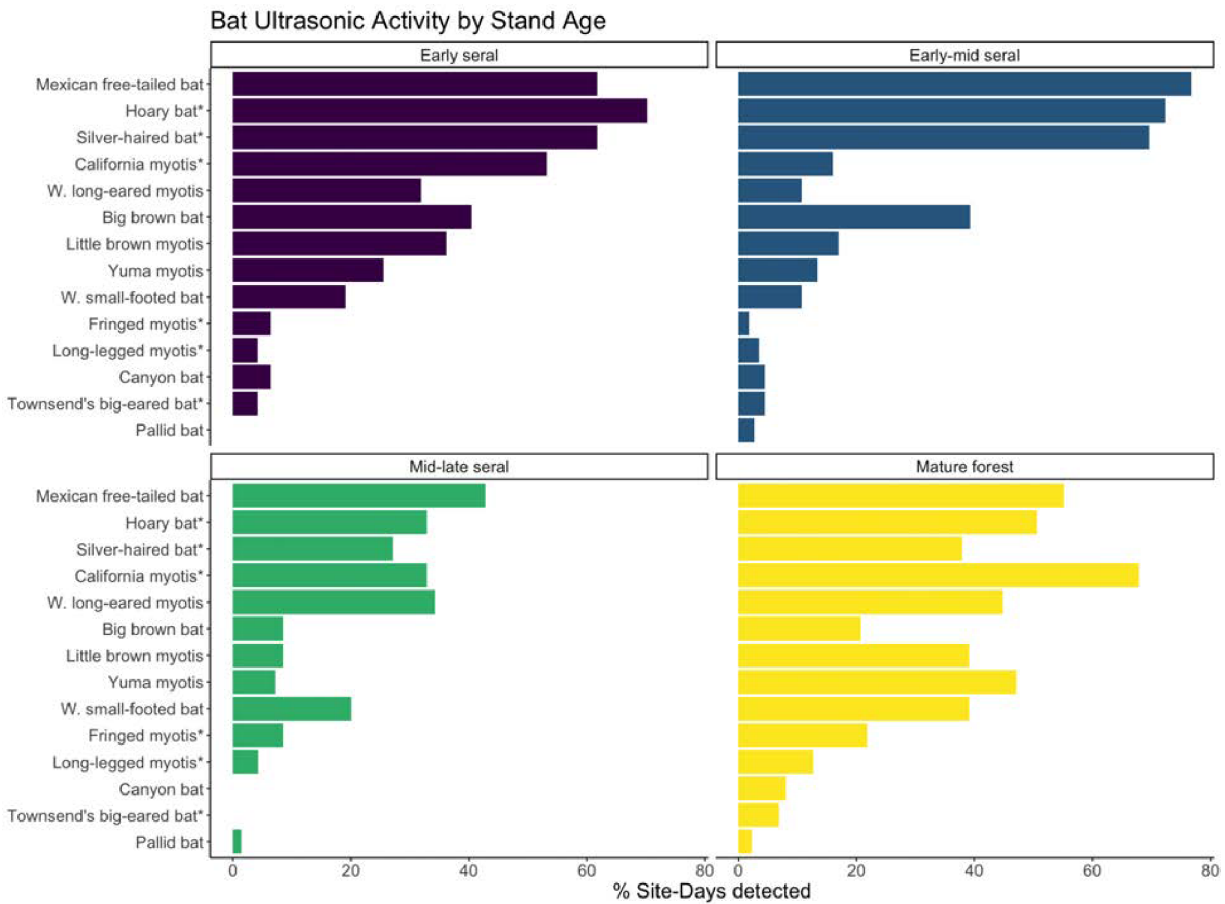
14 species were detected, including the pallid bat, Townsend's big-eared bat, big brown bat, hoary bat, silver-haired bat, California myotis, western small footed myotis, little brown myotis, fringed myotis, long-legged myotis, Yuma myotis, canyon bat, Mexican free-tailed bat, and long-eared myotis. The most commonly detected species (based on the number of site-days detected) included Mexican free-tailed bat, hoary bat, silver-haired bat, and California myotis (*Figure V-8*). Total activity per species based on ultrasonic detections mirrored the number of sites each species was detected at (*Figure V-10*), with the species occurring at most sites including Mexican free-tailed bat, hoary bat, silver-haired bat, and big brown bat. Across species, bat activity appeared to be lowest in mid-late seral stands (*Figure V-9*). We will need to run formal statistical tests that account for survey effort and vegetation structure to test the significance and strength of this pattern.

Detectability of bat species, estimated by the number of nights a species was detected per site, is variable. While most species were detected multiple nights per night, canyon bat, Townsend's big-eared bat, and pallid bat were most often detected once per site (*Figure V-11*). Low apparent occupancy and activity of these species may be due to low detectability resulting in false absences. Increasing the survey period or repeating surveys during a summer will help to avoid missing these species.



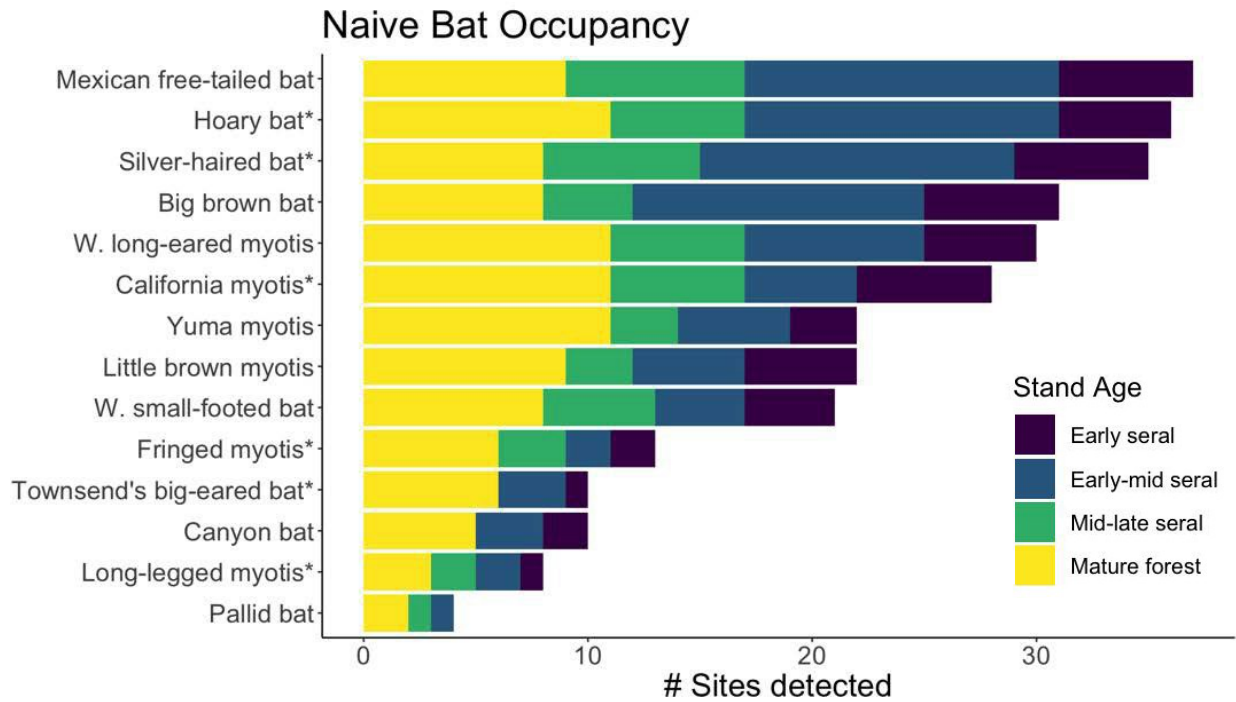
**Figure V-8.** Bat activity detected by ultrasonic recorders per species, defined by the species being recorded at a site at least once during a nightly survey period. The data analyzed thus far is unbalanced across stand ages and represents data from 6 early seral, 14 early-mid seral, 9 mid-late seral, and 11 mature forest stands.

\*Bat species listed as state sensitive under the Oregon Conservation Strategy.



**Figure V-9.** Bat species ultrasonic activity by stand age, demonstrating differences in community composition between stand age classes. Activity is represented by the % of total survey effort (Site-Days) yielding detections for each species per stand age class.

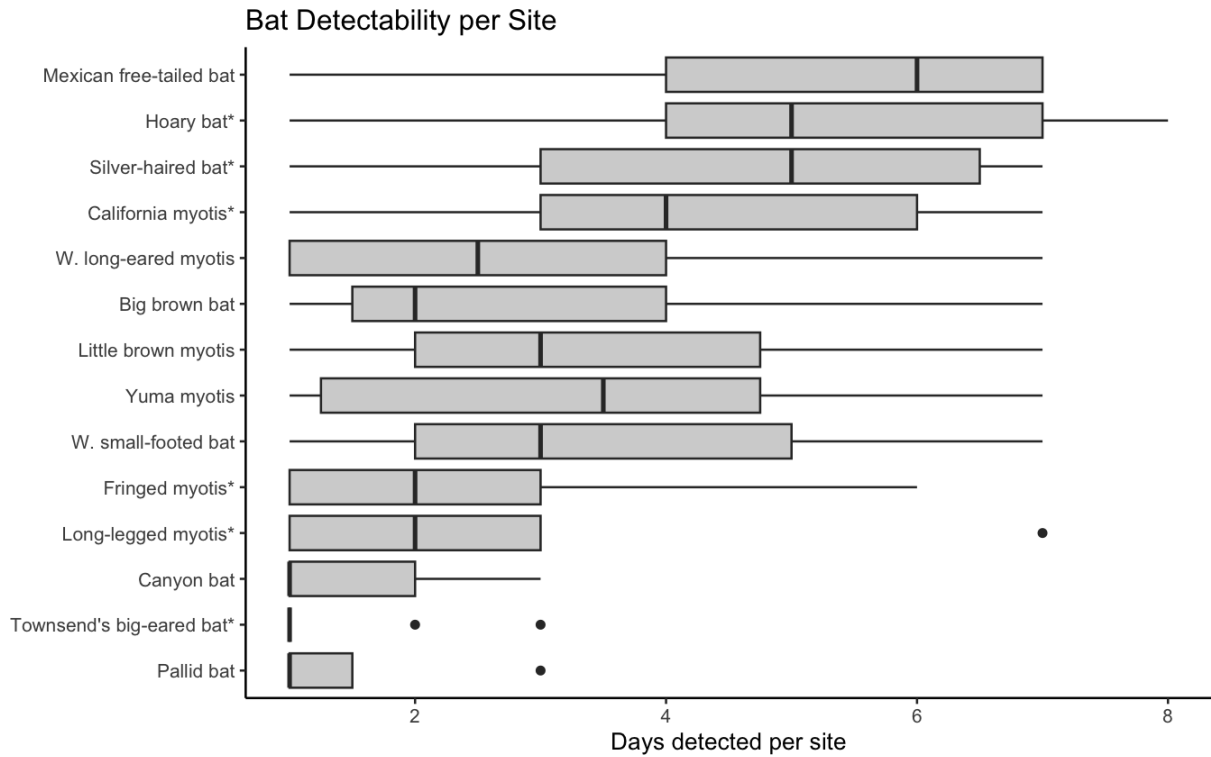
*\*Bat species listed as state sensitive under the Oregon Conservation Strategy.*



**Figure V-10.** Naive occupancy per bat species (i.e., the number of sites each bat species was detected at). The data analyzed thus far is unbalanced across stand ages and represents data from 6 early seral, 14 early-mid seral, 9 mid-late seral, and 11 mature forest stands.

\*Bat species listed as state sensitive under the Oregon Conservation Strategy.





**Figure V-11.** Detectability of each bat species by ultrasonic recorders represented as the # of days each species is detected per site. Sites had equal survey effort of 7 nights.  
\*Bat species listed as state sensitive under the Oregon Conservation Strategy.

### 3.4 Camera-Trapping

A total of 4,711 camera trap-nights of data were collected between 03 July and 08 October 2022, with an average of 42 trap-nights per camera per site (SD 14.5, range 22-71 days). Baited and trail cameras were set and collected on the same day at each site, so site survey effort was equivalent between camera set types unless batteries died or a camera was knocked out of place. A total of 32,481 photos were collected, 12,144 on baited camera sets and 20,367 on trail camera sets. Of these, 7893 baited camera photos (65%) and 6533 trail camera photos (33%) captured animal activity.

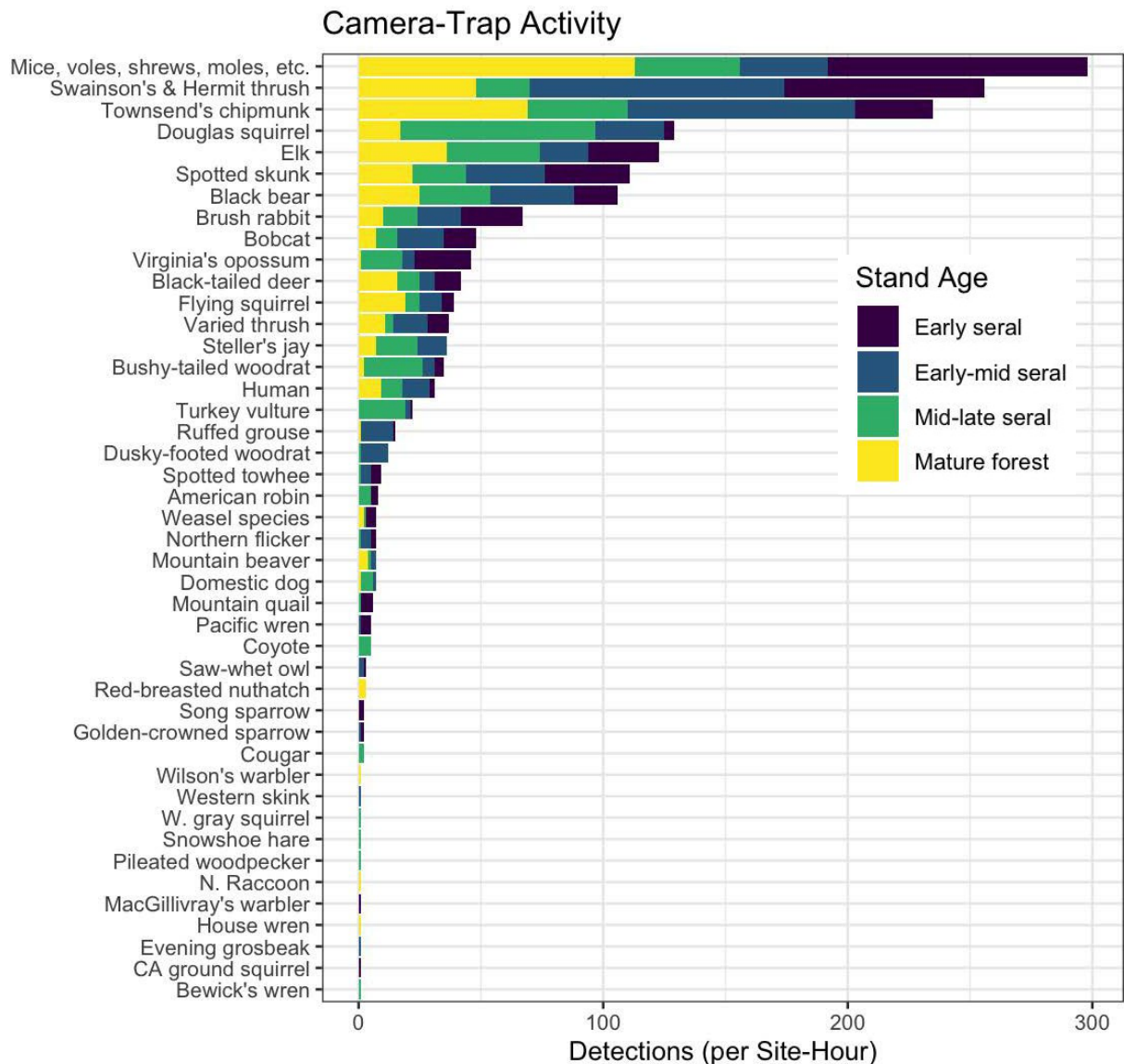
Baited cameras detected 41 species and trail cameras detected 33 species. A photo catalog of commonly detected species can be found at the bottom of this section. The most commonly detected species overall were mice, Swainson's or hermit thrushes (which often cannot be distinguished in photos), Townsend's chipmunks, Douglas squirrel, elk, spotted skunk, and black bear ([Figure V-12](#)). Species detected at the most sites included the Townsend's chipmunk, Swainson's or hermit thrush, black bear, spotted skunk, elk, mice and other small rodents, brush rabbit, black-tailed deer, bobcat, and flying squirrel ([Figure V-14](#)).

Notably, we detected apparent dusky-footed woodrats (*Neotoma fuscipes*) at 3 sites, which as far as we can tell have previously not been reported this far north in the Coast Range. Records show this species distribution in the Coast Range does not extend past around Bandon, Oregon, and extends eastward into the Willamette Valley. This species likely has not been previously detected on the Elliott State Forest due to limited survey efforts, however the possibility of northward range expansion should not be excluded. Further survey effort with improved photo quality may be needed to definitively confirm that these detections are indeed dusky-footed woodrats. Birds were detected more often than expected, particularly ground-foraging birds including thrushes, grouse, quails, Steller's jays, and spotted towhees, Songbirds including Bewick's wren, evening grosbeak, MacGillivray's warbler, golden-crowned sparrow, song sparrow, and Wilson's warbler were each detected once, however these provide the only detections for these species since the bioacoustics model is not yet able to identify them.

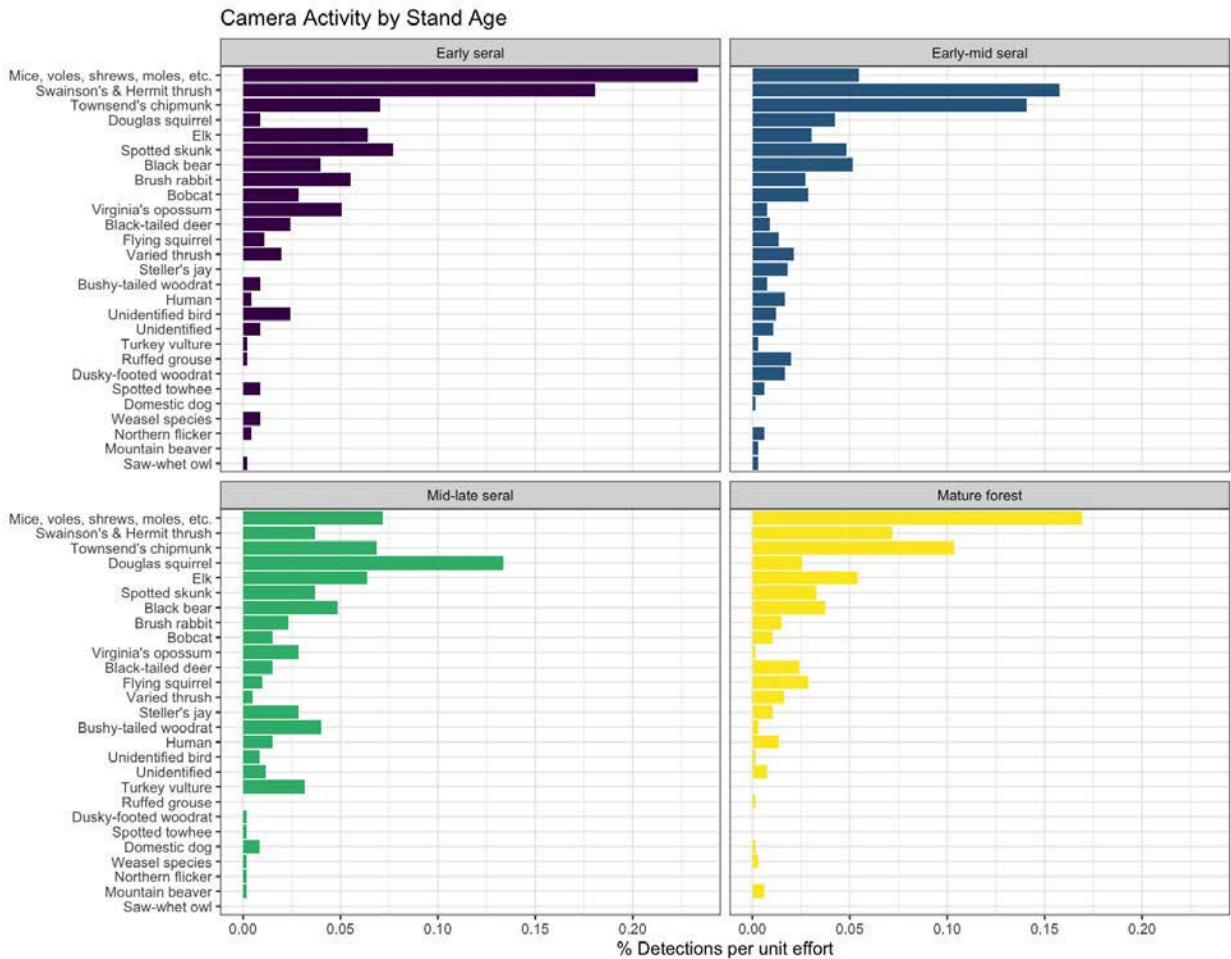
As expected, camera set types contributed data on different species. Elk, deer, humans, domestic dogs, and mountain beavers were more often detected at trail cameras, while chipmunks, thrushes, black bears, spotted skunks, and Virginia opossums are more often detected at baited cameras ([Figure V-15](#)). Some species were nearly exclusively detected by one method or the other, for example Virginia opossums, spotted skunks, weasel species, and turkey vultures are almost always detected at baited cameras, while elk, deer, humans, and mountain beavers are primarily detected at trail cameras. [Figure V-16](#) demonstrates how often we would miss these species at a site if we only used one camera set.

While most species were detected in most stand ages, camera-trap detections show apparent differences in community composition between stand age types ([Figure V-13](#)). Mature stands appear to have higher overall activity across most species than other age classes, and early seral stands tended to have the lowest activity. Survey effort per age class was not accounted for in stand comparisons, and further modeling will need to be done to determine community-level differences between stand ages. Given the elusiveness of many of these species, 56 sites do not provide enough data to compare amongst 4 stand age classes given the lack of apparent strong habitat preferences.

Latency to detection (LTD) for both survey methods is relatively low (mean across species 18.9 days [SD 11.5] for trail cameras and 15.2 days [SD 11.0] for baited cameras) compared to survey duration (42.5 days), indicating that a 40-day survey duration should detect most of these species (*Figure V-17, Figure V-18*). Note, however, that LTD is limited to the species that we detected given current survey effort, and given our low survey duration is likely underestimated for species with lower detection probabilities.

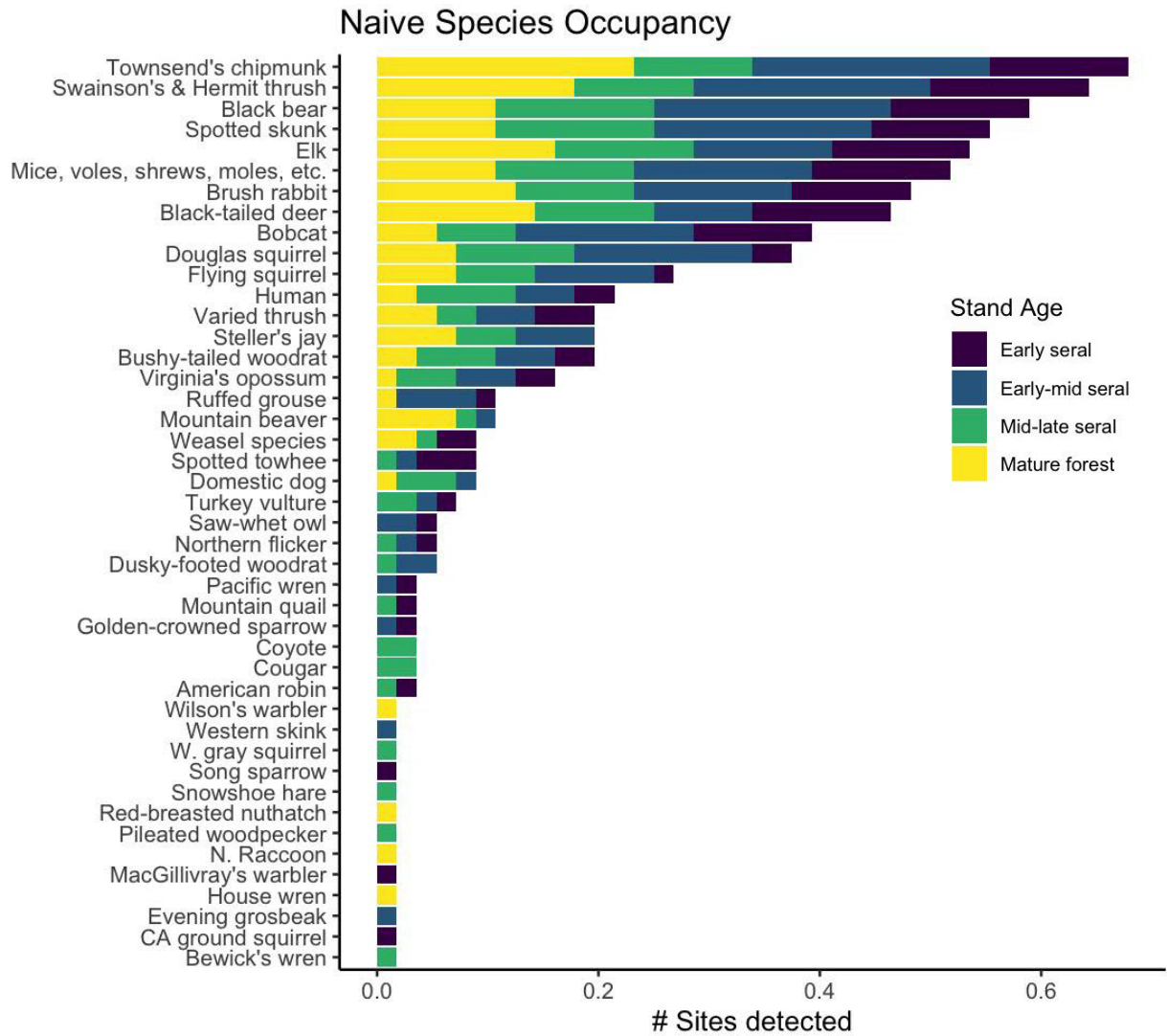


*Figure V-12. Total camera-trap detections per species, with each detection defined by the animal being observed at a site at least once during a one-hour survey period. The total number of detections is thus the number of site-hours a species was observed.*

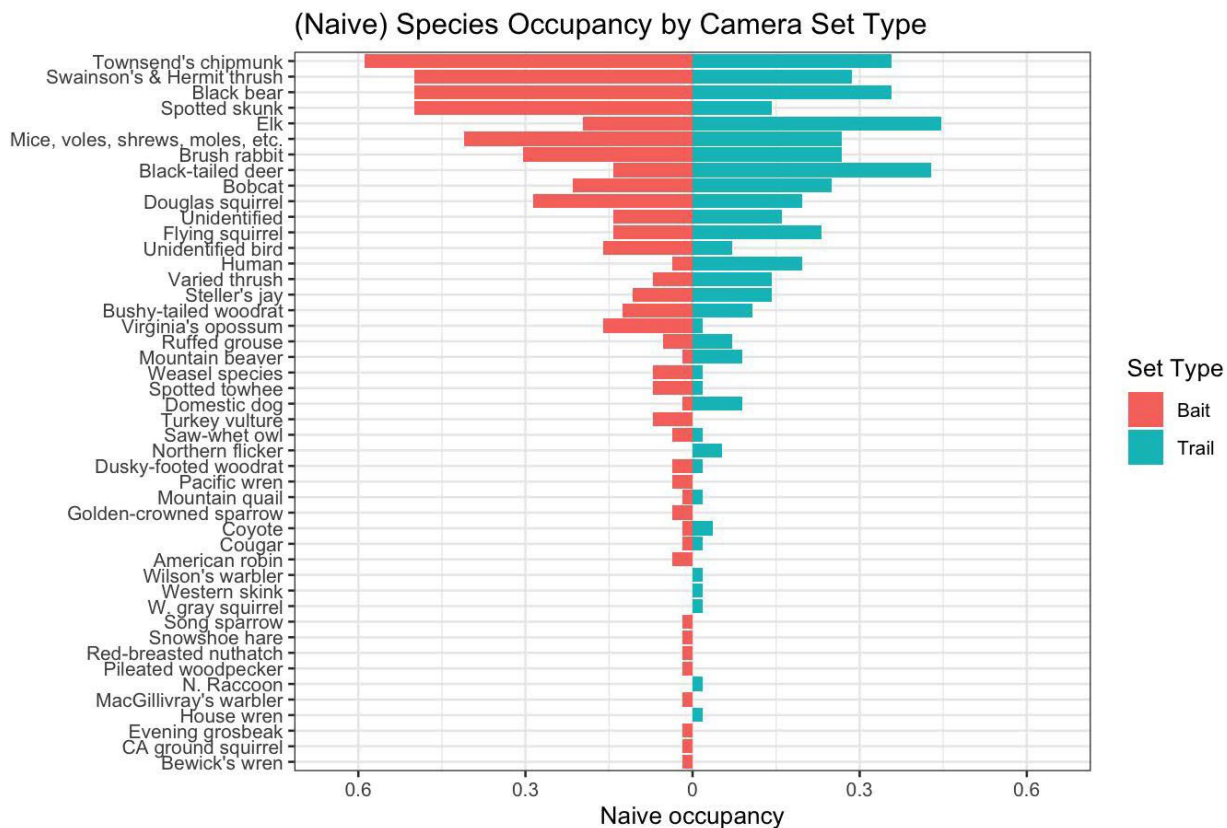


**Figure V-13.** Camera-trap species activity by stand age, demonstrating differences in community composition between stand age classes. Detections reflect each hour a species is detected at a site, standardized by survey effort (total sites x days) cameras were active within each stand age class.

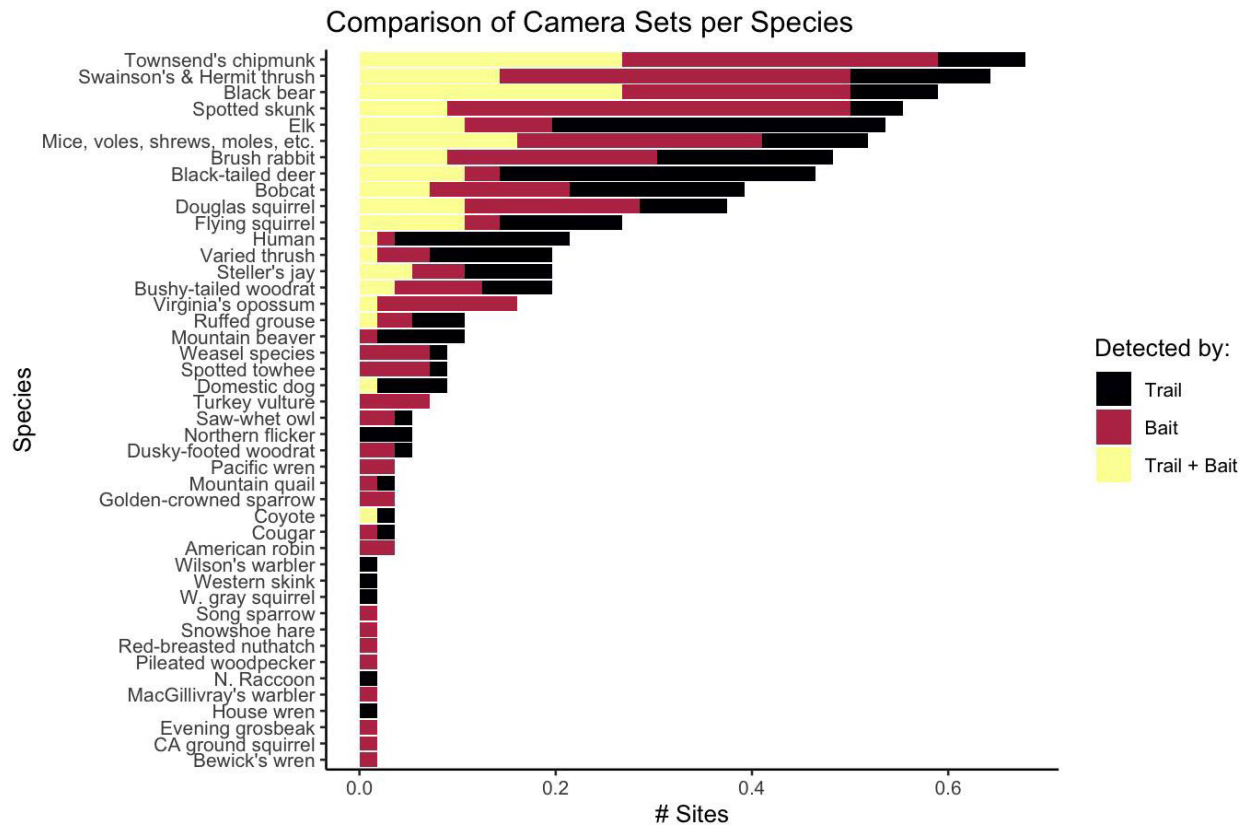




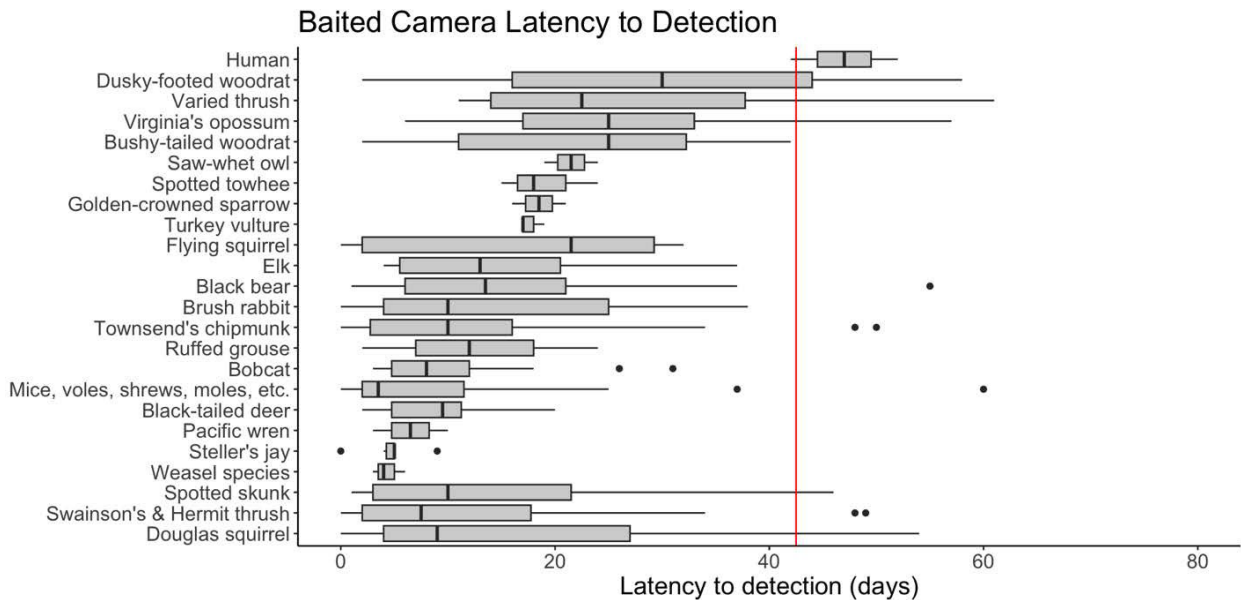
**Figure V-14.** Per-species naive occupancy of the ESRF (i.e., the proportion of sites a species was detected at), reflecting how common a species is on the ESRF without accounting for species detection probability.



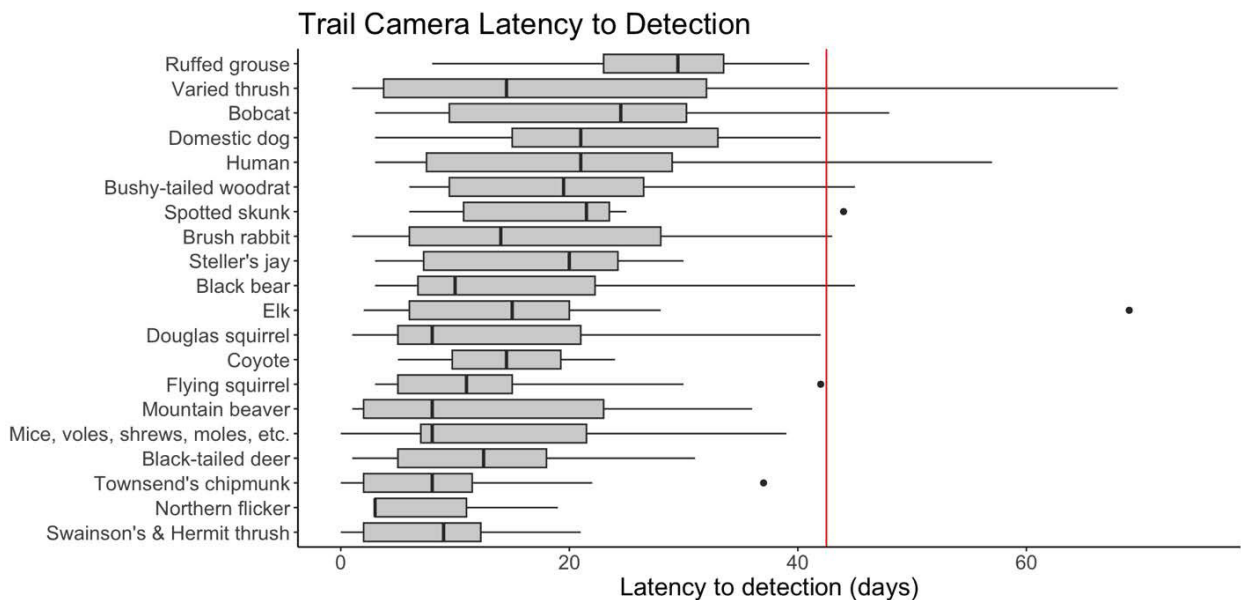
**Figure V-15.** Naive species occupancy by camera-trap set type, showing differences in species data collected by each method. Elk, deer, humans, domestic dogs, and mountain beavers are more often detected at trail cameras, while chipmunks, thrushes, black bears, spotted skunks, and Virginia opossums are more often detected at baited cameras.



**Figure V-16.** Contributions of each camera set type to naïve species occupancy. Some species are nearly exclusively detected by one method or the other, for example Virginia opossums, spotted skunks, weasel species, and turkey vultures are primarily detected at baited cameras, while elk, deer, humans, and mountain beavers are primarily detected at trail cameras.



**Figure V-17.** Per site latency to detection (i.e., the number of days before the species is first detected) for baited camera-traps. The red line reflects the average survey effort per site (~42.5 days); species with LTD below this line are likely to be detected by this survey effort while species above this line are less likely to be detected.



**Figure V-18.** Per site latency to detection (i.e., the number of days before the species is first detected) for trail camera-traps. The red line reflects the average survey effort per site (~42.5 days); species with LTD below this line are likely to be detected by this survey effort while species above this line are less likely to be detected.



Species Detected in Camera-Trap Photos (Page 1)



*Western spotted skunk*



*Swainson's thrush or Hermit thrush*



*Turkey vulture*



*Cougar*



*Flying squirrel*



*Townsend's chipmunk*



*Steller's jay*



*Brush rabbit*



### Species Detected in Camera-Trap Photos (page 2)



*Bobcat*



*Short-tailed weasel*



*Black-tailed deer*



*Sooty grouse*



*Northern raccoon*



*Elk with calf*



*Mountain beaver*



*Bushy-tailed woodrat*



### Species Detected in Camera-Trap Photos (page 3)



*American black bear*



*California ground squirrel*



*Coyote*



*Mountain quail*



*Varied thrush*



*Virginia opossum*



*Dusky-footed woodrat*



*Northern saw-whet owl*

### 3.5 Songbird Bioacoustics

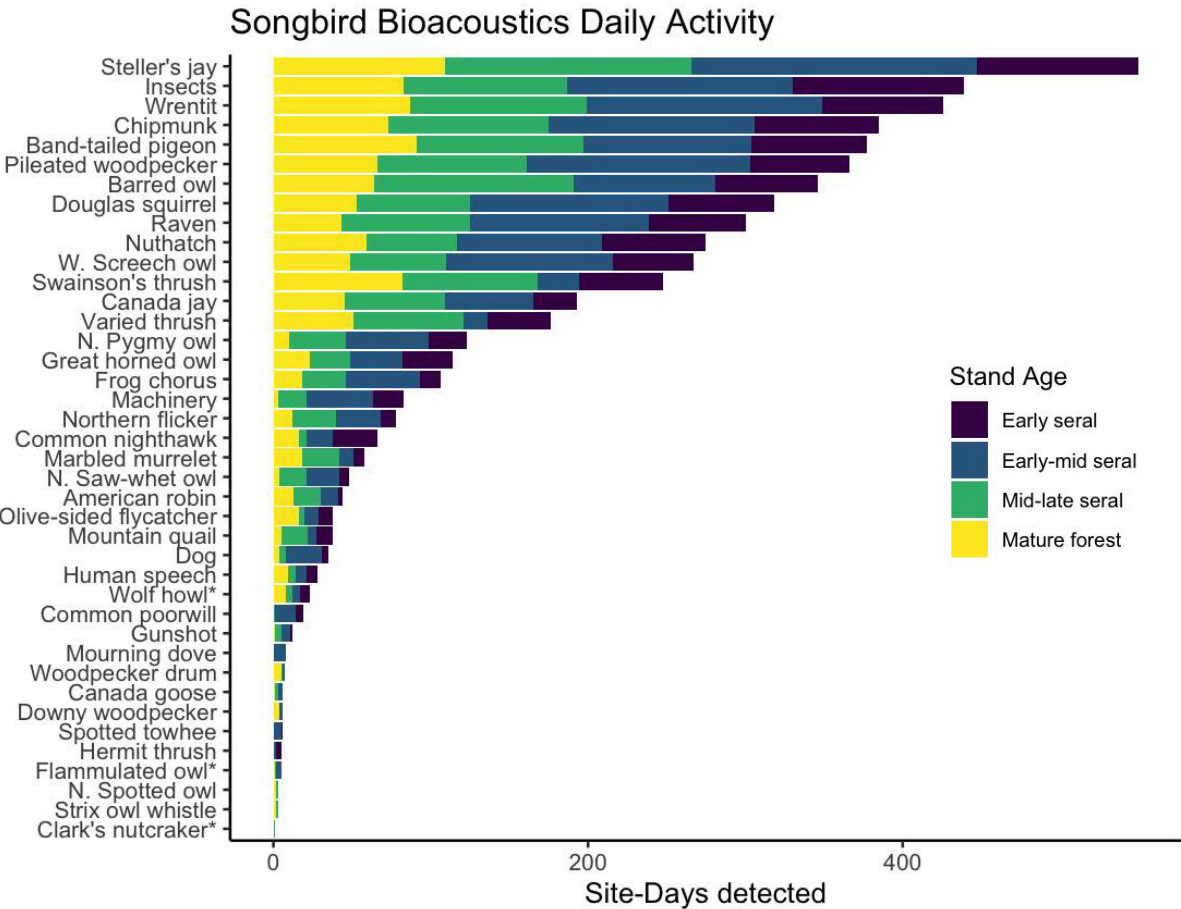
A total of 13,503 records containing 6,427 hours of acoustic data were collected at 21 sites between June 14 and September 13 2022. On average, recorders were active for 28 days and 7 hours (SD 5 days 5 hours, range 6 - 46 days).

Results presented herein are based solely on model classifications that have *not* been but need to be manually verified. Classification accuracy varies by species (see Table 2 in Ruff et al. 2022) and exact numbers of detections should be viewed with caution as misclassifications are present. Importantly, these results also only reflect a subset of total songbird activity, as only vocalizing songbirds that are classifiable via the PNW-CNet model can be detected under the current methods. We did not account for site-level survey effort in these preliminary results.

37 species were detected based on a 0.95 classification accuracy for the PNW-CNet model, including 3 species that do not occur in the Elliott State Forest (or western Oregon) and are most likely a result of model error. The species with highest activity based on songbird acoustic recorders included the Steller's jay, wrentit, chipmunk, band-tailed pigeon, pileated woodpecker, barred owl, Douglas squirrel, common raven, nuthatches (non-specific), western screech owl, and Swainson's thrush ([Figure V-19](#)). Overall animal activity appears similar across stand age classes, though there are differences within a species (e.g., spotted towhee are most active in early-mid seral stands; [Figure V-20](#)). Nine species were detected at all sites, including the Steller's jay, wrentit, band-tailed pigeon, western screech owl, chipmunk, barred owl, nuthatches (non-specific), common raven, and pileated woodpecker ([Figure V-21](#)). Other common species that occurred at more than 75% of sites included Douglas squirrel, Canada jay, Northern flicker, Swainson's thrush, great horned owl, varied thrush, and northern pygmy owl ([Figure V-21](#)).

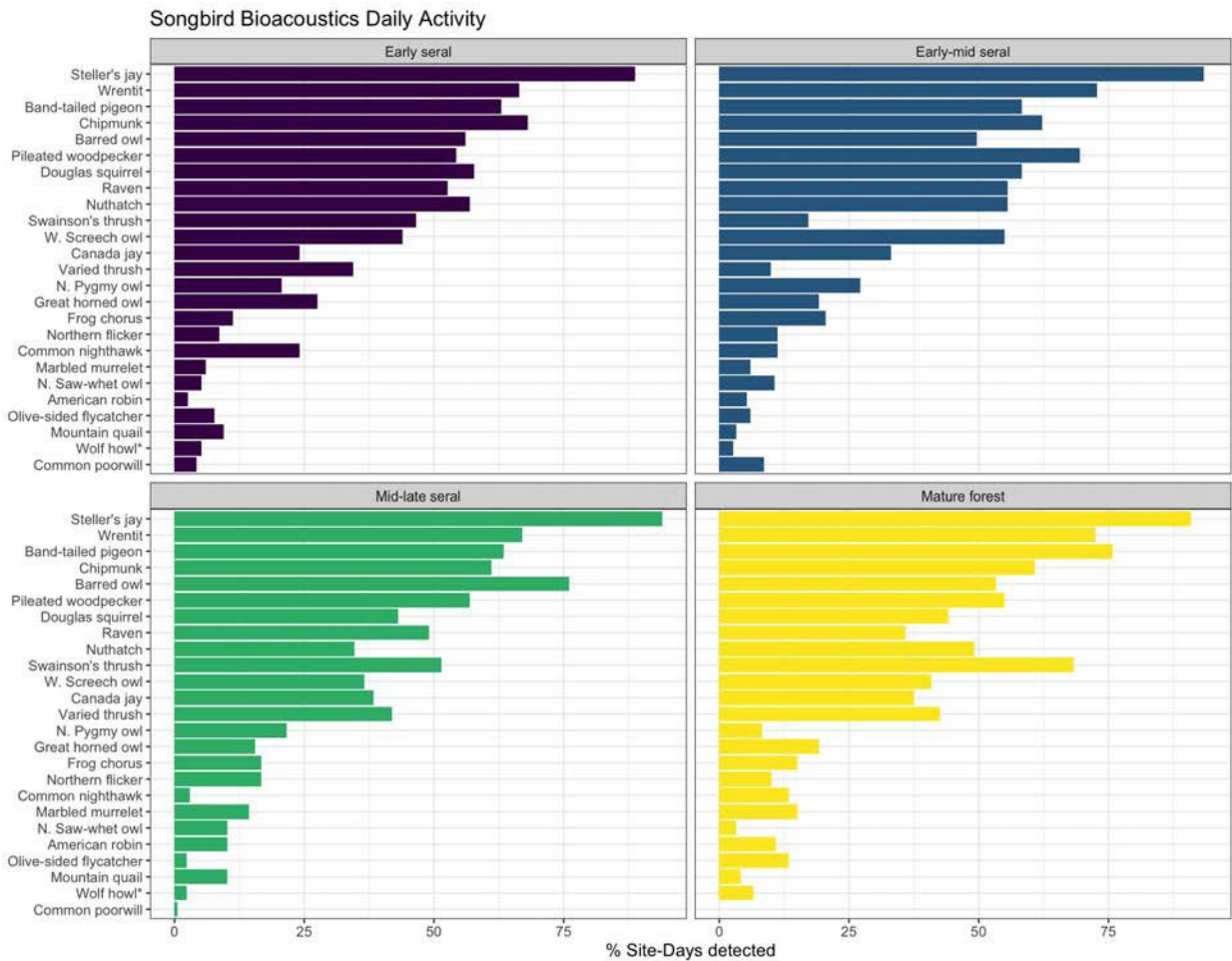
Latency to detection (LTD) ([Figure V-22](#)) as well as detectability ([Figure V-23](#)) based on songbird acoustic recorders is highly variable by species as well as within some species. The third quartile of LTD for 9 species is higher than the average survey duration, suggesting that the current survey duration would be likely to result in false absences for these species.



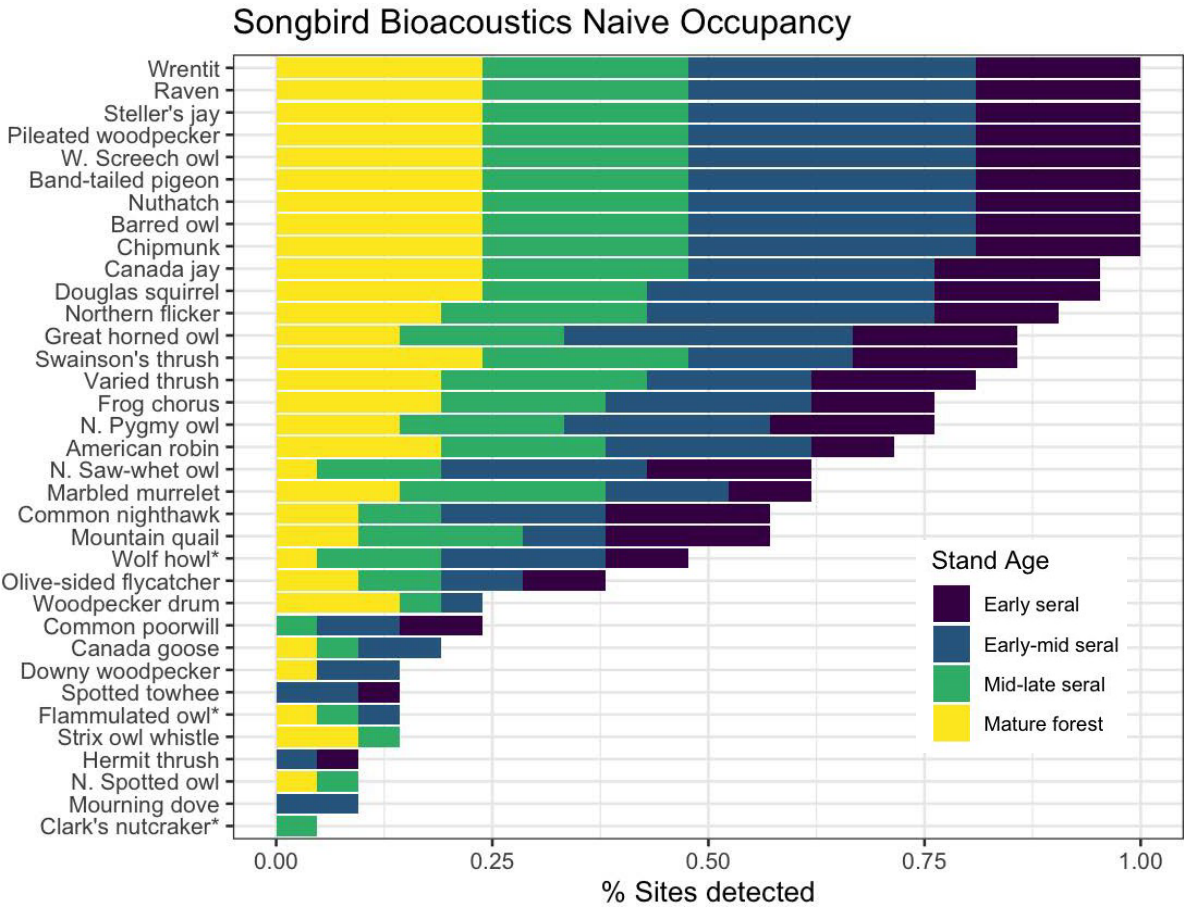


**Figure V-19.** Species-level activity by stand age, based on bioacoustics data. Activity is recorded as the number of days a species was detected at a site, added across sites. Note that classifications have not been verified and misclassifications are present in results (as in any uncorrected classification model results); see Ruff et al. (2022) Table 1 for classification accuracies per species.

\*These species are not known to be present on the ESRF and detections are likely a result of misclassification.

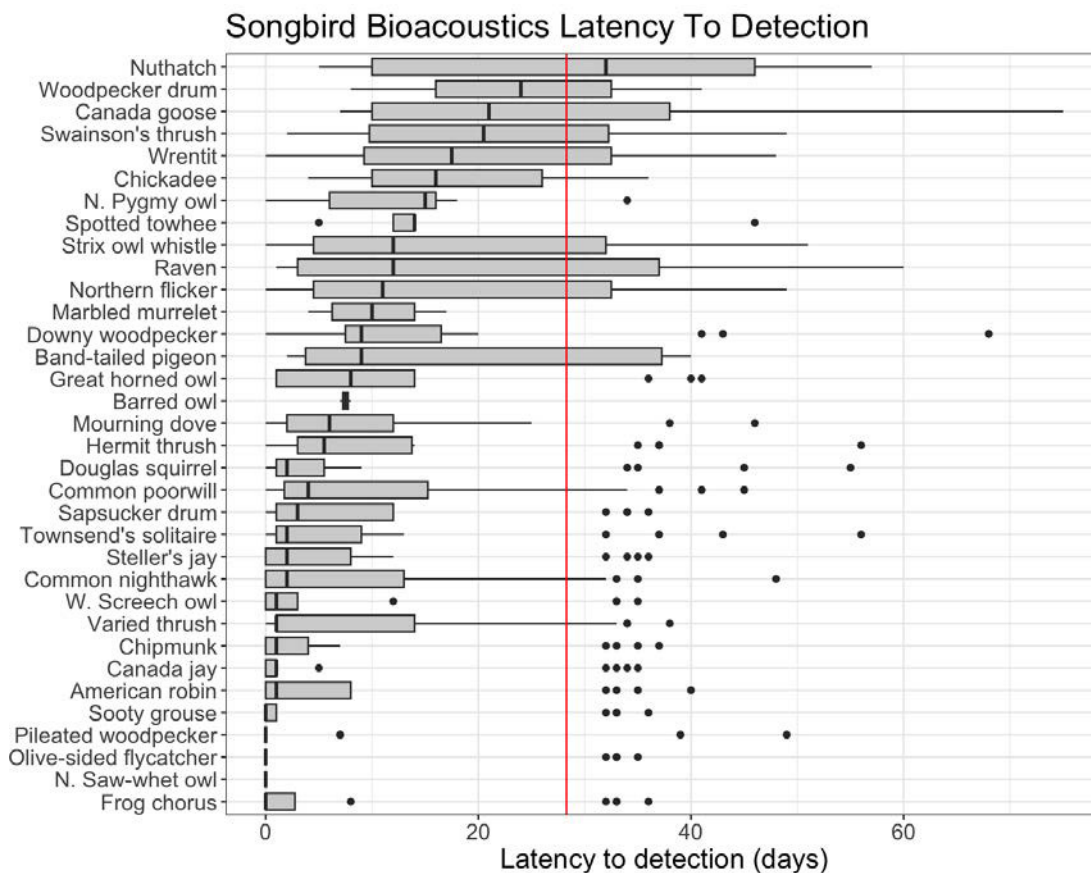


**Figure V-20.** Species-level activity by stand age for a subset of species, standardized by survey effort per stand age. Overall animal activity appears similar across stand age classes, though there are differences within a species (e.g., spotted towhee are most active in early-mid seral stands). Note that classifications have not been verified and misclassifications are present in results (as in any uncorrected classification model results); see Ruff et al. (2022) Table 1 for classification accuracies per species.



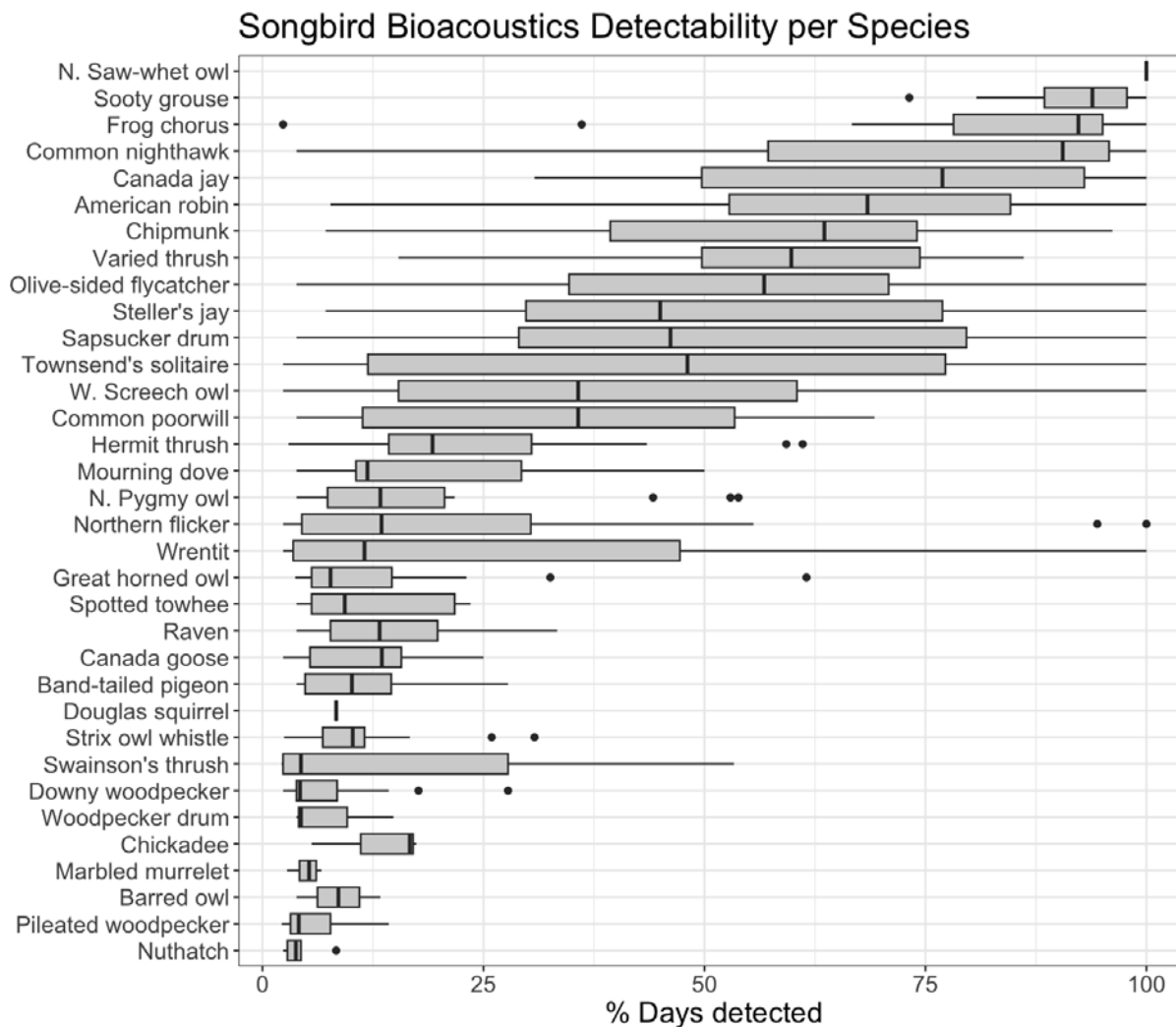
**Figure V-21.** Naïve species occupancy (i.e., proportion of sites a species was detected at) per stand age class). Steller's jay, wrentit, band-tailed pigeon, western screech owl, chipmunks, barred owl, nuthatches, ravens, and pileated woodpeckers occurred at all sites surveyed, indicating near-complete occupancy of the ESRF. Note that classifications have not been verified and misclassifications are present in results (as in any uncorrected classification model results); see Ruff et al. (2022) Table 1 for classification accuracies per species.

*\*These species are not known to be present on the ESRF and detections are likely a result of misclassification.*



**Figure V-22.** Latency to detection (i.e., the number of days a recorder is active before the species is detected) for songbird acoustic recorders. The red line represents the average survey effort (~28.5 days) per site; species with LTD below this line are most likely to be detected by our surveys, while species above this line are more likely to be missed.





**Figure V-23.** Detectability of species by songbird acoustic recorders based on the % of survey days each species was detected. Low detectability indicates that a species is more likely to be missed (false absence) with lower survey effort.

### 3.7 Species of Conservation Concern

#### 3.7.1 Northern Spotted Owl

During this year's surveys, we possibly detected northern spotted owls at 2 survey hexagons (hexagons mirror northern spotted owl home range sizes), however the majority of detected calls may have been from callback surveys conducted on nearby private land rather than from live animals (see [Figure V-24](#) for a summary of these detections). Barred owls were detected at 100% of surveyed sites on the ESRF (see [Figure V-26](#) for a summary of these detections), though at varying levels of activity. This has implications for northern spotted owl persistence on the ESRF as barred owls are associated with local extinction of spotted owl (Dugger et al. 2016; see Long and Wolfe 2019 for a review of barred owl effects on spotted owls). High barred owl density will likely also impact other species on the ESRF via high levels of novel predation (Ryan Baumbusch, unpublished dissertation work). If northern spotted owls are not detected after more intensive surveys in 2023, targeted surveys to determine whether northern spotted owls persist in previous strongholds on the ESRF may be warranted.

#### 3.7.2 Marbled Murrelet

Marbled murrelets were detected at 13 out of 21 sites (see [Figure V-22](#) for a summary). While these detections have not yet been manually validated, classification accuracy for marbled murrelets via the PNW-Cnet model is high (0.987 precision and 0.914 recall; Ruff et al. 2022). Interpreting marbled murrelet calls is an active area of research, as some of these detections are likely at stands under flight paths rather than stands that are actively used by murrelets.

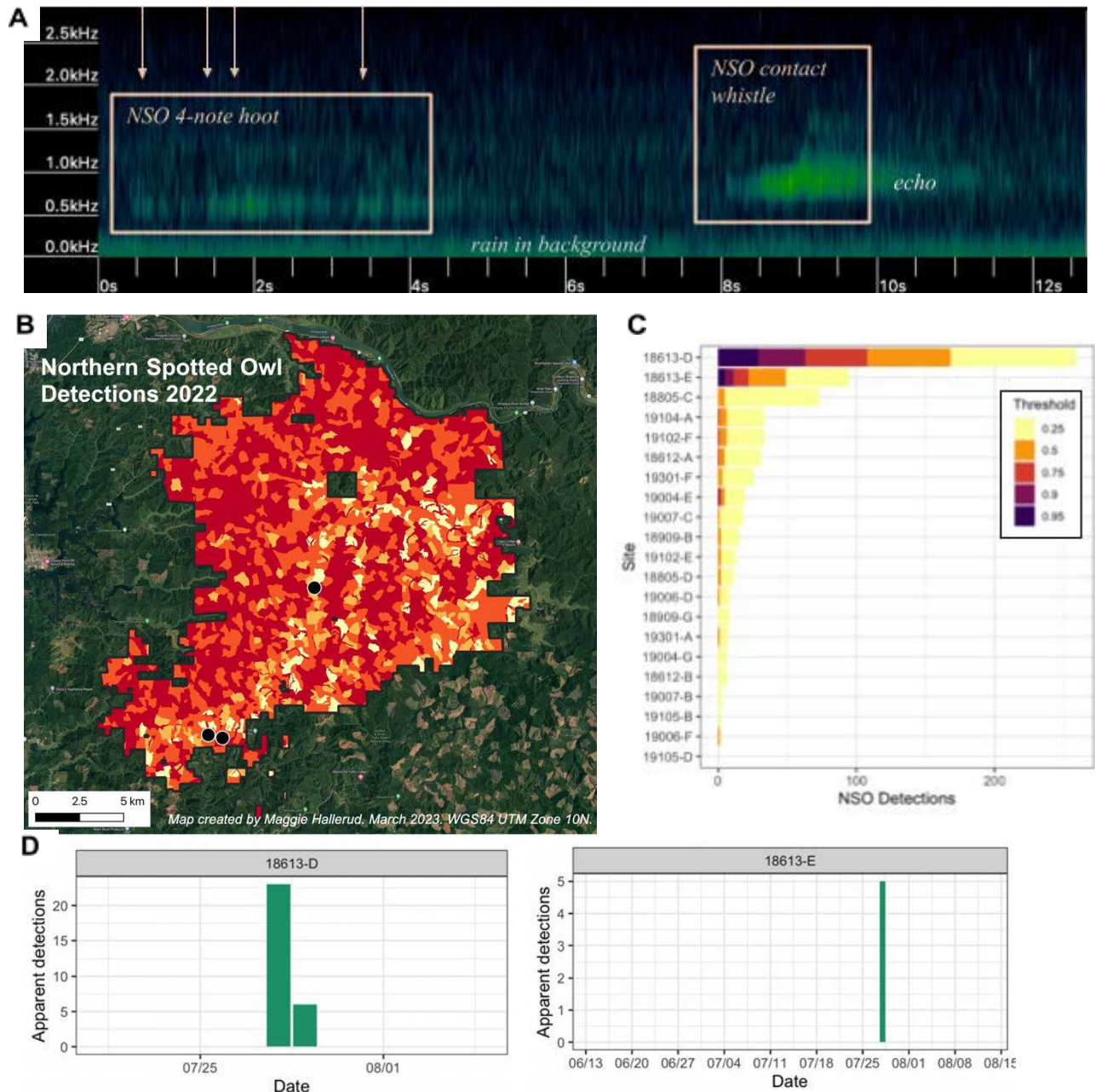
#### 3.7.3 Coastal Marten & Pacific Fisher

During our surveys, neither coastal martens nor fishers were detected. Given our limited survey effort per site and relatively limited number of sites, combined with the elusiveness of both species, more extensive surveys- potentially including scat detection dog surveys- are necessary to determine whether either species is absent on the ESRF. In particular, effort should be dedicated to surveying the southeast corner of the ESRF where martens from the Oregon Dunes would be most likely to enter.

Bobcats were detected much more frequently on the ESRF other areas in the central Coast Range (M. Hallerud, unpublished data). High densities are supported by a previous small-scale radio-collaring on the Elliott State Forest, which revealed that bobcats in this area have small home ranges (2 km<sup>2</sup> for females; Witmer & deCalesta 1986) relative to the known U.S. home range sizes for bobcats (mean of 16 km<sup>2</sup> for females; Ferguson et al. 2009). As the primary predator of coastal martens (Martin et al. 2022), increased bobcat density in intensively logged forests is one of the leading hypotheses for coastal marten absence in these forests (Eriksson et al. 2019). More data and a formal analysis are needed to determine whether bobcats are more abundant on the ESRF than other parts of the Coast Range, as well as whether this difference is due to forest management or some other variable.

#### 3.7.4 Sensitive Bat Species

We detected all 6 state sensitive bat species occurring in the Coast Range (fringed myotis, California myotis, hoary bat, long-legged myotis, silver-haired bat, and Townsend's big-eared bat) on the ESRF via passive ultrasonic recorders.

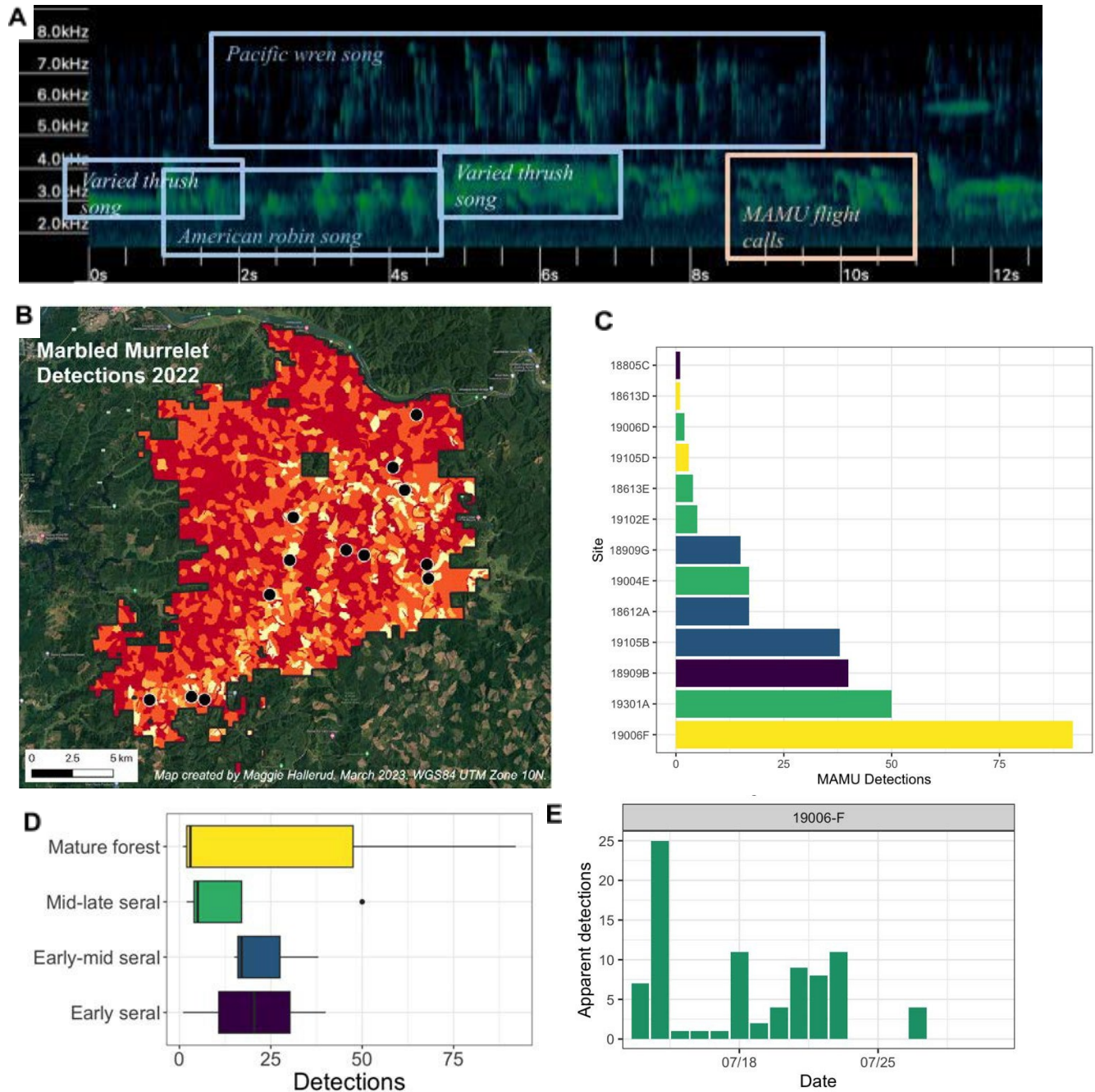


**Figure V-24.** Summary of data collected for northern spotted owl during the 2022 field season.

A) Spectrogram of spotted owl calls, including the song and a contact whistle. B) Map of sites with apparent northern spotted owl detections using a threshold of 0.90 (i.e., any northern spotted owl detection with a classification accuracy  $\geq 0.90$  is included). C) The number of apparent spotted owl detections per site, with colors representing different prediction accuracy thresholds. Note that the standard bioacoustics protocol is to manually review any putative spotted owl calls with a threshold of 0.25. D) Detection history for the two sites (see southmost sites on map) with the most spotted owl calls (based on calls above a 0.95 classification accuracy threshold).

DISCLAIMER: Calls 18613-D and 18613-E showed signals of callback surveys and should be regarded with caution. Contamination from callback surveys is a common problem in bioacoustics surveys for northern spotted owls (Damon Lesmeister, pers. comm.)



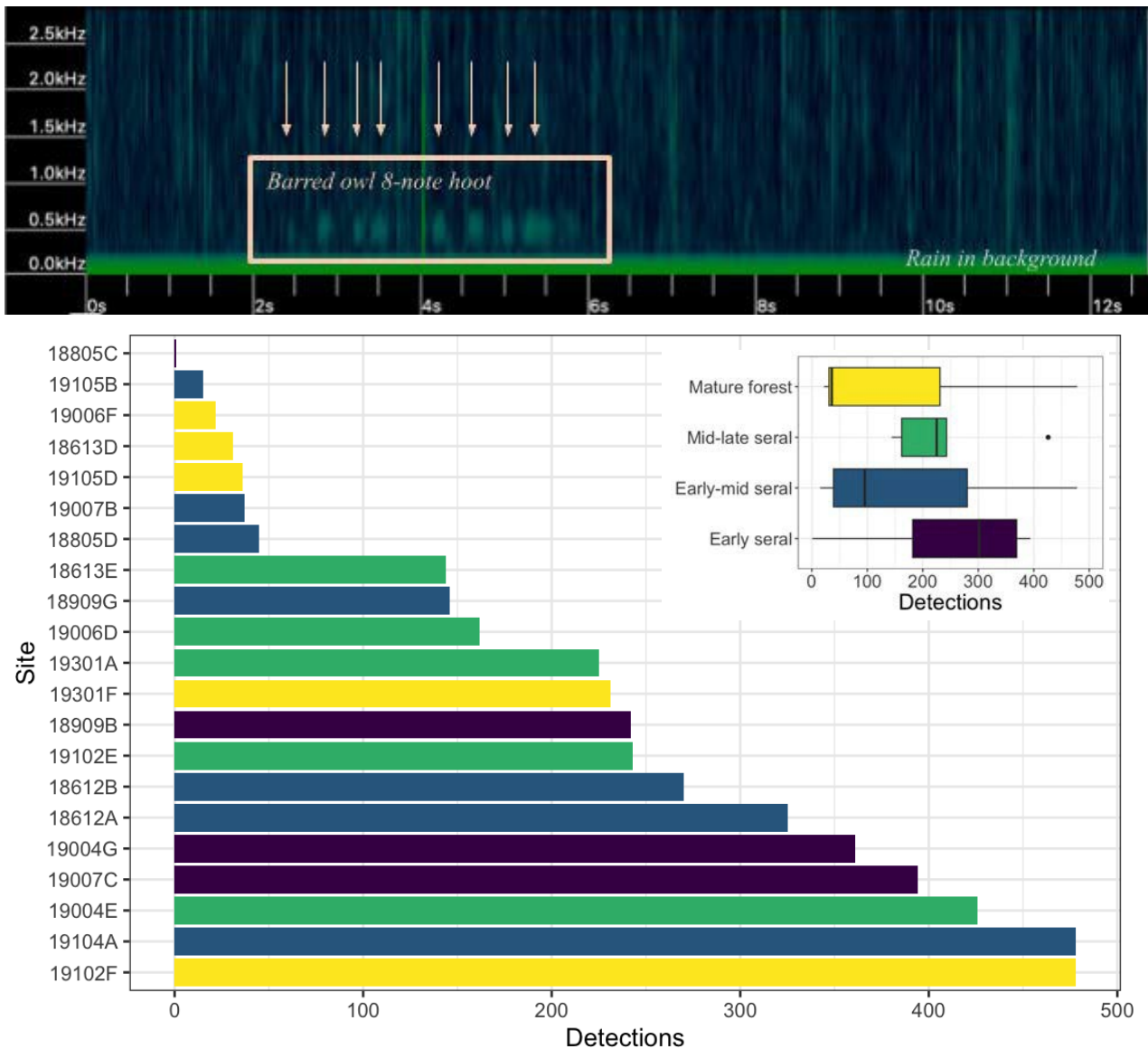


**Figure V-25.** Summary of data collected for marbled murrelets during the 2022 field season.

A) Spectrogram of marbled murrelet calls. Murrelet calls were often detected during dawn and dusk choruses, so detections rarely occur in isolation from other species. B) Map of sites with apparent marbled murrelet detections using a threshold of 0.95 (i.e., any murrelet detection with a classification accuracy  $\geq 0.95$  is included). C) The number of stand age classes. D) Summary of marbled murrelet detections per site by stand age class. E) Detection history for the site where the most marbled murrelet calls were detected (based on a 0.95 classification accuracy threshold). Apparent marbled murrelet activity was not as consistent over time at any other sites with detections.

DISCLAIMER: Ongoing work is being done to determine what a bioacoustics detection of marbled murrelet means, and these detections should not be interpreted as 'occupancy' without further research.





**Figure V-26.** Summary of barred owl bioacoustics detections. Top: Spectrogram of the 8-note “who cooks for you” barred owl call. Bottom: Barred owl detections per site and by stand age. Barred owls were detected at every site surveyed via bioacoustics, and every owl visually identified during the 2022 field season was a barred owl.

### 3.8 Cost and Effort Per Survey Site

Below are estimates for equipment and labor costs per biodiversity site, not including planning/analysis time.

#### Field Equipment

Summary of start-up equipment costs per site (not including basics for the crew- GPS, compass, inReach, backpacks, first aid kits, etc.):

Equipment	Quantity	Cost
Bat recorder	1	\$800
Songbird recorder	1	\$550
Trail cameras	2	\$240
Malaise trap	1	\$200
Blue vane traps	2	\$30
Pitfall traps	8	\$30
<b>Total</b>		<b>\$1850</b>

Most of this equipment can be reused over many years, with trail cameras and recorders often lasting 10 years before they begin to fail and malaise traps and pitfall trap covers lasting indefinitely. Blue vane traps need to be replaced more frequently as the UV attractant fades. Costs for continuing to use this equipment are relatively insignificant: batteries, cat food, scent lure, and propylene glycol which cost ~\$40 per site per season.

#### Field Labor

Generally, 4 sites per day can be visited by a crew for each task, for a total of 12-16 sites per week (depending on drive times) per crew. An additional ~5 hours of labor per week are needed for equipment management and packing trucks. An estimate of field labor required per site, including drive time between sites, are provided below:

Task	Hours
Camera setup	3
Recorder setup	1
Invertebrate setup	6
Collecting invertebrates	6
Transferring invertebrate samples to ethanol	1
Vegetation surveys	4
Equipment retrieval	1

#### Sample Processing

Summary of time required for pre-analysis sample and data processing tasks:

Task	Hours of Labor
Data entry	2
Cleaning invertebrate samples	15
Invertebrate DNA extraction	8
Library prep for DNA sequencing (196 samples)	4
Photo sorting	1-2
Songbird acoustics classification	1
Bat ultrasonics classification	4
Dendrochronology (managed stands only)	1-3

## 4 Continuing Research Plan

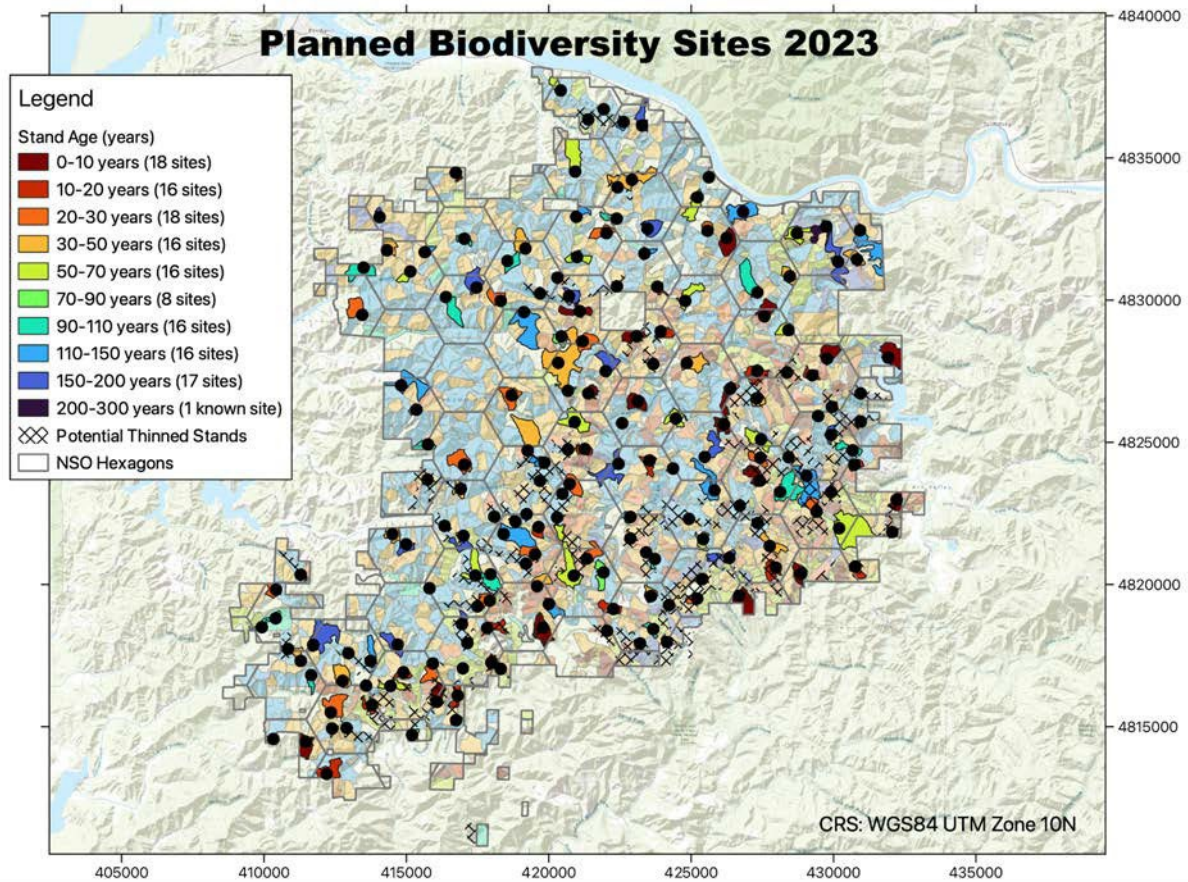
### 4.1 Processing 2022 Data

Continued work on biodiversity data collected in 2022, in combination with data collected in 2023, will include:

- Investigating concordance of survey results when stands are surveyed by multiple spatially independent (i.e., >500 meters apart) sites.
- Calculating species accumulation curves per taxa for the number of sites, number of devices (in the case of invertebrates), and survey duration (in the case of cameras and songbird bioacoustics).
- Assessing the level of spatial autocorrelation within biodiversity metrics and species occurrences.
- Assessing the detection probabilities of invertebrate taxa per pitfall trap, blue vane trap, or malaise trap.
- Investigating the effects of landscape variables (e.g., precipitation, temperature, coastal proximity, aspect, topographic ruggedness, geography, surrounding forest matrix, etc.) on biodiversity metrics
- Running formal occupancy models (MacKenzie et al. 2017) on camera-trap data and abundance estimation on bioacoustics data (Perez-Granados and Traba 2021)
- Developing species distribution models for taxa of interest
- Assessing stand age landscape thresholds for biodiversity on taxon and species levels (e.g., Harris and Betts 2023)

### 4.2 Study Design

Biodiversity surveys will be expanded during summer 2023 under Matt Betts' USDA Agriculture and Food Research Initiative grant. The motivation of these surveys will be to understand the influence of management history (reserve, intensive logging, extensive/ecological forestry) and stand age on biodiversity. We are aiming to survey 240 sites located throughout the ESRF. See [Figure V-27](#) for proposed sites on the ESRF.



*Figure V-27. Sites on the ESRF that we plan to survey for biodiversity during the 2023 field season.*

#### 4.3 Field Method Changes

Biodiversity surveys during summer 2023 will follow many of the same methods as the 2022 field season, with some minor adjustments: Some sites will only have 1 malaise trap (rather than 2), and baited cameras, trail cameras, and songbird acoustic recorders will only be set at half of the sites (N=120). Three overstory surveys will be conducted at 20 meters and 0, 120, and 240 degrees from site center where tree species cover, basal area, and DBH will be recorded. Five soil cores will be collected at site center and 10 meters in each cardinal direction and processed for soil fungi using DNA metabarcoding. We are exploring adding natural cover transects for surveying amphibian and reptile diversity, as well as extending camera-trap surveys through the winter (recommended in Kays et al. 2020) and resurveying for fall/winter songbirds to account for seasonal differences in activity and species diversity. We will also spray paint blue vane trap collection jars yellow which anecdotally improves pollinator captures.

The field season will start much earlier (end of April) so that all cameras and bioacoustics recorders can be set at the beginning of the season and collect data season-long, rather than placing these devices throughout the summer as we did last year. This will also allow time for the crew to scout sites and adjust for stands that are inaccessible or otherwise unsuitable prior to beginning surveys, and should speed up invertebrate sampling later in the season. See Table V-2 for the planned field season schedule.



#### 4.4 Crew & Schedule

8 crew members were hired, including 2 Coast Range-experienced crew leads. Crew members will work in pairs throughout the summer. For efficiency, crews will work in separate regions of the ESRF each week and will camp near field sites most weeks. The main field season is planned to run from April 16 -August 31 and crews will work ~10-hour days Monday-Thursday, with the potential to expand into September as needed.

## 5. Considerations for Long-Term Work

### 5.1 Accounting for Existing Variation Among Stands

Our preliminary surveys demonstrate that there is a substantial amount of background variation in biodiversity within and between forest stands, even within a stand age x management group. Historical management and disturbance history likely play large roles in structuring vegetation communities within stands (*personal comm.* Andrew Merschel) and likely impact other taxa, and we recommend accounting for historical factors (e.g., fire history, replanting or natural regrowth, herbicide application history at the site, etc.) within the study design. Current vegetation structure may be used as a surrogate for stand history (*personal comment* Andrew Merschel) Specifications, however, would need to be developed.

Since variation within stand ages and management types is already high, we recommend that any additional treatment levels (e.g., testing extensive treatment types or restoration treatments) be considered independently from the TRIAD-based biodiversity surveys to avoid adding confounding factors. For example, extensive stands surveyed for the TRIAD study should receive the same treatment; alternative methods for extensive forestry should be designed as a separate experiment and conducted elsewhere.

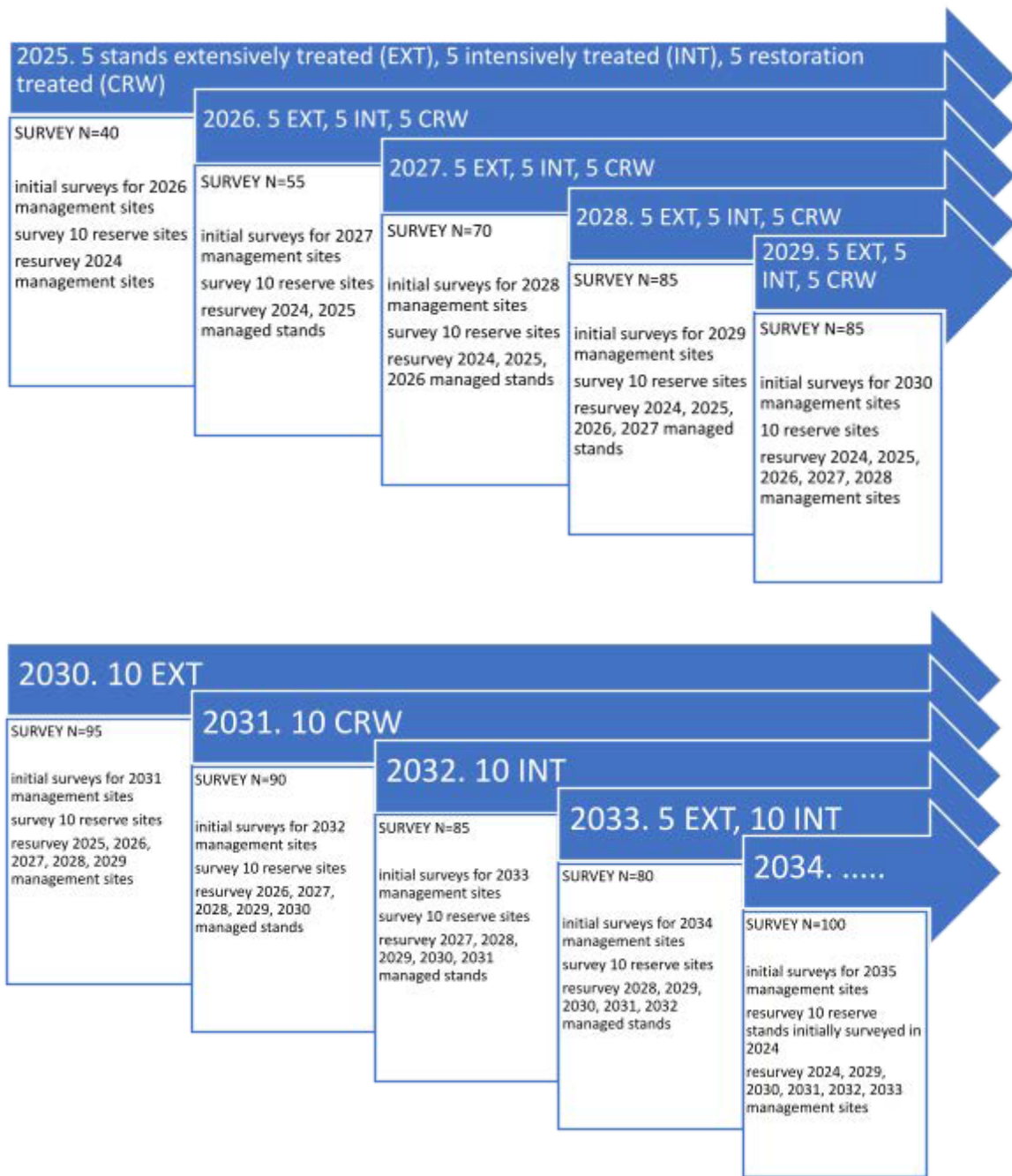
### 5.2 Long-Term Study Design

Given the goals of the ESRF TRIAD plan, the variable timescale and necessarily adaptable spatial implementation and timing of forestry treatments, and the site impact of surveys, a site network that varies over time will be superior to defining a permanent survey network *a priori*. As a long-term research forest, the ESRF biodiversity surveys will be able to reflect temporal trends in species abundances, climate, and other factors that could not be addressed on shorter time-frames. Sampling all management types across time will allow for temporal trends and interannual variability to be measured, as well as stand development across timescales.

We suggest defining permanent sites for stands that will not undergo further management (e.g., conservation restoration watersheds, riparian zones, and designated reserves) to study how biodiversity develops once management is halted. These sites should be spatially stratified across the ESRF so as to represent all landscape and geographic/climatic contexts and can be rotationally surveyed (e.g., 10% of the sites are surveyed each year and 10 years). Sites surveyed in 2022 and 2023 that will not undergo further management would be ideal candidates since recent surveys will be most reflective of historic ODF management and the gap in forest-wide management between ODF and OSU ownership.

For stands undergoing any standardized management (e.g., extensive/intensive stands and stands designated for restoration in the CRW), we recommend selecting a subset of stands in each treatment type for each year that management occurs. Surveyed stands in each subset (i.e., each management year) should be balanced across management types (e.g., extensive, intensive, restoration) and spatial context, as possible. We recommend surveying the selected stands in a BACI framework where surveys occur 1-2 years before management to establish a baseline, 1 year after management to assess immediate effects, 2-5 years after management to assess site recovery, and every 10 years going forward to assess longer term effects. These survey timelines may be adjusted based on variability seen in the data; more frequent surveying should be conducted initially (e.g., for the first 10 years post-treatment) at a subset of sites to determine the optimal timeline by management type and/or stand characteristics.

See below for an example of what a survey timeline may look like:



**Figure V-28.** Example survey timeline for 10 years, where stands are surveyed rotationally. Under this design, 40 total extensive stands (EXT), 45 total intensive stands (INT), 35 restoration (CRW) stands, and 100 reserve stands would be surveyed over time in the first 10 years. Note that a real timeline would be highly dependent on the timeline of forestry treatments.

### 5.3 Site Placement

During surveys, site disturbance is inevitable due to the loose soils and steep slopes throughout most of the Elliott. Given this disturbance, the exact site center may need to be varied by 10-20 meters each year to avoid causing heavy soil and vegetation disturbance due to overuse of transects. While device placement should be varied for invertebrate trapping, microsite placement for cameras and acoustic recorders should remain constant over time (as possible)

because even small changes in microsite placement have been shown to affect results when using single-device arrays (e.g., Kolowski & Forrester 2017; Kays et al. 2021).

Stands should only be considered for biodiversity monitoring if they are accessible in the long-term. For ease of access and to allow for sites to be adjusted as needed, only stands immediately adjacent to roads should be considered for monitoring. Due to the ruggedness of the ESRF, site centers should be a maximum of 150 meters from a road- whether that road is walkable or drivable- for crew safety and efficiency. If site access requires hiking along an old road, hiking distance to the site should be limited to ~2 miles one-way, otherwise the number of sites a crew can complete will be limited and emergency scenarios will be exacerbated.

#### 5.4 Method Improvements

Survey method recommendations fall into 3 major categories: 1) minor changes to existing field methods, 2) adding or changing survey methods, and 3) developing analytical methods.

Minor changes to current field methods include setting songbird recorders to capture the peak of songbird vocalizations during the early breeding season, setting camera-traps earlier in the season so that data is collected throughout the season, and adding soil fungi surveys. Method changes that would require substantially more effort but provide much more robust datasets that account for seasonal changes in animal activity and community composition include collecting camera-trap data for a continuous 12-months, including regularly rebaiting baited cameras (e.g., monthly), and resurveying for birds in winter.

The only major pitfall with existing survey methods was for pollinators. We surveyed for pollinators using 2 blue vane traps per site, however, our sample yield was extremely low. Many pollinator surveyors spray paint the collection jars of blue vane traps yellow which anecdotally increases captures. While we did not spray paint collection jars in 2022, however we will spray paint jars in 2023 in an effort to improve yields. Additionally, our sampling effort was relatively low compared to other studies that set 10-20 blue vane traps per site in addition to hand-netting, but whether low yields were due to primarily surveying closed-canopy forests or due to low sample effort is currently unknown. The viability of surveying for pollinators in low-quality habitat with low effort should be evaluated and potentially replaced with higher effort, dedicated pollinator surveys in early seral and/or roadside habitats. Major remaining gaps in our biodiversity surveys are amphibians, rare plant species, and canopy diversity. In the future, natural cover transects for amphibians, vegetation surveys for rare plants, and eDNA or climbing surveys for canopy diversity may be considered.

On the analytical side, the main improvements relate to automated classification of data, particularly songbird bioacoustics data but also camera-trap data. Initial songbird analysis demonstrates the need for improved post-processing methods for bioacoustics data for various reasons: 1) The current regional model for bioacoustics classification (PNW-CNet; Ruff et al. 2022) is limited to 37 of the most common species. As a result, species richness data is limited as most of the 100+ bird species present in the Coast Range are currently undetectable. 2) Classification accuracy varies by species and is relatively low for some species, meaning that detections are overestimated for some species and underestimated for others. The PNW Bioacoustics Lab run by Damon Lesmeister has increasingly improved and expanded PNW-Cnet and it is currently the best model for regional bioacoustics datasets. Funding improvements on this model would serve long-term bioacoustics data collection not only on the ESRF, but also throughout the Pacific Northwest. The Lesmeister lab is also working on a



regional automated classifier for camera-trap photos, and improvements on this model would save many hours of work manually sorting camera-trap photos.

Solutions to handling bioacoustics data in the meantime could include running data through additional bioacoustics models such as BirdNet (Wood et al. 2022) or proprietary software such as Kaleidoscope Pro (Wildlife Acoustics) to search for species that are missing from PNW-Cnet. When species-level accuracy rates are not already available for a model-species combination, a subset of records should be manually reviewed to calculate species-level accuracy rates per model. Another avenue that may be explored is analyzing soundscapes rather than individual species (Pijanowski et al. 2011).

Efficiencies in invertebrate analysis such as morphospecies barcoding (discussed above) are also being explored, however we are still waiting on DNA sequence data and are unable to draw any conclusions on these methods thus far.

### 5.5 Method Caveats

A primary challenge with biodiversity surveys is that a unified study design is unable to optimally survey for every species due to different life history traits which affect optimal scale and survey effort. This interspecific variation will affect all of our animal sampling, however the greatest effect will be on sampling methods for wide-ranging species - camera-traps and bioacoustics - because our effective sampling area is much smaller relative to these home ranges. Interspecific variation in detection rates implies that intraspecific comparisons are valid, but interspecific comparisons of detections should be avoided. Additionally, caution should be used when comparing aggregate species measures (e.g., species richness and evenness) between sites because the species detected may not be functionally equivalent. The solution to this is modeling abundance, occupancy, habitat use, etc. on a *per-species basis* from the detections of each species, then using these results (rather than raw detections) to compare between species. For some species (e.g., marbled murrelets), the interpretation of detections is an area of active research so care must be taken to not overinterpret.

The second primary challenge in our survey methods is the temporal variability introduced in our bat and invertebrate sampling given strong phenological shifts in these taxonomic communities. While surveying sites multiple times per season might improve the ability to disentangle site-level and survey period effects, this is logistically not feasible. Alternatively, during our 2023 surveys we will limit all invertebrate sampling to a 2-month period and we will cover a spatially representative subset of sites during each survey period so that we can hopefully model temporal variation in invertebrate abundance and composition.

### 5.6 Disentangling Biodiversity Monitoring vs. Sensitive Species Monitoring

Biodiversity survey sites likely will not meet all of the objectives of monitoring required for forest management. For example, any site where species of extreme conservation concern are detected (i.e., northern spotted owls, marbled murrelets, coastal martens, Franklin's bumblebee) should be consistently monitored for that species going forward. These sites should not be converted into biodiversity monitoring sites due to the site impact and potential disturbance to the species. Instead, the most appropriate survey method should be the only method used at that site (e.g., bioacoustics for owls, baited camera-traps for martens, visual surveys for murrelets). Targeted monitoring of these rare, elusive species will also provide much better information on how they are responding to forestry treatments.

## 5.7 Challenges & Opportunities of Long-Term Monitoring with Emerging Technologies

While using emerging technologies for monitoring puts research on the Elliott State Forest on the leading edge, the challenge is that emerging methods are constantly changing. In an ideal world, the exact same methods would be used to collect data on the Elliott throughout its lifetime as a research forest, but in reality methods are constantly being advanced. In the case of methods that have been used for decades such as camera-trapping, the main changes may be as simple as updating camera-trap models every decade. For rapidly advancing methods such as DNA-based biodiversity monitoring, the entire methodology should be updated frequently to keep pace with newer, better methods as well as cheaper sequencing technologies -- for example, whole genome sequencing of bulk samples may be a feasible route in the future as opposed to metabarcoding and barcoding which only sequence a single locus. To prepare research on the Elliott State Research Forest to be adaptable and able to take advantage of emerging monitoring techniques through the future, careful attention needs to be given to ensuring that any data collected can be translated into a format that is compatible to long-term datasets. This is critical to ensuring that biodiversity data will be comparable before and after forestry treatments across the next 50 years.

## 5.8 Setting Crews up for Success

The complexity of these surveys requires special attention to field logistics, and planning for maximum crew efficiency will not only be the best use of the crew's time but also will help to avoid burnout which can lead to accidents and injuries in the field. For the best use of the crew's time, the crew should be based as near as possible to the forest and may camp near sites during work days. For camping to be safe and feasible, basic gear should be provided and crews should be carefully trained in Leave No Trace principles and bear safety.

While biodiversity surveys are a great way for technicians to gain experience, current division of labor requires each technician to know 12 methods: baited and trail camera-trapping, bat and bird bioacoustics, pitfall traps, blue vane traps, malaise traps, soil cores, understory surveys, overstory surveys, coarse woody debris surveys, and tree coring, as well as basic field skills (GPS, compass, pacing transects, etc.) and site selection. While none of these methods alone are particularly complicated, there are myriad important details to making each method successful. To ensure the crew is not overloaded with protocols, this upcoming season we are planning to subdivide tasks throughout the season (e.g., scouting, site selection, and setting cameras and recorders in May, invertebrate trapping and soil coring in June-July, and vegetation surveys in August) and training crew members the week prior to starting each new phase of data collection.

In future years, a 'divide and conquer' approach may be worth considering, where the crew is subdivided between methods (e.g., 2 crew members responsible for cameras and bioacoustics, 2-4 crew members responsible for invertebrate surveys, 2 crew members responsible for vegetation surveys and soil cores). Whether a 'divide and conquer' or 'all hands on deck' approach is more efficient and better for data quality will partially depend on experience levels of crew members and whether crew members will be working under an experienced crew lead or independently. Crew leads as well as a dedicated field coordinator who can provide continuity over time would be hugely beneficial to crew management and ultimately data quality.

## Appendix V: References Cited

- Appel, C. L., D. B. Lesmeister, A. Duarte, R. J. Davis, M. J. Weldy, and T. Levi. 2023. Using passive acoustic monitoring to estimate northern spotted owl landscape use and pair occupancy. *Ecosphere* 14(2): e4421. <https://doi.org/10.1002/ecs2.4421>
- Apps, P. J. & J. W. McNutt. 2018. How camera traps work and how to work them. *African Journal of Ecology* 56(4): 702-709. <https://doi.org/10.1111/aje.12563>
- Borker, A. L., P. Halbert, M. W. Mckown, B. R. Tershy, & D. A. Croll. 2015. A comparison of automated and traditional monitoring techniques for marbled murrelets using passive acoustic sensors. *Wildlife Society Bulletin* 39(4): 813-818. <https://doi.org/10.1002/wsb.608>
- Clark, K., I. Karsch-Mizrachi, D. J. Lipman, J. Ostell, and E. W. Sayers. 2016. GenBank. *Nucleic Acids Research* 44(D1): D67-72. <https://doi.org/10.1093%2Fnar%2Fgkv1276>
- Driessen, M. M., P. J. Jarman, S. Troy, & S. Callander. 2017. Animal detections vary among commonly used camera trap models. *Wildlife Research* 44(4): 291-297. <https://doi.org/10.1071/WR16228>
- Dugger, K. M., E. D. Forsman, A. B. Franklin, R. J. Davis, G. C. White, C. J. Schwarz, K. P. Burnham, J. D. Nichols, J. E. Hines, C. B. Yackulic, P. F. Doherty, Jr., L. Bailey, D. A. Clark, S. H. Ackers, L. S. Andrews, B. Augustine, B. L. Biswell, J. Blakesley, P. C. Carlson, M. J. Clement, L. V. Diller, E. M. Glenn, A. Green, S. A. Gremel, D. R. Herter, J. M. Higley, J. Hobson, R. B. Horn, K. P. Huyvaert, C. McCafferty, T. McDonald, K. McDonnell, G. S. Olson, J. A. Reid, J. Rockweit, V. Ruiz, J. Saenz, and S. G. Sovern. 2016. The effects of habitat, climate, and Barred Owls on long-term demography of Northern Spotted Owls. *The Condor* 118(1): 57–116. <https://doi.org/10.1650/CONDOR-15-24.1>
- Elbrecht, V., T. W. A. Braukmann, N. V. Ivanova, S. W. J. Prosser, M. Hajibabaei, M. Wright, E. V. Zakharov, P. D. N. Hebert, & D. Steinke. 2019. Validation of COI metabarcoding primers for terrestrial arthropods. *PeerJ* 7: e7745. <https://doi.org/10.7717/peerj.7745>
- Eriksson, C. E., K. M. Moriarty, M. A. Linnell, and T. Levi. 2019. Biotic factors influencing the unexpected distribution of a Humboldt marten (*Martes caurina humboldtensis*) population in a young coastal forest. *PLoS One* 14(5): e0214653. <https://doi.org/10.1371/journal.pone.0214653>
- Ferguson, A. W., N. A. Currit, and F. W. Weckerly. 2009. Isometric scaling in home-range size of male and female bobcats (*Lynx rufus*). *Canadian Journal of Zoology* 87(11): 1052-1060. <https://doi.org/10.1139/Z09-095>
- Fidino, M., G. R. Barnas, E. W. Lehrer, M. H. Murray, & S. B. Magle. 2020. Effect of lure on detecting mammals with camera-traps. *Wildlife Society Bulletin* 44(3): 543-552. <https://doi.org/10.1002/wsb.1122>
- Harris, S. H. and M. G. Betts. 2023. Selecting among land sparing, land sharing, and Triad in a temperate rainforest depends on biodiversity and timber production targets. *Journal of Applied Ecology* 00: 1-14. <https://doi.org/10.1111/1365-2664.14385>

Holinda, D., J. M.. Bugar, & A. Cole Burton. 2020. Effects of scent lure on camera trap detections vary across mammalian predator and prey species. *PLOS ONE* 15(5): e0229055. <https://doi.org/10.1371/journal.pone.0229055>

Ji, Y., T. Huotari, T. Roslin, N. M. Schmidt, J. Wang, D. W. Yu, and O. Ovaskainen. 2020. SPIKEPIPE: A metagenomic pipeline for the accurate quantification of eukaryotic species occurrences and intraspecific abundance change using DNA barcodes or mitogenomes. *Molecular Ecology Resources* 20: 256–267. <https://doi.org/10.1111/1755-0998.13057>

Kays, R., A. Hody, D. S. Jachowski, & A. W. Parsons. 2021. Empirical evaluation of the spatial scale and detection of camera-trap surveys. *Movement Ecology* 9(41). <https://doi.org/10.1186/s40462-021-00277-3>

Kays, R., B. S. Arbogast, M. Baker-Whatton, C. Beirne, H. M. Boone, M. Bowler, S. F. Burneo, M. V. Cove, P. Ding, S. Espinosa, A. L. Sousa Goncalves, C. P. Hansen, P. A. Jansen, J. M. Kolowski, T. W. Knowles, M. G. Moreira Lima, J. Millspaugh, W. J. McShea, K. Pacifici, A. W. Parsons, B. S. Pease, F. Rovero, F. Santos, S. G. Schuttler, D. Sheil, X. Si, M. Snider, & W. R. Spironello. 2020. An empirical evaluation of camera trap study design: How many, how long and when? *Methods in Ecology and Evolution* 11(6): 700-713. <https://doi.org/10.1111/2041-210X.13370>

Kolowski, J. M., T. D. Forrester. 2017. Camera trap placement and the potential for bias due to trails and other features. *PLOS ONE* 12(10): e0186679. <https://doi.org/10.1371/journal.pone.0186679>

Leray, M., J. Yang, C. P. Meyer, S. C. Mills, N. Agudelo, V. Ranwez, J. T. Boehm, and R. J. Machida. 2013. A new versatile primer set targeting a short fragment of the mitochondrial COI region for metabarcoding metazoan diversity: Application for characterizing coral reef fish gut contents. *Frontiers in Zoology* 10(1): 34. <http://dx.doi.org/10.1186/1742-9994-10-34>

Lesmeister, D. B., C. Appel, R. J. Davis, C. B. Yackulic, & Z. J. Ruff. 2021. Simulating the effort necessary to detect changes in northern spotted owl (*Strix occidentalis caurina*) populations using passive acoustic monitoring. Res. Pap. PNW-RP-618. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 55 p.

Lesmeister, D. B., J. M. A. Jenkins, Z. J. Ruff, R. J. Davis, C. L. Appel, A. D. Thomas, S. Gremel, D. Press, T. Chestnut, J. K. Swingle, T. Wilson, D. C. Culp, H. Lambert, C. McCafferty, K. Wert, B. Henson, L. Platt, D. Rhea-Fournier, & S. Mitchell. 2022. Passive acoustic monitoring within the Northwest Forest Plan: 2021 annual report. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 13 p.

Long, L. L. and J. D. Wolfe. 2019. Review of the effects of barred owls on spotted owls. *The Journal of Wildlife Management* 83(6): 1281-1296. <https://doi.org/10.1002/jwmg.21715>

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2017. *Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence*. Elsevier.

Marks-Fife, C. A. 2022. Survey Protocol for the Red Tree Vole: Version 4.0. Portland, OR. U.S. Department of the Interior, Bureau of Land Management, Oregon/Washington, and U.S. Department of Agriculture, Forest Service Regions 5 and 6. 68 p.



- Martin, M. E., M. S. Delheimer, M. W. Gabriel, G. M. Wengert, K. M. Moriarty. 2022. Combined field and clinical methods clarify mortality causes and survival patterns of Pacific martens. *The Journal of Wildlife Management* 86(1): e22131. <https://doi.org/10.1002/jwmq.22131>
- Moriarty, K. M., M. Linnell, B. Barry, J. Golding, and J. Tucker. 2019. DRAFT Coastal Marten: Areas of Interest Survey Protocol. v5. 18 June 2019.
- Perez-Granados, C. and J. Traba. 2021. Estimating bird density using passive acoustic monitoring: a review of methods and suggestions for future research. *Ibis* 163(3): 765-783. <https://doi.org/10.1111/ibi.12944>
- Pijanowski, B. C., A. Farina, S. H. Gage, S. L. Dumyahn, and B. L. Krause. 2011. What is soundscape ecology? An introduction and overview of an emerging science. *Landscape Ecology* 26: 1213-1232.
- Ratnasingham, S. and P. N. Hebert. 2007. BOLD: The Barcode of Life Data System. *Molecular Ecology* 7(3): 355-364. <https://doi.org/10.1111/j.1471-8286.2007.01678.x>
- Rodriguez, R. M., T. J. Rodhouse, J. Barnett, K. M. Irvine, K. M. Banner, J. Lonneker, and P. C. Ormsbee. 2019. North American Bat Monitoring Program regional protocol for surveying with stationary deployments of echolocation recording devices: Version 1.0, Pacific Northwestern US. Natural Resource Report NPS/UCBN/NRR—2019/1975. National Park Service, Fort Collins, Colorado.
- Rocha, D. G., E. E. Ramalho, & W. E. Magnusson. 2016. Baiting for carnivores might negatively affect capture rates of prey species in camera-trap studies. *Journal of Zoology* 300(3): 205-212. <https://doi.org/10.1111/jzo.12372>
- Ruff, Z., D. B. Lesmeister, J. M.A. Jenkins, and C. M. Sullivan. 2022. PNW-Cnet v4: Automated species identification for passive acoustic monitoring. preprint. <https://dx.doi.org/10.2139/ssrn.4167074>
- Sollins, P. 1982. Input and decay of coarse woody debris in coniferous stands in western Oregon and Washington. *Canadian Journal of Forest Research* 12(1): 18-28. <https://doi.org/10.1139/x82-003>
- Srivathsan, A., E. Hartop, J. Puniamoorthy, W. T. Lee, S. N. Kutty, O. Kurina, and R. Meier. 2019. Rapid, large-scale species discovery in hyperdiverse taxa using 1D MinION sequencing. *BMC Biology* 17: 96. <https://doi.org/10.1186/s12915-019-0706-9>
- Srivathsan, A., L. Lee, K. Katoh, E. Hartop, S. N. Kutty, J. Wong, D. Yeo, and R. Meier. 2021. ONTbarcoder and MinION barcodes aid biodiversity discovery and identification by everyone, for everyone. *BMC Biology* 19(1): 217. <https://doi.org/10.1186/s12915-021-01141-x>
- Stewart, F. E. C., J. P. Volpe, and J. T. Fisher. 2019. The debate about bait: a red herring in wildlife research. *Journal of Wildlife Management* 83(4): 985-992. <https://doi.org/10.1002/jwmq.21657>
- U.S. Fish and Wildlife Service (USFWS). 2012. Protocol for Surveying Proposed Management Activities That May Impact Northern Spotted Owls. 2011 NSO Survey Protocol - 2012 revision. 09 January 2012. USFWS, Portland, OR.

U.S. Fish and Wildlife Service (USFWS). 2021. Protocol for surveying proposed management activities that may impact northern spotted owls using passive autonomous recording unit methods. Draft Pilot Version 0.1 for 2021 Survey Season Testing. USFWS, Portland, OR.

Wildlife Acoustics. Song Meter Comparison: Which of our song meters is right for your research? <https://www.wildlifeacoustics.com/products/song-meter-sm4-vs-mini-vs-micro>

Witmer, G. W. and D.S. deCalesta. 1986. Resource use by unexploited sympatric bobcats and coyotes in Oregon. *Canadian Journal of Zoology* 64(10): 2333-2338.  
<https://doi.org/10.1139/z86-347>

## Acknowledgements

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## **Appendix W: Terrestrial Amphibian and Reptile Surveys on the Elliott State Research Forest**

Preliminary Report Oct. 2023

Maggie Hallerud, Taal Levi, Matt Betts

### **Introduction**

Terrestrial salamanders are among the most abundant vertebrates in North American forests and have been proposed as ideal bioindicators of ecosystem health in forested systems due to their small home range size, high densities, limited movement, and sensitivity to disturbance relative to other vertebrate classes (Welsh and Droege 2002). In the context of the Elliott State Research Forest (ESRF), amphibians have been proposed as indicators of headwater stream habitat quality and connectivity due to their sensitivity to microclimate and sedimentation changes caused by logging (Olson et al. 2007). In addition to their utility as bioindicators, amphibians are the most threatened vertebrate class (40.7% of species are globally threatened, compared to 26.5% of mammals) and continue to show ongoing declines primarily due to climate change and habitat loss, including timber harvest (Luedtke et al. 2023). Monitoring amphibians on the ESRF is thus key to understanding the health of biodiverse headwater streams as well as the sensitivity of this threatened taxa to forest management practices.

### **Objectives**

- 1. Collect baseline species occurrence records for herpetofauna across the ESRF.**
- 2. Understand broad habitat associations of terrestrial amphibians and reptiles on the ESRF.**

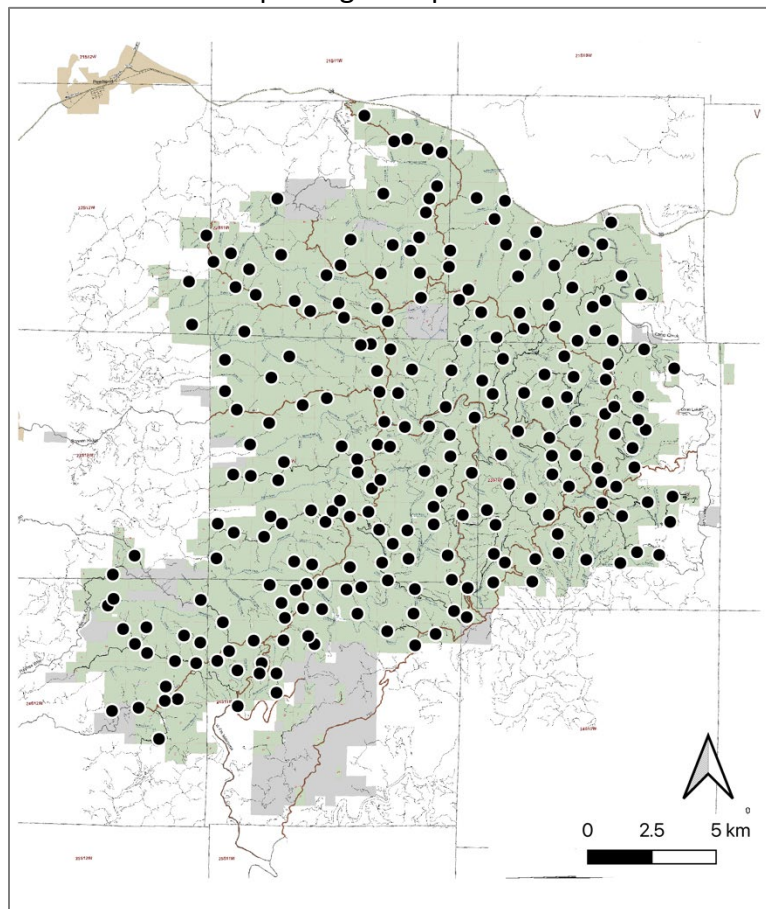
### **Methods**

With a crew of 10 observers, we conducted natural cover surveys targeting terrestrial salamanders between April 26, 2023 and May 30, 2023 at 235 sites across the ESRF (see Figure W-1). Surveys were 30 minutes long and conducted along two transects about 10 meters apart, each surveyed by a different observer, for a total survey effort of 1 hour per site. Starting at site center, observers followed a constant direction (often following an elevational contour for feasibility purposes) and searched for amphibians and reptiles at ground level under natural cover objects such as logs, rocks, ferns, moss, leaf litter, bases of stumps, etc. Surveys were minimally destructive to microhabitats and cover objects were only moved if they could be replaced. When an amphibian or reptile was encountered, the species and microhabitat where they were found (e.g., “under mossy log”) were recorded and, when possible, photos were taken to verify identification. At the end of each survey, the distance covered was recorded. Importantly, animals were not handled at any point during these surveys and they sometimes moved away before identification could be confirmed. In these cases, we recorded as much detail as we could. In addition to these dedicated surveys, locations of amphibians and reptiles that were encountered incidentally throughout the field season (late April through mid-September) were noted.

This report includes all amphibian and reptile detections during dedicated surveys and most incidental encounters.



**Figure W-1.** Sites surveyed for amphibians during the 2023 field season.  
Basemap: Oregon Dept. State Lands.



## Results

The following results are based on field identifications and have not been photo-verified yet. In total, we observed individual amphibians or reptiles on 436 occasions, with 37 of these observations happening incidentally outside of natural cover surveys. Natural cover survey transects were 60 meters long on average (standard deviation 20 m, range 23 – 150). On average, 1.6 individual amphibians or reptiles were encountered per site (standard deviation 1.8, range 0 – 12). Amphibians or reptiles were encountered at 162 (69%) of sites surveyed.

Salamanders were most commonly observed (81% of observations), followed by frogs (10%), lizards (10%), and snakes (5%). Western redback salamanders (*Plethodon vehiculum*) and ensatina (*Ensatina eschscholtzii*) were the most commonly observed species (60% of all observations, 74% of salamander observations), with other salamander species each making up <1% – 6% of all salamander observations (see Table W-1). Amphibians were occasionally locally abundant at or near sources of water, however this abundance was generally temporally limited. See maps of species detections on pages 4-7.

**Table W-1.** Summary of amphibian and reptile species detections. Including the number of sites each species was observed at and the number of total observations (number of animals encountered) for each species. These results are based on field identifications and have not been photo-verified yet.

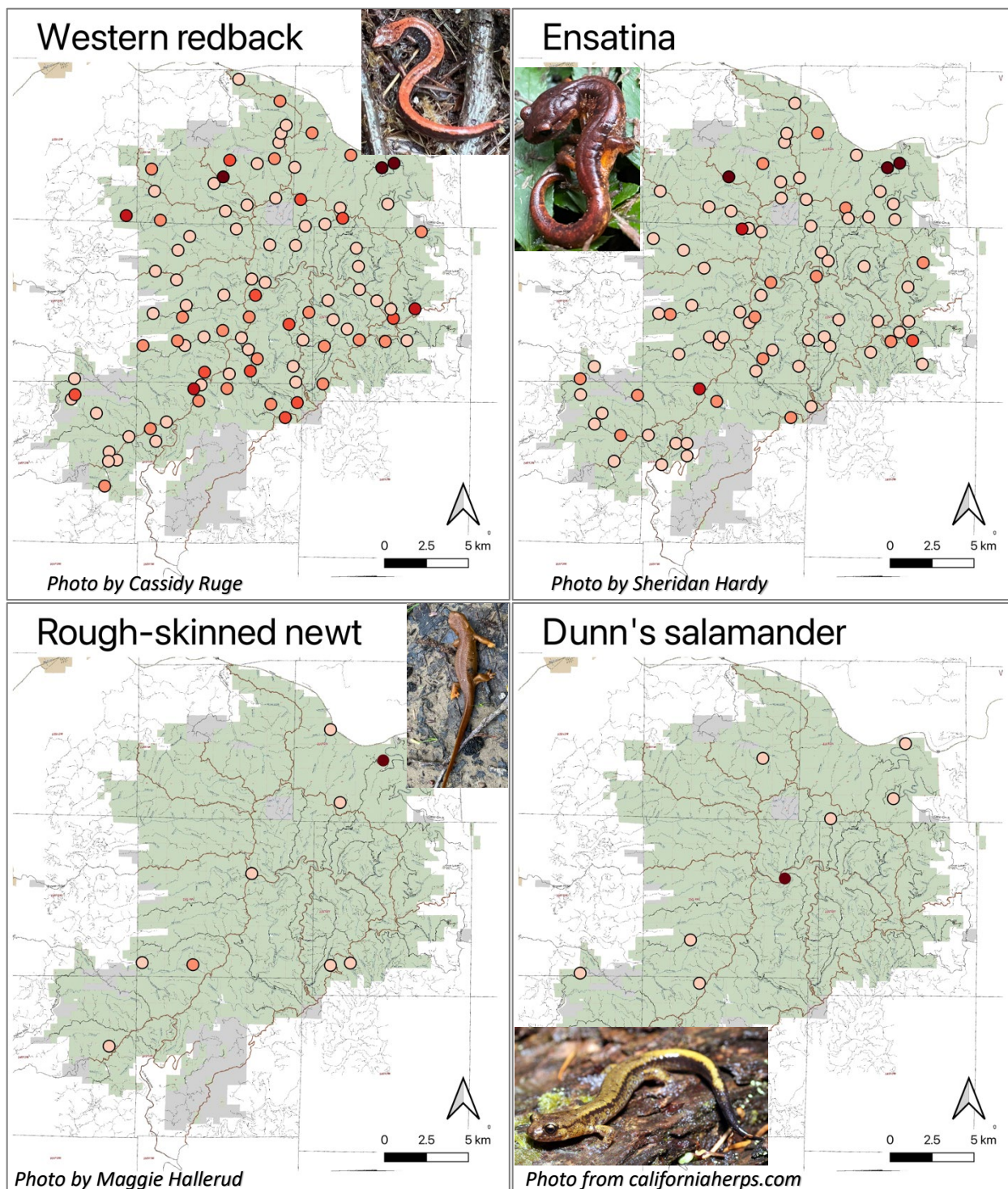
Species	Sites	
	Observed	Observations
<b>Salamanders</b>	<b>144</b>	<b>353</b>
Western redback salamander ( <i>Plethodon vehiculum</i> )	91	153
Ensatina ( <i>Ensatina eschscholtzii</i> )	78	109
Rough-skinned newt ( <i>Taricha granulosa</i> )	9	18
Dunn's salamander ( <i>Plethodon dunnii</i> )	8	18*
Coastal giant salamander ( <i>Dicamptodon tenebrosus</i> )	7	7
Clouded salamander ( <i>Aneides ferreus</i> )	4	7
Northwestern salamander ( <i>Ambystoma gracile</i> )	4	22**
Southern torrent salamander ( <i>Rhyacotriton variegatus</i> )	3	3
Unknown salamander	14	16
<b>Frogs</b>	<b>14</b>	<b>35</b>
Pacific tree frog ( <i>Pseudacris regilla</i> )	7	27***
Tailed frog ( <i>Ascaphus truei</i> )	5	5
Northern red-legged frog ( <i>Rana aurora</i> )	3	3
<b>Lizards</b>	<b>17</b>	<b>32</b>
Northern alligator lizard ( <i>Elgaria coerulea</i> )	8	11
Western fence lizard ( <i>Sceloporus occidentalis</i> )	8	11
Western skink ( <i>Plestiodon skiltonianus</i> )	6	6
Unknown alligator lizard ( <i>Elgaria spp.</i> )	2	2
Unknown lizard	1	2
<b>Snakes</b>	<b>12</b>	<b>16</b>
Northwestern garter snake ( <i>Thamnophis ordinoides</i> )	9	11
Red-spotted garter snake ( <i>Thamnophis sirtalis concinnus</i> )	1	1
Western terrestrial garter snake, Mountain variety ( <i>Thamnophis elegans elegans</i> )	1	1
Unknown snake	3	3

\*Most Dunn's salamander detections (estimated at ~10 observations) came from a streamside site where the species was locally abundant.

\*\*Most northwestern salamander detections (estimated at ~20 observations) came from egg masses at two locations.

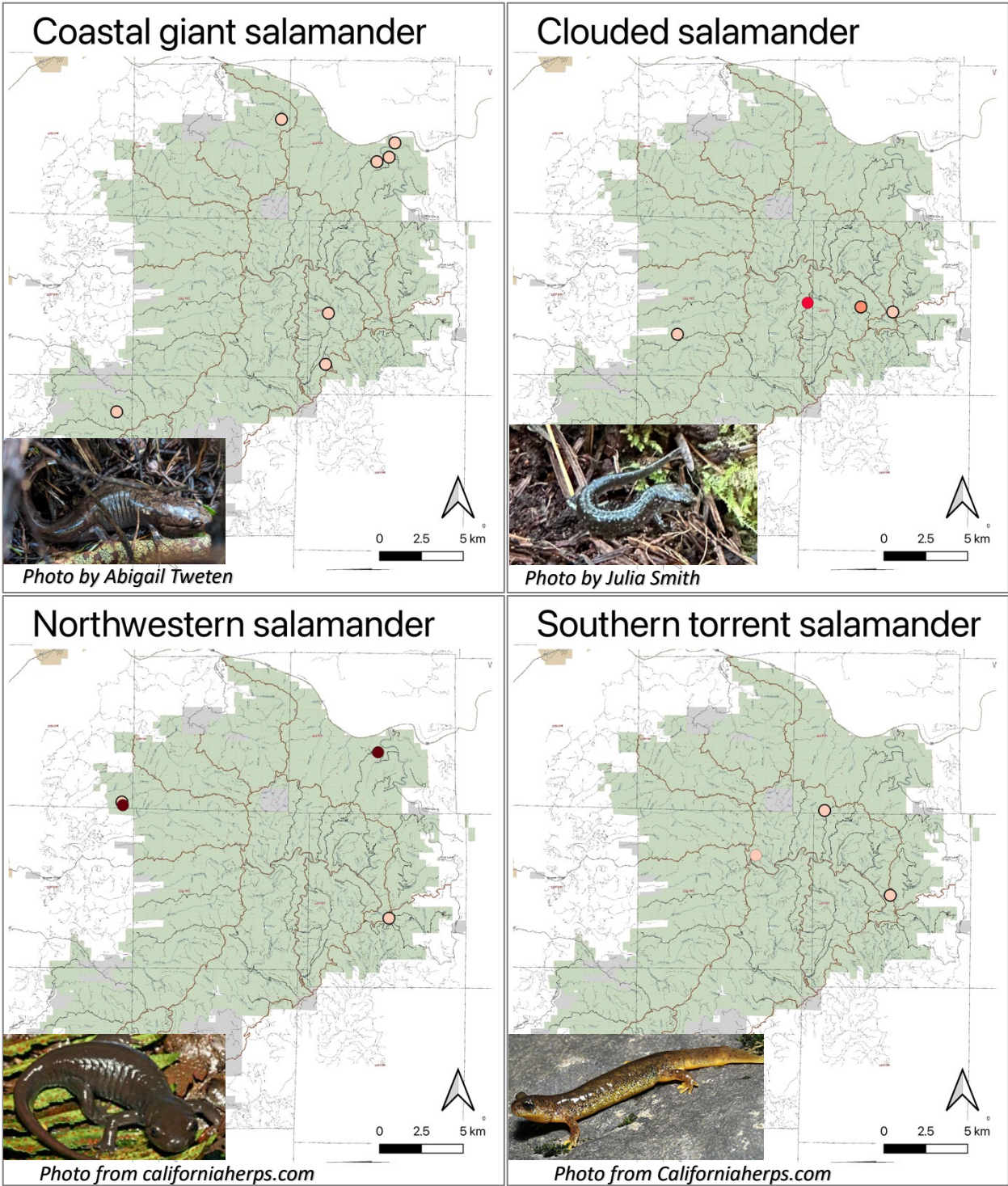
\*\*\*Most Pacific tree frog detections (estimated at ~20 observations) came from Pacific tree frog choruses heard at two campsites adjacent to rivers.

**Figure W-2: Species Detection Maps:** Dark red points ● indicate locations with >5 observations, ● for 4 observations, ● for 3 observations, ● for 2 observations, and ● for 1 observation of the given species. Basemap: Oregon Dept. State Lands.



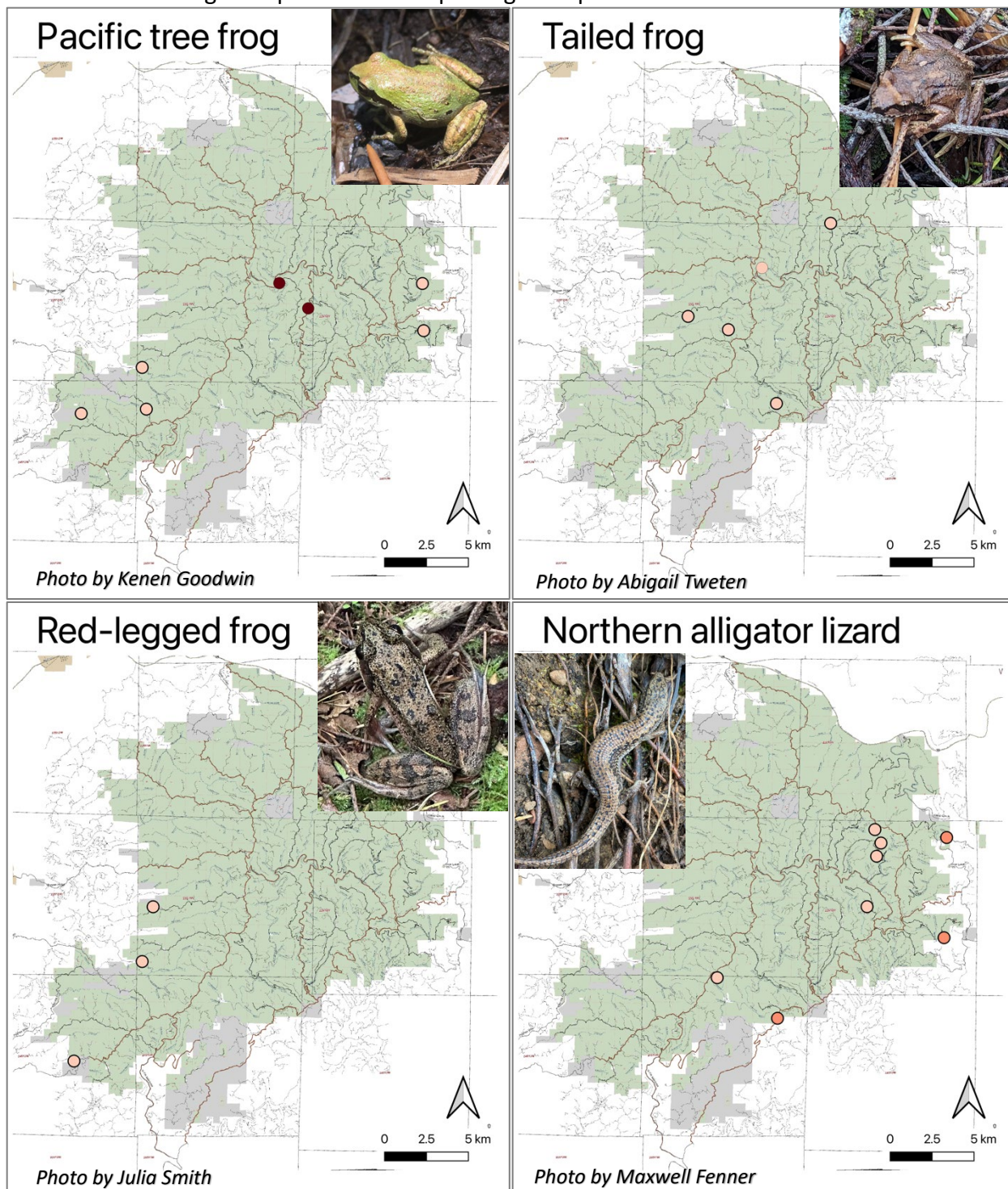


**Figure W-3: Species Detection Maps:** Dark red points ● indicate locations with >5 observations, ● for 4 observations, ● for 3 observations, ● for 2 observations, and ● for 1 observation of the given species. Basemap: Oregon Dept. State Lands.

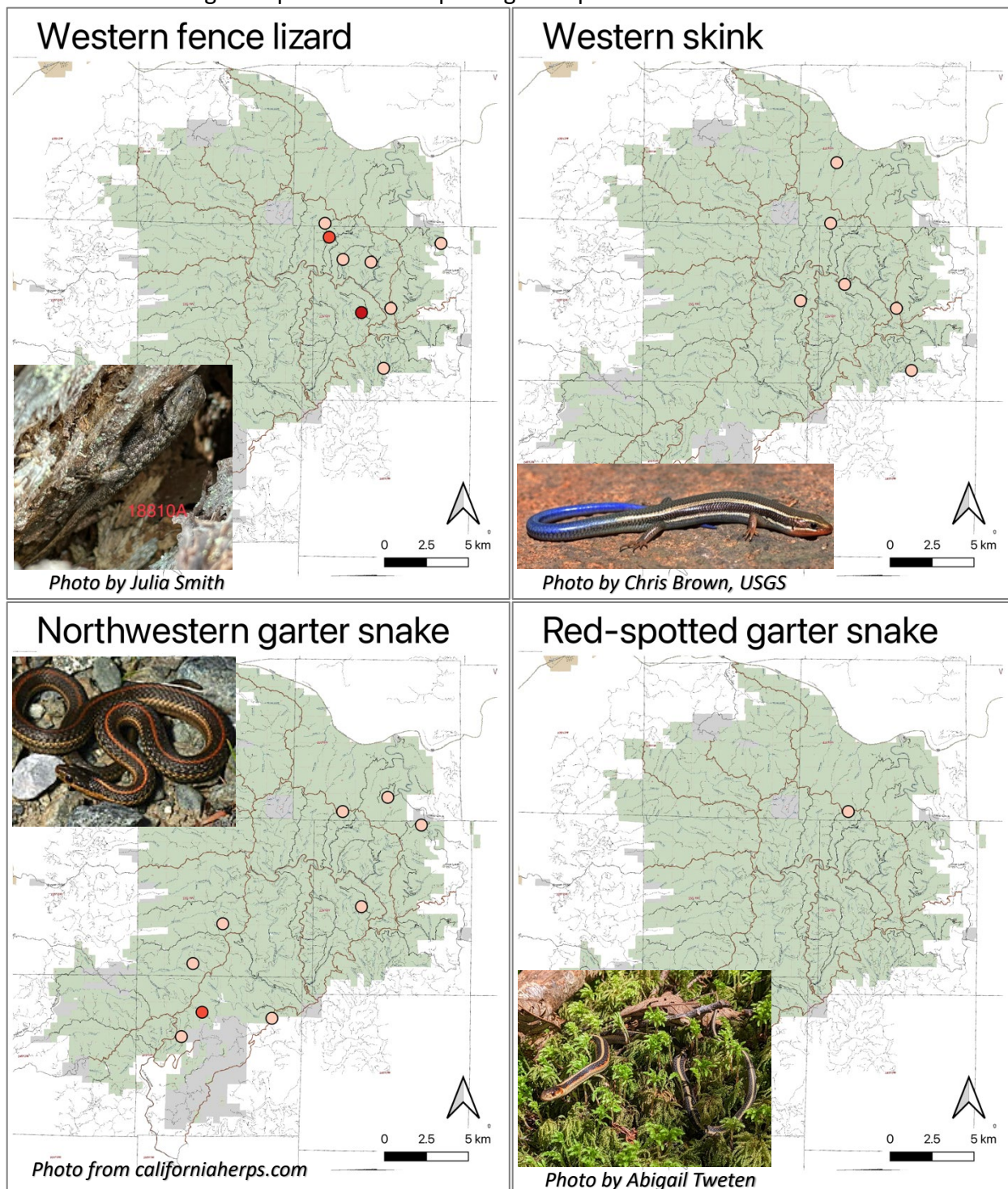




**Figure W-4: Species Detection Maps:** Dark red points ● indicate locations with >5 observations, ● for 4 observations, ● for 3 observations, ● for 2 observations, and ● for 1 observation of the given species. Basemap: Oregon Dept. State Lands.



**Figure W-5: Species Detection Maps:** Dark red points ● indicate locations with >5 observations, ● for 4 observations, ● for 3 observations, ● for 2 observations, and ● for 1 observation of the given species. Basemap: Oregon Dept. State Lands.



### **Key Takeaways**

These surveys were targeted at detecting terrestrial salamanders and were minimally effective at detecting other herpetofauna including frogs, snakes, and lizards. Different methods will be necessary for surveying these taxa (e.g., stream-based surveys for frogs, natural cover surveys during late summer for snakes and lizards). Relatively low effort natural cover surveys are sufficient to detect western redback salamanders and ensatina, however our surveys did not detect less common species in meaningful numbers. While western redback salamanders and ensatina are functionally important due to their high abundance and commonality throughout the Pacific Northwest, questions focused on salamander diversity or rare salamander species would necessarily require increased survey effort or altered methods (e.g., stream-based surveys, more destructive natural cover surveys, and/or standardized cover board surveys).

Amphibians were occasionally found at high abundance in or near water (e.g., coastal giant salamander larvae in Footlog Creek, Dunn's salamanders adults along Elk Creek, and northwestern salamander egg masses in watering holes and puddles). For amphibian species with aquatic early life stages (i.e., all but western redback salamander, ensatina, clouded salamander, and Dunn's salamander), a process of first identifying breeding streams and then surveying surrounding forest would likely be more efficient.

Notably, species that were not detected on the ESRF include California slender salamanders, foothill yellow-legged frogs (California populations recently listed as federally endangered and threatened in August 2023), and western pond turtles (proposed for Endangered Species Act listing in September 2023). Our survey methods were likely not sufficient to detect these species, and optimized surveys for these species (i.e., destructive natural cover plots for slender salamanders, stream-based visual and/or eDNA surveys for foothill yellow-legged frogs, and aquatic-based visual and/or eDNA surveys for western pond turtles).

A final consideration for future surveys is to account for possible variable detectability across forest age and forest structure. This can be accomplished either by recording observations separately per transect or plot and by re-surveying sites within a season while also recording other variables that may affect detectability (e.g., forest structure, observer, weather, etc.). Without accounting for detectability, inference relating habitat effects to amphibian counts could be erroneous.



### **Appendix W: References Cited**

Luedtke, J.A., Chanson, J., Neam, K. et al. 2023. Ongoing declines for the world's amphibians in the face of emerging threats. *Nature*. <https://doi.org/10.1038/s41586-023-06578-4>

Olson, D. H., P. D. Anderson, C. A. Frissell, H. H. Welsh, Jr., and D. F. Bradford. 2007. Biodiversity management approaches for stream-riparian areas: perspectives for Pacific Northwest headwater forests, microclimates, and amphibians. *Forest Ecology and Management* 246(1): 81-107.

Welsh, Jr., H. H. and S. Droege. 2002. A case for using plethodontid salamanders for monitoring biodiversity and ecosystem integrity of North American forests. *Conservation Biology* 15(3): 558-569.

### **Acknowledgements**

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## **Appendix X: Preliminary report**

### **Foliar microbiome diversity monitoring at the Elliot State Forest 2022-2023**

Yung-Hsiang Lan<sup>1</sup> and Jared LeBoldus<sup>1,2</sup>

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#### **Introduction**

The foliar fungal community is important for host resistance to diseases (Saikkonen et al 1998). Foliar microbiomes can also be related to plant physiological traits such as stomatal conductance (Arnold and Engelbrecht 2007) and affect host responses to abiotic stress. *Nothophaeocryptopus gaeumannii* is the most abundant member of Douglas-fir needles (Gervers et al 2022). It also causes a common disease known as Swiss Needle Cast (SNC) on the Oregon coast. The disease occurs when pseudothecia emerge in the spring blocking the stomata, affecting gas exchange and reducing tree growth., This growth loss results in more than \$200 million in productivity form Douglas-fir forests per year (Maguire et al 2002).

Forest harvest and management plans will be implemented at the Elliott State Forest in the coming years. As part of the longterm plan management strategy the impacts of different management regimes on the ecosystem will be monitored. The main objective of this study is to develop a sampling strategy that could be used to monitor the diversity of the foliar microbiome community pre- and post- forest harvest. Our research goals are to (1) characterize the foliar microbiome community of old-growth Douglas fir across the Elliott State Forest; (2) to evaluate the incidence and severity of SNC across the Elliot State Forest prior to harvest; and (3) correlate the foliar microbiome community with SNC incidence and local microclimate.

#### **Field methods**

In fall 2022, nine mature Douglas-fir trees were selected to represent the environment and stand conditions at the Eliot State Forest (Fig. X-1). Within the selected trees, four are in foggy area

and five are in non-foggy area. For each tree, we first measured the length from the tree-top to the lowest contiguous (vertical distance < 2m) branch. This distance was considered the canopy depth. Canopy depth is divided into five equal length vertical zones, then at each vertical zone we flagged at four aspects (N, E, S, and W) for the following sampling (Fig. X-2). In November 2022, we collected 2.5-year-old needles for foliar microbiome analysis (Fig. X-3), and in June 2023 we collected 3-year-old needles, which is the same cohort we took previously, for foliar microbiomes to see the dynamics of fungal communities, as well as for scanning SNC infections when the pseudothecia emerge in spring. Samples were temporarily stored at 5°C after collection. Microbiome samples were then stored at -20°C before processing, SNC samples were stored at 5°C before taping on index cards.

To address the environmental differences among canopies at foggy and unfoggy plots, we selected one tree from foggy area and one tree from non-foggy area, temperature and humidity sensors (HOBO Onset MX2301A) were placed at each sample location (5 heights × 4 aspects × 2 trees).

## **Lab methods and data analysis**

### *Microbiomes*

Foliar samples were lyophilized for 24 hours and stored at -80 °C. DNA samples were extracted by using OPS 96 well SYNERGY plant extraction kit. The ITS2 region was first amplified using the 5.85-Fun and ITS4-Fun primers, a 3-6 bp length heterogeneity spacer, and then followed by illumina adaptor sequences (Gervers et al 2022). The amplified samples were normalized and purified by Just-A-Plate (Charm Biotech) and QIAquick PCR purification kit. The completed library was sent to the Center for Quantitative Life Science at OSU for genome sequencing.

Sequencing data was trimmed and paired using R (v.4.2.2, R Core Team 2022), and the following packages: DADA2 (v1.25.2, Callahan et al., 2016), ggplot2 (Wickham 2016), phyloseq (McMurdie and Holmes, 2013), and vegan (Oksanen et al 2022). To identify the fungal

species in the sequences, the UNITE general FASTA release was used as fungal taxonomy matrix (<https://unite.ut.ee/repository.php>). Using Non-metric multidimensional scaling (NMDS) to examine the foliar fungal community diversity, and Permutational Multivariate Analysis of Variance (PERMANOVA) to test if environmental variables are important to the fungal community.

### *SNC evaluation*

For each sample, we first evaluated the needle retention of 4 years of needles, then randomly selected fifty 3-year-old needles, taped them on an index card, and stored at -20°C until further examination. Initially, we recorded the incidence of pseudothecia, defined as how many needles with pseudothecia occlusion within 50 needles (Fig. X-4). For a subset of 10 needles with pseudothecia presence, we conducted density counts to evaluate infection severity.

We applied a generalized linear mixed effect model by R to test if foliage retention or SNC incidence is different at plots, canopy heights, and branch directions.

## **Preliminary results**

### *Phyllosphere microbiome*

The preliminary analysis showed that (1) the fungal phyllospheric communities were significantly different at foggy and non-foggy plots ( $p=0.0001$ ), and among the different sampling heights ( $p=0.002$ ). Also, the fungal communities in the phyllosphere were different while they collected in 2022 and 2023 ( $p=0.005$ ). However, the communities did not differ among sampling direction ( $p=0.38$ ) (Fig. X-5). (2) *N. gaeumannii* was abundant in most samples (Fig. X-6), other needle pathogens, such as *Rhabdocline* spp., and some lichen associated species, like *Cliostomum griffithi* and *Scoliciosporum* spp, were also detected in the phyllosphere (Fig X-6).

### *Foliage retention*

Figure X-7 showed the foliage retentions between foggy and non-foggy plots at 5 canopy height levels. The preliminary analysis showed that foliage retention was significantly different at foggy and non-foggy plots ( $p=0.0009$ ). Needle retention in the foggy plots were 0.62 years less than non-foggy plots. Also, South facing needles were 0.35 years significantly more than north facing needles ( $p=0.005$ ). However, needle retention was not statistically different at 5 canopy heights.

### *SNC incidence*

Figure X-8 showed the SNC incidence of 3-year-old needles between foggy and non-foggy plots at 5 canopy height levels. The preliminary analysis showed that SNC incidence was significantly different at foggy and non-foggy plots ( $p=0.02$ ). SNC incidence in the foggy plots were 52% more than non-foggy plots. Also, SNC incidence at the most bottom canopy (level 1) was 29% significantly higher than SNC incidence at the most top canopy (level 1) ( $p=0.007$ ). However, SNC incidence was not statistically different in 4 directions.

### **Data under processing and would be completed later this year.**

#### *Microclimate among canopies at fog and fog-free area*

Currently we have collected weather data since November 2022. But they need some calibration and adjustments before analysis. We should be able to have some preliminary data to show the temperature, relative humidity, and dew point temperature among canopies by the end of September.

### *SNC disease severity index*

Tree canopies are the most productive area in the forest because of photosynthesis, they also create microhabitat for wildlife and epiphytic plants, including invertebrates, birds, and mammals. In addition, tree canopies serve as habitat for a diversity of micro-organisms.

The foliar fungal community is important for host resistance to diseases (Saikkonen et al 1998). Foliar microbiomes can also be related to plant physiological traits such as stomatal conductance



(Arnold and Engelbrecht 2007) and affect host responses to abiotic stress. *Nothophaeocryptopus gaeumannii* is the most abundant member of Douglas-fir needle communities (Gervers et al 2022). It also causes a common disease known as Swiss Needle Cast (SNC) on the Oregon coast. The disease occurs by blocking the stomata when pseudothecia emerge in the spring, affecting gas exchange and reducing tree growth. This growth loss results in more than \$200 million in productivity losses from Douglas-fir forests per year (Maguire et al 2002).

To characterize SNC and foliar microbiomes among tree canopies at the Elliott State Forest, mature (~120-150 years old) and young (~30 years old) Douglas-fir trees will be selected from different inventory plots based on the previous ground surveys. We will collect samples from the south facing side at top of the trees and the bottom of the contiguous canopy (vertical distance between branches < 2m) for each tree. Samples will be taken in spring while Douglas-fir is bud-breaking, because *Nothophaeocryptopus gaeumannii* is getting mature at the same time. Due to the different SNC disease patterns, 3-year-old needles of mature trees and 2-year-old needles of young trees will be collected for both SNC disease examination (Lan et al 2019) and foliar microbiome analysis. We will use SNC disease severity index, combined by the incidence of needles with pseudothecia presence and the density of pseudothecia occlusion on the infected needles, to evaluate the SNC infections. For foliar microbiome analysis, we will amplify the ITS2 region with appropriate PCR primers and followed by illumine adaptors for MiSeq sequencing (Gervers et al 2022). Also, to study if microclimate relates to the SNC severity and foliar microbiome communities, temperature and humidity sensors (HOBO Onset MX2301A) will be placed at some trees where the samples are taken.

## Appendix X: References Cited

- Arnold, A.E., Engelbrecht, B.M.J., 2007. Fungal endophytes nearly double minimum leaf conductance in seedlings of a neotropical tree species. *J. Trop. Ecol.* 23, 369-372.
- Callahan, B.J., McMurdie, P.J., Rosen, M.J., Han, A.W., Johnson, A.J.A., Holmes, S.P., 2016. DADA2: High-resolution sample inference from Illumina amplicon data. *Nature Methods*, 13(7), 581–583.
- Gervers, K.A., Thomas, D.C., Roy, B.A., Spatafora, J.W., Busby, P.E., 2022. Crown closure affects endophytic leaf mycobiome compositional dynamics over time in *Pseudotsuga menziesii* var. *menziesii*. *Fungal Ecol.* 57-58, 101155.
- Lan, Y.-H., Shaw, D.C., Beedlow, P.A., Lee, E.H., Waschmann, R.S., 2019. Severity of Swiss needle cast in young and mature Douglas-fir forests in western Oregon, USA. *For. Eco. Manag.* 442, 79-95.
- Maguire, D.A., Kanaskie, A., Voelker, W., Johnson, G., 2002. Growth of young Douglas-fir plantations across a gradient in Swiss Needle Cast severity. *West. J. Appl. Forestry* 17(2), 86-95.
- McMurdie, P.J., Holmes, S., 2013. Phyloseq: An R package for reproducible interactive analysis and graphics of microbiome census data. *PLoS ONE* 8(4):e61217.
- Oksanen, J., Simpson, G., Blanchet, F., Kindt, R., Legendre, P., Minchin, P., O'Hara, R., Solymos, P., Stevens, M., Szoecs, E., Wagner, H., Barbour, M., Bedward, M., Bolker, B., Borcard, D., Carvalho, G., Chirico, M., De Caceres, M., Durand, S., Evangelista, H., FitzJohn, R., Friendly, M., Furneaux, B., Hannigan, G., Hill, M., Lahti, L., McGlinn, D., Ouellette, M., Ribeiro Cunha, E., Smith, T., Stier, A., Ter Braak, C., Weedon, J., 2022. *Vegan: Community Ecology Package*. R package version 2.6-4, <https://CRAN.R-project.org/package=vegan>
- R Core Team (2022). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>
- Saikkonen, K., Faeth, S.H., Helander, M., Sulliva, T.J., 1998. Fungal endophytes: a continuum of interactions with host plants. *Annu. Rev. Ecol. Syst.* 29, 319-343.
- Wickham, H., 2016. *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag New York.

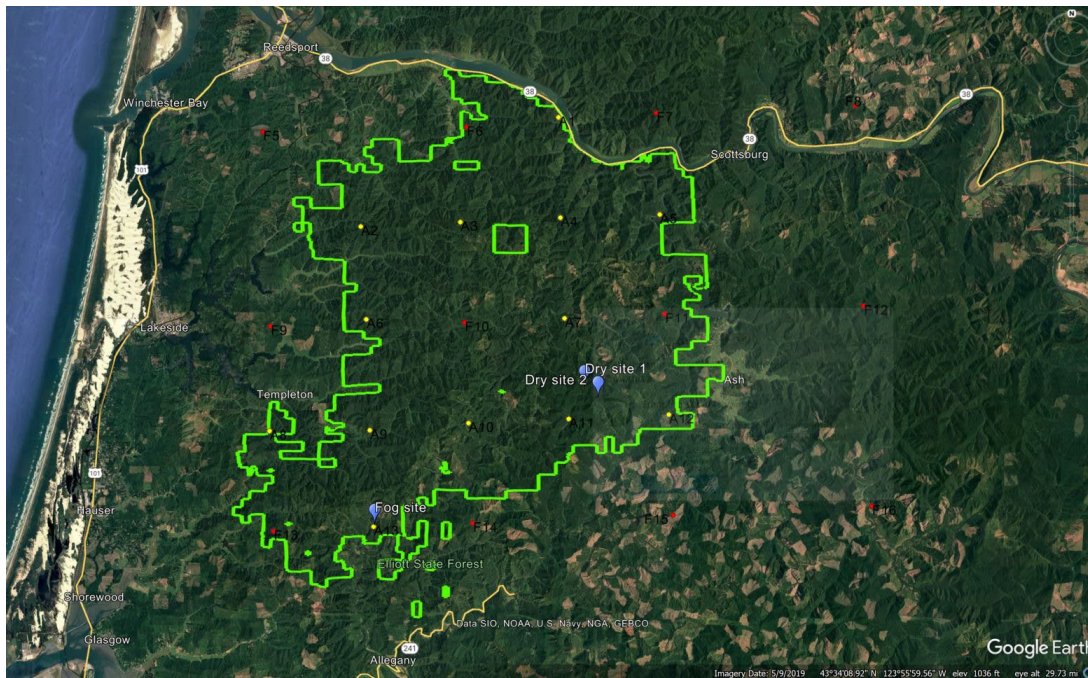


Figure X-1. Map of study area. The green line is the boundary of Elliott State Forest. Blue dots are the tree locations.

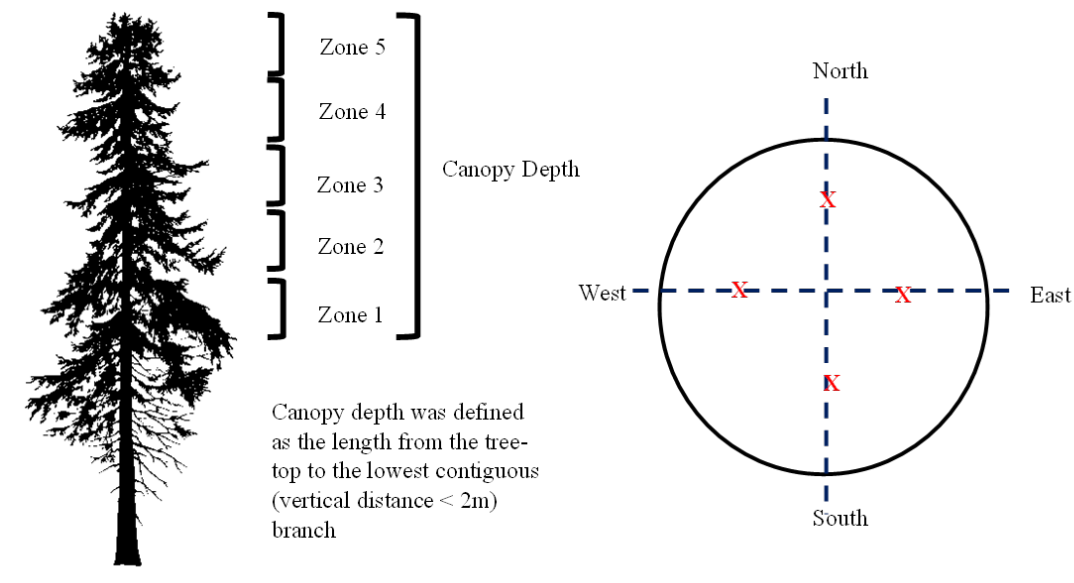


Figure X-2. Sampling layout for monitoring old growth canopy microbiomes (left). Samples are collected separately from 4 aspects within each zone (right).





Figure X-3. The tree climbers were taking microbiome samples on the tree. (Photos by Brian French)



Figure X-4. Picture of pseudothecia. The white dots on the needle are stomates, the black dots on the stomates are pseudothecia. (Photo by Yung-Hsiang Lan)



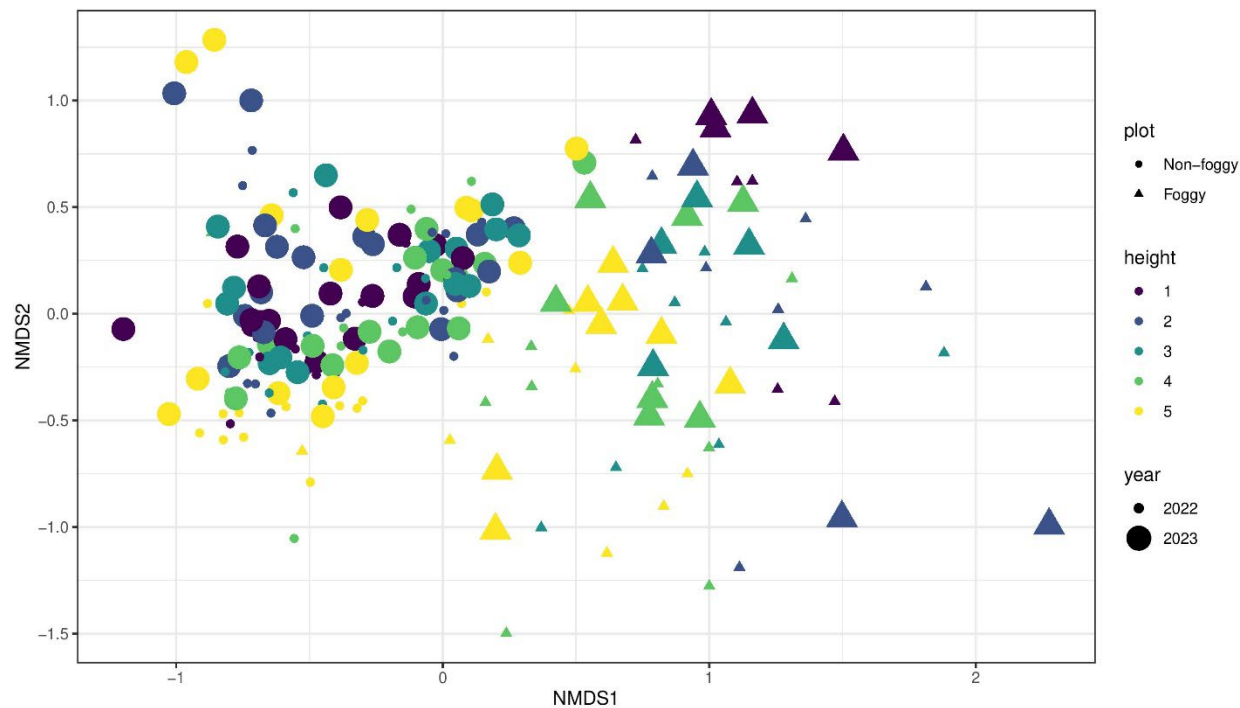


Figure X-5. Non-metric multidimensional scaling (NMDS) results of all ASVs. Height 1 to 5 represent the canopy height beginning at the bottom to the top of trees.

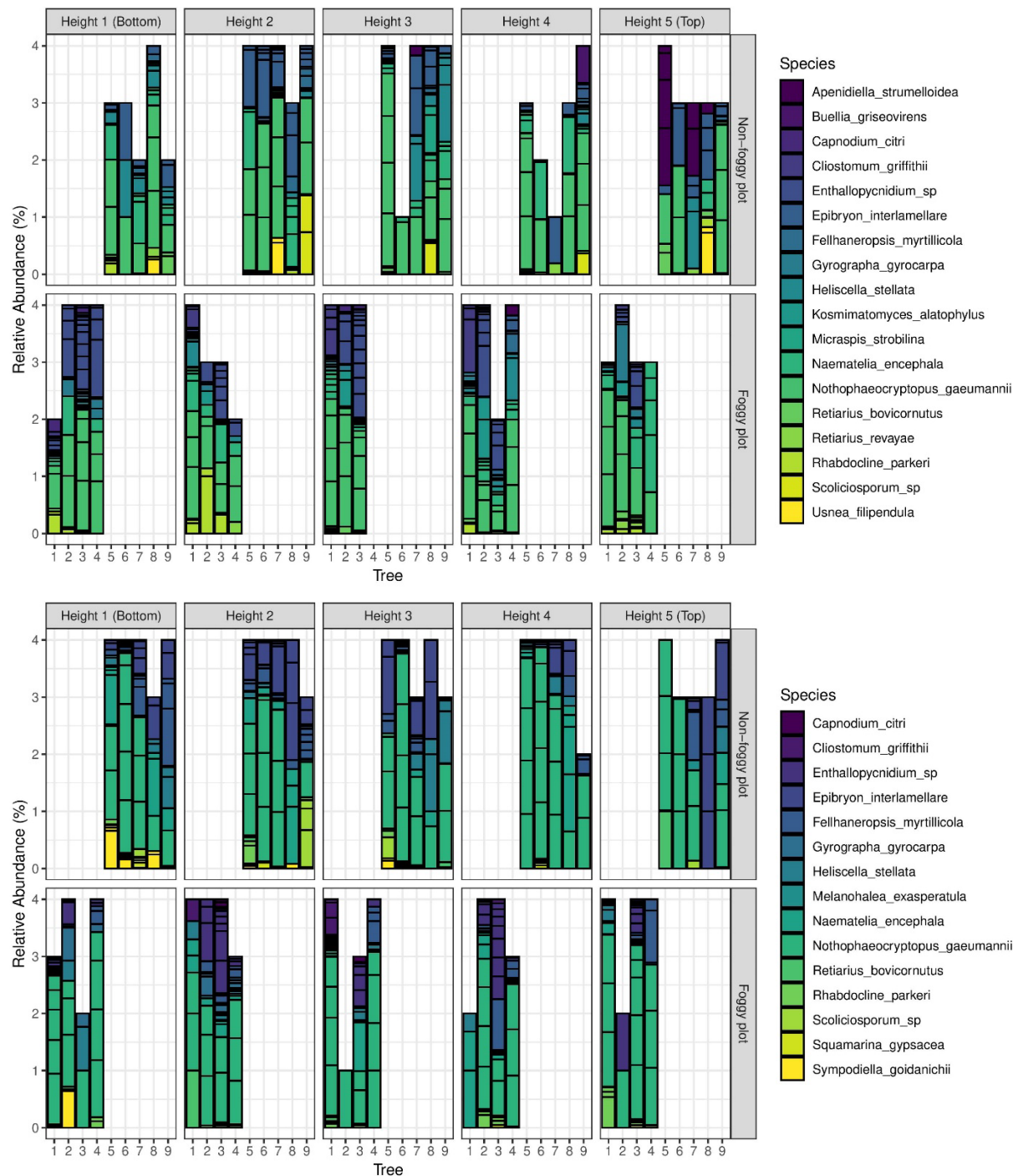


Figure X-6. The relative abundance of the known species of the 100 most abundant ASVs (amplicon sequence variants). The top figure was from 2022 collection, and the bottom figure was from 2023 collection. Height 1 to 5 represent the canopy height beginning at the bottom to the top of trees.

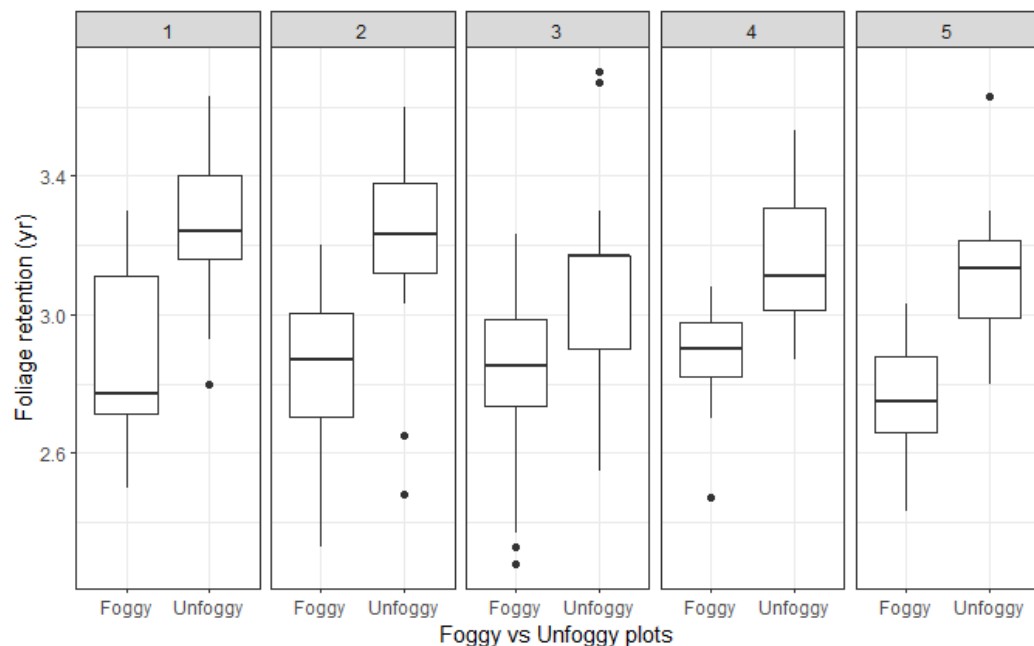


Figure X-7. Foliage retention. Numbers 1 to 5 represent the canopy height beginning at the bottom to the top of trees.

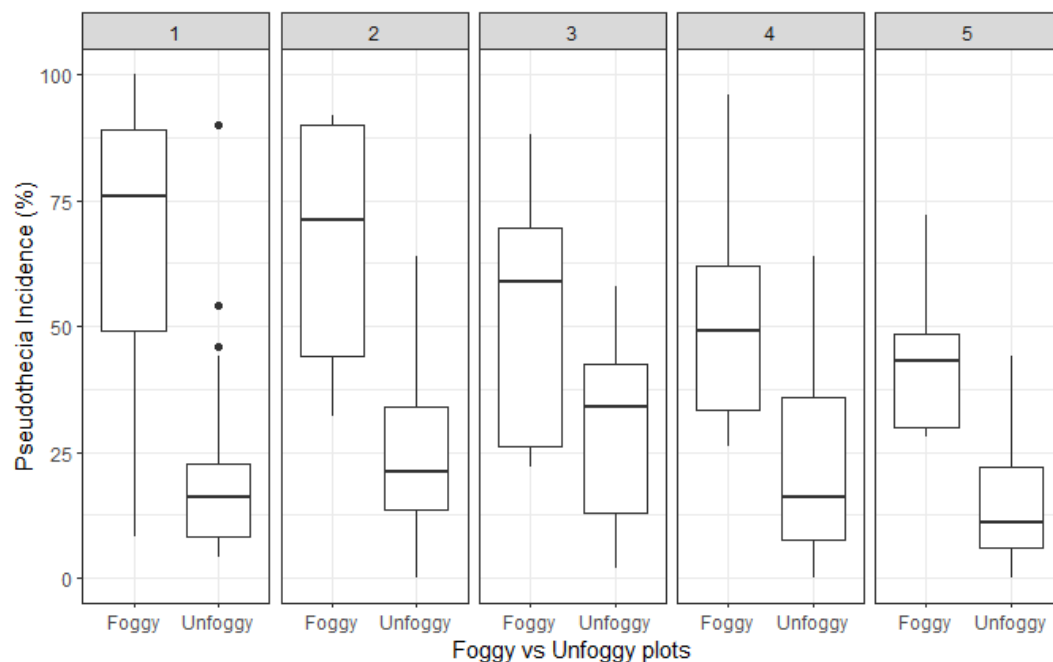


Figure X-8. SNC incidence. Numbers 1 to 5 represent the canopy height beginning at the bottom to the top of trees.