Title: Experimental Evaluation of Plethodontid Salamander Responses to Forest Harvesting

Investigators:
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Project Duration:
2 years, beginning June, 2014

Objectives:

A. **Correlate Oregon slender salamander (OSS; *Batrachoseps wrightii*) and Ensatina salamander (ENS; *Ensatina eschscholtzii*) occupancy and abundance with CWD density and distribution at both the site and landscape scale.**

Summary of accomplishments towards First objective:
Site Selection- Over the course of the project, we continually added sites to the study (>10 acres in size, <2500 ft. in elevation within western Cascade Range, OR, and had not been harvested in >50 years) from ownership databases in two geographic blocks: the Clackamas Block and the Snow Peak Block. We started with 66 units and finished with 88 due to site contributions from Oregon Department of Forestry and the Bureau of Land Management (BLM). We had two types of study plots in the experiment: control units, which were to remain unharvested throughout the study, and clearcut harvested (treatment) experimental units, which were to undergo harvest at some point during the study. Treatment units received from 1-4 years of pre-treatment sampling. Thirty-nine and 49 units occurred on the Clackamas and Snow Peak Blocks, respectively. Port Blakely owns 13 units on the Clackamas Block, Weyerhaeuser owns 17 units, and BLM owns 9 units; on the Snow Peak Block, Oregon Department of Forestry (ODF) owns 6 units, BLM owns 7 units, and Weyerhaeuser owns 36 units.

- 2014 season: We sampled 55/66 harvest units in the 2014 season, while 12 units were actively harvested. Harvested units were sampled again one year after harvest.
- 2015 season: We sampled 61/74 harvest units in the 2015 season. We did not sample 13 units because they were being harvested.
- 2016 season: We sampled 76/88 harvest units in 2015. We did not sample 12 units because they were being harvested

Sampling methods- We assigned a random starting point in each harvest unit for field crews to begin OSS/ENES sampling. This point served as the center for a single 9*9 m plot. Once the first plot was identified, a random azimuth was selected and six additional plots were established with a distance of 40 m between them. We searched plots in three sequential 10 minute intervals. Observers switched back and forth on every interval. As soon as both OSS and ENES were detected, sampling ceased. If OSS and ENES were not detected, all three intervals were completed. Observers followed a "light touch" sampling protocol in which cover objects were returned to their original position and in which disturbance to habitat features such as decayed logs was minimized. We sampled all seven plots in each harvest unit. During sampling, crews counted coarse woody debris based on length (1-5, 6-15, >15 m), width (large end; 25-50, >50 cm), and decay (none, Stage 1, and Stage 2) classes. Decay classes were based on those in Maser and Trappe (1984). In addition, crews recorded air temperature, soil moisture (at each of four points within each plot), and date.
Statistical methods- We were interested in three quantities: ψ (probability that a harvest unit is occupied by OSS/ENES), θ (probability that a sampling plot is occupied by OSS/ENES), and λ (abundance

in the sampling plot). We expected that forest harvesting will affect ψ, as harvest treatments are applied uniformly across units. However, our expectation was that θ and λ for OSS would be associated with distributions of coarse woody debris *within* the harvest units, regardless of whether the unit was assigned to the treatment or control group. Given the range of habitat associations for ENES, we did not expect to see a relationship between θ and λ and coarse woody debris. Our sampling design (three search intervals of each of seven plots within each of the 88 harvest units) allowed us to estimate these quantities. Details on the statistical models used to estimate these quantities (under different sampling designs) are provided in Royle and Nichols (2003), Nichols et al. (2008), Mordecai et al. (2011), and Pavlacky et al. (2012).

Results- In our final sampling season, twenty-two of the 76 sampled stands were harvested units and 54 were control units.

Oregon Slender Salamanders- We found OSS on sampling plots in 39/76 (51%) of the units. We found OSS on sampling plots in 6/22 (27%) of the harvested units and 33/54 (61%) of control units. On the Clackamas block, 3/11 (33%) harvested units and 13/23 (57%) control units had OSS detections. On the Snow Peak block, 3/11 (33%) harvested units and 20/31 (65%) control units had OSS detections.
Ensatina Salamanders- We found ENES on sampling plots in 36/76 (47%) of the units. We found ENES on sampling plots in 1/22 (5%) of the harvested units and 35/54 (65%) of control units. On the Clackamas block, 0/11 (0%) harvested units and 9/23 (39%) control units had ENES detections. On the Snow Peak block, 1/11 (9%) harvested units and 26/31 (84%) control units had ENES detections.

Summary information for sampling covariates indicated that plots in the Snow Peak block contained ~40% more downed wood than plots on Clackamas (Table 1). Stands in both blocks had the same average sampling date (~May 14).

Using the model described in Kroll et al. (2015), we estimated treatment-specific occupancy and abundance for both OSS and ENES in 2015 and 2016. We note that 2015 and 2016 are the post-treatment years for both responses. We did not find evidence for treatment differences in occupancy for either species in 2015 and 2016 (Figure 1). We estimated a substantial amount of uncertainty (wide credibility intervals) in treatment estimates for both OSS and ENES in 2015 and 2016 (as of 2016, a total of 22 treatment units have been sampled). Similarly, abundance was lower in 2015 and 2016 on treatment plots for both OSS and ENES in 2015 and 2016 (Figure 2). We note that OSS abundance was lower on Control units in 2015 and 2016 compared to 2013 and 2014, indicating inter-annual variability not attributable to the treatments. Given the data types (Poisson count data vs. binomial detection data), abundance estimates were more precise than occupancy estimates for 2015 and 2016. As a result, our confidence in the abundance responses is higher.

Occupancy and abundance probabilities increased with downed wood counts for both OSS and ENES across the course of this study (2013-2016; Figures 3 and 4). The effect was less pronounced for ENES, a species that has higher dispersal rates relative to OSS, and thus shows less reliance on downed wood structures.

Problems, barriers, proposed changes to First objective-

The analysis of the field data and the simulations in Kroll et al. (2015) indicates that our sample size of 88 harvest units was sufficient to answer our research questions. However, the annual variation in temperature and moisture is likely to have resulted in the observed decrease in occupancy over time. Our expectation is that the estimate of the treatment effect for both occupancy and abundance will become more precise with each additional year of sampling as the sample size of treatment units will increase with time.

B. Quantify relationship between Oregon slender salamander (OSS; *Batrachoseps wrightii*) and ensatina salamander (ENS; *Ensatina eschscholtzii*) occupancy and abundance with heartwood quantity.

Summary of accomplishments towards Second objective-

Justification- We hypothesize that heartwood content will be positively associated with both OSS and ENS occupancy and abundance, particularly as time since harvest increases. The Oregon slender salamander has a strong reliance on decayed coarse woody debris. A large portion of the geographic distribution of the Oregon slender salamander (OSS) occurs in forests managed intensively for wood production. In contrast, Ensatina salamanders (ENES) are associated with a broad range of habitat types. Reduced harvest rotation lengths can lead to lower input of total CWD and CWD heartwood at both the harvest unit and landscape scale (Bunnell and Houde 2010, Maguire and Batista 1996). Heartwood is more durable but has lower initial moisture content than sapwood, thus the overall effect of reduced heartwood on OSS or ENS habitat quality is unclear.

Sampling Status- We have sampling data on all units that include CWD length (1-5, 6-15, >15 m), width (large end; 25-50, >50 cm), sapwood width (none, <3 cm, > 3 cm), and heartwood decay class (none, Stage 1, Stage 2) (Maser and Trappe 1984).

Problems, barriers, proposed changes to Second objective:

We were unable to detect differences in CWD decay status, condition, length and width across treatments. We did find a block effect in the amount of CWD with a greater amount found in the Snow Peak Block. We hypothesize that differences in these CWD characteristics between control and treatment units would not emerge within the timeframe of this project. Further, we did not control for historical harvest practices. All units in the study have been subject to previous harvest protocols implemented by multiple ownerships and constrained by evolving industrial regulations. This variation in the amount and quality of downed wood makes current assessment of CWD response to study manipulations implausible. However, we have generated a series of hypotheses regarding microhabitat use within and around CWD that merits further study.

Comprehensive Summary:

This collaborative project successfully described the relationship between terrestrial salamander occupancy and habitat conditions associated with harvested timberlands in the western Oregon Cascades. We established sampling protocols and a BACI experimental design to quantify the detection and occupancy probabilities Oregon slender salamanders and Ensatina salamanders at the sampling plot and harvest unit spatial scales. Oregon slender salamanders are currently a candidate for listing under the Endangered Species Act and are only found on the western slopes of the Oregon Cascades. Ensatina, however, are widespread throughout the Pacific Northwest region. We predicted that both species would have a negative association with harvested plots but that the presence of CWD would dampen that treatment effect. We therefore designed a study to track salamander occupancy in units across the western Oregon Cascade Range that were gradually harvested over time.

We found a strong relationship between OSS and downed wood. Within both control and harvested units, plot occupancy and abundance increased with the number of downed wood structures. This relationship was found with ENES as well, but was less pronounced. This was predicted as OSS have narrow home ranges and are thought to have limited dispersal distances, while ENES are less reliant on CWD due to higher dispersal potential.

Detection rates for both OSS and ENES were high relative to other terrestrial salamander studies. However, we found no evidence for a treatment effect on occupancy rates for either OSS or ENES. We did find that abundances for both OSS and ENES were reduced post-harvest and relative to control units. It is important to note that a substantial amount of uncertainty exists in these estimates as both only two years of post-harvest data currently exist. Inter-annual variability also prevents us from making strong conclusions and suggests a strong climate effect.

This project would be strengthened with additional field seasons to control for between-year variation in climate conditions and to generate more harvested units. Currently, only 22 of our 88 units have been harvested, with agreements with all parties to continue participation in the study for the next 5 years. We have demonstrated that these salamanders are present in these landscapes; but further time is needed to increase confidence in our estimates of occupancy.

Graduate and/or undergraduate Engagement:

Carly Rathburn, an undergraduate student in OSU's Department of Fisheries and Wildlife, participated in the 2014 and 2015 sampling seasons and received 4 internship credits for her involvement (2014). As part of the OSU FW Dept. internship requirements, Carly submitted a report outlining her experiences and accomplishments pertaining to this experience (available upon request). She gained significant experience in multiple skill set areas, including sampling techniques, animal identification, safety skills, and experimental design.

Luke Lemieux, an undergraduate in OSU's Department of Fisheries and Wildlife, participated in the 2015 sampling season and received 4 internship credits for his involvement. Internship reporting requirements changed in 2015 and instead of a report on his experience, Luke participated in a survey on skill acquisition. He gained significant skills in data collection, sampling techniques, animal identification, and orienteering.

Jackson Curtis Meyer, an undergraduate in OSU's Department of Fisheries and Wildlife, participated in the 2015 sampling season. Jackson gained significant skills in data collection, sampling techniques, animal identification, and safety.

Eric Jacobs, an undergraduate in OSU's Department of Fisheries and Wildlife, participated in the 2015 sampling season. Eric gained significant skills in data collection, sampling techniques, animal identification, and safety.

Shelby Bauer, an undergraduate in OSU's Department of Fisheries and Wildlife, participated in the 2016 sampling season. Shelby gained significant skills in data collection, sampling techniques, animal identification, and safety.

Adam Field, an undergraduate at University of California at Santa Cruz, participated in the 2016 sampling season. Adam gained significant skills in sampling techniques, animal identification, and orienteering.

List of presentations, posters, etc.:

Kroll, A.J., T.S. Garcia, J. Jones, B. Murden, J. Johnson, S. Peterman, M. Rochelle. 2016. *Persistence and abundance of Plethodontid salamanders in production ecosystems*. The Wildlife Society Annual Conference, Raleigh, North Carolina. Symposium: Response of amphibians and reptiles to anthropogenic disturbance.

Kroll, A.J., T. Garcia, B. Murden, J. Jones, J. Johnson, S. Peterman, and M. Rochelle. 2015. Oregon slender salamander responses to intensive forest management. Joint Annual Meeting of the Oregon Chapters of The Wildlife Society and Society of American Foresters (29 April-1 May), Eugene, OR.

Garcia, T.S., A.J. Kroll, M. Rochelle, K. Dugger, J. Johnson, B. Murden and B. Lachenbruch. 2014. Oregon Forest Industries Council Board Meeting, June 17, 2014. Oregon State University, Corvallis, OR.

Garcia, T.S and T. Chestnut. 2014. Sampling techniques for terrestrial salamanders: The good, the bad, and the ugly. Society for Northwestern Vertebrate Biology Annual Meeting, Pasco, Washington.

Kroll, A.J., T. Garcia, J. Jones, B. Murden, J. Johnson, S. Peterman, and M. Rochelle. 2014. Multi-scale responses of Oregon slender and Ensatina salamanders to forest management. 21th Annual Conference, The Wildlife Society, Pittsburgh, PA.

Kroll, A.J. T.S. Garcia, J. Jones, B. Murden, J. Johnson, S. Peterman and M. Rochelle. 2014. Multi-scale responses of Oregon Slender salamander and Ensatina to forest management. North America Congress for Conservation Biology. Missoula, Montana.

Peterman, S., J. Johnson, M. Rochelle, T. Garcia, B. Murden, J. Jones, and A.J. Kroll. 2014. Experimental evaluation of Oregon Slender Salamander and Ensatina responses to forest management. 48th Annual meeting of the Oregon Chapter of The Wildlife Society, Bend, OR.

Kroll, A.J. 2014. Responses of terrestrial amphibians in production ecosystems. Joint Annual Meeting of the Society of Northwest Vertebrate Biologists and the Washington Chapter of The Wildlife Society , Pasco, WA.

List of publications, thesis citations:

Kroll, A.J., T.S. Garcia, J. Jones, K. Dugger, B. Murden, J. Johnson, S. Peterman, M. Brintz and M. Rochelle. 2015. Evaluating multi-level models to assess occupancy state responses of Plethodontid salamanders. PLoS ONE 10(12): e0145899. doi: 10.1371/journal.pone.0145899

Table 1: Summary information for sampling covariates, Clackamas and Snow Peak blocks, Oregon Cascades, 2016.

	Clackamas (n=34)				***Snow Peak (n=42)***			
	Control		**Treatment**		**Control**		**Treatment**	
Covariate	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**	**Average**	**SD**
Date	May 27	19 days	May 17	21 days	May 18	17 days	May 29	20 days
Downed wood (# of pieces)	2	1.7	1.7	1.5	3.4	2.7	3.4	2.2
Air temperature (°C)	15.7	5.2	20.9	6.5	12.5	4.9	17.3	5.2
Soil temperature (°C)	10.6	1.9	12.6	2.8	10.5	2	14.5	2.4
Elevation (m)	606	208	634	216	632	215	548	154

Figure 1: Treatment × Year occupancy estimates (90% credibility intervals) for Oregon slender and Ensatina salamanders, Oregon Cascades, 2013-16**.**

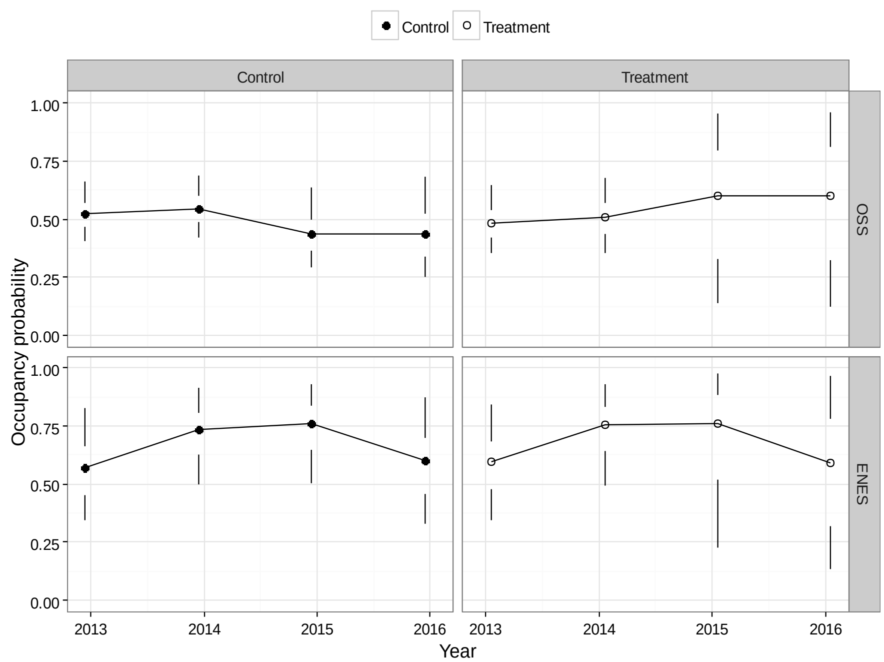


Figure 2: Treatment × Year abundance estimates (90% credibility intervals) for Oregon slender and Ensatina salamanders, Oregon Cascades, 2013-16.

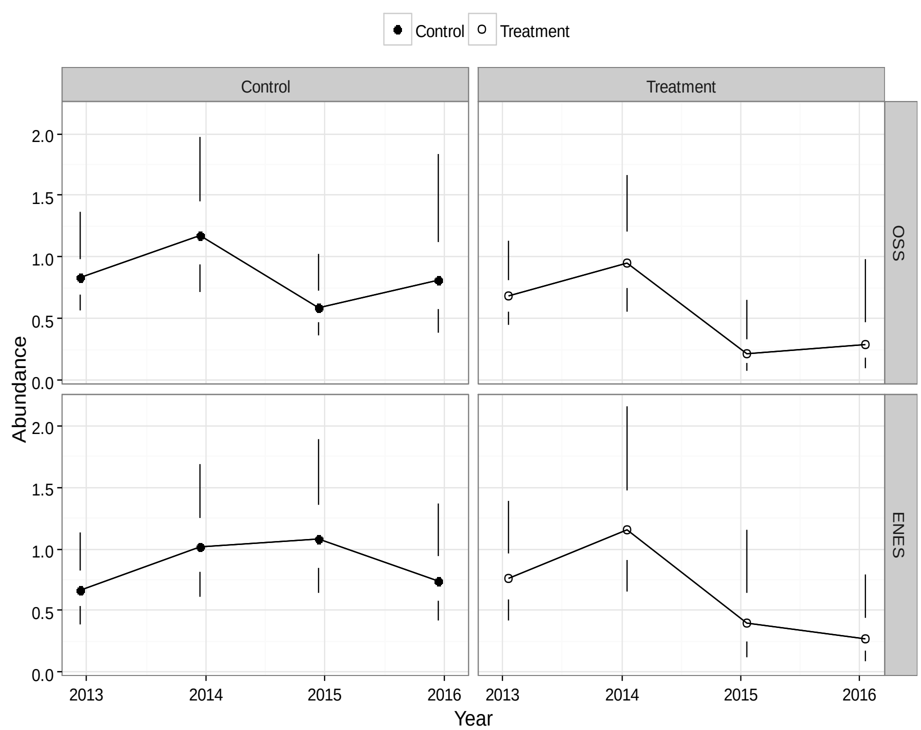


Figure 3: Plot occupancy estimates across counts of downed wood for Oregon slender and Ensatina salamanders, Oregon Cascades, 2013-16.

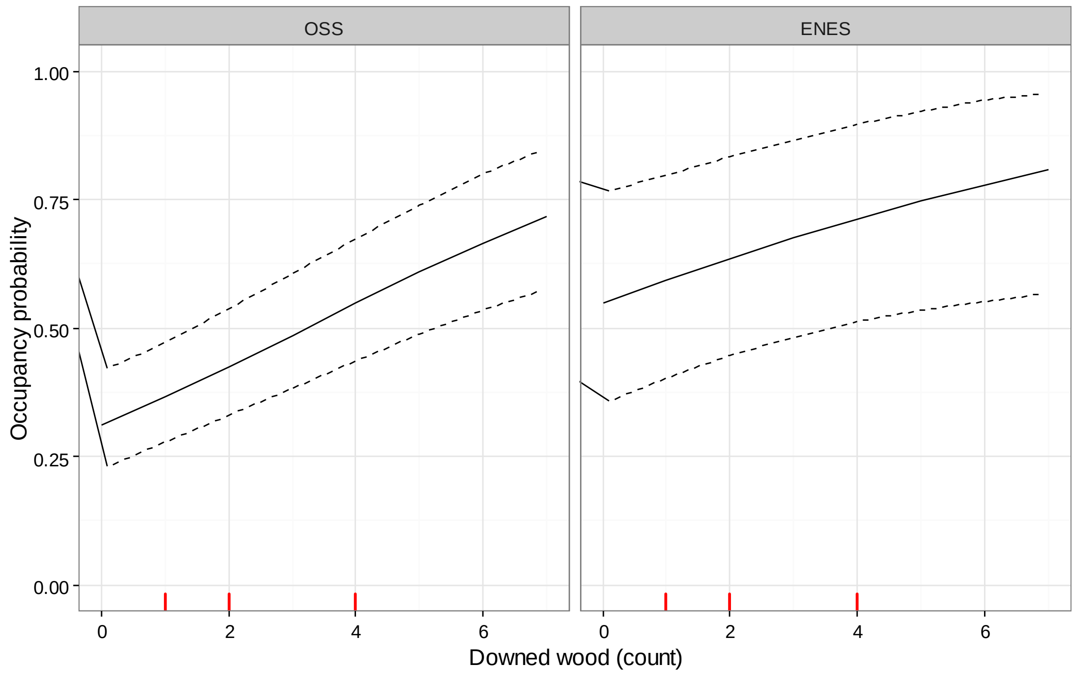
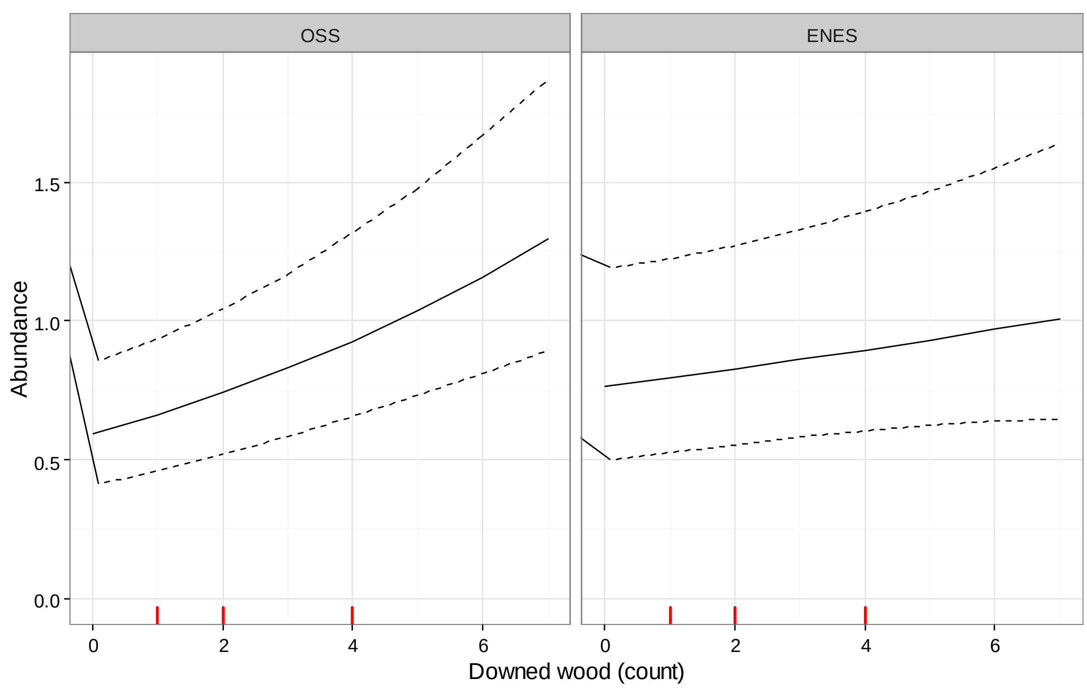


Figure 4: Plot abundance estimates across counts of downed wood for Oregon slender (OSS) and Ensatina (ENES) salamanders, Oregon Cascades, 2013-16.



Literature Cited

Kroll, A.J., T. Garcia, B. Murden, J. Jones, J. Johnson, S. Peterman, and M. Rochelle. 2015. Oregon slender salamander responses to intensive forest management. Joint Annual Meeting of the Oregon Chapters of The Wildlife Society and Society of American Foresters (29 April-1 May), Eugene, OR.

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Royle, J. A., and J. D. Nichols. 2003. Estimating abundance from repeated presence-absence data or point counts. Ecology 84:777-790.