Oregon State University
College of Forestry

Fish and Wildlife Habitat in Managed Forests Research Program

Progress Reports

Dec 6, 2018

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Fish and Wildlife Habitat in Managed Forests

Final Report

Title: Assessing pollinator response to natural and anthropogenic disturbances in mixed-conifer forests

Investigators: Dr. James W. Rivers (OSU), Dr. James H. Cane (USDA Pollinating Insect Research Unit)

Objectives:

1. Evaluate how natural and anthropogenic disturbances structure pollinator communities in early seral forests.
2. Assess whether changes in pollinator diversity and abundance are linked to changes in pollination services.
3. Test whether remote sensing data (e.g., LiDAR) can be used to discern differences in pollinator communities.

Summary of Accomplishments toward Objectives: We established n=42 study sites within the vicinity of the Douglas Complex in southern Oregon based on satellite-derived relative differenced normalized burn ratio (RdNBR) values that represent post-fire changes in stand basal area. Our study sites were located on Bureau of Land Management (BLM) landownership and represented the full range of fire severity within the ~19,700 ha complex; this included low fire severity (n=10), moderate-low fire severity (n=7), moderate-high fire severity (n=8), and high fire severity (n=9) sites. We established an additional n=8 study sites on BLM land that were subjected to high fire severity and were also salvage logged. We sampled bee communities using blue vane traps (BVTs) every 3-4 weeks from May-September 2016 and 2017, and measured bee floral resources and nesting habitat. We assessed relationships between bee abundance, bee species richness, and flowering plant density patterns using generalized linear mixed models.

Over both years we collected 3,220 bees representing 26 genera and 105 species/morphospecies. Bee abundance increased markedly with burn severity: **for every 100-unit increase fire severity (RdNBR) we captured 17-42% more individual bees**, depending on when sampling took place (RdNBR: $F_{1,162}$=33.99, P=<0.001; Fig. 1). This translated to an average of 20x more individual bees collected at the highest severity burn sites compared to the least burned sites, with the greatest difference between abundance occurring in the late summer (RdNBR*collection period: $F_{3,162}$=3.46, P=0.017). Bee richness was also positively related to burn severity,

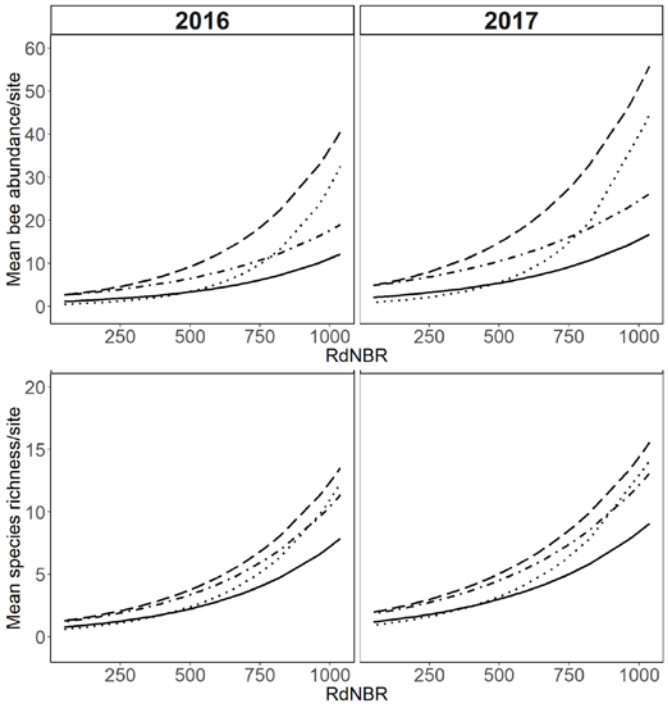


Fig 1. Stand-scale bee abundance and richness increased with burn severity during both years and all sampling periods. Lines represent collections undertaken in late spring (solid line), early summer (long dash), mid-summer (dash-dot) and late summer (dotted line).

increasing 18-29% for every 100-unit increase in RdNBR, equating to **an average of 11x more bee species in the highest severity burn relative to the lowest severity burn site** (RdNBR: $F_{1,162}$=56.67, P=<0.001; Fig. 1). Bee habitat also changed along the burn severity gradient: the number of flowering /ha increased with burn severity ($F_{1,152}$=66.84, P<0.001), and the difference was greatest during the late summer (RdNBR*collection period: $F_{3,152}$=6.54, P<0.001).

We also found that **salvage logging did not influence the overall abundance ($F_{1,84}$=0.50, P=0.48) or observed richness ($F_{1,84}$=0.21, P=0.65) of bees collected during the study**. However, nonparametric comparisons of bee species richness show a faster rate of species accumulation in stands that were not logged relative to logged stands, when floral resources were more densely concentrated in logged sites (Fig. 2).

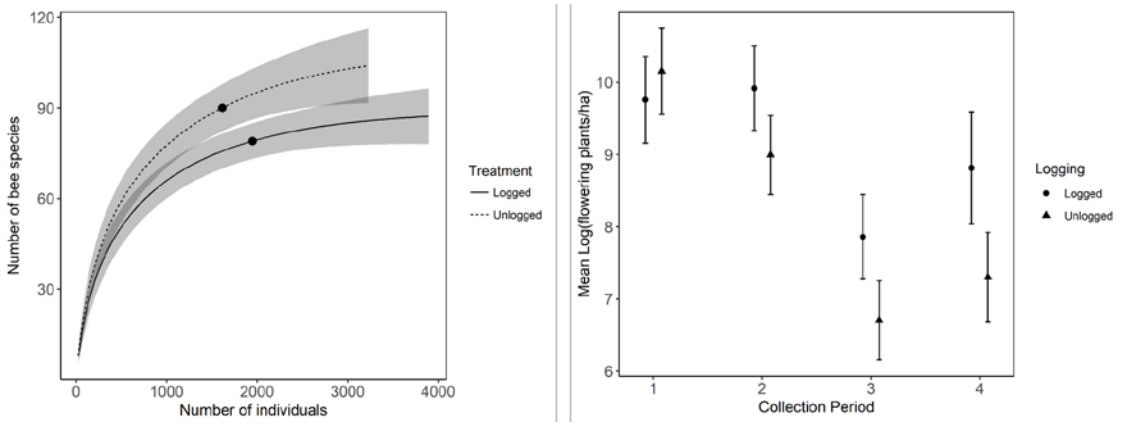


Fig 2. Observed bee abundance and richness were similar in salvage logged and unlogged stands, but the rate at which new species were added was greater in unlogged sites (left). Conversely, flowering plant density (right) was similar during the late spring (Collection Period 1) and early summer (Collection Period 2) and greater in logged stands in the mid-summer (Collection Period 3) and late summer (Collection Period 4).

In 2016, we also measured reproductive output of the alfalfa leafcutter bee (*Megachile rotundata*) by placing two bee nest boxes on each plot with a standardized number of pre-emergent adult bees still in cocoons. After 10 weeks, we collected the nest boxes and quantified the number and size of new cocoons produced on stands as a measure of relative reproductive output. We collected a total of 182 cocoons from nests, with plots that experienced high severity fire and were subsequently salvage logged had greater reproductive output (mean = 4.6 cocoons/nest, SD=8.7) relative to stand that experience low fire severity (mean = 0.7 cocoons/nest, SD=1.7). However, there was high variation in reproductive output among treatments, likely due to modest sample sizes. Therefore, we modified our approach and in the following year and instead used the blue orchard bee (*Osmia lignaria*) to quantify reproductive output. We used similar methods from the previous year, seeding adult cocoons in two nesting structures per stand in April 2017. Throughout the season, we monitored nest boxes and collected video data to assess female foraging trip length, an index of floral resource availability. We collected nest boxes in June 2017, and after cocoons developed into adults (October 2017), we took nest boxes to the Pollinating Insect Research Unit in Logan, Utah and X-rayed each nest to view contents. We compared the number of offspring, proportion of females, cocoon mass, and survival time of offspring with mean burn severity at the local (100m radius from center of site) and landscape (1000m radius from center of site) scales.

We collected >11,000 *O. lignaria* offspring from all sites (~211 offspring/nest box) with an average sex ratio of 51% female. We found that though the number of offspring was similar across the burn severity gradient at both local and landscape scales, **but the proportion of female offspring increased with the mean burn severity at the landscape scale** (P=0.04, R^2=0.32; Fig. 3), indicating more resources for producing offspring were available when burn severity increased.

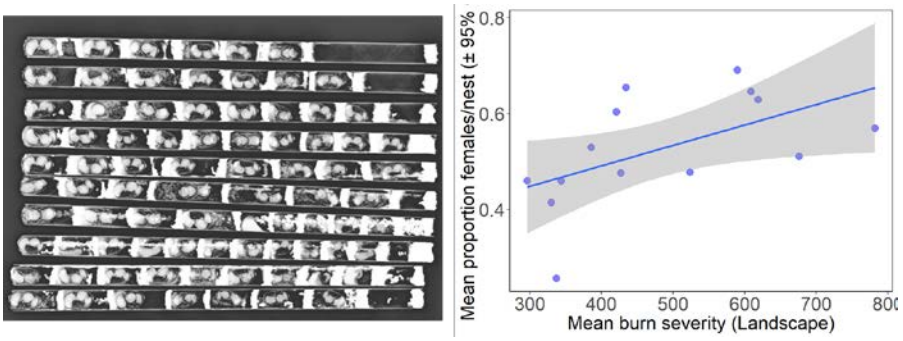


Fig. 3 | Blue orchard bee reproductive output was high among experimental stands. X-ray images (left) were used to quantify offspring sex ratio, which were female biased when nests were located in more severely burned landscapes (right).

Several habitat variables were significantly linked to fire severity and bee population metrics; however, field-based habitat measurements, such as flowering plant density, canopy cover, and nesting habitat, are labor-intensive to collect at large scales. In addition, it is unknown how bee diversity is linked to habitat variables at different spatial scales. Therefore, as part of study objective #3 we will use bee, flower, and habitat data collected over the course of this study to discern if remotely sensed LiDAR data can be used to predict bee diversity measures. We are currently evaluating this important, yet heretofore unaddressed component of how bees respond to landscape-scale changes in habitat within managed temperate forests. Current LiDAR-derived variables being explored include tree basal area, vegetation height, and rumple value (a proxy for canopy cover).

In addition to our empirical research, we also organized and hosted a workshop in March 2017 titled, "*Pollinators in Managed Forest Landscapes.*" The primary goal of the workshop was to bring together resource managers and pollination scientists to develop an agenda for pollinator research in managed forests of the Pacific Northwest. Researchers from across the country shared results from recent and ongoing projects focused on pollinators within managed forests, and resource managers were engaged to discuss how current management actions may impact native pollinators. Our attendance far exceeded expectations, with >90 participants in the one-day event, including students, researchers, and land managers. Attendees had the option of receiving continuing education credits from Society of American Foresters and The Wildlife Society for attending. We collaborated with speakers who participated in the event to develop a research agenda for future research of pollinators in managed temperate conifer forests that was published in the *Journal of Forestry* (Rivers et al., 2018). We expect that this review will serve as the foundation for future work on this topic in the Pacific Northwest, and that it will spark interest in this topic by scientists, forest managers, and policy makers alike.

We also co-organized the “Native Bee Workshop” at the Oregon Chapter of the Wildlife Society Annual Meeting in March 2018. This full-day workshop introduced participants to native pollinators of Oregon, with a focus on native bee taxonomy and ecology. Participants learned to identify the major bee families and genera of the Pacific Northwest, as well as methods for monitoring and studying bee populations. The workshop also included hands-on identification practice using structure-based characteristics of native bees. Participants included students, researchers, and land managers who were interested in incorporating pollinator monitoring into their scientific or conservation work.

Problems and Barriers: We did not encounter any significant problems or barriers that prevented us from meeting our research objectives, only making minor adjustments to the proposed methods based on new information about the study area. For example, our initial site selection found that salvage logging in the

Douglas Complex only occurred on stands experience high fire severity, preventing us from looking at the influence of logging severity across the entire fire severity gradient. We also intended to use potted *Helenium autumnale* for our pollination experiment but learned that these plants were challenging to work with under field conditions, so we instead chose to use in situ native plants for this experiment instead. Finally, we suspect that the limited number of alfalfa leafcutter bees that were raised on sites may have been due to phenological mismatches between flowering of local plants and the timing that bees emerged from cocoons. Therefore, in 2017 we used mason bees for this experiment that were better matched to the timing of local floral resources.

In addition to addressing the initial research objectives we proposed, we have also expanded the objectives of our study in several significant ways. First, we collected pilot data to evaluate the quality of roadside habitats for bees, as forest roads represent an additional anthropogenic disturbance type within forested landscapes. In addition, undergraduate students tested >800 individual bees for escape propensity from the traps being used in our study. Their findings on the influence of bee identity and size on escape rate from the traps, as well as the influence of temperature and time of day, will contribute to our understanding of potential biases and limitations of a widespread technique for quantifying native bee communities throughout the world. Additionally, we mentored two students from the OSU URSA Engage program (https://apli.oregonstate.edu/research/programs/ursa-engage) with research projects developed from our mason bee study. They are continuing to investigate the diversity of pollen types used for provisioning mason bee offspring along the fire severity gradient, as well as the survival time of mason bee offspring.

List of names and brief overview of graduate and/or undergraduate engagement in project: Three young professionals worked as research assistants on this project during the 2016 field season: Ian Lively (B.S., OSU), Nicole Scavo, and Katarzyna Szczurek. All three were interested in pursuing graduate school careers and learned field-, laboratory- and museum-based methods for working with bees, as well as collecting data for an independent project investigating trap bias in BVTs. Nicole Scavo is currently working on an M.S. in entomology. Two OSU undergraduate students volunteered with laboratory tasks in early spring 2017. During the 2017 field season, we employed 4 full-time young professionals: Ian Lively (crew lead), Katarzyna Szczurek (crew lead), Lisa Zander, and Sydney Watkins. We also employed 2 OSU undergraduate students: Kendra DelToro and Lacy Haig, who assisted with some fieldwork and conducted an experiment on campus to better understand bee escape propensity from the traps being employed in our field studies. In 2018, we employed one undergraduate in the lab, Mariel King, who worked on analyzing X-ray images from the mason bee project. Two URSA Engage students, Kendra DelToro and Nicole Bell, mentioned above, conducted studies developed from the mason bee work. Nicole will be pursuing the study as an undergraduate Honors College thesis. In addition, student Briana Price is receiving an internship credit for training in the lab on related research.

List of Presentations, Posters etc.:

Galbraith, S.M., Cane, J.H., and J.W. Rivers. 2018. Native bee reproductive output is influenced by wildfire severity in mixed conifer forest. Entomological Society of America Annual Meeting, Vancouver, B.C.

Galbraith, S.M., and J.W. Rivers. 2018. Managing forests for pollinator habitat. Bureau of Land Management Reforestation Training at Horning Seed Orchard, Colton, Oregon.

DelToro, K., Galbraith, S.M., and J.W. Rivers. 2018. Understanding the influence of wildfire severity on native bee survival. Society for the Advancement of Chicanos/Hispanics and Native Americans in Science, San Antonio, TX.

DelToro, K., Galbraith, S.M., and J.W. Rivers. 2018. Understanding the influence of wildfire severity on native bee survival. Summer Undergraduate Research Symposium, Oregon State University, Corvallis, OR.

Bell, N., Galbraith, S.M., A. Moldenke, and J.W. Rivers. 2018. Quantifying the influence of wildfire severity on offspring food provisions in a native bee. Summer Undergraduate Research Symposium, Oregon State University, Corvallis, OR.

Galbraith, S.M., J.H. Cane, A. Moldenke, and J.W. Rivers. 2018. Bee diversity linked to wildfire severity in mixed-conifer forest. Forest Health in Oregon: State of the State 2018. Oregon State University, Corvallis, Oregon.

"Native Bee Workshop" co-organized by Sara Galbraith and Joe Engler (U.S. Fish and Wildlife Service) at the Oregon Chapter of The Wildlife Society to introduce participants to the ecology of Oregon's native bees and basic methods used to study and monitor pollinator populations. Oregon Chapter of The Wildlife Society Annual Meeting, Portland, OR.

Galbraith, S.M., J.H. Cane, and J.W. Rivers. 2018. Reproductive response of a native solitary bee across a gradient of forest wildfire severity. Oregon Chapter of The Wildlife Society Annual Meeting, Portland, OR.

"Pollinators in Managed Forest Landscapes" workshop organized by Jim Rivers and Sara Galbraith to bring together researchers and resource managers to establish a research agenda for pollinator research within managed forest landscapes. Corvallis, OR.

Galbraith, S.M. 2017. Bee diversity is linked to wildfire severity and salvage logging in Oregon mixed conifer forest. FIRE Symposium, Corvallis, OR.

Galbraith, S. M, J. H. Cane, A. R. Moldenke, and J. W. Rivers. 2017. Bee diversity is linked to wildfire severity and salvage logging in Oregon mixed-conifer forest. Contributed oral presentation at the annual meeting of the Ecological Society of America, Portland, OR.

Galbraith, S. M, J. H. Cane, and J. W. Rivers. 2017. The influence of wildfire burn severity and post-fire management on bee community composition in mixed-conifer forest. Invited oral presentation at the annual meeting of the Pacific Branch of the Entomological Society of America, Portland, OR.

Galbraith, S. M, J. H. Cane, and J. W. Rivers. 2017. The influence of wildfire severity and post-fire management on pollinator communities in mixed-conifer forest. Invited oral presentation at Pollinators in Managed Forest Landscapes Workshop, Oregon State University, Corvallis, OR.

Galbraith, S. M., J. H. Cane, and J. W. Rivers. 2017. The influence of wildlife severity and post-fire management on pollinator communities in a mixed-conifer forest. Contributed oral presentation at the annual meeting of the Oregon Chapter of The Wildlife Society, Pendleton, OR.

Rivers, J. W. 2016. Pollinator response to natural and anthropogenic disturbances in mixed-conifer forests. Douglas Complex Status Review Meeting for the Bureau of Land Management, Roseburg, OR.

Galbraith, S. M. 2016. The influence of fire severity and post-fire management on bee community composition in a mixed-conifer forest. Oregon State University Postdoctoral Association Annual Research Symposium, Corvallis, OR. ***Won award for best overall presentation***.

Publications and Manuscripts in Review:

Rivers, J.W., Galbraith, S.M., Cane, J.H., Schultz, C.B., Ulyshen, M.D. and Kormann, U.G., 2018. A review of research needs for pollinators in managed conifer forests. *Journal of Forestry* 116:563-572.

Galbraith, S. M., J. H. Cane, A. Moldenke, and J. W. Rivers. In review. Wild bee diversity increases with wildfire burn severity in mixed-conifer forest. *Oikos*.

Publications in Preparation:

Galbraith, S. M., J. H. Cane, A. Moldenke, and J. W. Rivers. 2019. Wild bee similarity interacts with logging and season in post-wildfire mixed conifer forest. For *Forest Ecology and Management*.

Galbraith, S. M., C. J. Dunn, J.H. Cane, and J. W. Rivers. 2019. LiDAR-derived habitat variables for predicting bee diversity in mixed conifer forest after wildfire. For *Forestry*.

Rivers, J. W., S. M. Galbraith, A. Moldenke, and J. H. Cane. 2019. Demographic response of solitary bees across a natural gradient of wildfire severity. For *Ecological Applications.*

Fish and Wildlife Habitat in Managed Forests

Final Report

Title: Predicting Stream Nutrient Concentrations from Landscape Metrics to Develop Better Nutrient Criteria

Investigators: Alba Argerich, Kevin Bladon, Jeff Hatten, Sherri Johnson

Objectives:

The overall goal of this project is to increase our understanding of the factors and processes driving natural variability (both temporal and spatial) in background nutrient concentrations to better inform nutrient criteria. Specifically, we aimed to:

a) Synthesize stream nutrient concentration, landscape, and climate data from Trask.
b) Identify primary and secondary controls of nutrient concentrations at a catchment scale by modeling the relationship between stream nutrient concentrations and landscape and climate variables.
c) Create a model to predict magnitude, duration, and frequency of stream nutrient concentrations at a catchment scale.

Summary of Accomplishments toward Objectives:

During the duration of the project we have examined the temporal and spatial variability of nitrogen (N) and phosphorus (P) concentrations under natural conditions, i.e., pre-harvest, in the Trask River Watershed in the Cascade Range of Oregon.

Spatial variability:

To understand the spatial variability of nutrient concentrations we have examined in-stream N and P species collected at eleven sub-catchments in the Trask Watershed (Fig. 1) across multiple pre-harvest years during summer time. We then have cross-related nutrient concentrations with landscape characteristics to understand their role in regulating the observed spatial patterns. Specifically, we aimed to answer:

- Is the spatial variability of stream water N and P species associated with geology, vegetation, sub-catchment slope, elevation, mean distance from the hillslope to the stream, and specific conductance when the watershed is transitioning from wet to dry?
- Are different descriptors of variability (mean, maximum, and CV) in stream water N and P species influenced by distinct landscape characteristics during this transitional period?

Temporal variability:

The temporal variability of nutrient concentrations has been examined by analyzing the responses to the four Trask catchments (Fig. 1) to five isolated storm events that occurred over the course of one calendar year.

Specifically, we wanted to answer how N and P concentrations and exports:

- differed across catchments in the same region through the wet season, and
- differed across seasons in response to precipitation and discharge.

The objectives have been accomplished by:

- Running chemical analyses of water chemistry samples which have included nitrogen (nitrate, ammonium, dissolved organic nitrogen, and total dissolved nitrogen) and phosphorus species (soluble reactive phosphorus and total dissolved phosphorus).
- Creating a database of water chemistry data from storm samples and compiling it with the existing Trask stream water database.
- Creating a database of landscape and climate metrics from the Trask using GIS tools.
- Identifying relevant landscape and climate metrics that explain spatial variability in nutrient concentrations using statistical models.
- Identifying relevant landscape and climate metrics that explain temporal variability in nutrient concentrations using statistical models.

Main results:

Spatial variability: Mean total dissolved nitrogen (TDN) concentration across sub-catchments and years was 0.14 ± 0.11 mg N L^{-1} (mean ± SD). TDN was mainly composed of nitrate (70%), followed by dissolved organic nitrogen (26%), and the rest being composed by ammonium (3%). GS1 showed the highest mean TDN concentration (0.39 ± 0.06 mg N L^{-1}), while mean TDN concentrations in the rest of the sub-catchments were below 0.18 mg N L^{-1}.

Mean total dissolved phosphorus (TDP) concentrations across sub-catchments and years was roughly one order of magnitude lower than total dissolved nitrogen (0.019 ± 0.018 mg P L^{-1}). TDP was primarily composed of soluble reactive phosphorus (SRP; 73%), with the rest being composed by dissolved organic phosphorus (DOP). Highest mean concentrations were observed in PH2 (0.062 ± 0.021 mg P L^{-1}) and PH3 (0.043 ± 0.007 mg P L^{-1}), followed by RK1 (0.026 ± 0.008 mg P L^{-1}) and PH4 (0.023 ± 0.005 mg P L^{-1}). The remaining sub-catchments showed mean TDP concentrations below 0.019 mg P L^{-1}. Variability of SRP and DOP among sub-catchments was approximately twice as great in RK (CV = 70 and 235 %, respectively) than in the other catchments (CV = 32–38 and 108–150 %, respectively).

Not surprisingly, nitrate mean and maximum concentrations showed a strong, significant, positive relationship with red alder on the hillslope. Characteristics that reflect weathering and opportunities for biogeochemical activity (geologic composition, hillslope distance to the stream, and specific conductance) were significant for P species, in addition to elevation.

Temporal variability**:** Our research has shown that, during storm events, catchments of relatively undisturbed systems can have contrasting responses in nutrient concentrations. In particular, nitrate concentrations in GS (Fig.1) were notably larger and had more variability than the other three catchments.

Comparisons of nutrient concentrations between the five storm events indicated strong differences in nutrient responses across the events, especially for nitrate and total dissolved nitrogen, which generally declined with each subsequent observed storm. Soluble reactive phosphorus, on the other hand, showed a completely different pattern; the lowest soluble reactive phosphorus concentrations occurred when nitrate concentrations were maximal.

Finally, we observed that nutrient responses exceeded proposed annual nutrient criteria for Total Nitrogen and Total Phosphorus (Fig. 2) for northwestern Oregon. These results highlight the need to continue working toward development of nutrient guidelines that reflect the natural, site-specific variability in nutrient concentrations that incorporate seasonal patterns.

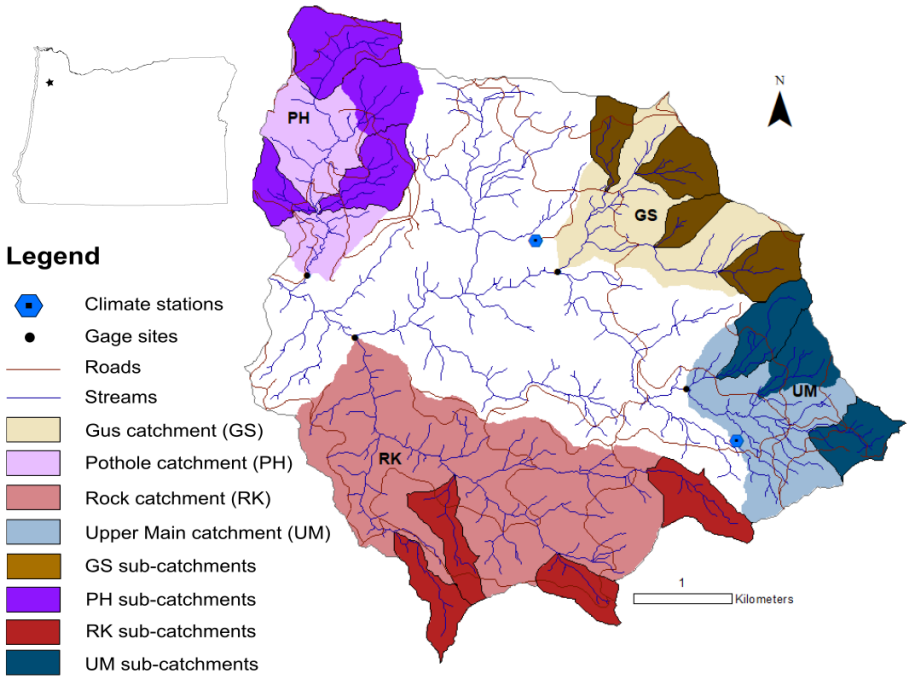


Figure 1. Map of the Trask River Watershed showing catchments and sub-catchments for Gus (GS), Pothole (PH), Rock (RK), and Upper Main (UM).

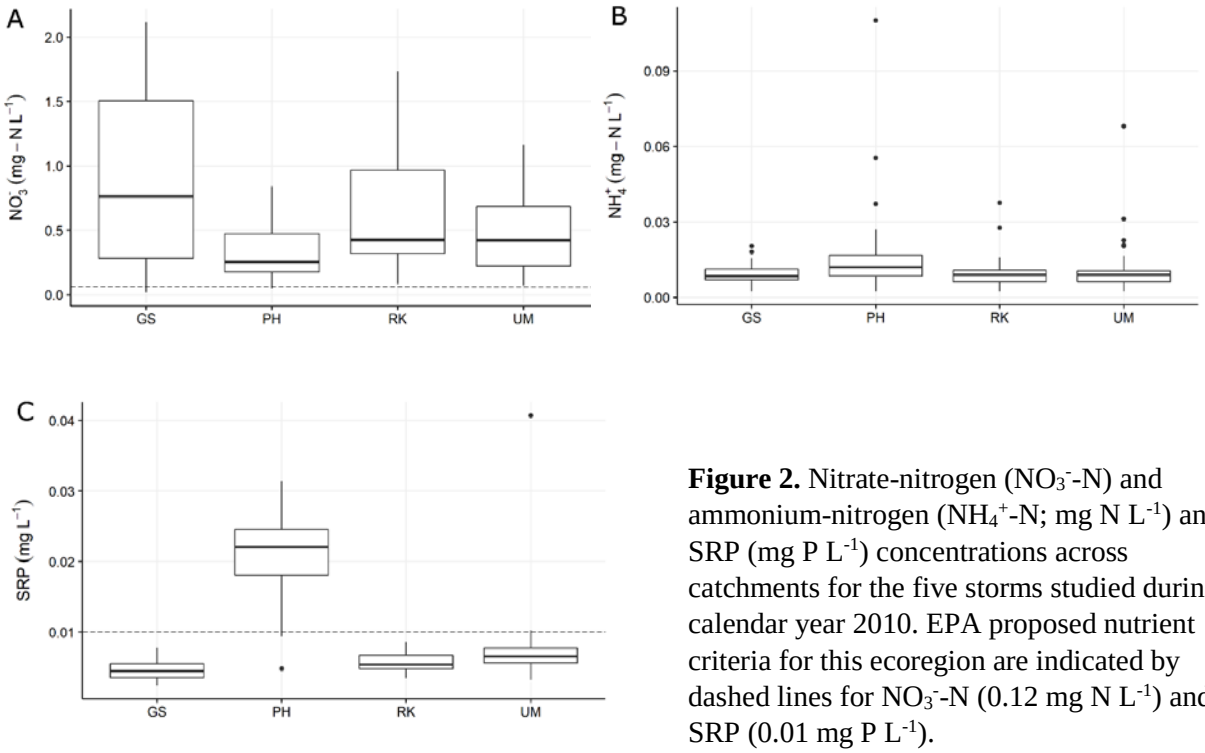


Figure 2. Nitrate-nitrogen (NO_3^--N) and ammonium-nitrogen (NH_4^+-N; mg N L^{-1}) and SRP (mg P L^{-1}) concentrations across catchments for the five storms studied during calendar year 2010. EPA proposed nutrient criteria for this ecoregion are indicated by dashed lines for NO_3^--N (0.12 mg N L^{-1}) and SRP (0.01 mg P L^{-1}).

Problems and Barriers:

Initially we hoped to integrate the water chemistry data from Hinkle and Alsea with the Trask data, but this task has been proved difficult. There are differences in sampling frequencies and methodologies across the different studies and these hinder transfer of the statistical model created for Trask.

We feel that the study would be much more valuable if post-harvest data were included in the study. We propose to expand the initial objectives (variability of nutrient concentrations under natural conditions) to include the nutrient concentrations response to forest-harvest (see next section of planned work).

Planned Work:

Analyze additional storm water samples collected during the Trask Watershed Study - these did not get analyzed because they were not the primary scope of work and involved post-harvest period. The additional data will serve to expand the database to incorporate storm water responses after forest harvest. These data will allow us to create a more robust manuscript that will encompass natural variability in nutrient concentrations and compare it with the variability observed after forest harvest.

List of names and brief overview of graduate and/or undergraduate engagement in project: [e.g., thesis, research experience for UG, etc.]

MS thesis: Casey Steadman, Natural variability of nitrogen and phosphorus in a forested headwater stream system in the Oregon Coast Range, Master of Science in Water Resources Science presented on December 7, 2017.

Undergraduate experience: Emilee Mowlds, undergraduate student in the Mentored Employee Program, worked on this project between Fall 2016 and Spring 2017. She assisted in the chemistry lab with acid washing, organization of samples to be analyzed, and learned analytical techniques for analyzing water chemistry, including manual methods and the Lachat auto-analyzer instrument.

List of Presentations, Posters etc.:

C. Steadman, A. Argerich, K. Bladon, and S. Johnson. An evaluation of nitrogen and phosphorus responses to rain events in a forested watershed. Abstract H52D-04. American Geophysical Union Fall Meeting. December 11-15, 2017. New Orleans, LA. Oral presentation.

C. Steadman, K. Bladon, A. Argerich, and S. Johnson. Geological and hydrological influences on nitrogen and phosphorus concentrations in forested headwater catchments of the northern coast range of Oregon. 7th Annual Pacific Northwest Water Research Symposium. March 6-7, 2017. Corvallis, OR, USA. Poster.

C. Steadman, K. Bladon, A. Argerich, and S. Johnson. Spatial and temporal heterogeneity of nitrogen in forested headwater catchments of the Northern Coast Range of Oregon. Abstract B33B-0592. American Geophysical Union Fall Meeting. December 12-16, 2016. San Francisco, CA, USA. Poster.

C. Steadman, A. Argerich, K. Bladon, and S. Johnson. Early trajectory of chemical water quality response to disturbance by forest harvesting in the northern coast range of Oregon. Society for Freshwater Science Annual Meeting. May 21-26, 2016. Sacramento, CA, USA. Poster.

C. Steadman, A. Argerich, K. Bladon, and S. Johnson. Effects of disturbance by forest harvesting on limiting nutrients in the Trask Watershed of the northern Coast Range of Oregon. Western Forestry Graduate Research Symposium. April 22, 2016. Corvallis, OR, USA. Poster. Award for 2nd best poster.

C. Steadman, K. Bladon, A. Argerich, and S. Johnson. Spatial and Temporal Variability of Nitrogen and Phosphorus in Headwater Catchments of the Northern Coast Range of Oregon. Sixth Annual Pacific Northwest Water Research Symposium. April 18-19, 2016 Corvallis, OR, USA. Poster.

List of Publications, Thesis Citations:

Casey Steadman, 2017. “Natural variability of nitrogen and phosphorus in a forested headwater stream system in the Oregon Coast Range”, Master of Science in Water Resources Science, Dept. of Forest Engineering, Resources and Management, College of Forestry, Oregon State University, Corvallis, Oregon.

Steadman, C., K. Bladon, A. Argerich, and S. L. Johnson. Nitrogen and phosphorus responses to precipitation and landscape characteristics in a forested headwater stream system. To be submitted TBD.

Other outputs: Archived database of storm water chemistry data of the Trask Watershed Study during pre-harvest.

Fish and Wildlife Habitat in Managed Forests

Progress Report

Title: Experimental Evaluation of Plethodontid Salamander Response to Forest Harvesting

Investigators: Tiffany Garcia, AJ Kroll, Jessica Homyack, Claudine Reynolds, and David Shaw

Objectives:

1) Quantify Oregon Slender salamander (OSS; *Batrachoseps wrightii*) and Ensatina salamander (ENES; *Ensatina eschscholtzii*) occupancy and abundance across harvested and control treatment stands.

2) Correlate the quantity and quality of course woody debris (CWD) within stands and across treatments to identify mitigating effects of understory habitat structure.

Summary of Accomplishments toward Objectives:

Over the course of this long-term Before/After, Control/Impact experiment, we have surveyed eighty eight units from the harvest plans of Weyerhaeuser, Port Blakely, ODF and BLM (>10 acres in size, <2500 ft in elevation within western Cascade Range, OR, and had not been harvested in >50 years). Fifteen stands serve as long-term controls (not harvested during the project) and 73 stands will be, or have been, harvested over the 2013-2019 study period. All 88 stands are known to be occupied by OSS, the rarer of the two salamander species. During the 2018 season, we sampled 41 harvest units and 37 control sites. Ten units had been harvested within the last year and therefore were not sampled.

We use an occupancy analytical approach using detections and non-detection data from multiple site visits on each of 7 sub-plot (9x9m) we set up in each stand every year. 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. Many terrestrial salamanders have detection probabilities less than 1, but our surface sampling technique allows for high detection rates without destroying the downed wood. 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.

We estimated treatment-specific occupancy and abundance for both species in 2013-2018. Interestingly, estimated mean occupancy for both species was lower in 2016-2018 than 2013-2015 on control sites (Figure 1). We also found that the estimated harvest impact on OSS occupancy probability was 0.80 (90% CRI: 0.42, 1.6), indicating lower mean values than expected under control conditions. However, the 90% posterior credible intervals overlapped 1.0, indicating uncertainty in the direction of the mean harvest effect. For ENES, the estimated harvest impact on occupancy probability was lower than 1 and we did not see overlapping posterior credible intervals, indicating a difference between the control and harvest treatments in response. In conclusion, we found lower occupancy probabilities in harvested stands for ENES but not for OSS.

Similar trends were detected in mean abundance estimates for both species. In control sites, we found interannual variability not attributable to the treatments (Figure 2). The estimated harvest impact was 0.75 (0.46, 1.2) for OSS abundance, indicating lower mean values than expected under control conditions. Similar to our occupancy findings, the 90% posterior credible intervals overlapped 1.0, indicating uncertainty in the direction of the mean harvest effect. For ENES, the estimated harvest impact was 0.3 (0.2, 0.6), with no overlapping posterior credible intervals. As such, abundance was estimated to be lower in harvested stands for ENES.

Our model also allowed for variation in occupancy and abundance for both salamander species in association with subplot-level downed wood count. In both cases, we found evidence of a positive association between occupancy and abundance of Oregon slender salamanders and Ensatinas with downed wood count (Figure 3). The model estimates indicated an expected 20% (90% CRI: 13, 28) higher odds of occupancy for each unit difference in wood count and a 9% (90% CRI: 6, 11) higher abundance for subplots with a unit higher count in downed wood. This result supports the oft-noted preference of both species for woody debris as a habitat substrate. We did not manipulate coarse woody debris directly in our study and our strength of inference is weaker than that for the main treatment effect (harvest).

Figure 1. Occupancy probability for Oregon slender salamanders and ensatina salamanders during 2013-2018 survey years. Harvest began in 2015. The impact of harvest was estimated from the expected pre-to-post change on harvested sites (blue) relative to control sites (red).

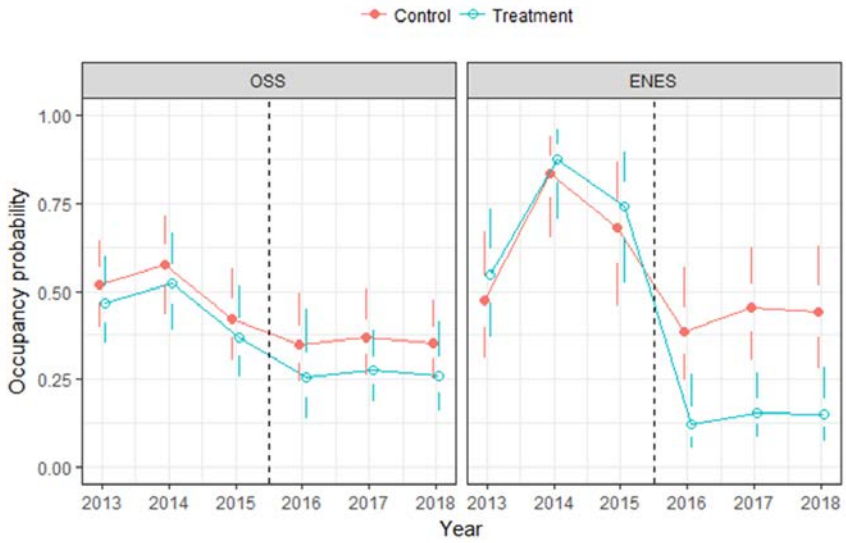


Figure 2. Abundance probability for Oregon slender salamanders (OSS) and ensatina salamanders (ENES) during 2013-2018 survey years. Harvest began in 2015. The impact of harvest was estimated from the expected pre-to-post change on harvested sites (blue) relative to control sites (red).

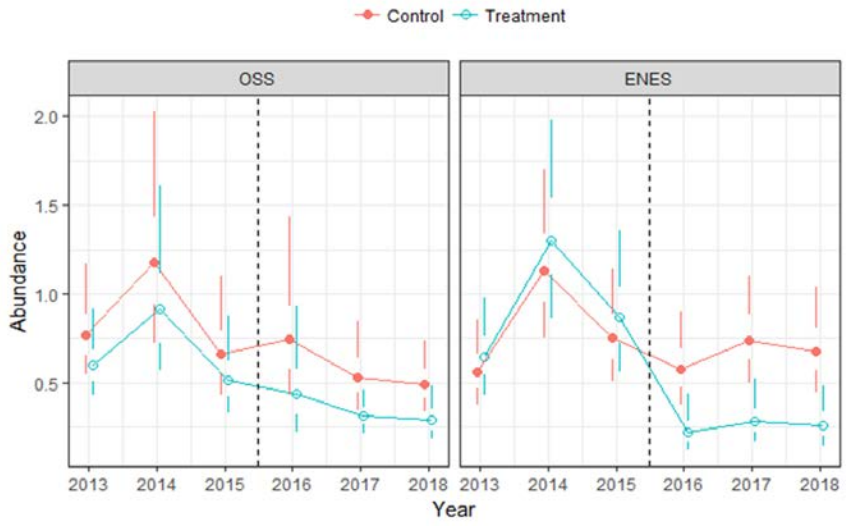
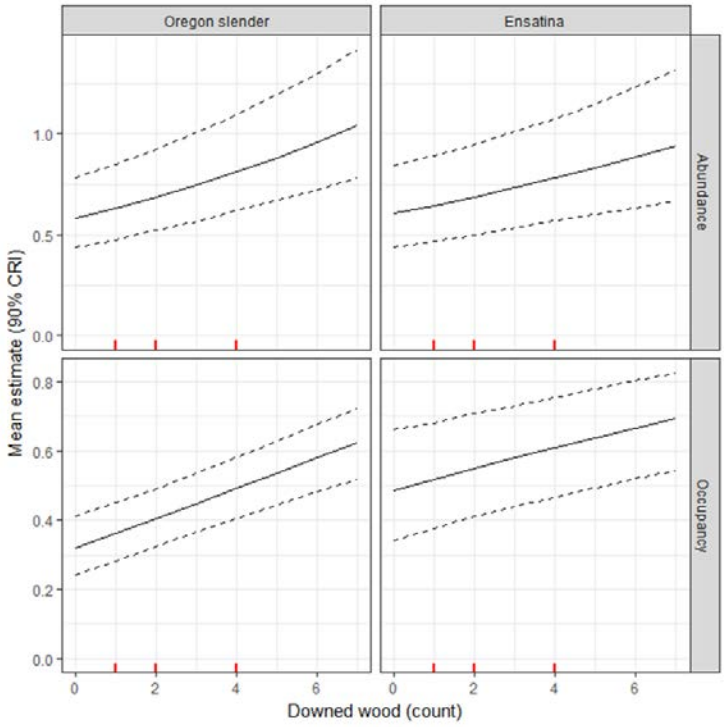


Figure 3. Mean estimates for occupancy and abundance of Oregon slender salamanders and Ensatina salamanders as a function of downed wood counts within the sampled plots. Ticks show 25th, 50th, and 75th percentiles.



Problems and Barriers:

As we approach our final sampling season for this project, we anticipate the need to resurvey these stands at regular intervals until the tree canopy closes. Given the life history of these terrestrial organisms (i.e., long lived, dependence on refuge, reclusive nature), it is difficult to make conclusions regarding the long term impacts of forest harvest on population dynamics with only 7 years of data. We feel it is important to revisit these sites every 5 years over the next 20 years to accurately assess the refuge capacity of CWD in harvested units for both species, and if occupancy and abundance estimates change with canopy closure, soil moisture levels, seasonal precipitation conditions, and decay rates of the downed wood.

Planned Work:

We are in the process of summarizing our results over the 2013-2018 sampling years. These data will be presented in publication format and submitted to the Journal of Applied Ecology in early 2019.

We will conduct an additional field season in the spring of 2019. We plan to continue to use the 'light touch' sampling methods and occupancy analytical approaches to estimate Plethodon salamander occupancy and abundance in forested landscapes as a function of course woody debris abundance and distribution. We will continue to randomly generate a GPS point within each sampled unit to designate the center for a single 9*9 m plot; 6 additional plots will be assigned based on a random azimuth, each separated by 40m. Each plot will be sampled for 3 10-min intervals or until both a OSS and ENS are detected. CWD data in post-treatment plots will include sampling methods used in pre-treatment units (CWD length, width, sapwood width, and decay class). Again, we will analyze presence and absence data

to estimate 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).

The 2019 data will be summarized with survey records from the entire 7 year study when available. Additional publications will be written in the summer of 2019 that explore the competitive relationships between OSS and ENS in managed landscapes.

List of names and brief overview of graduate and/or undergraduate engagement in project: [e.g., thesis, research experience for UG, etc.]

We hired four research technicians for the 2018 sampling season, three of which were recruited from the OSU Dept. of Fisheries and Wildlife undergraduate student group. Two of these technicians identify as part of an underrepresented group in the STEM fields. A'naka Smith and Mark Stevens both graduated from OSU in the spring of 2018, while Jose Ruiz graduated the previous winter.

List of Presentations, Posters etc.:

Garcia, T.S., A.J. Kroll, M. Rochelle, J. Johnson, J. Homyack, C. Reynolds, and D. Shaw. Terrestrial Salamanders in Managed Forests: Impacts of Harvest Practices on Oregon Slender Salamander (*Batrachosepts wrightii*) and Ensatina (*E. eschscholtzii*) Occupancy and Abundance. 2018. Society of American Foresters Annual Meeting, Portland, Oregon, USA. Invited Symposium Presentation.

Garcia, T.S., A.J. Kroll, M. Rochelle, J. Johnson, J. Homyack, C. Reynolds, and D. Shaw. Terrestrial Salamanders in Managed Forests: Impacts of Harvest Practices on Oregon Slender Salamander (*Batrachosepts wrightii*) and Ensatina (*E. eschscholtzii*) Occupancy and Abundance. 2018. The Wildlife Society National Meeting, Cleveland, Ohio, USA. Oral Presentation.

List of Publications, Thesis Citations:

Garcia, T.S., J. Jones, J. Johnson, and A.J. Kroll. In preparation. Terrestrial salamander response to forest management. Target Journal: Journal of Applied Ecology.

Fish and Wildlife Habitat in Managed Forests

Progress Report

Title: Does a Lack of Structures for Nest Building Limit Red Tree Vole Occupancy of Actively Managed Forests?

Investigators: Damon Lesmeister, John Bailey, Mark Linnell

Objectives:

1) To continue to test if the lack of suitable structures for nest building limits red tree vole occupancy of younger stands (lack-of-structure hypothesis) and to examine additional alternative or complementary hypotheses e.g. does lack of inter-tree branch connectivity limit use of nests by tree voles?

2) To quantify the latency to colonization of nest platforms by red tree voles

3) To quantify occupancy and visitation rates to nest platforms by potential predators of red tree voles.

Summary of Accomplishments toward Objectives:

We have broadly disseminated our work including presentations by undergraduate and graduate students, and by investigators. This has included addressing our main hypothesis (lack-of structure) using data from the first year of data collection (Figure 1; Linnell et al. 2018). We are interested in the multi-year effects of our main hypotheses and are continuing field work. We have collected and processed all additional data collected from summer 2018, including photographic data.

We have implemented additional experimental approaches to examine hypotheses complementary to our main hypothesis (lack-of-structure): does lack of inter-tree branch connectivity, such as what would occur during commercial thinning operations, limit use of nests in young forests by tree voles. This work will be a chapter in a graduate student thesis. We have completed treatment – elimination of branches connecting to adjacent trees – of 26 trees containing nest platforms and will compare these using photographic data to control trees (n = 26) within the same stands.

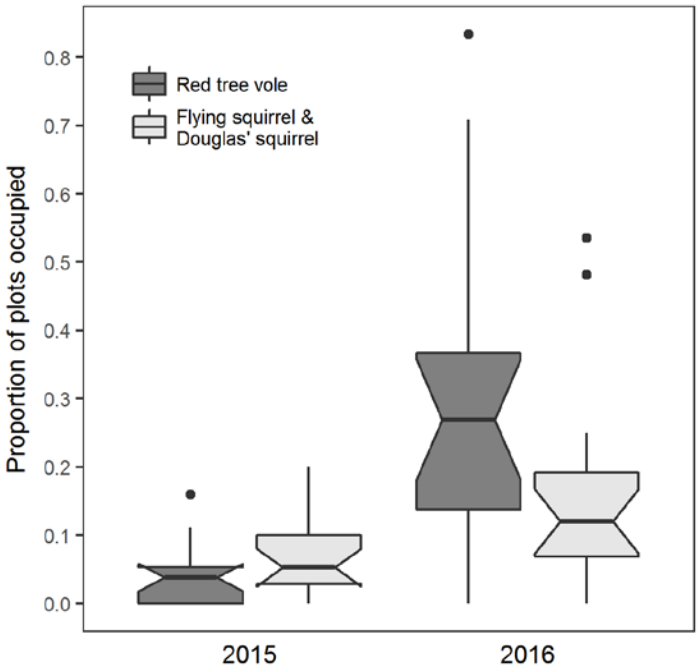


Figure 1. Box plots showing the change in site-level use before (2015) and 1-year after (2016) installation of artificial nest platforms for arboreal rodents at 17 young forest sites in the central Coast Range of Oregon (44º20'N, 123º35'W). Each site averaged 25 ± 6 artificial nest platforms. Medians are the horizontal bars, notches indicate 95% confidence intervals of the medians, the boxes represent interquartile ranges, whiskers are 1.5 inter-quartile ranges beyond the boxes, and dots represent extreme data points >1.5 inter-quartile range beyond the boxes.

Problems and Barriers:

We did not fully anticipate the time needed to process photographic data collected. We are just now working to summarize 2 years of photographic data, including all of the 2018 field season data. Some platforms have become occupied by wasps, making them inaccessible to tree climbers to check for red tree vole sign.

Planned Work:

Winter/Spring 2019: Summarize photographic data from 2017-2018 and prepare manuscript using photographic data and occupancy models to examine use patterns by tree voles and their predators

Summer 2019: Field work: check platforms and collect additional photographic data

Fall/Winter 2019: Graduate student to complete thesis; continued manuscript preparations by investigators.

List of names and brief overview of graduate and/or undergraduate engagement in project:

Preston Durham, MS student, Forest Engineering, Resources & Management

Araya Jensen: Araya finished her Associates degree in Spring 2018 and is enrolled at OSU for winter 2019. She worked for us during in 2017/18 and was the lead presenter of a poster.

Charlie Hengemihle: Charlie is an undergraduate in the fisheries and wildlife department and worked for us during the 2018 field season.

Natasha Nemyre: Natasha is post-baccalaureate student in the fisheries and wildlife department and worked for us during the 2018 field season.

We have maintained a balance between male and female field technicians throughout the project and will continue to look for opportunities to diversify our field crews.

List of Presentations, Posters etc.:

Durham, W. D., D. B. Lesmeister, J. D. Bailey. 2018. Red tree voles: the importance of individual tree structure and interconnected branch pathways in young conifer forests. Western Forestry Graduate Research Symposium. Corvallis, OR. April 13. (poster)

Durham, W. D., D. B. Lesmeister, J. D. Bailey. 2018. Red tree voles: the importance of individual tree structure and interconnected branch pathways in young conifer forests. 2018 Society of American Foresters National Convention. Portland, OR. October 3. (paper)

Jensen, A. A., D. B. Lesmeister, K. M. Wert, M. A. Linnell, and J. K. Swingle. 2018. Unique insights into arboreal rodent behavior and species interactions using remote cameras at artificial nests. 89th Annual Meeting of the Northwest Scientific Association. Olympia, WA. March 28. (poster)

Lesmeister, D. B., M. A. Linnell, and J. K. Swingle. 2018. Red tree vole response to artificial nests: testing the lack-of-structure hypothesis. 89th Annual Meeting of the Northwest Scientific Association. Olympia, WA. March 28. (paper)

Swingle, J. K., D. B. Lesmeister, M. A. Linnell, and A. A. Jensen. 2018. Red tree vole occupancy in young forests in the Oregon Coast Range. Joint Annual Meeting of Oregon Chapter of the Wildlife Society, Washington Chapter of the Wildlife Society, Society for Northwestern Vertebrate Biology, and Northwest Partners in Amphibian and Reptile Conservation. Portland, OR. February 15. (paper)

List of Publications, Thesis Citations:

Linnell, M. A., D. B. Lesmeister, J. D. Bailey, E. D. Forsman & J. K. Swingle. 2018. Response of arboreal rodents to increased availability of nest substrates in young forests. *Journal of Mammalogy* **99**, 1174-1182.

Fish and Wildlife Habitat in Managed Forests

Progress Report

Title: Identifying distribution boundaries at the upper extent of fish in streams using environmental DNA

Investigators: Brooke Penaluna, Lead PI; Ivan Arismendi, CoPI; Tiffany Garcia, CoPI; Jessica Homyack, CoPI; Taal Levi, CoPI; and Dana Warren, CoPI

Objectives: We propose a comparison study that evaluates the upper end of fish distributions in streams of Oregon and Washington comparing traditional electrofishing techniques to eDNA detection. We will (1) assess whether eDNA can identify the end of fish distributions at their upper extent and (2) compare those data to electrofishing data.

Summary of Accomplishments toward Objectives: We completed all field work. We worked closely with land managers of Weyerhaeuser, Hancock Forest Management, and Port Blakely to select sampling sites on their land and to have access to their electrofishing data to compare to forthcoming eDNA results. We have compiled all electrofishing and habitat data from the land managers into a database.

Problems and Barriers: We did not have any substantial problems or barriers to this work. We were able to complete our field work as planned. The electrofishing work revealed that the last fish at all sites was either Coastal Cutthroat Trout or sculpins. Consequently, we plan to evaluate the end-of-fish from our eDNA samples using primers that focus on these two fish groups. Jenn Allen in Taal Levi's lab developed a Coastal Cutthroat Trout primer, which is working smoothly and efficiently, and is completing the any sculpin primer. We will be publishing the primer development in our publication as part of this work.

Planned Work: We are currently extracting samples in the lab and hope to have extractions completed by March 2019. Once extractions are completed, we can run the samples on the ddPCR using the Coastal Cutthroat Trout primer and sculpin primer. Then, we will analyze our results, compare them to the electrofishing data, and assess the ability of eDNA to identify the end-of-fish.

List of names and brief overview of graduate and/or undergraduate engagement in project: We have two undergraduate student lab technicians that have been trained by Jenn Allen in Taal Levi's lab to complete the eDNA extractions.

Acacia Pepper (work study, FW undergraduate)

Makenzie Weber (STEM leader, FW undergraduate)

List of Presentations, Posters etc.: We plan to give data-related presentations when the fieldwork, eDNA lab work, and data analyses have been completed. This project has provided the opportunity to interact with forest managers and land owners to discuss collaborations related to the upper-extent-of-fish and Coastal Cutthroat Trout.

List of Publications, Thesis Citations: This work will be submitted as a final report, and as a publication. We aim for completion in 2019.

Fish and Wildlife Habitat in Managed Forests

Progress Report

Title: Quantifying fish response to management creating riparian forest canopy gaps

Investigators: Dana Warren, Maryanne Reiter

Objectives:

Our objective was to learn about how canopy gaps that create localized increases in stream light affect stream ecosystem processes and stream biota. We were particularly interested in understanding whether a canopy gap – as a small change in light could yield a biological response while having only a minimal effect on stream temperature.

We hypothesized that the creation of a riparian gap in closed canopy stands would lead to increases in primary production, greater macroinvertebrate biomass and ultimately increases in fish abundance and biomass. Given the high degree of light limitation for primary production in these systems, we expected to see a strong biological response while keeping physical (temperature) responses to a minimum. Further, with the anticipated responses in stream primary production, we also expected greater nutrient retention in the canopy gap reaches relative to the close-canopy reference reaches.

Summary of Accomplishments toward Objectives:

We are still finalizing data analysis but we have some prelimary results that generally support our expectations. The light and algal standing stock data indicate a strong positive responses in stream primary production to the gap, which is a critical first step in the pathway/process that we expected to lead to a positive response in fish. We have completed pre- and post-treatment fish assessments and we are conducting analyses on those data this fall. At this time, preliminary data from the two sites where we have completed an initial analysis suggest a moderate response in the fish – particularly in juvenile abundances. Temperature data were collected at multiple sites along each reach. There is a great deal of data to be QAQC'ed before analysis of temperature responses can be conducted. We are in the process of downloading data from the loggers, organizing the data across sites, and doing data quality checks on the temperature data.

Problems and Barriers:

As in 2017, fires were also an issue this year. We did a better job of getting our data early but there was a fire in August 2018 that limited access to two of our sites. This meant that (1) we were not able to do a final set of nutrient releases at these two sites (only 2 of 3 planned reps were completed), (2) we were not able to collect temperature sensors until October – thereby delaying our work with those data, and (3) we were not able to recapture fish for growth assessments until October. An additional issue that has arisen in analysis is the lack of data from a few sites in last year's surveys (due to fire and other logistical constraints). We still feel that we have a robust study design, but for some data collections, we have fewer replicates than we had initially planned.

Planned Work:

During the remainder of the funding period for this grant (Fall 2018, and Winter, Spring, and Summer of 2019), we will:

1. Finish water chemistry measurements,
2. Analyze fish responses to the gaps and prepare a fish-focused manuscript
3. Analyze nutrient, light and algal responses to the gap and prepare a lower trophic level and nutrient response manuscript
4. Analyze water temperature responses to the gaps and prepare a manuscript focused on temperature responses relative to responses in stream light.
5. Complete and defend an MS thesis for the graduate student supported by this project, Allison Swartz. (One or more of the above manuscripts will be the core of thesis)

List of names and brief overview of graduate and/or undergraduate engagement in project: [e.g., thesis, research experience for UG, etc.]

- This project is supporting one MS student
  - Allison Swartz

- This project supported in total three undergraduate students over two summers:
  - Alvaro Cortes (this student is from an underrepresented group in the sciences).
  - Cedar Mackeness,
  - Brook Mackeness

- In summer 2018 Allison Swartz and I also mentored two teachers enrolled in an NSF Research Experience for Teachers (RET) program. The teachers conducted small projects to measure air temperature and terrestrial insect community responses to the gaps.
  - Corey Culp – Highschool math teacher in Mackenzie school district
  - Nate Day – Higschool science teacher in Mackenzie school district

- Undergraduate theses/projects:
  - In Fall/Winter 2017, Alvaro Cortes conducted an undergraduate research project that build off of his field work experience and used data collected during on his work on this project.
    - Alvaro presented his undergraduate research at the Oregon Chapter of the American Fisheries Society in 2018. His poster focused on fish response to drought. While this study question is not related to gaps in streams, his project was made possible because he was an undergraduate technician on the gap project in summer 2017 and some of the data that he collect that summer as part of the gap study was used in his thesis work. This is an example of how funding from one effort can be leveraged to enhance learning opportunities that extend beyond that project.
    - Alvaro contributed the results from his project to a larger study in my lab and in so doing earned co-authorship on the manuscript that has been submitted from that work. This In review manuscript is listed below as a publication from this FWHMF project even though it is not directly related to our initial study objectives because it would not have been possible without support for Alvaro from this program.
  - In Fall 2018 (and anticipated into winter and spring of 2019), Cedar Mackeness is writing his undergraduate Honors thesis on a study he is conducted that leverages the light gap experiment (see progress report 2 for specifics on that work).

List of Presentations, Posters etc.:

Warren, D. 2017. Oregon Society of American Foresters (SAF) Riparian Workshop, World Forestry Center, Portland, OR. *Changing forests – Changing streams: Riparian forest, stream light, and fish.* August 2017 (Invited talk)

Swartz, A., and D. Warren, 2018 D. Benthic primary production responses to a riparian forest canopy gap. Oregon American Fisheries Society Annual Meeting. Eugene, OR. March 13-16. (Poster)

Cortes, A., M. Kaylor, A. Swartz,and D. Warren, 2018. Influence of climate variability on Cutthroat Trout and Coastal Giant Salamander in headwater streams. Oregon American Fisheries Society Annual Meeting. Eugene, OR. March 13-16. (Poster)

Warren, D. 2018. University of British Columbia, Vancouver, BC. Canada. *Riparian forest structure, stream light, and bottom-up drivers of fish production in forested headwaters.* May 2018. (Invited talk)

Warren, D. 2018. McKenzie River Watershed Council, Springfield, OR. *Riparian forest structure, stream light, and bottom-up drivers of fish production in forested headwaters.* April 2018 (Invited talk)

Warren, D., and A. Swartz. 2018. NCASI 2018 West Coast Regional Meeting, Vancouver, WA. *How the creating riparian forest canopy gaps affects algae, invertebrates and fish in headwater streams*. (Sept. 24-26, 2018) (Invited talk)

Warren, D.R. M. Kaylor, A. Swartz, and E. Heaston. 2018. Light as fundamental driver of stream ecosystems at the HJ Andrews Experimental Forest, Oregon. NSF LTER All Scientists Meeting. Monterey CA, Asilomar conference center. Sept. 29 – Oct. 4. (Poster)

Swartz, A, and D. Warren. 2018. Influence of a riparian canopy gap on a forested headwater stream. NSF LTER All Scientists Meeting. Monterey CA, Asilomar conference center. Sept. 29 – Oct. 4. (Poster)

List of Publications, Thesis Citations: [published or anticipated]

Published

None

In Review

Kaylor, M.J., B.J. VerWey, **A. Cortes,** and **D.R. Warren.** ***In Review***. Drought impacts to trout and salamanders in cool forested headwater ecosystems in the western Cascade Mountains, OR. Submitted to: *Hydrobiologia*

In Preparation/planned

Swartz, Rivera, Mackeness, Warren – Stream predator responses to the creation of a riparian forest canopy gap in headwater ecosystems. (Target journal: *Ecological Applications*)

Swartz, Perakis, Warren – Localized increases in light associated with riparian forest canopy gaps increase stream primary production and nutrient uptake at the reach scale. (Target journal: *Ecosystems*)

Swartz, Reiter, Warren – Canopy gap effects on stream temperature in headwater ecosystems (Target journal: *Ecohydrology*)

Fish and Wildlife Habitat in Managed Forests

Progress Report

Title: Early Seral Habitat Longevity in Production Forests in the Oregon Coast Range

Investigators: Matthew Betts (PI), Scott Harris (CoPI)

Objectives:

Our objective is to quantify the relationships between bird abundance/occupancy and stand-scale habitat variables in production forest stands aged 0 to 30 years, in the Oregon Coast Range. This age range will encompass vegetation development from stand initiation through canopy closure. Combining these species-specific "yield curves for birds" with management-relevant metrics of stand structure and composition (e.g., amount of hardwood, crop tree density) will be of high utility to forest managers and policy makers tasked with integrating biodiversity and timber production objectives.

Summary of Accomplishments toward Objectives:

1. We refined our **study plan** and developed a **site selection** strategy and **protocols** for the summer 2018 field season, including soliciting and incorporating feedback from other researchers.
2. We conducted **outreach** with three private landowners and the State of Oregon, and secured appropriate research agreements and access permissions.
3. Following the hiring of 2 field technicians, we conducted a successful, accident-free, **field season** from mid-May through July 2018. We collected bird abundance and vegetation data at 158 sites.
4. We participated in an **Occupancy Analysis** workshop to learn critical analysis skills for this specific project.
5. We started **preliminary analysis** of our 2018 data in order to refine, if necessary, our 2019 data collection strategy.

Problems and Barriers:

During our first field season, the most significant challenge was to balance logistical efficiency with random selection of study sites. For example, we had to eliminate randomly-selected sites that were too remote (i.e., requiring an hour or more of driving) from a block of sites that were in closer proximity. We do not expect that this will bias our results, but we can test for potential biases (e.g., 'elevation', 'distance to edge') formally in analysis. Because our 10-minute bird counts were restricted to the hours between dawn and 10am, we found that an average efficiency was 5 to 7 sites per surveyor per day (3 surveyors and 2 vehicles).

One of our project objectives is for Scott Harris to receive training in diversity, equity, and inclusion to inform hiring decisions. Scott has been in communication with the Outreach and Engagement at OSU, but has not yet participated in training due to schedule conflicts.

Planned Work: [if progress report]

1. We are currently completing data entry for the 2018 field season. Upon completion, we will conduct **preliminary occupancy analysis** using stand age and hardwood cover as primary covariates. We will compare our results with the data from the 2008-2009 Ellis-Betts Study (Ellis and Betts 2011). At that point, we will determine which option to pursue for the 2019 field season in order to maximize inference and statistical power for our research objective. Our options are to either 1) survey additional randomly-selected sites, or 2) re-survey the original Ellis-Betts sites.

2. We will conduct year-end annual **outreach** with landowners involved in this study.

3. We will hire two field crew and conduct our second and final **field season** between May and July 2019.

4. Following the 2019 field season, we will analyze data and prepare a **manuscript** for submission to a peer-reviewed journal by May 2020. Prior to submission, we will conduct **outreach** with all landowners.

List of names and brief overview of graduate and/or undergraduate engagement in project: [e.g., thesis, research experience for UG, etc.]

Under the advisement of Matt Betts, Scott Harris (graduate student) has been substantially engaged in all phases of project conceptualization, development, management, field data collection, analysis, and reporting.

After a nationwide posting for field crew, we hired two recent graduates of the Fish and Wildlife program at Oregon State University. Both expressed an interest to return again in 2019 (although this question was asked before we started vegetation surveys!).

List of Presentations, Posters etc.:

Our proposal was presented as a poster at the Western Forestry Graduate Research Symposium (WFGRS) in 2017, at Oregon State University. The poster was awarded 3rd place (from approximately 50 poster presentations).

At the end of the current calendar year, we will provide a summary to each of the four landowners involved in the study (Weyerhaeuser, Hancock Forest Management, Starker Forests, Oregon Dept. of Forestry).

List of Publications, Thesis Citations: [published or anticipated]

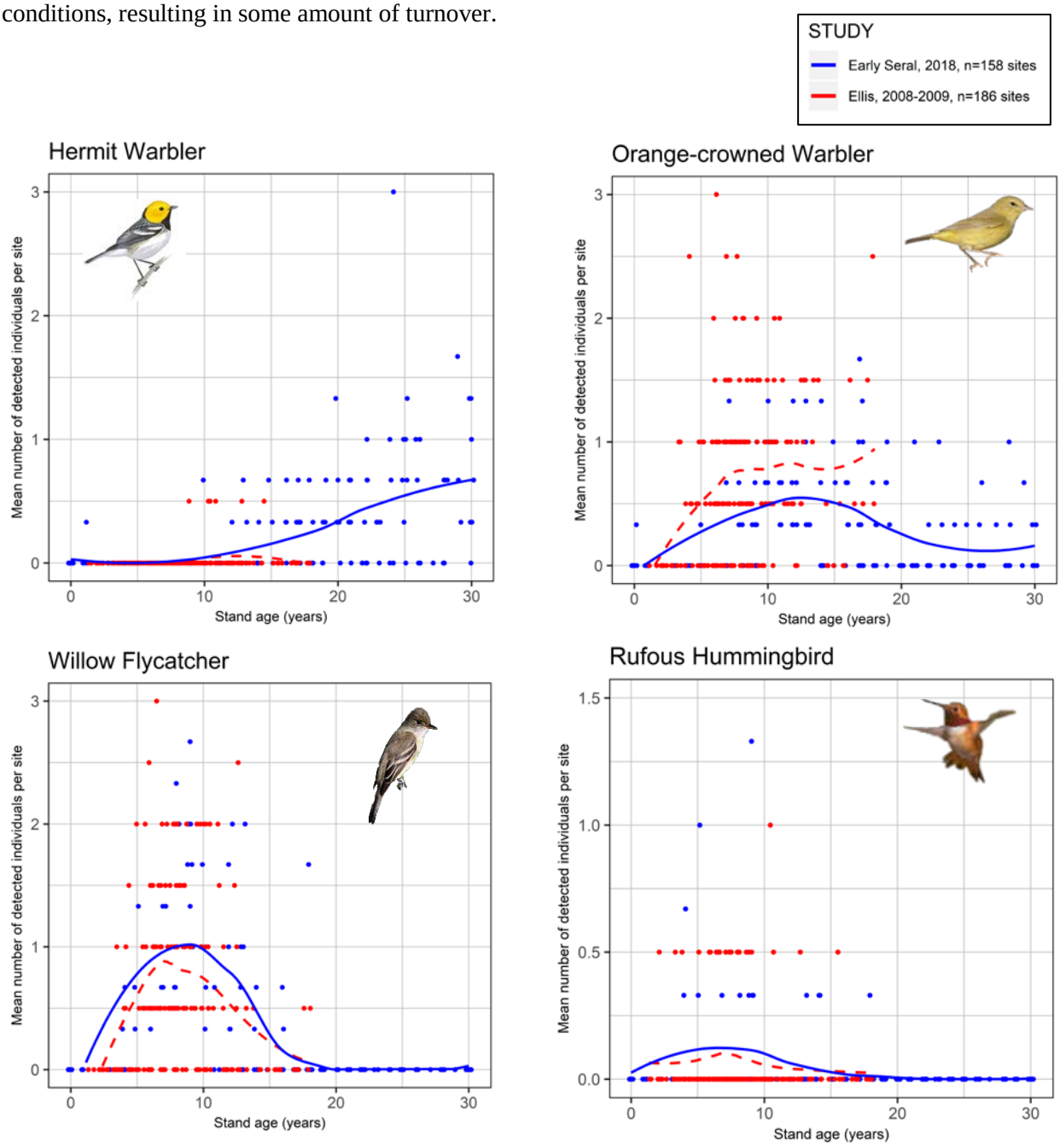
We anticipate publishing results in the journal *Forest Ecology and Management* or *Canadian Journal of Forestry*. Results will also be published as a chapter in the PhD dissertation of Scott Harris. Because this study provides a very rich dataset, we anticipate significant opportunities for additional research publications. For example, we could expand upon stand-level conclusions by including landscape-scale co-variates.

Literature Cited:

Ellis, T. M., and M. G. Betts. 2011. Bird abundance and diversity across a hardwood gradient within early seral plantation forest. Forest Ecology and Management 261:1372–1381.

Preliminary Results:

The below figures are raw bird abundance data from the 2018 field season (funded through this FWHMF grant), compared to raw data from the Ellis-Betts 2008-2009 Study. Dots are the mean number of detections for a species over all visits to each site (3 visits for ES and 2 for Ellis-Betts). Curves are loess-smoothed. Confidence bands on the curves were removed to make the figures easier to read. Both studies were conducted in approximately the same study area in the northern Oregon Coast Range. The Ellis-Betts data are from 186 non-randomly-selected sites aged 0 to 18 years. The ES sites are from 158 randomly-selected sites aged 0 to 30 years. Although preliminary, these figures suggest two conclusions: 1) dynamic changes in the bird communities occur across a wide range of ages that include canopy closure at approximately 16 to 22 years, and 2) there are species-specific responses to changing stand conditions, resulting in some amount of turnover.



Fish and Wildlife Habitat in Managed Forests

Progress Report

Title: Biodiversity in Natural and Managed Early Seral Forests of Southern Oregon

Investigators: Meg Krawchuk, Matthew Betts, James Rivers, A.J. Kroll, Jake Verschuyl, Mark Swanson

Objectives: Our objective in this study is to conduct a large-scale retrospective study of biodiversity (plant, pollinator and bird communities) in early seral Douglas-fir/white fir/western hemlock forest types of southwestern Oregon. We will compare responses to 1) community development, structure, and biodiversity after stand replacing fire on public lands (*SRFire*), 2) after wildfire and timber salvage/management on public lands (*FSalvage*), and 3) managed regeneration plantation forestry on private lands (*IFM*). We will stratify our sampling across three different periods of early stand development: *young* (1 to 5 years since disturbance), *adolescent* (6 to 12 years), and *old* (13 to 20 years) periods.

We will document how plantation forestry alters biodiversity and temporal characteristics of the early seral period from its primary natural counterpart, stand-replacing wildfire. At the same time, we will investigate the extent to which active management may support species and communities traditionally associated with natural disturbance. Plant communities, pollinators (here we focus on bees), and birds together provide a robust and useful suite of metrics for quantifying early seral biodiversity. Focusing on plant communities, including tree, shrub, forb, and herbaceous assemblages, provides the fine lens necessary to forward understanding of form and function of primary producers in early seral forests. Bees (e.g., *Bombus* and *Xylocopa*) and birds (songbirds and woodpeckers) represent higher trophic levels, providing deeper understanding of community dynamics. These taxa serve as indicators for other taxonomic groups and can be relatively easily sampled over large geographical areas, making them ideal for the scale of work described here.

Research question: How does biodiversity vary between early seral environments initiated by *SRFire, FSalvage, and IFM*?

- How do these patterns change with time since disturbance, e.g., younger early seral through older early seral? For what species, and what are their structural and functional characteristics?
- Are there key environmental gradients (i.e., covariates) that allow us to predict spatial variability in *SRFire* outcomes?
- How long does early seral habitat last on a given site type and how does this vary spatially, across environmental gradients? What environmental gradients underpin variability in "the end of early seral" among treatments.

The current management paradigm means a complicated slurry of pre- and post-fire management landscapes. For simplicity, our *SRFire* sites will focus on stand replacing fire burning through mature forests on public lands that have not been clear cut in the past and were not treated with herbicides. The BLM management framework in this area results in the majority of burned sites being planted post-fire, however herbicide treatments are not allowed and many seedlings fail or are severely outcompeted by the vigorous herb and shrub layer during the early pre-forest stage. This "complex but not fully natural" early seral community is representative of the area and we propose is potentially more important to understand than fully natural early seral given the patchwork of ownership and harvest structure that severely affects natural seed source on many sites for obligate seeding trees. Our *FSalvage* sites will focus on salvage logging on public lands after stand replacing fire through mature forests that have not been clear cut in the past; we will aim to constrain variability in salvage intensity and other post-fire management, but assume that sites will have been planted following salvage. Our *IFM* sites will focus on regenerating clear cut plantation forests, including common site preparation, planting, and silviculture activities.

Summary of Accomplishments toward Objectives: In July 2018, the ESFB project brought on Graham Frank as a Ph.D. student in the Department of Forest Ecosystems, supervised by lead PI Krawchuk. Graham will be responsible for the day-to-day progress of the project going forward, including leading summer field crews, data analysis, and manuscript preparation, with careful advising from Meg and the complement of Co-PIs. Note that funding from FWHMF began in September 2018; funding for Graham's PhD program (stipend, benefits, and tuition) is a substantial component of our FWHMF budget. Partner funding from NCASI supports the reminder of the research program.

This summer was a pilot field season focused on ground-truthing study sites initially identified using geospatial layers of burn severities, potential vegetation types (PVTs), and harvest records from the USFS, BLM, Roseburg Forest Products, and Weyerhaeuser. PVTs represent the modelled long-term vegetation association for a site in the absence of disturbance or management, and we have specifically focused only on Douglas-fir and Douglas-fir/tanoak PVTs to help ensure balanced comparisons between burned areas and intensively managed plantations. The second major filter applied to potential study sites was to select burn sites with no harvesting in recent years before the fire and with at least 75% basal area mortality, to ensure that burned stands also represent mature forests that have experienced stand replacing disturbance. In the field, much of our work has been ensuring that the apparent disturbance history of each stand matches expectations, and that the disturbance has occurred consistently enough across an area that we can treat it as a discrete sampling unit. We have also paid close attention to logistical considerations, making sure that study sites are accessible by the existing network of intact forest roads and that individual sites do not represent an unacceptable risk to the health and safety of research technicians. Fully completing the work of ground-truthing sites in the field is still being held up by the recently contained Klondike fire, which burned in the 2002 Biscuit Fire scar through summer into October. The surrounding unburned USFS and BLM lands that match our criteria for potential vegetation type and burn severity are currently closed.

Currently, we are working towards paring down useable sites identified this summer to sites—and areas within those sites—that we actually plan to sample in the coming years. This process is being based off of a number of important covariates that we want to keep as consistent as possible between our categories to minimize the influence of spurious correlations on our final results. These covariates include stand size, aspect, elevation, slope, past management, and landscape context. The high availability of candidate intensive forest management sites on the landscape, of which we've visited dozens, should give us flexibility in selecting sites that match burned sites as closely as possible in these covariates.

We have signed collaborative agreements including data sharing and road access with our two private industrial partners, Weyerhaeuser and Roseburg Forest Products. We have established partnerships with BLM (Medford and Roseburg offices) and USFS (Rogue River-Sikiyou National Forest) and to establish effective communication for this public-private lands project.

Problems and Barriers: The active fire season in SW Oregon in 2018 resulted in reduced availability and access to old, complex "unmanaged" early seral in the study region. Two pieces of good news are that there still appear to be plenty of promising candidate sites to fill out our "old" age class of the stand-replacing fire category in the 2002 Biscuit footprint, and that the closures associated with the Klondike fire burning in that region have been lifted. Graham is requesting access to key areas of within the northern edge of the 2002 Biscuit fire, on BLM and USFS lands, to visit those sites.

The 2002 Timbered Rock Fire was initially identified as an ideal candidate for old early seral in the region, in addition to the 2002 Biscuit Fire. However, the 2018 Miles Fire burned through almost the entire area of the Timbered Rock burn scar this summer. We did scope out a handful of candidate sites in the remaining sliver of Timbered Rock scar with no reburn once the area reopened, but most had been

harvested too recently prior to Timbered Rock to be considered “mature forest”. Accordingly, that area is now un-useable for our study. This summer was an excellent reminder of the importance of vigilance, nimbleness, and back-up plans/multiple options in the context of this study.

Planned Work: This academic year Graham Frank will be developing nuanced research questions and hypotheses that nest within our overarching research questions for the project, as part of the development of his PhD proposal. This winter we will refine field protocols to best leverage existing work from co-PIs Rivers, Betts, and Swanson in the region. We are currently recruiting the field team and organizing logistics.

Summer 2019 will be our first full field season, and we anticipate visiting one third of our total proposed sites to collect data on avian, bee, and plant community and forest structure. The field portion of this project is largely supported by funds from NCASI.

The following is a general summery of the study design and sampling. Field sample locations will be allocated according to three levels of disturbance history (*SRFire*, *FSalvage*, and *IFM*) and across three levels of time (young, adolescent, old early seral) since most recent disturbance for a total of nine study strata. Each stratum will be characterized by 10-15 sample sites with three sample points nested within each site, for a minimum total of 270 points across 90 sites (9 strata × 10 sites × 3 points = 270). We will increase sample sites from the minimum whenever possible, recognizing the terrain, environment, and access all make these field sites challenging. Initial geospatial data analysis, based on datasets described below in ‘Overview of sample site selection’ indicates adequate existing opportunities for sampling each of the nine strata. Field data will be collected by two field teams, each responsible for 15 sample sites (15 sites × 3 points = 45 sample points) per year. One third of the total 270 sites will be visited each year. In each year, each sample point will be visited four times over three sampling sessions.

Sample session #1 will focus on the bird breeding seasons and early bee season. Birds will be identified by sight and sound in the field based on two distinct visits to each point each point (separated by 48 hours) using three, five-minute sub-intervals. The bird sample protocol aims to support detectability estimates and robust analyses of avian communities. For the 9.77-m (300-m2) plot surrounding each point count location, live and dead tree structure (live trees, snags, downed wood) will be inventoried, and basic plant cover by life form will be tallied. Blue vane traps will be set to sample bee communities, and each trap will be set in place for 48 hours following protocols developed by co-PI Rivers. Floral resources for bees will be measured using transect methods developed by Rivers. With two field teams of two researchers each visiting three sample points (one site) per day, session #1 will be completed within 7 weeks, with crews working 5 days per week (approx. May 15th to June 30th). Crews will spend the majority of afternoons, Fridays, and one full week in the lab after session #1 processing bee samples.

Sample session #2 will focus on quantifying plant communities and include a single visit to all points established in session #1. Field teams will sample plant communities and forest structure at one site per day, inventoried for the 5.64-m radius (100-m2) plot surrounding each point count location; this plot size is smaller than that used for general characterization of bird habitat in session #1 due to increased effort required for broad plant community identification. Unknown plants will be brought back for identification and plant voucher specimens will be archived. The timing of session #2 coincides with peak flowering season for plants, aiding in identification. Each research team will include one technician with strong botanical skills. Session #2 will be completed within 4 weeks (approx. July 9th to Aug. 3rd).

Sample session #3 will focus on late season bees and their floral resources, and include two visits to all points established in session #1. Blue vane traps will be set for 48 hours to sample bee communities and floral resources for bees will be measured using established transect methods. Session #3 will be completed within 4 weeks (approx. Aug. 6th to Aug. 31st). One field technician will be kept on for two months following the field season to help the PhD student process bee samples and complete data entry.

Taxonomic identification of bees will occur in the lab based on keys and collections recently compiled by Rivers, and as needed we will verify specimens with taxonomist e.g., Andrew Moldenke (OSU).

List of names and brief overview of graduate and/or undergraduate engagement in project: [e.g.,

Graham Frank. PhD student recruited for this project. In charge of the summer 2018 pilot field season, will pursue his PhD work focused on this project (Fall 2018 through Fall 2022) and will be responsible for the day-to-day progress of the project going forward, including leading summer field crews, data analysis, and manuscript preparation.

Skye Greenler. PhD student recruited into FERM starting Fall 2018 (with Bailey), who worked as a field technician on the project in summer 2018.

List of Presentations, Posters etc.:

None completed.

List of Publications, Thesis Citations:

None completed.

At minimum expecting one PhD dissertation (Graham Frank), four journal publications.

Fish and Wildlife Habitat in Managed Forests

Progress Report

Title: Black-Backed Woodpecker Vital Rates in Unburned and Burned Forest Within a Fire-Prone Landscape

Investigators: Dr. James Rivers (OSU), Dr. Jake Verschuyl (NCASI)

Objectives: Our core study objectives are focused on comparing woodpecker vital rates between unburned and burned forest, and include: (1) conducting breeding surveys for woodpeckers; (2) quantifying nest survival and post-fledging survival of Black-backed Woodpeckers (BBWOs); (3) evaluating nest survival of non-focal woodpeckers; (4) measuring vegetation at nest-sites and post-fledging BBWO locations; and (5) assessing whether past management actions support successful BBWO nesting. In addition to our core objectives, we aim to leverage tagging efforts to collect pilot data on natal dispersal of BBWOs to expand our research on this species.

Summary of Accomplishments toward Objectives: During summer 2018 were able to make significant progress towards study objectives. We undertook >180 surveys for woodpeckers, as well as their potential predators during the nest (e.g., squirrels) and fledgling stage (e.g., *Accipiter* hawks); these survey locations were established in the Fremont-Winema National Forest (n=50 points) and the Sun Pass State Forest (n=12 points). Surveys consisted of passive listening counts for all aforementioned groups, followed by targeted call playback surveys for BBWOs only. A total of 8 woodpecker species were detected during surveys which include the six species shown in Table 1, as well as the Downy Woodpecker and Pileated Woodpecker. Nearly 3x as many BBWOs were detected via playback surveys than passive counts (44 vs. 15 individuals, respectively). We also detected Northern Pygmy-Owl, Cooper's Hawk, Common Raven, Steller's Jay, chipmunk sp., and squirrel sp. as potential predators during the course of surveys.

Table 1. Number of nests located for cavity-nesting bird species during targeted searches for the Black-backed Woodpecker. * denotes woodpecker species detected during point count-call playback surveys.

Species	# nests
Black-backed Woodpecker*	18
Hairy Woodpecker*	21
Northern Flicker*	13
Williamson's Sapsucker*	7
White-headed Woodpecker*	6
Red-breasted Sapsucker*	4
American Three-toed Woodpecker	1
Mountain Chickadee	3
White-breasted Nuthatch	2
Red-breasted Nuthatch	1
Total	**76**

During the course of the summer, we compiled >400 person-hours searching for nests and located 18 active BBWO nests, with 10 nests in unburned forest and 8 nests in burned forests. We obtained >28 hours of nestling provisioning video data from 9 nests during the peak of nestling growth that will allow for understanding whether food availability differs between burned and unburned forest. Of the BBWO nests we located, 16 of 18 were successful and fledged young; a single nest in each of the two forest types failed due to apparent predation, We captured, color-banded, took morphological measurements, and obtained blood samples from 17 chicks that originated from the 8 nests that were safe enough to support tree climbing. From this sample, we attached radio-tags to 7 juvenile woodpeckers in unburned forest and 3 individuals in burned forests and spent >215 person-hours tracking these individuals. Three radio-tagged birds underwent mortality 2-4 weeks after tagging (all due to apparent raptor predation), 1 bird removed its transmitter when still alive, and the other 6 individuals remained alive to the end of the tracking period (ending 3 Sept) and thus survived the dependent fledgling period to reach independence. Vegetation at nest sites and at locations were fledglings were found alive were also quantified to assess whether variation in habitat measures may be linked to survival rates.

One exciting avenue in which we plan to expand the project is to undertake telemetry flights to determine juvenile dispersal locations in late fall after tagging and then again in the following spring. These flights are provided free of charge through LightHawk (https://www.lighthawk.org/), a conservation organization that provides aerial support for conservation-based research projects. By undertaking these flights we expect to gain information regarding (1) juvenile overwinter survival, (2) dispersal between natal areas and breeding sites, and (3) the type of breeding habitat (burned or unburned) used by BBWOs relative to the habitat in which they are reared (burned or unburned). All of these topics are currently unknown for BBWOs inhabiting unburned forest, so this aspect of the project has the potential to significantly expand the project by leveraging resources obtained from funding groups (OSU, NCASI, ODF).

Problems and Barriers: Two challenges arose during 2018 field work that will likely reshape some components of field work in 2019. First, although a large number of occupancy surveys for woodpeckers were conducted, they required a significant amount of time in the field yet yielded only modest data. This was true even for our focal species (BBWO) despite using call playback surveys that increase detectability and serve as a standard survey technique for this species. We suspect this was due primarily to the low breeding density of BBWOs within unburned forests. In addition, occupancy surveys took a substantial amount of time away from nest searching efforts, and it appears that focusing on nest searching alone should help to increase beyond the sample sizes obtained in 2018. Given this finding, occupancy surveys are not planned for 2019 at the current time so that more time can be dedicated to nest searching efforts. The second challenge that arose was locating large areas of forest that experienced high-severity wildfire in recent years (<3 years) and was found within a reasonable driving distance from our base at the Chemult Ranger Station. We did undertake nest-searching for BBWO in the vicinity of the Pelican Fire, but that resulted in a 4-hour round trip that made for exceptionally long days for our field crew. No fires occurred closer to Chemult during summer 2018, so there appear to be limited opportunities for assessing breeding in burned forests closer to our base. Thus, we are working to determine whether housing/camping opportunities near the Pelican Fire can be procured for the 2019 field season so we can continue to quantify vital rates in burned forests, but it remains unclear if such resources are available.

Finally, we undertook an aerial telemetry flight with a LightHawk pilot in October 2018 and detected only a single radio tag in our study area, even though we placed out several stationary “test tags” on trees to quantify the accuracy of tag relocation from the plane. On further investigation, we learned that there was an issue with the radio tags we purchased that resulted in the batteries not extending as long as the warranty period. We have sent remaining tags to the manufacturer who is in the process of coming up with a solution. Although disappointing, this tag failure has not impacted our core study objectives, and we will have another opportunity to obtain pilot data on dispersal following the 2019 field season, assuming the tag manufacturer can remedy the issue.

Planned Work: Our planned work remains as outlined in our project proposal with respect to core study objectives. We will continue to quantify the vital rates of Black-backed Woodpeckers during the breeding season on established study sites by searching for nests, monitoring them for survival, and assessing the number of offspring produced. For the subset of nests that produce offspring and are safe to climb, we will remove offspring from nest cavities to attach VHF radio tags to quantify survival, movement, and habitat use during the juvenile period. In addition, we will quantify adult provisioning behavior from videos obtained during summer 2018-2019.

List of names and brief overview of graduate and/or undergraduate engagement in project: Four young professionals worked as research assistants on this project during the 2018 field season: Amanda Holland (OSU alum), Cameryn Brock, Brett Howland, and Meredith Kuzel. All four were interested in pursuing graduate school in the future and gained experience with a number of methods needed for working with breeding birds. In addition, we actively recruited undergraduate volunteers from the Louis Stokes Alliance for Minority Participation (LSAMP) Program at OSU but had limited success; however,

we were able to provide Mateo Garcia, a student in the program, with a research experience with tracking birds and quantifying habitat use of fledgling woodpeckers. Finally, we provided a demonstration of wildlife radio telemetry to the LSAMP Bridge Program at the start of the fall 2018 term, which included 55 underrepresented minority STEM students and 15 of their peer advisors. Students were instructed on the use of wildlife telemetry and were provided with hands-on experience to use telemetry equipment to locate hidden radio tags to simulate field work with this technique.

List of Presentations, Posters etc.: Rivers, J. W. 2018. Black-backed Woodpecker vital rates in unburned and burned forest within a fire-prone landscape: update from the 2018 field season. Oral presentation for the National Council for Air and Stream Improvement, Vancouver, WA.

List of Publications, Thesis Citations: Black-backed woodpecker vital rates in burned and unburned conifer forest within a fire-prone landscape. Anticipated for submission to *The Condor*.

Fish and Wildlife Habitat in Managed Forests

Progress Report

Title: How Do Riparian Forest Gaps Affect Macroinvertebrates and Fish Diet in Headwater Streams

Investigators: Dana Warren

Objectives:

We identified 3 goals in our proposal:

(1) Characterize macroinvertebrate community responses to riparian gap implementation
(2) Compare invertebrate communities to fish diets
(3) Determine if the gaps affect invertebrate IBI assessments of water quality.

Summary of Accomplishments toward Objectives:

We have collected macroinvertebrates before and after a gap experiment in each of four paired stream reaches using a before-after control-impact (BACI) study design. In the post-treatment year (2018) we also collected fish diet data from a minimum of 12 fish in each stream reach in 5 total stream pairs.

In spring 2018, the undergraduate student supported on this project sorted and identified macroinvertebrates from the pre-treatment sample collections (in summer 2017).

In summer 2018, the undergraduate student collected post-treatment invertebrate samples and fish diets. During the summer he finished 2017 benthic sample identification and started summer 2018 benthic sample identification

In fall 2018, benthic sample identification from the past summer was completed in four reach pairs, providing full before-after community assessments for 4 stream experimental gaps. Fish diet sorting and identification is ongoing. Preliminary data analysis has been completed on the overall community response to gaps but the focus here in the fall term has been on completing identifications. We will conduct analyses in the winter term and with these analyses, we will be able to address our study objectives. The student will write up results from this work as in his honors thesis during the winter and spring terms of 2019, and the thesis will explicitly include an assessments of all 3 of the above objectives.

Problems and Barriers:

Macroinvertebrate sample sorting and identification takes a long time. The extra time needed to complete the sorting and identification lead us to reduce the number of sites where we are conducting a full assessment of macroinvertebrates (from 6 to 4).

Planned Work:

As noted above, in the winter and spring of 2019, we plan to complete our analyses and write up results. The initial focus will be on writing an undergraduate honors thesis, but the thesis will be written in "paper format" with the explicit intention of later submission to a peer-reviewed journal.

List of names and brief overview of graduate and/or undergraduate engagement in project: [e.g., thesis, research experience for UG, etc.]

- This project is supporting one undergraduate student
  - Cedar Mackeness

List of Presentations, Posters etc.:

None yet, but Cedar plans to present his results on fish diet at the Oregon chapter of the American Fisheries Society.

List of Publications, Thesis Citations: [published or anticipated]

Anticipated:

Mackeness, C. Effects of canopy gaps on macroinvertebrate communities and fish diet in western Oregon stream ecosystem. OSU Honors college thesis