

Washington State Department of Natural Resources' Riparian Validation Monitoring Program for Salmonids on the Olympic Experimental State Forest – 2016 Annual Report



Published in 2017

Kyle D. Martens

Washington State Department of
Natural Resources, Forest Resources
Division

1111 Washington Street SE
Olympia, WA 98512



WASHINGTON STATE DEPARTMENT OF
NATURAL RESOURCES
PETER GOLDMARK | COMMISSIONER OF PUBLIC LANDS

This page left blank intentionally.

Scientific Advisory Group for Riparian Validation Monitoring:

Dr. Patrick Connolly – Research Fisheries Biologist, U. S. Geological Survey

Dr. Martin Liermann – Statistician (Biology), NOAA Fisheries

Dr. J. Ryan Bellmore – Research Fish Biologist, Pacific Northwest Research Station, U. S. Forest Service

Acknowledgements

DNR would like to thank Dr. Patrick Connolly of the USGS, Dr. Ryan Bellmore of the U.S. Forest Service’s PNW Research Station, Dr. Martin Liermann of NOAA Fisheries and Dr. Scott Horton (now retired) of DNR for their membership in the Scientific Advisory Group. Ellis “Sky” Cropper, Elizabeth “Lizzy” Monaghan and Caroline Walls for conducting the field work and date entry. Dr. Teodora Minkova of DNR for providing editing, guidance and managerial support on validation monitoring. Warren Devine of DNR for providing data management, editing, and field support of the project. Hannah Yourd for editing the report. Angus Brodie and Allen Estep of DNR for providing managerial support. Alex Foster for helping edit this report and assisting with snorkel surveys, Dr. Brooke Penaluna for allowing collaboration on her study using eDNA, and Dr. Rebecca Flitcroft of the for advising on the presence-absence models of the U. S. Forest Service Pacific Northwest Research Station.

Suggested Citation:

Martens, K. D. 2017. Washington State Department of Natural Resources’ Riparian Validation Monitoring Program for salmonids on the Olympic Experimental State Forest – 2016 Annual Report. Washington State Department of Natural Resources, Forest Resources Division, Olympia, WA.

Washington State Department of Natural Resources
Forest Resources Division
1111 Washington St. SE
Mail stop: 47014
Olympia, WA 98504
www.dnr.wa.gov

Acronyms and Abbreviations

AIC – Akaike’s Information Criterion

COH – Coho Salmon

CTT – Cutthroat Trout

DNR – Washington Department of Natural Resources

eDNA – Environmental DNA

HCP – Habitat Conservation Plan

IP – Intrinsic Potential

OESF – Olympic Experimental State Forest

ONP – Olympic National Park

SaSI – Salmonid Stock Inventory

STH – Steelhead/rainbow trout

Executive Summary

The purpose of the Riparian Validation Monitoring Program is to assess the salmonid response to the Riparian Conservation Strategy implemented by Washington State Department of Natural Resources (DNR) as part of the state lands Habitat Conservation Plan (HCP). The study goal is to document whether the strategy is achieving the desired outcome of maintaining or improving salmonid habitat and expressing stable or positive effects on salmonids. This program fulfills the agency's continual commitment for riparian validation monitoring in the HCP.

The program uses observational monitoring of 50 watersheds within the Olympic Experimental State Forest (OESF) and 4 reference watersheds in the neighboring Olympic National Park to monitor DNR type-3 watersheds of the OESF, as described in the monitoring study plan (Martens 2016). As not all of the 54 watersheds can be sampled within a summer, 20 watersheds will be sampled annually, while an additional 10 to 15 watersheds per year will be sampled on a 2 or 3 year rotation. Before sampling of the rotating panels begin, a 1-2 year methodology experiment is to be conducted to determine the best method for assessing salmon-habitat relationships. After all watersheds have initially been sampled, and on a six-year rotation thereafter, the status of salmonids on the OESF will be assessed to discover any potential effects from current DNR management practices. If any potential negative effects are found, an experimental study will be explored to assess the cause and effect relationships between current DNR management, stream habitat, and salmonids.

In 2016, DNR finalized a study plan (Martens 2016) and completed the first year of field work. Starting in August 2016, DNR conducted multiple-pass removal (n=17) and pool-only (n=7) juvenile salmonid abundance surveys in the annual panel of sampling watersheds to begin the assessment of OESF salmonid conditions and determine the best method for sampling in the watersheds. Exploratory snorkel surveys were also conducted in the Clearwater River Watershed to determine sampling sites and methods for sampling larger streams of the OESF. As a measure of adult abundance in the watersheds, adult coho redd surveys were conducted within all of the annual watersheds from November through mid-January. Finally, ten models were developed and evaluated using the data collected in 2015 and 2016 to estimate salmonid presence and absence in all DNR type-3 watersheds to understand how the 50 OESF watersheds represent salmonids across the entire population of OESF watersheds. This report covers activities performed by DNR from January through December 2016.

DNR sampling found wide variations in salmonid species assemblage, densities, biomass, and coho redd abundance throughout the OESF watersheds in 2016. Based on these results, DNR plans to: 1) start the planned sampling scheme using the annual (as a measure of year to year variability) and rotating panels of watersheds (as a measure of spatial variability) using multiple-pass removal; 2) continue adult redd monitoring as sampled in 2016; 3) conduct a snorkeling effort to collect information on both small and large fish within the mainstem Clearwater River that includes a channel unit/instream wood habitat survey; and 4) use the best salmonid presence and absence model (Combination model) to estimate salmonid species assemblages for all OESF type-3 watersheds and determine how each of the 50 OESF watersheds represents the entire population of OESF watersheds.

Table of Contents

Introduction.....	1
Study Area	2
Study Design	2
Monitoring conducted in 2016.....	4
<i>Results</i>	5
Juvenile Salmonid Methodology Testing	7
<i>Results</i>	10
Juvenile Salmonid Watershed Presence/Absence Models.....	11
<i>Results</i>	14
Discussion and Recommendations for 2017.....	16
<i>Discussion</i>	16
<i>Recommendations for the Riparian Validation Monitoring Program</i>	18
References.....	19

Figures

Figure 1 Map of the state lands of the OESF and 2016 monitoring locations.....	3
Figure 2 Salmonid abundance and biomass estimates from OESF watersheds sampled during the 2016 field season.	6
Figure 3 Coho redds found in OESF watersheds in 2016.	7
Figure 4 Diagram of sampling areas conducted for multiple-pass removal versus pool-only sampling.	8
Figure 5 Comparison of multiple-pass removal electrofishing to pool-only sampling within 7 OESF watersheds (reach to reach).	9
Figure 6 Comparison of fish densities between pool-only electrofishing over the habitat reaches to pool-only sampling over the entire fish-bearing distribution of a stream (reach to stream).	11
Figure 7 Evaluation of Intrinsic Potential (IP) model and WDFW SASI data to determine species presence and absence in in OESF watersheds.....	12
Figure 8 Leave one out validation of the combination model for determining species presence and absence in OESF watersheds.	15
Figure 9 Map of expected fish species assemblages in DNR type-3 watersheds in the OESF with >50% state lands using the combination model.....	16

Tables

Table 1. The percent that each model correctly predicted the species presence of absence in OESF basin based on leave-one-out model validation.....	14
---	----

Introduction

The Riparian Validation Monitoring Program was designed to meet Washington State Department of Natural Resources' (DNR) commitment for Riparian Validation Monitoring as described in the state lands Habitat Conservation Plan (HCP). The HCP allows for the long-term certainty in forest management (primarily timber harvest) through an incidental take permit under the Endangered Species Act (DNR 1997). The primary goal of Riparian Validation Monitoring Program is to determine if the Riparian Conservation Strategy is meeting the desired outcome of maintaining or improving salmonid habitat and expressing stable or positive effects on salmonids. The objective of Validation Monitoring in the HCP is "to evaluate cause-and-effect relationships between habitat conditions resulting from implementation of the conservation strategies and the animal populations these strategies are intended to benefit" (DNR 1997). Validation Monitoring is the most complex and difficult of the three types (implementation, effectiveness, and validation) of monitoring required under the HCP. While DNR is committed to conduct validation monitoring on spotted owls, marbled murrelets and salmonids, Riparian Validation Monitoring (salmonids) is currently the only type of validation monitoring being conducted.

Additional benefits to DNR from Riparian Validation Monitoring:

- Increases knowledge, confidence, and flexibility in DNR management practices.
- Provides current information on salmonid conditions in the OESF that may alleviate the perception that DNR lands are negatively impacting salmonids on the Olympic Peninsula (Smith 2000; WRIA 21 Lead entity 2011).
- Supplies information for DNR models such as those used in the OESF Environmental Impact Statement or forest land plan that were designed to predict future habitat conditions under different management alternatives.
- Monitors the effects of climate change on salmonids in the Pacific Northwest.
- Establishes stronger relationships with natural resource agencies, departments, and tribal nations.

This report covers activities performed by DNR from January through December 2016. In 2016, the first year of monitoring under the Riparian Validation Monitoring study plan (Martens 2016), DNR conducted 1) population surveys to determine juvenile salmonid densities (fish/m) and biomass (g/m^2) estimates in 17 of the 20 watersheds from the annual panel of sites; 2) a methodology experiment (year one of potentially two) to determine the best approach for assessing juvenile salmonid-habitat relationships in the OESF; 3) adult redd surveys; and 4) snorkel surveys in the larger DNR type-1 or type-2 areas of the Clearwater River Watershed. In addition, a model was developed to predict salmonid species presence and absence for all watersheds of the OESF.

Study Area

The OESF covers a conglomeration of 270,000 acres of state lands managed by DNR throughout the western side of the Olympic Peninsula in Clallam and Jefferson counties of Washington State (Figure 1). It is bordered by the Pacific Ocean to the west, the Strait of Juan de Fuca to the north, and the Olympic Mountains to the east and south. The OESF experiences large quantities of rainfall mostly in the spring, winter, and fall with precipitation averaging between 84 to 170 inches per year (<https://www.nps.gov/olym/planyourvisit/weather.htm>), and supports a diversity of landscapes ranging from low gradient valleys to steep mountains with elevations ranging from sea level to 3,400 ft. OESF forests mostly contain western hemlock mixed with some Douglas fir and western red cedar, but also areas of Sitka spruce near the coast and Pacific silver fir in higher elevations. Much of the OESF is now dominated by younger tree stands (0-50 years old) with patches of old growth forest preserved across the landscapes.

State lands of the OESF contain over 2,700 miles of streams including portions of several major rivers such as: the Queets, Clearwater, Hoh, Bogachiel, Calawah, Sol Duc, Quillayute, Dickey, Ozette, Sekiu, Hoko, Clallam, and Pysht (DNR 2013). The majority of fish-bearing streams are classified as DNR Type-3 streams (segments of natural waters that are not classified as Type 1 or Type 2 water and have a moderate to slight fish, wildlife, and human use) and have been found to contain summer populations of juvenile coho salmon (*Oncorhynchus kisutch*), rainbow trout/steelhead (*O. mykiss*), coastal cutthroat trout (*O. clarkii clarkii*), lampreys (*Lampetra* spp.) and/or sculpins (*cottus* spp.; Martens 2016). Other species that have been documented in the past or are assumed to occur within the streams or lakes of the OESF include: sockeye salmon (*O. nerka*), pink salmon (*O. gorbuscha*), chum salmon (*O. keta*), Chinook salmon (*O. tshawytscha*), bull trout (*Salvelinus confluentus*), mountain whitefish (*Prosopium williamsoni*), dace (*Cyprinidae* spp.), minnows (*Phoxinus* spp.), and suckers (*Catostomus* spp.; DNR 2013).

Study Design

Monitoring will initially follow an observational approach that will assess patterns of salmonid abundance over the entire OESF and potentially detect management practices that could be negatively impacting salmonids. After all watersheds have been sampled at least once, and on six-year rotations thereafter, information will be assessed to determine the need for more comprehensive experimental studies. These experimental studies, if needed, will likely be arranged within or partially within the network of existing watersheds. In addition, the program will continuously look for opportunities either within the existing network of status and trends watersheds (Minkova et al. 2012), DNR planned harvests, or in coordination with other operational studies conducted on DNR lands to add experimental studies.

This program uses the 50 OESF and 4 reference watersheds in the Olympic National Park that have been monitored as part of the Status and Trends Monitoring of Riparian and Aquatic Habitat program since 2012 (Figure 1; Minkova et al. 2012; Minkova and Devine 2016). The 50 monitored OESF watersheds were selected to be representative of the OESF: a stratified random

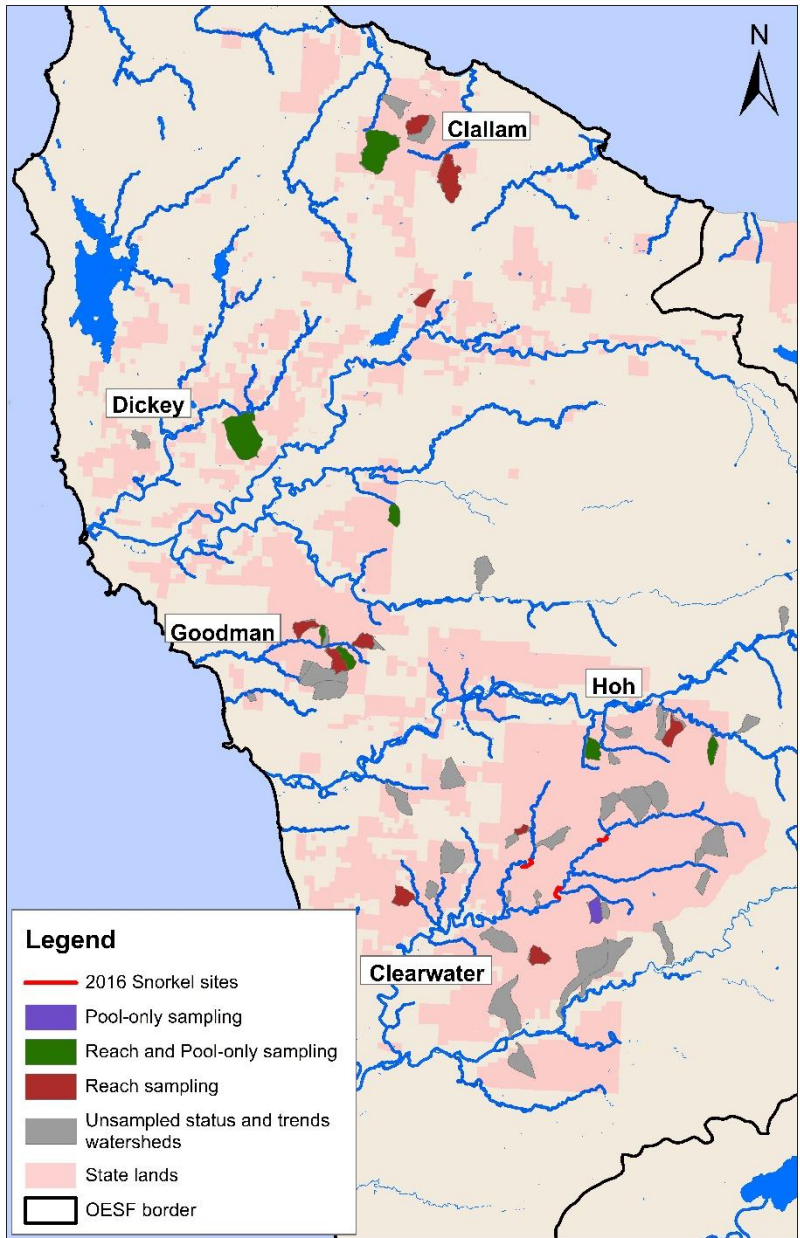


Figure 1 Map of the state lands of the OESF and 2016 monitoring locations

sampling approach, that designated strata according to the median slope value in each watershed, was applied to all type-3 watersheds in the OESF that contained at least 50 percent DNR ownership. Five of these watersheds were removed from riparian validation monitoring sampling after initial sampling in 2015 (due to fish barriers or sampling difficulties), while one (694) was re-added in 2016 after fish presence was discovered despite previous electrofishing efforts that had concluded that there were no fish present. The selection of the four reference watersheds used different criteria: mainly ease of access and ecological conditions close to the OESF sample. There are currently 46 OESF watersheds and 4 reference watersheds used for riparian validation monitoring. As not all watersheds can be monitored within a year, watersheds will be

sampled on a rotating basis with 20 sites monitored annually and the remaining 30 sites sampled using a two (15 additional sites) or three year (10 additional sites) rotation, resulting in a total of 30 to 35 sites sampled per year. During the first one or two years of monitoring, juvenile salmonid sampling will only be conducted in the annual panel of watersheds (20) using two sampling techniques to determine the best method for assessing juvenile salmonid-habitat relationships. In addition, adult redd surveys will be conducted to determine the number of coho adults spawning in the annual panel of watersheds and snorkel surveys will be developed and conducted in larger portions of the Clearwater River to assess juvenile and adult use of larger waters (DNR Type-1 or 2 streams). Finally, in 2016, DNR collaborated with the U. S. Forest Service Pacific Northwest Research Station to collect water samples within a portion of the watersheds for environmental DNA (eDNA) analysis as part of a broader multi-state (Washington, Oregon and California) study that will help to identify most of the aquatic species (fish, amphibians, and macroinvertebrates) in the watersheds (<https://www.fs.fed.us/pnw/lwm/aem/people/penaluna.html>).

Monitoring conducted in 2016

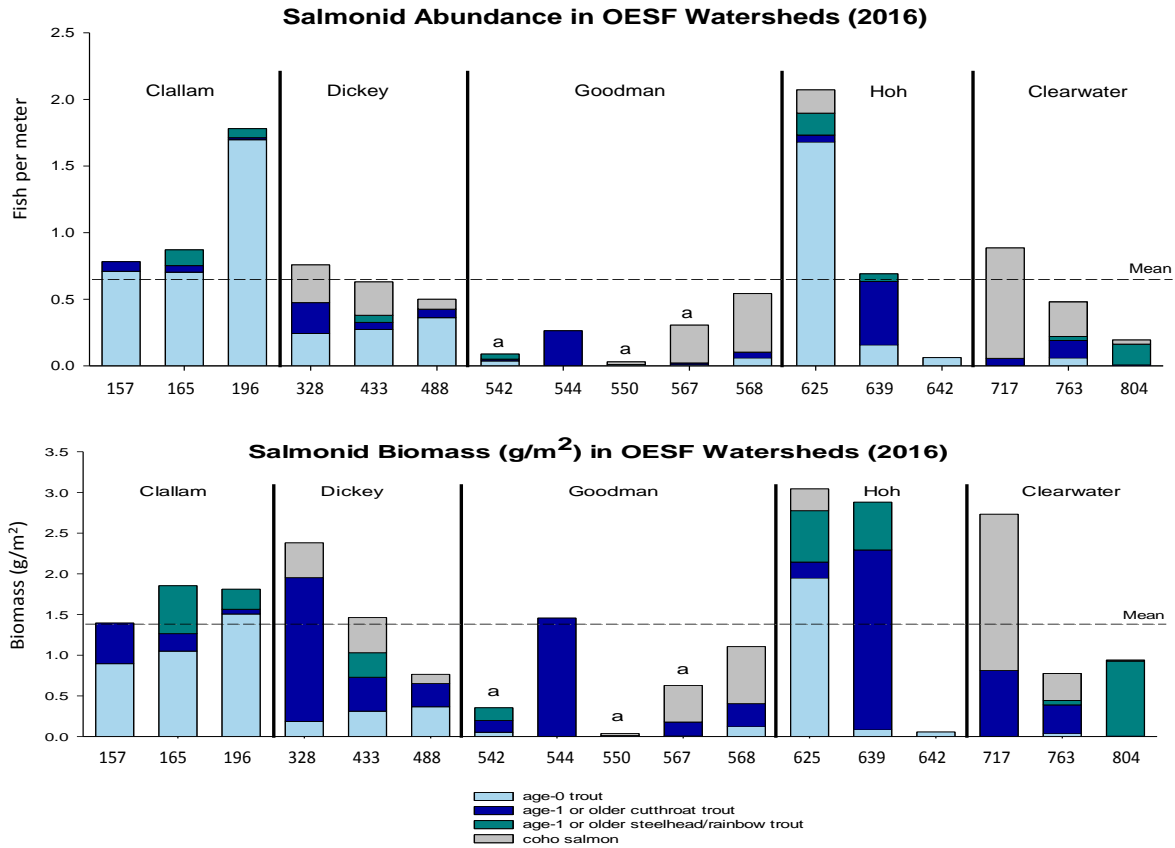
In 2016, juvenile sampling was designed to collect initial population level data from the 20 annually sampled watersheds, as well as to conduct an experiment using two methodologies to describe the populations of salmonids within each watershed (see “Juvenile Salmonid Methodology Testing” section below). Field crews sampled 17 watersheds using multiple-pass removal electrofishing within the previously established habitat reaches (i.e., 100m to 190 m), with 7 of the watersheds resampled using a pool-only methodology developed by Gresswell et al. (2006). A pool habitat unit is defined as a slow-moving, channel-spanning unit with uniform flow that would hold water if flow were turned off. Habitat reach lengths were either the equivalent of 20 bankfull widths, or a minimum of 100 m long starting above the 100-year flood plain of the mainstem stream into which it flows (Minkova and Devine 2016). Multiple-pass removal surveys were conducted over the entire habitat reach with block nets placed at the beginning and ends of the habitat reaches. Backpack electrofishing was then conducted over the entire habitat reach moving from the bottom of the reach to the top of the reach and then back down. The field crew would repeat each pass (i.e., bottom to top and back down) between 3-6 times using the charts from Connolly (1996) to ensure the required precision of the estimate. In the pool-only methodology, backpack electrofishing was conducted in each pool (forward and backward pass without block nets) starting from the mouth and moving upstream through the entire fish-bearing distribution, including the habitat reach. Channel unit habitat surveys were conducted alongside both the multiple-pass removal and pool-only methods. These surveys identified channel units based on the field guide of Minkova and Vorwerk (2015) and measured each unit for length (m), wetted width (m), average depth (cm), and maximum depth (cm) and visually estimated fish habitat within each pool. In addition to the work outlined in the study plan, DNR filtered water samples from 14 of the watersheds as part of a collaboration with the U. S. Forest Service Pacific Northwest Research Station for eDNA analysis.

Adult coho redd surveys were conducted in all of the 20 annual panel watersheds in which juvenile coho were found during sampling in 2015 (Martens 2016) or 2016 as a measure of adult abundance within the watersheds. Surveys were initiated during the first week of November and lasted through mid-January following the methods from Washington Department of Fish and Wildlife. Each stream was surveyed three times, once each in November, December, and January.

Downstream snorkel surveys were conducted in the larger waters (DNR type-1 or 2) of the Clearwater River Watershed, in which two snorkelers swam side by side following the methods of Thurow (1994). The goal of the surveys was to count larger fish (>200 mm) and get a relative abundance of smaller fish in the larger streams and rivers of the OESF that are not accounted for within the 50 OESF DNR type-3 watersheds. Exploratory snorkeling surveys found that access to portions of the Clearwater River Watershed was difficult. As a result, only three 1-kilometer sections (one in the Snahapish River, and two in the upper portions of the mainstem Clearwater River; Figure 1) were completed in 2016. This initial work was conducted to explore the watershed and help develop a more rigorous method for future sampling.

Results

Fish abundance and biomass estimates from multiple-pass removal revealed a broad range of fish densities (fish/m) and biomass (g/m^2) within the OESF in 2016 (Figure 2). Several smaller watersheds (DNR type-3) located in the Goodman Watershed went dry in both 2015 (Martens 2016) and 2016 and as a result had low fish abundance and biomass. Watersheds 328, 544 and 639 had relatively higher biomass when compared to the other watersheds, even though they had low to average fish densities. Coho salmon were not found in any of the type-3 watersheds of the Clallam Watershed in 2016, but were found in 2015 during exploratory sampling. Juvenile steelhead were present in more of the watersheds in 2016 than in 2015 (Martens 2016). Data collected from three studies (Edie 1975; Lestelle 1978; Martin 1985) conducted over multiple years in the 1970s or '80s in unlogged watersheds, showed that the average juvenile fish densities in those studies were higher (by 33 fish per 100 m) than the densities that were found in 2016. While data from the '70s and '80s studies could be used as reference conditions before logging, there is an expectation of high year to year variability within salmonid metrics and several more years of sampling will be needed before any confidence will be attained in the degree of salmonid changes or the causes of any potential differences.



^a These streams lost surface flow connection during the summer and were resampled after reconnection in the fall

Figure 2 Salmonid abundance and biomass estimates from OESF watersheds sampled during the 2016 field season.

Coho redd numbers were generally small (< 5 total redds), with the largest number of redds found in the Dickey Watershed (Figure 3). Four watersheds in which juvenile coho had been found in either 2015 or 2016 did not contain coho redds in 2016. In 2017, redd numbers will be used to see if there are any correlations between coho redd numbers and juvenile fish densities.

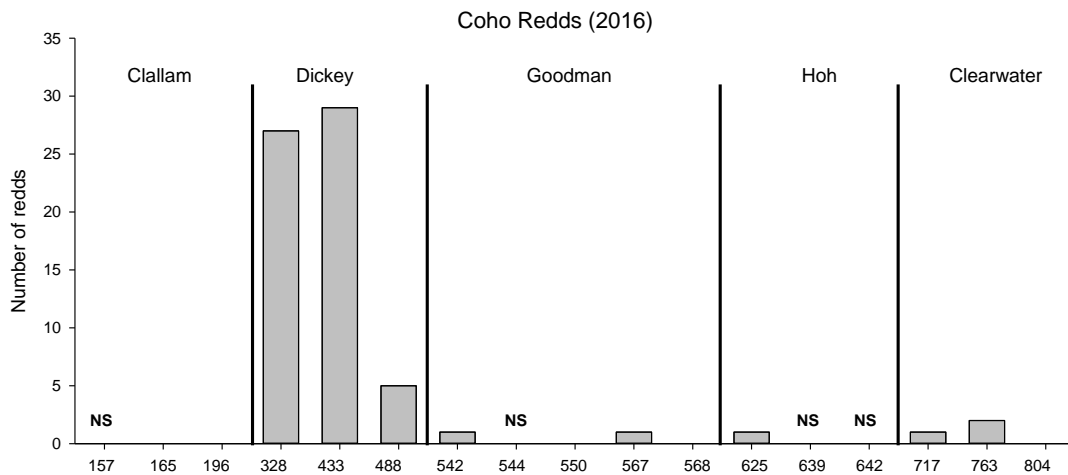


Figure 3 Coho redds found in OESF watersheds in 2016. NS= not surveyed

In the two mainstem Clearwater River snorkel sections, mountain whitefish, juvenile and resident cutthroat, and juvenile and resident steelhead/rainbow trout were found in pools when habitat was present, especially instream wood. The Snahapish River section contained more consistent numbers of juvenile coho and steelhead compared to the two sections in the mainstem Clearwater River, though these surveys were only designed to count the larger resident fish and migrating adult salmon but only the relative abundances of smaller juvenile fish (<200 mm). No mountain whitefish were detected in the upper portion of the Snahapish River and no bull trout were found in either the Snahapish or mainstem Clearwater rivers.

Juvenile Salmonid Methodology Testing

In 2016, DNR conducted the first of potentially two years of methodology testing to determine the best method for assessing juvenile salmonid-habitat relationships (Martens 2016). The goal of this testing was to determine 1) how pool-only sampling would estimate fish abundance and biomass compared to the more rigorous multiple-pass removal sampling (reach to reach comparison) and 2) how estimates of fish densities at the habitat reach level would describe fish densities over the entire stream (reach to stream comparison). In the first comparison (reach to reach), the total number of fish estimated using multiple-pass removal surveys was compared to the number of fish collected from pool-only sampling within the existing habitat reaches. For the second comparison (reach to stream), the average fish density from all pools using the pool-only method within the habitat reaches was compared to the average density of fish in all pools over the entire fish-bearing distribution (Figure 4). These comparisons were evaluated for accuracy, the number of sites that could be sampled in a season, the amount of habitat data available per method, and the ability to assess juvenile salmonid-habitat comparisons.

Multiple-pass removal used a variable-pass technique (3-6 passes) to ensure high precision while limiting the number of electrofishing passes to the minimum amount needed to achieve the required precision. Backpack electrofishing closely followed the methods outlined in Martens and Connolly (2014). These surveys were conducted over the existing habitat reaches used in the Status and Trends Monitoring of Riparian and Aquatic Habitat Program (Minkova and Devine 2016). The pool-only surveys started at the mouth of each stream, sampled through each habitat reach to allow for the reach to reach comparisons, and continued over the fish-bearing distribution of the stream. This pool-only sampling was conducted with a backpack electrofisher, sampling every pool and cascade (a high gradient [$>7.5\%$] confined channel that often includes small partial channel-spanning pools; Montgomery and Buffington 1997), following the methods of Gresswell et al. (2006). Channel habitat unit surveys accompanied both the pool-only and multiple-pass removal surveys. These surveys identified habitat units and their dimensions following the protocol of Minkova and Vorwerk (2017). This sampling was planned in all 20 annual sampling watersheds, with the understanding that it was likely to be reduced based on the amount of time required to sample each watershed.

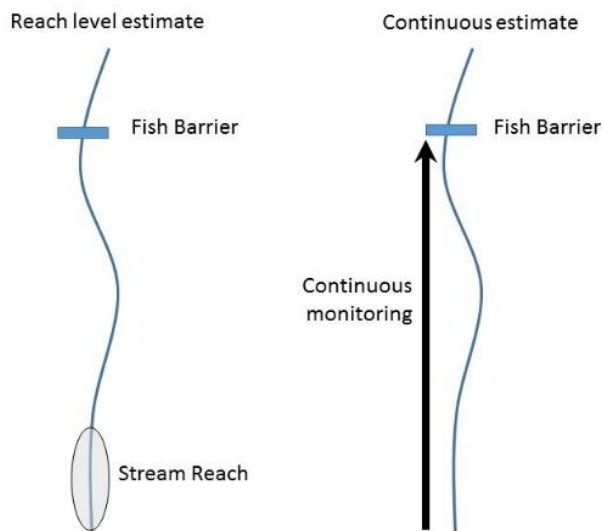


Figure 4 Diagram of sampling areas conducted for multiple-pass removal versus pool-only sampling.

In 2016, field crews were able to sample 17 watersheds using multiple-pass removal and 7 watersheds using the pool-only method. The number of watersheds available for species comparisons was further reduced as not every species was present within each of the comparison watersheds. Linear regressions were used to determine the relationships between multiple-pass removal and pool-only sampling within the habitat reaches (reach to reach comparison) and for

pool-only sampling in the habitat reaches to the pool-only sampling over the streams (reach to reach comparison).

All but one of the multiple-pass removal surveys were conducted in one day using a three-person crew (one survey was conducted over two days due to equipment problems), while the mean number of days to sample a stream using the pool-only method was 2.8 days with the same three-person crew (this includes two streams that could not be finished by the end of the field season). Using a three month field season of 52 sampling days (assumes no holidays, meetings, required trainings, injuries, equipment failure, or bad weather that prevents sampling; July 15th to

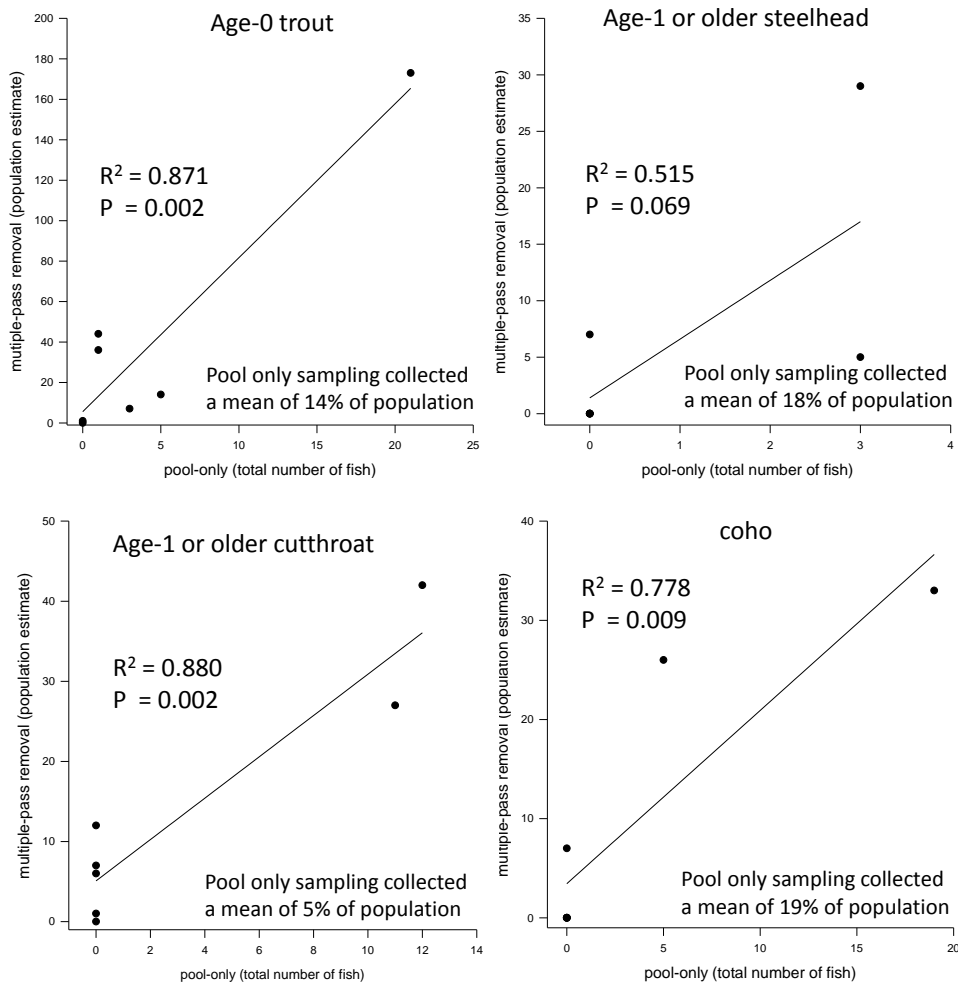


Figure 5 Comparison of multiple-pass removal electrofishing to pool-only sampling within 7 OESF watersheds (reach to reach).

October 15th), would allow for 52 sites sampled with multiple-pass removal surveys or 19 sites sampled using the pool-only sampling method (14 sites in 2016). In 2016 (August through October), the actual amount of sampling days were reduced to 38 due to crew injuries, equipment failures, and bad weather operating under a four-day 10-hour work week. Based on

2016, using the pool-only method and the current plan of 20 annual sites plus an additional 10 or 15 rotating sites (2 or 3 year rotating panel) would require around 84 or 98 days to complete.

Results

The reach to reach comparison revealed a significant relationship ($P < 0.05$) for all species except for steelhead in 2016 and for all species if the significant requirement was relaxed to <0.10 (Figure 5). While there was a significant relationship for most groups, pool-only sampling collected less than 20% of the population compared to multiple-pass removal sampling. Since the relationships were significant, there is a possibility of using multiple-pass removal to expand the pool-only data, though this would result in a further increase in the number of days required for sampling within the limited summer field season. The habitat reach to stream comparisons found no significant differences between densities from the habitat reach (pool-only) to the densities from the entire fish-bearing stream (pool-only sampling; Figure 6), though there were patches of higher and lower densities throughout the stream. There were no attempts to adjust the pool-only population numbers based on differences found between methods in the reach to reach comparison, since the amount of time required to complete both methods would further reduce the number of watersheds sampled per year which would ultimately reduce the ability to make inferences over the entire OESF.

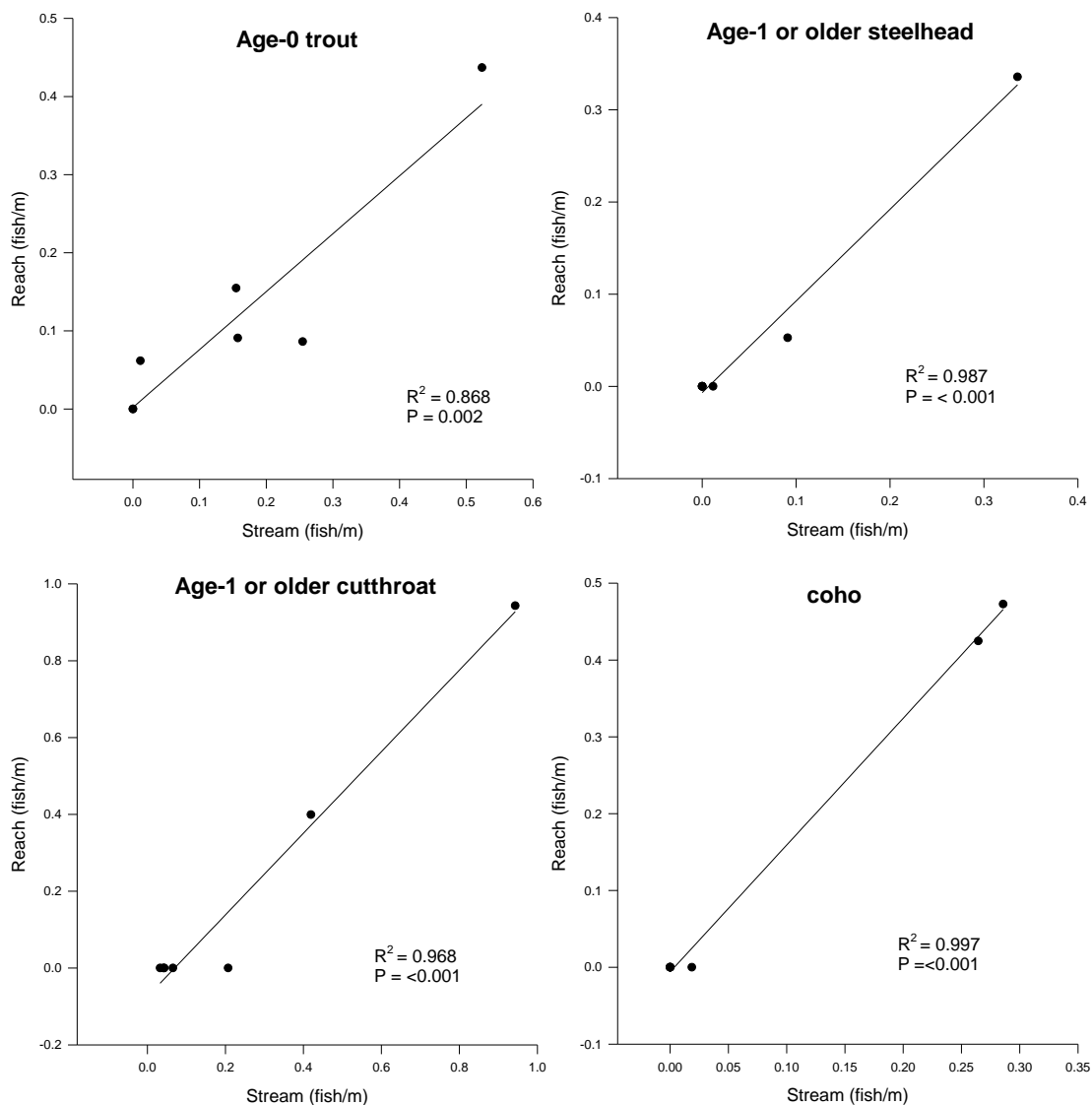
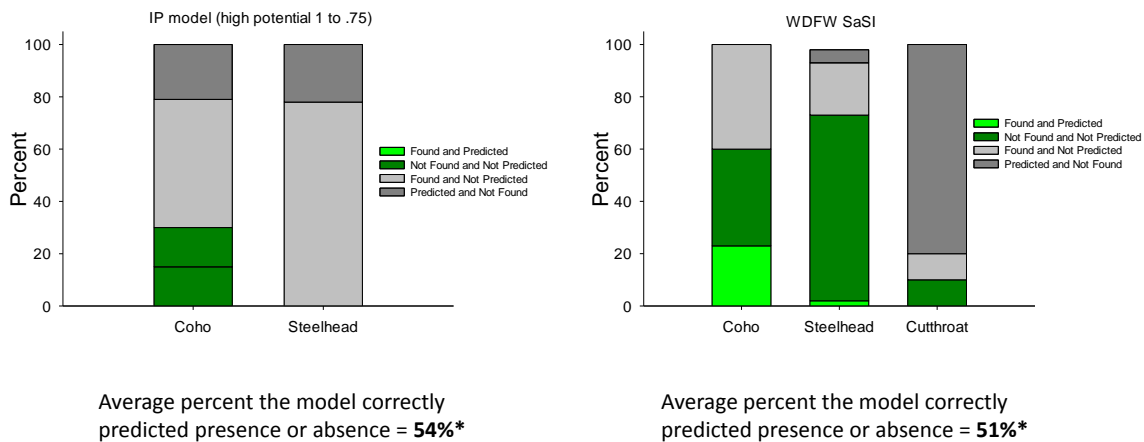


Figure 6 Comparison of fish densities between pool-only electrofishing over the habitat reaches to pool-only sampling over the entire fish-bearing distribution of a stream (reach to stream).

Juvenile Salmonid Watershed Presence/Absence Models

Since the 50 OESF monitoring watersheds were selected based on the median watershed slopes, estimates of salmonid assemblages for every watershed within the OESF were needed to determine how the 50-watershed sample represents the entire population of OESF watersheds (243) in relation to salmonid presence or absence. After exploratory sampling in 2015 and examining potentially useful existing information on species distribution (Intrinsic potential models [IP; Burnett et al. 2007] and WDFW's SaSI layers), it was discovered that existing data could only predict species presence and absence around 50% of the time (Figure 7).

Furthermore, since steelhead were found in 23% of the watersheds in 2015, one would expect to find the absence of steelhead in 77% of the watersheds assuming that 2015 sampling was representative of all watersheds within the OESF. With fairly low confidence in the existing data on species occurrence, improved models were needed to predict species assemblages over OESF watersheds.



* Data was compared to fish sampling results in 2015

Figure 7 Evaluation of Intrinsic Potential (IP) model and WDFW SASI data to determine species presence and absence in in OESF watersheds.

Using species presence and absence data from 2015 and 2016, and readily available DNR GIS derived metrics of watershed conditions, ten potential models were developed for predicting species presence and absence. Individual species models were run separately for coho, cutthroat, and steelhead (all of the salmonids found in OESF type-3 watersheds during sampling 2015 and 2016) and species assemblage models were run for coho, cutthroat, and steelhead; cutthroat and steelhead; coho and cutthroat; coho only; and cutthroat only (the only species assemblage combinations found in the streams of the OESF). Since all of the models predict the probability (0-100%) that a fish species or species assemblage occurs in a watershed, a set cut-off level was needed to determine whether a fish species was present or absent in each watershed. As this cut-off is fairly arbitrary and could change whether a species was present or not in a watershed, two cut-off levels (50% and 75%) were evaluated (e.g. when using the 50% cut-off, if a species had a probability of occurrence of 49% it would be considered absent within a watershed, but if the probability of occurrence was 50% than it would be considered present). Using the species assemblage method, prediction of species assemblages were limited to only species assemblages that were found in OESF in 2015 or 2016 and may account for potential impacts that one species may have on another. With the species assemblage models, the fish presence was determined by

the model with the highest probability of occurrence (e.g. if the model of coho and cutthroat had a higher probability than the model with coho, cutthroat and steelhead, than only coho and cutthroat would be predicted to be present in the watershed). An initial list of 21 metrics was trimmed down to 12 metrics (5 geophysical metrics and 7 land management metrics) to remove metrics that were highly correlated ($r > 0.7$) and therefore would have been redundant. Geophysical metrics evaluated included area, median watershed slope, minimum elevation, the number of stream nodes (intersections between two streams) within a watershed, and percent of volcanic sediment; while land management metrics included percent of DNR land; percent of area harvested between 1985-1999, percent of area harvested between 2000-2016, percent of area harvest from 2012-2016, percent of area in long deferral from harvest, road density, and the number of road crossings. Geophysical and land management metrics for each species or species assemblage and model type were selected based on the combinations of metrics that produced the lowest Akaike's Information Criteria value (AIC; Burnham and Anderson 2003). Based on the 10 models and the combination of geophysical (5) and land management (7) metrics evaluated within each model, 930 potential combinations were run and evaluated for each species and species assemblage (8) resulting in a total of 7,440 combinations being assessed. Accuracy of the ten final models for each species or species assemblage (after the metrics of the individual models were determined) were then evaluated using leave-one-out validation, where each model was run repeatedly leaving one data point out for each repetition to evaluate the predicted result to what was found in the watershed. Using leave-one-out validation, each final model was run 38 times (fish data was available in 38 watersheds) using 37 data points to recreate the top model with a different watershed left out for each run to compare the model prediction (for the one watershed left out) to what was found in the watershed during sampling. This allowed the model to be evaluated over all 38 watersheds without collecting any new data.

Models

- Model 1 (Individual, Logistic, 50% probability, geophysical metrics) – Independent species logistic regression models using only watershed metrics with a greater than 50% chance of occurrence
- Model 2 (Individual, Logistic, 75% probability, geophysical metrics) – Independent species logistic regression models using only watershed metrics with a greater than 75% chance of occurrence
- Model 3 (Assemblage, Logistic, geophysical metrics) – Fish assemblage logistic regression models using only watershed metrics, the model with the highest chance of occurrence was selected
- Model 4 (Individual, Logistic, 50% probability, all metrics) – Independent species logistic regression models using all metrics with a greater than 50% chance of occurrence
- Model 5 (Individual, Logistic, 75% probability, all metrics) – Independent species logistic regression models using all metrics with a greater than 75% chance of occurrence
- Model 6 (Assemblage, Logistic, all metrics) – Fish assemblage logistic regression models using all variables, the model with the highest chance of occurrence was selected

- Model 7 (Individual, ANN, 50% probability, geophysical metrics) - Independent artificial neural network models using only watershed metrics with a greater than 50% chance of occurrence
- Model 8 (Assemblage, ANN, geophysical metrics) – Fish assemblage artificial neural network models using only watershed metrics, the model with the highest chance of occurrence was selected
- Model 9 (Individual, ANN, 50% probability, all metrics) – Independent species artificial neural network using all variables with a greater than 50% chance of occurrence
- Model 10 (Assemblage, ANN, all metrics) – Fish assemblage artificial neural network models using all metrics, the model with the highest chance of occurrence was selected

Results

All ten models estimated species presence or absence correctly in over 62% of the watersheds (Table 1). Model 1 was the most accurate model for determining coho presence or absence (82%). Cutthroat presence or absence was highest in models 3, 6, and 8 (93%). Model 8 was determined to be the best of the three models in predicting both presence and absence of cutthroat, while models 3 and 6 could only predict presence. Model 8 was also the best model (77%) for predicting steelhead presence and absence. Creating a final combination model using model 1 for coho and model 8 for cutthroat and steelhead resulted in an average of 84% success in predicting species presence or absence using leave-one-out validation (Figure 8 and Figure 9).

Table 1. The percent of the time that each model correctly predicted each species’ presence or absence in OESF watersheds based on leave-one-out model validation.

Model	Coho	Cutthroat	Steelhead	Average
1	82%	91%	72%	81%
2	70%	88%	70%	76%
3	74%	93%	65%	78%
4	81%	91%	70%	81%
5	81%	88%	70%	76%
6	70%	93%	65%	82%
7	74%	90%	68%	77%
8	77%	93%	77%	82%
9	74%	88%	69%	77%
10	65%	88%	63%	74%
Combination	82%	93%	77%	84%

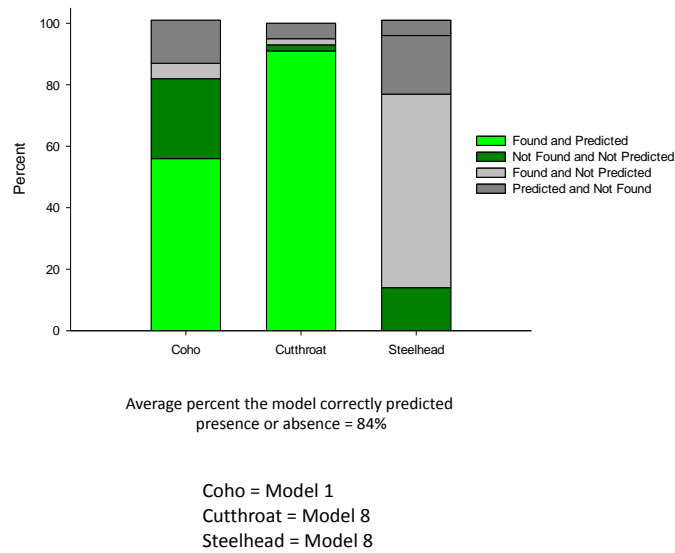


Figure 8 Leave one out validation of the combination model for determining species presence and absence in OESF watersheds.

After model evaluation, models that used a >50% probability of occurrence cut-off for predicting presence and absence were either more accurate or equal to the models that used a >75% probability of occurrence cut-off. The species assemblage models versus the individual species models produced mixed results between the watersheds, though using the highest probability of occurrence between all possible species assemblages (species assemblage method) may be better than trying to determine a specific cut-off (e.g. >50 or >75%) when determining presence or absence (individual species models). There were no clear advantages of using logistic regression or ANN, with the best coho model using logistic regression and the best cutthroat and steelhead models using ANN. Model accuracy followed the percentage of species found within the watersheds (cutthroat = 82% of watersheds, coho = 62% of watersheds, and steelhead = 23% of watersheds) in 2015, as cutthroat were the most often present species in the OESF followed by coho and then steelhead. As such, it was easier to predict steelhead absence and cutthroat presence, since steelhead absence and cutthroat presence were likelier to occur in each watershed.

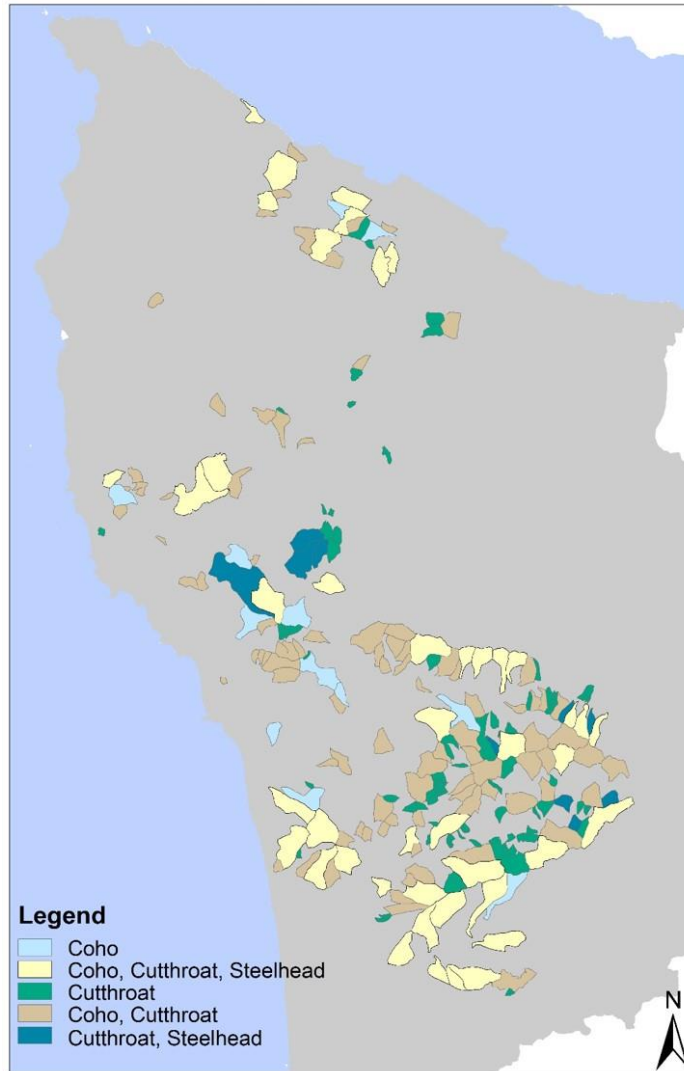


Figure 9 Map of expected fish species assemblages in DNR type-3 watersheds in the OESF with >50% state lands using the combination model.

Discussion and Recommendations for 2017

Discussion

In 2016, DNR sampling found wide variations in salmonid species assemblage, densities, biomass, and coho redd abundance within OESF watersheds. Age-1 or older steelhead and cutthroat densities were lower than the densities of age-0 trout in all but one of the watersheds. Since steelhead and cutthroat typically don't migrate until they spend two years, and as many as seven years, in freshwater (Wydoski and Whitney 2003; Peven et al. 1994), this could be an indication of a within watershed migration sometime after the fish's initial summer in DNR type-3 watersheds. This potentially may be due to a lack of winter habitat, low year to year survival,

or a combination of both. It is currently unknown what the cause of this reduction is or whether an early migration would result in lower or higher adult returns. A few DNR type-3 watersheds within the Goodman Watershed have gone dry two years in a row either forcing fish movement or reducing survival of salmonids within these watersheds. Overall, juvenile fish densities found in 2016 (n=17) were lower (by 33 fish per 100 m) compared to similar sized unlogged watersheds (n=4) studied for 2-3 years in the 1970's and 80's (Edie 1975; Lestelle 1978; Martin 1985). Watersheds will be monitored into the future to see if these preliminary observations are part of a larger pattern, or are due to expected high levels of year to year and site variability typically found with salmonids. It will take time to effectively assess the current condition of salmonids on DNR land in the OESF and a much larger timeframe (>10 years) to distinguish effects of current DNR management practices from the potential lag effects of past management practices, climate change, or other forces such as ocean conditions and fish harvest outside of state land.

Initial juvenile methodology testing found that pool-only sampling would take 2.8 times as many days as multiple-pass removal per watershed. In addition, while pool-only sampling was significantly correlated with multiple-pass removal population estimates, it produced less than 20% of the amount of fish when compared with the population estimate from multiple-pass removal. Initial results found a strong relationship in fish density estimates from sampling in the habitat reaches near the mouth of streams compared to sampling over the entire fish-bearing portion of the watersheds. Due to the amount of time required to conduct pool-only sampling, the low percentage of fish collected, and the relationship between stream density estimates to the habitat reach density estimates, DNR will sample all watersheds using multiple-pass removal electrofishing within the habitat reaches. In addition, DNR may attempt to conduct single-pass electrofishing without block nets in upstream reaches to better understand longitudinal differences in fish densities within streams between years (if timing allows).

The Riparian Validation Monitoring Program plans to use the combination presence and absence model since it was able to predict species presence or absence in 84% of the cases based on leave-one-out validation. This model will be used to predict species occurrence for the total population of the watersheds within the OESF. If time permits, randomly selected watersheds outside of the 50 OESF monitoring watersheds will be sampled to further validate this model. Since the watersheds were originally selected based on a habitat metric (median slope; Minkova et al. 2012) and not based on the fish species or species assemblages found in the watersheds, the current allocation of watersheds may be unbalanced for sampling the fish species of the OESF which could result in certain species being under sampled (or not sampled) within the current sampling scheme. This model will help to identify the degree to which individual watersheds represent the entire population of watersheds across the OESF and weigh each watershed based on how it represents the entire population of watersheds in the OESF. These weights can be used to extrapolate information collected from the 50 watersheds to the entire population of watersheds. If a portion of OESF watersheds are not represented or are underrepresented in the current sample of 50, new watersheds may be added to the sample to better represent the watersheds of the OESF.

Recommendations for the Riparian Validation Monitoring Program

- Begin sampling in mid-July rather than early August to take advantage of better weather conditions to ensure a longer sampling season.
- Continue with the planned sampling scheme using annual (as a measure of year to year variability) and rotating panels of watersheds (to increase sample size and thus power to capture spatial variability).
- Add watershed 694 back in to the sampling watersheds based on finding that salmonids were in the watershed.
- Continue with existing redd surveys.
- Concentrate snorkeling efforts on a larger reach within the mainstem Clearwater River, recording both counts of large and small fish, and use a third volunteer to take individual channel unit habitat measurements and count instream wood.
- End the methodology sampling experiment after the summer of 2016 and start sampling of the rotating panels in 2017.
- Use the combination presence and absence model to predict species assemblage for all DNR type-3 OESF watersheds. If time allows, sample OESF watersheds outside of the 50 study watershed sample to further validate the model.

References

- Burnett, K.M., G. H. Reeves, D. J. Miller, S. Clarke, K. Vance-Borland, and K. Christiansen. 2007. Distribution of salmon-habitat potential relative to landscape characteristics and implications for conservation. *Ecological Applications* 17(1):66-80.
- Burnham, K. P., and D. R. Anderson. 2003. *Model Selection and Multimodel Inference: a Practical Information-theoretic Approach*. Springer Science & Business Media.
- Connolly, P. J. 1996. Resident Cutthroat Trout in the Central Coast Range of Oregon: Logging Effects, Habitat Associations, and Sampling Protocols. Doctoral Dissertation. Oregon State University. Corvallis, Oregon.
- Eddie, B.G., 1975. A census of the juvenile salmonids of the Clearwater River basin, Jefferson County, Washington, in relation to logging. University of Washington. Seattle, Washington.
- Gresswell, R. E., C. E. Torgersen, D. S. Bateman, T. J. Guy, S. R. Hendricks, and J. E. B. Wofford. 2006. A Spatially Explicit Approach for Evaluating Relationships among Coastal Cutthroat Trout, Habitat, and Disturbance in Small Oregon Streams. *American Fisheries Society Symposium* 48:457-471.
- Lestelle, L.C., 1978. The effects of forest debris removal on a population of resident cutthroat trout in a small headwater stream. University of Washington. Seattle, Washington.
- Martens, K. D., and P. J. Connolly. 2014. Juvenile Anadromous Salmonid Production in Upper Columbia River Side Channels with Different Levels of Hydrological Connection. *Transactions of the American Fisheries Society* 143(3):757-767.
- Martens, K. D. 2016. Washington State Department of Natural Resources' Riparian Validation Monitoring Program for salmonids on the Olympic Experimental State Forest - Study Plan. Washington State Department of Natural Resources, Forest Resources Division, Olympia, WA.
- Martin, D.J., 1985. Production of cutthroat trout (*Salmo clarki*) in relation to riparian vegetation in Bear Creek, Washington. Doctoral dissertation. University of Washington. Seattle, Washington.
- Minkova, T., J. Ricklefs, S. Horton, and R. Bigley. 2012. Riparian Status and Trends Monitoring for the Olympic Experimental State Forest. Study Plan. DNR Forest Resources Division, Olympia, WA.
- Minkova, T., and M. Vorkwerk. 2015. Field Guide for Identifying Stream Channel Types and Habitat Units in Western Washington. Washington State Department of Natural Resources, Forest Resources Division, Olympia WA.
- Minkova, T. and W. Devine. 2016. Status and Trends Monitoring of Riparian and Aquatic Habitat in the Olympic Experimental State Forest. Habitat Status Report and 2015 Project Progress Report. Washington State Department of Natural Resources, Forest Resources Division, Olympia, WA.

- Montgomery, D.R., and J. M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. *Geological Society of America Bulletin* 109(5):596-611.
- Peven, C. M., R. R. Whitney, and K. R. Williams. 1994. Age and length of Steelhead Smolts from the Mid-Columbia River Basin, Washington. *North American Journal of Fisheries Management* 14(1):77-86.
- Smith, C. J. 2000. Salmon and Steelhead Habitat Limiting Factors in the North Washington Coastal Streams of WRIA 20. Washington State Conservation Commission, Lacey, Washington.
- Thurow, R. F. 1994. Underwater Methods for Study of Salmonids in the Intermountain West. General Technical Report (INT-GTR-307). U. S. Department of Agriculture, Forest Service, Intermountain Research Station.
- Washington State Department of Natural Resources (DNR). 1997. Final Habitat Conservation Plan: Washington State Department of Natural Resources, Olympia, Washington, 223.
- Washington State Department of Natural Resources (DNR). 2013. Olympic Experimental State Forest HCP Planning Unit Forest Land Plan Revised Draft Environmental Impact Statement. Olympia, Washington.
- WRIA 21 Lead Entity. 2011. WRIA 21 Queets/Quinault Salmon Habitat Recovery Strategy. <http://www.onrc.washington.edu/MarinePrograms/NaturalResourceCommittees/QuinaultIndianNationLeadEntity/QINLE/OrganizingDocs/WRIA21SalmonHabRestorStrategyJune2011EditionFINAL.pdf>
- Wydoski, R. S., and Whitney R. R. 2003. Inland fishes of Washington. American Fisheries Society, Bethesda, Maryland in association with University of Washington Press, Seattle and London.