2018

Washington State Department of Natural Resources' Riparian Validation Monitoring Program (RVMP) for Salmonids on the Olympic Experimental State Forest – 2017 Annual Report

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WASHINGTON STATE DEPARTMENT OF
NATURAL RESOURCES
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Acronyms and Abbreviations

BACI – Before-After-Control-Impact

COH – Coho Salmon

CTT – Cutthroat Trout

DNR – Washington Department of Natural Resources

eDNA – Environmental DNA

HCP – Habitat Conservation Plan

OESF – Olympic Experimental State Forest

ONP – Olympic National Park

RVMP – Riparian Validation Monitoring Program

STH – Steelhead/rainbow trout

UAV - Unmanned aerial vehicles

Executive Summary

The purpose of the Riparian Validation Monitoring Program (RVMP) is to assess the response of salmonids to the Washington State Department of Natural Resources' (DNR) Riparian Conservation Strategy. The goal of the study is to document whether the strategy is achieving the desired outcome of maintaining or improving salmonid habitat and expressing stable or positive effects on salmonid populations. Observational monitoring is used to identify potential effects. If negative effects are found, the RVMP will recommend experimental studies to evaluate cause-and-effect relationships between salmonids, habitat, and current DNR management practices. The RVMP fulfills the agency's long-term commitment to riparian validation monitoring in the state trust lands Habitat Conservation Plan (HCP). The RVMP monitors 54 DNR Type-3 watersheds, as well as an index section of the Clearwater River to assess the status of multiple species and life stages of salmonids. As not all of the watersheds can be sampled within a summer, 20 watersheds and the Clearwater River index section are sampled annually, while an additional 10 to 15 watersheds per year are sampled on a 2- or 3-year rotation (sampling schedule).

In 2017, DNR completed the second year of fieldwork for the RVMP. Starting in mid-July, DNR conducted multiple-pass removal (n=35) surveys of juvenile salmonid abundance in the annual (n=20) and first rotating panel (n= 10 or 15) of watersheds. Redd surveys were also conducted to determine abundance of adult coho salmon (*Onchorhynchus kisutch)* within 22 of the watersheds. Habitat and snorkel surveys were conducted over a 12-kilometer index section of DNR managed land on the Clearwater River. In addition to the work described in RVMP, a culvert removal-monitoring project was initiated, eDNA samples were collected in collaboration with researchers with the U.S. Forest Service's Pacific Northwest Research Station, and the use of unmanned aerial vehicles (UAV or drone) were evaluated for conducting habitat surveys on the Clearwater River.

RVMP sampling revealed a range of salmonid species assemblages, densities, biomass, and coho redd abundance across the OESF. Despite this range of conditions, mean salmonid densities between 2016 and 2017 were similar (within 0.15 fish per meter). Snorkeling and habitat surveys in the Clearwater River suggest low levels of instream wood over the entire 12-kilometer section. In particular, an analysis of salmonid densities in slow-water sections revealed higher densities of juvenile salmonids in areas that contained key pieces of instream wood (>45 centimeter diameter and >2 meter length) compared to areas without key pieces over the lowest 6.5 kilometers. Increasing the amount of key pieces of instream wood in this area may increase juvenile salmonid densities. If external funding for instream wood additions could be obtained, and ideally implemented in 2020 or later, existing DNR monitoring efforts could be used to monitor the stream and salmonid response.

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Introduction

The Riparian Validation Monitoring Program (RVMP) was designed to meet Washington State Department of Natural Resources' (DNR) commitment for Riparian Validation Monitoring as described in the state trust lands Habitat Conservation Plan (HCP). The HCP allows for long-term certainty of forest management (primarily timber harvest) under the Endangered Species Act (DNR 1997). The primary goal of RVMP is to determine if the Riparian Conservation Strategy is meeting the desired outcome of maintaining or improving salmonid habitat with 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). Due to the time required to collect data, amount of data needed, and the ability to locate animals, Validation Monitoring is the most complex and difficult of the three types of monitoring (implementation, effectiveness, and validation) required under the HCP. The first step in evaluating cause-and-effect relationships is to determine if detectable effects are present from DNR management practices. The RVMP uses observational monitoring to understand the status and trends of salmonids on the OESF and their relationships with stream habitat and management practices. If this monitoring detects a negative trend, experimental designs will be recommended to evaluate the cause-and-effect relationships. While specifically designed to meet DNR's commitment to the HCP, the RVMP provides additional benefits to DNR.

Benefits to DNR from Riparian Validation Monitoring Program:

- Increases knowledge, confidence, and flexibility in DNR land management practices.
- Increases the ecological knowledge on the relationships between salmonids, habitat, and management.
- Provides current information on salmonid conditions in the OESF that may alleviate the perception that practices on DNR-managed lands are negatively affecting salmonids on the Olympic Peninsula (Smith 2000; WRIA 21 Lead entity 2011).
- Supplies information for DNR models such as those in the OESF Forest Land Plan and Environmental Impact Statement that were designed to predict future habitat conditions and impacts on fish 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.

DNR manages the approximately 270,000 acres of state trust lands in the OESF under an experimental management approach called integrated management. Under this approach, the entire land base is managed for both revenue production and ecological values rather than creating large zones to be managed primarily for one objective or another. DNR's integrated management approach is designed to create and maintain a "biologically diverse working forest, with healthy streams and wetlands, a mix of tree species, and a diversity of forest structures at the stand and landscape level". The approach focuses on creating structural diversity at the forest stand level and a variety of forest developmental stages at the landscape level. Overall, it is expected that integrated management will provide quality timber for harvest and habitat for native species. Riparian conservation is achieved through riparian buffers as well as protecting, maintaining, and restoring habitat complexity to mimic the structural diversity created through natural disturbances and forest succession. Minimum buffer widths are 30 and 46 meters in fish bearing streams (depending on the size of the stream) with expanded widths for areas with unstable slopes or areas at risk to severe windthrow (DNR 2016). A small amount of variable retention harvest (starting at least 7.6 meters outside the 100-year floodplain) is allowed within the buffers providing that models do not predict negative impacts on stream shade, instream wood recruitment, and peak flows. Forest harvest can also be conducted for restoration and research purposes. Thinning is allowed in all buffers unless they occur in unstable areas. Overall, DNR management is designed to be flexible as our understanding of new technologies, techniques, and management impacts on the land develop using an adaptive management approach (DNR 2016).

This report covers activities performed by RVMP from January through December 2017. In 2017, DNR conducted 1) population surveys to determine juvenile salmonid densities (fish/meter) and biomass (grams/meter^2) estimates in 35 watersheds from the annual panel (n=20) and the first rotating panel (n=15) of watersheds; 2) adult coho redd surveys; 3) pre-removal monitoring of the Bear Creek culvert replacement project; 4) snorkel and habitat surveys in the Clearwater River; and 5) an assessment on the use of UAVs (unmanned aerial vehicles; commonly referred to as drones) for conducting habitat surveys.

Study Area

The OESF covers a conglomeration of approximately 270,000 acres of state trust lands managed by DNR throughout the western side of the Olympic Peninsula. The OESF contains portions of both 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). It supports a diversity of landscapes ranging from low gradient valleys to steep mountains with elevations ranging from sea level to

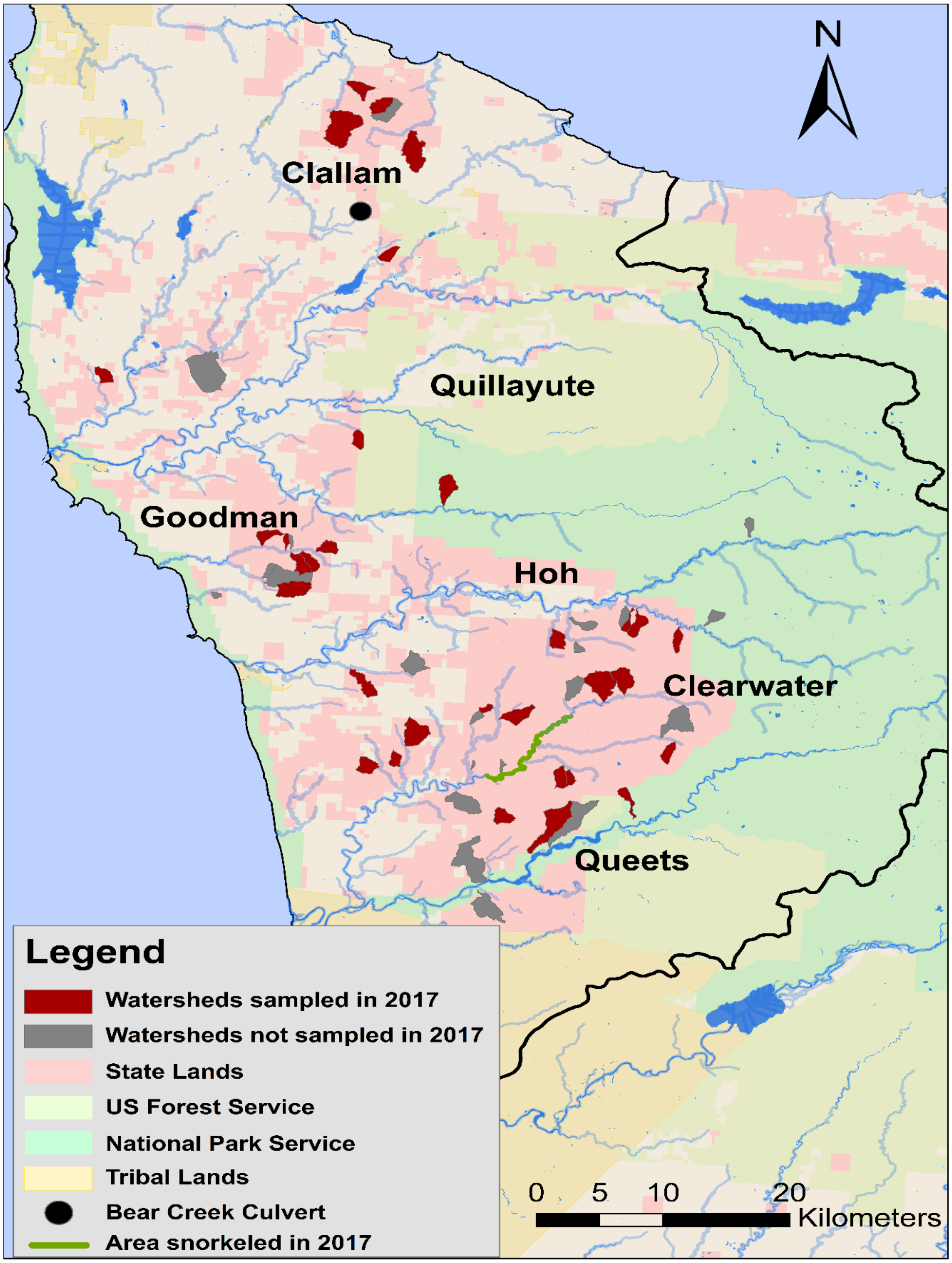

Figure 1. Map of 2017 sampling locations (Type-3 monitored watersheds, Bear Creek culvert, and snorkel surveys) with larger drainages and state, federal, and tribal managed lands in the Olympic Experimental State Forest.

3,400 feet. OESF forests mostly contain western hemlock (*Tsuga heterophylla*) mixed with Douglas fir (*Pseudotsuga menziesii*) and western red cedar (*Thuja plicata*), but also areas of Sitka spruce (*Picea sitchensis*) near the coast and Pacific silver fir (*Abies amabilis*) in higher elevations. Much of the OESF is dominated by younger tree stands (0-50 years old) with patches of old growth forest preserved across the landscapes. Riparian forest conditions on the OESF are mostly in the earlier stages of forest development (less than 80 years) with around 70 percent of riparian areas in earlier stages dominated by hardwoods or young conifers.

State trust 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 (the smallest fish-bearing streams defined as "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"; see Bigley and Deisenhofer 2006). In the OESF, these streams have been found to contain summer populations of juvenile coho salmon (*Oncorhynchus kisutch*), rainbow trout/steelhead (*O. mykiss*), coastal cutthroat trout (*O. clarkii clarkii*), lamprey (*Lampetra spp*.) and/or sculpin (*Cottus spp.*; Martens 2016).

Methods

Study design

Monitoring follows an observational approach that assesses status and trends of salmonid abundance and detects management practices that could negatively affect salmonids. As not all of the watersheds can be sampled within a summer, 20 Type-3 watersheds and the Clearwater River index section are sampled annually, while an additional 10 to 15 Type-3 watersheds per year are sampled on a 2- or 3-year rotation (sampling schedule). After all watersheds have been sampled at least once and every six-years thereafter (reporting schedule), information will be assessed to determine the need for comprehensive experimental studies. This analysis will typically include six samples from the annual watersheds and either two (three-year panel) or three (two-year panel) samples of the rotating panel of watersheds. A decision on whether to use a two- or three-year rotating panel will be based on the amount of watersheds a field crew can reliably sample over a typical summer. 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 to add experimental studies within the existing network of habitat monitoring watersheds (Minkova et al. 2012), DNR planned harvests, or in coordination with other operational studies conducted on DNR managed lands. While not specifically designed to monitor bull trout (*Salvelinus confluentus*), RVMP sampling includes 12 kilometers of bull trout critical habitat in the Clearwater River and 19 Type-3 watersheds that confluence with bull trout critical habitat (Appendix 1). For more information on DNR management effects on bull trout please refer to the OESF Forest Land Plan Environmental Impact Statement.

The RVMP uses the 50 watersheds in the OESF and four unharvested 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 originally selected using a stratified random sampling approach that separated watersheds into a range of groups based on the median slope of each watershed for all Type-3 watersheds in the OESF that contained greater than 50 percent DNR ownership. Selected watersheds are intended to be representative of the DNR's forests within the OESF. Five of these watersheds were removed from the RVMP after initial sampling in 2015 due to fish barriers or sampling difficulties. One watershed (694) was re-added in 2016 after fish presence was discovered despite previous electrofishing efforts. The four unharvested watersheds were selected using different criteria: mainly ease of access and similar ecological conditions. A 12-kilometer section of the Clearwater River was identified for snorkeling based on access and land ownership. Beyond the activities outlined in the RVMP study plan (Martens 2016), a culvert removal effectiveness project was initiated and the use of UAV's were evaluated as part of the program's efforts. In 2016 and again in 2017, 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).

Juvenile population monitoring

Juvenile abundance surveys were conducted within habitat reaches identified in the Status and Trends Monitoring of Riparian and Aquatic Habitat program (Minkova et al. 2012). Surveys were designed for a three-person crew to complete in one day to maximum the number of watersheds surveyed over a summer. Juvenile abundance estimates used multiple-pass removal electrofishing with a variable-pass technique (3-6 passes) to assure high precision of the population estimate. These methods closely follow those of Martens and Connolly (2014), where the number of passes are determined by charts developed by Connolly (1996) that set acceptable catch limits by pass. Block nets were placed at the beginning and end of a sampling reach to ensure a closed population. All sampling was conducted in mid-July through mid-October during base flows. Stream habitat surveys that identify and measure stream characteristics (breaks in streams typically created through changes in elevations or obstructions to flow, sometimes referred to as habitat or channel units) such as pools, riffles, runs, and cascades, were conducted following each survey (Bisson et al. 2006). The surveys determined habitat 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). Data from the habitat and fish abundance surveys were combined to determine abundance and biomass per length (m), per area (m^2), and per volume (m^3) with the reach.

Some studies found that fish densities are inconsistent over the length of streams (Gresswell et al. 2006; Welty et al. 2015; Le Pichon et al. 2017). In 2016, DNR conducted a study to assess differences between fish densities estimated within a reach to densities over the anadromous distribution of Type-3 watersheds. This sampling found strong relationships (r^2 =0.87-0.99) for fish densities (coho, age-0 trout, age-1 or older cutthroat trout and age-1 or older steelhead) between the reach and the entire stream (Martens 2017). Based on this strong relationship as well as the additional time required for sampling the entire stream, only reach-level surveys will be conducted going forward. The minimal differences between fish densities in the reach and stream may be due to an even distribution of fish abundance over the anadromous length (the maximum distance an anadromous fish can move up a stream) of most DNR Type-3 streams, and/or a sample reach long enough to capture the fluctuations in fish abundance.

Redd Surveys

DNR redd surveys covered the entire fish-bearing distribution of streams or the first 1,000 meters for each DNR Type-3 watershed with known coho salmon occurrence (coho were found in 62 percent of the basins during initial sampling in 2015). Due to sampling time constraints, the redd survey protocol was adjusted to cover a maximum distance of 1,000 meters. In 2016, the entire fish distribution of the watershed was sampled. While most streams could be sampled in one day, watershed 433 accounted for 36% of the sampling time. Given limitations in funding and staffing levels in 2017, a 1,000-meter limitation was established to ensure an even distribution of watersheds. Surveys began in November and ended in mid-January following the methods of Gallagher et al. (2007). For year-to-year comparisons, the 2017 redd numbers were adjusted to only include redds within the first 1,000 meters of the watershed. A protocol for redd surveys is currently under development and should be ready for the 2018 survey season.

Pre-removal culvert monitoring project

During reviews of last year's annual report, the Olympic Regional Office requested that the RVMP explore monitoring for the effectiveness of the region's culvert replacement program. Currently, most culverts are selected for removal based on a set of physical characteristics and not based on the fish passage ability of each culvert. As such, there is little information on whether replaced culverts are improving salmonid conditions in streams of the OESF. This study will attempt to document any changes to upstream fish assemblages or populations after a culvert is reconstructed. The Bear Creek road crossing and culvert (Figure 1 and Figure 2) were identified for monitoring following an assessment of all culverts scheduled for replacement in 2018 or 2019. Two years of pre-removal monitoring are planned followed by at least three years of post-removal monitoring using a Before-After-Control-Impact (BACI) design. Sampling includes juvenile population estimates (as described above) in 100 meters of stream directly above the culvert (treatment) and 100 meters of stream directly below the culvert (control). A BACI design improves the ability to detect effects since a portion of the inter-annual variation is accounted for by the correlation between treatment and control sites (Zimmerman et al. 2012). For a BACI design to be effective, treatments must have sufficient contrast in order to detect changes in fish abundance (Crawford and Rumsey 2011). Juvenile abundance estimates will use multiple-pass removal electrofishing as described above.

Figure 2. Picture of the Bear Creek culvert scheduled for replacement in 2018.

Clearwater River snorkel and habitat survey

Snorkeling surveys of larger Type-1 and Type-2 streams (see Bigley and Deisenhofer 2006 for a description on DNR stream types) of the OESF are conducted to sample streams not covered within the existing 54 Type-3 watersheds. The pre-existing Status and Trends Monitoring of Riparian and Aquatic Habitat program that provides habitat data to the RVMP only monitors Type-3 watersheds (Minkova et al. 2012), so additional sampling is needed to meet the requirements of the HCP. Snorkeling surveys are used to help understand the distribution and use of larger resident, anadromous adult, and juvenile salmonids in larger systems, as well as provide information on possible connections with Type-3 watersheds. The section of Clearwater River was chosen because it is fully contained within state managed lands and any impacts could only be attributed to DNR management practices. Methods closely followed the protocols of Thurow (1994) with a two to three person crew snorkeling in a downstream direction. Habitat units were separated into pool, glides, and riffles and measured with a laser rangefinder. Instream wood pieces were counted into two overlapping groups (all pieces >10 cm diameter and > 2 m length, and key pieces >45 cm diameter and >2 m length). Substrate groups (sand, gravel, cobble, boulder and bedrock) were visually estimated for each habitat unit. Reach comparisons were conducted assessing fish densities in pool and glide habitat units (here after referred to as slow-water habitat) with and without key pieces of instream wood. Tests were conducted using a student’s t-test and an alpha level of 0.05.

Clearwater River habitat and UAV survey comparison

The use of UAVs to collect data over a large area in a short amount of time has potential to reduce sampling costs. UAVs have successfully been used to measure substrate (Woodget and Austrums 2017), habitat units (Casado et al. 2015), and instream wood (MacVicar et al. 2009) under certain stream environments. Simple habitat measurements such as the ones collected during the Clearwater River snorkel and habitat survey may be more efficiently captured using UAVs. Before UAVs can be widely used for collecting habitat data, tests are needed to compare land-based surveys to surveys with UAVs. The Clearwater River habitat survey offered an opportunity to compare land-based habitat surveys with aerial UAV surveys. A week after the Clearwater River habitat survey, a UAV was flown to capture imagery over a section of stream previously sampled by the habitat survey. The imagery was processed and converted to an orthophoto, which was imported into ESRI's ArcMap and digitally classified. Data were then used to classify habitat units and instream wood. Due to problems with the imagery (excessive shading), substrate classification and comparisons between land-based and UAV surveys were not conducted.

Results

Fish population monitoring

Fish densities decreased in nine watersheds and increased in seven watersheds between 2016 and 2017. Overall, the average fish densities of the watersheds in 2017 showed a slight increase (0.15 fish per meter or 15 fish per 100 meters) from 2016 (Figure 3). Multiple-pass removal electrofishing was completed within 35 watersheds, successfully sampling all watersheds in the annual panel (n=20) and all potential watersheds in a first rotating panel (n=15). In addition, two potential unharvested watersheds (566 and 744) on the OESF were sampled to increase the number and diversity of unharvested watersheds. Due to a combination of the number of fish and length of the reach, only three-passes were completed in watershed 165 before the crew abandoned efforts due to fading daylight. Only two passes were completed in watershed 196 due to miscommunication and concerns of fish safety. Individual watersheds within the Goodman drainage had lower densities of fish compared to other drainages (Figure 4). Watersheds in the Clallam drainage contained the highest densities of fish. Watersheds 550 and 567 were too shallow or dry to sample during the middle of the summer but were sampled after the onset of rain in the early fall. Watershed 820 was completely dry, and after reviewing thermograph data it was determined that it rarely flows during the summer field season (mid-July to mid-October).

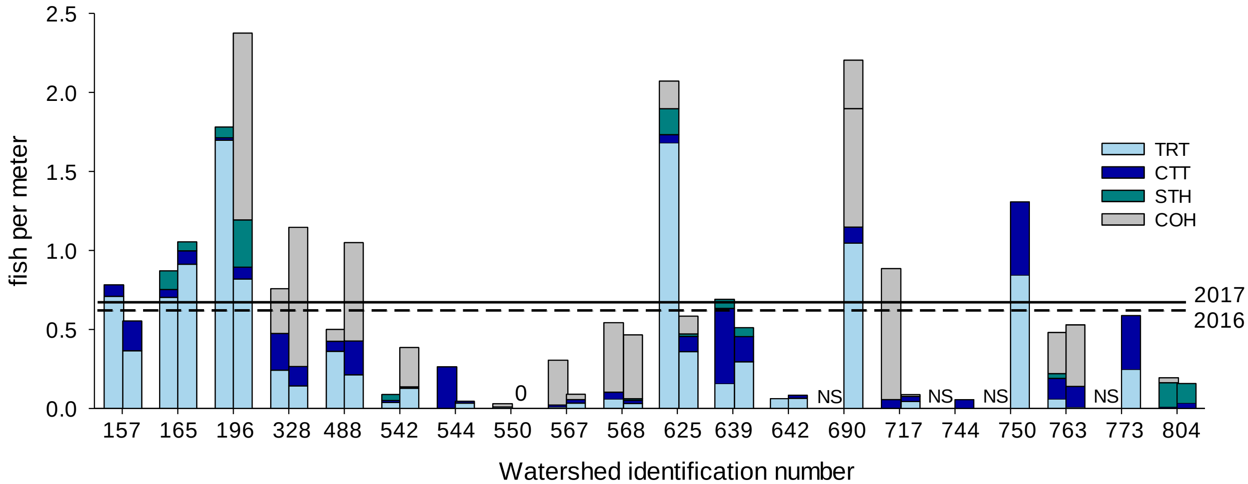

Figure 3. Comparison of watersheds sampled in 2016 and 2017. The solid and dashed lines represent the averages for 2016 and 2017. All watersheds that were sampled were included in calculation of the average. TRT = age-0 trout; CTT = age-1 or older cutthroat trout; STH = age-1 or older steelhead trout; COH = juvenile coho; NS = not sampled.

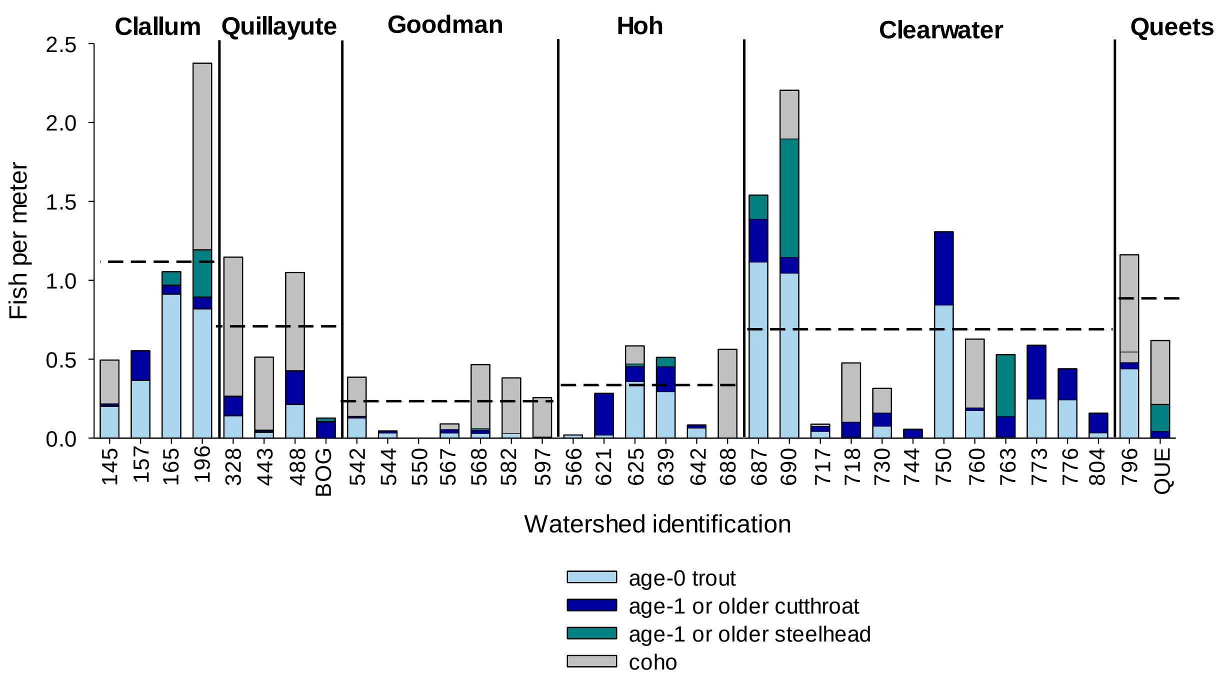

Figure 4. Fish densities (fish per meter) of all sites sampled in 2017 by drainage. The dashed lines represent the average densities by watershed. Watershed 550 was sampled after going dry in the mid-summer and no fish were present. Watershed fish densities averages were calculated over all watersheds including watershed 550.

Adult coho redd surveys were conducted in 22 of the 35 watersheds (only 22 were known to have coho present) with an average of 1.4 redds per watershed. Watersheds 328 and 760 contained the most redds (redds = 5; Figure 5). In watersheds sampled in 2016 and 2017 (adjusted to only reflect the first 1,000 meters) there was an overall decrease in the number of redds per watershed from 2.58 redds per watershed to 1.17 redds per watershed (Figure 6). The largest reduction was in watershed 328, where redds dropped from 20 to 5. Overall, in 2017 redd numbers increased in three watersheds (196, 550, and 568), decreased in six watersheds (328, 488, 542, 567, 625, 717) and did not change in three watersheds (165, 763, 804).

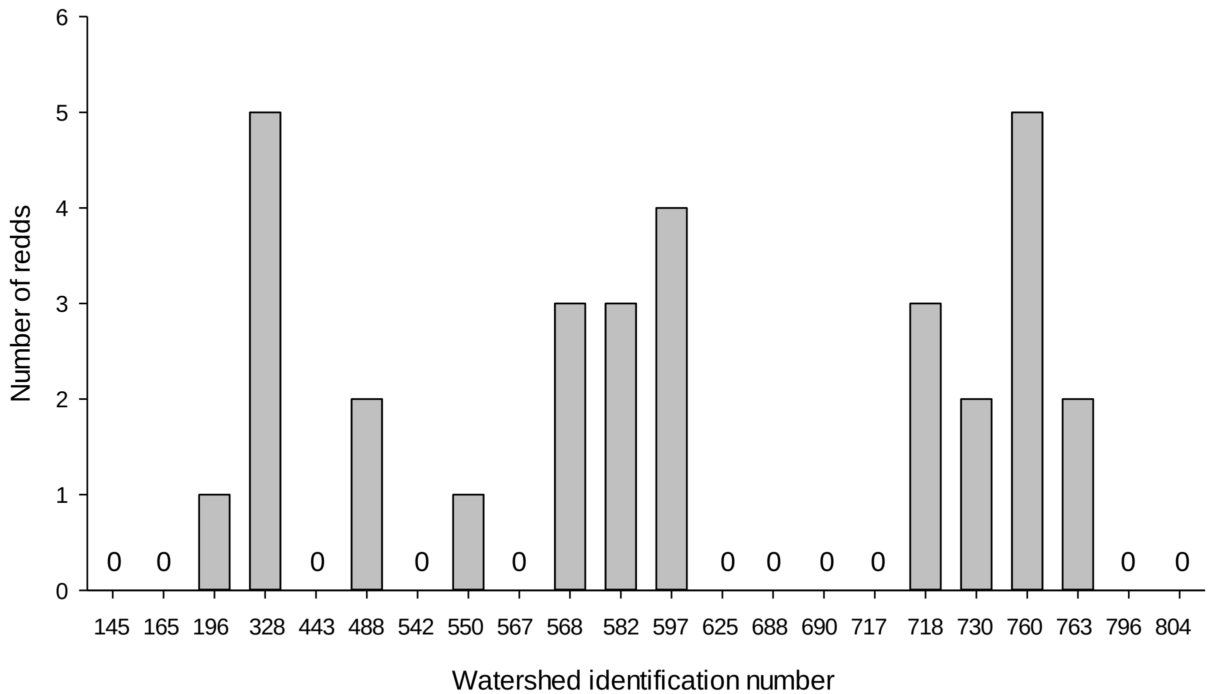

Figure 5. Number of redds surveyed in 2017 within watersheds where juvenile coho were present. Many of the watersheds were sampled and no redds were present. This includes watersheds in annual and rotating panel watersheds sampled in 2017.

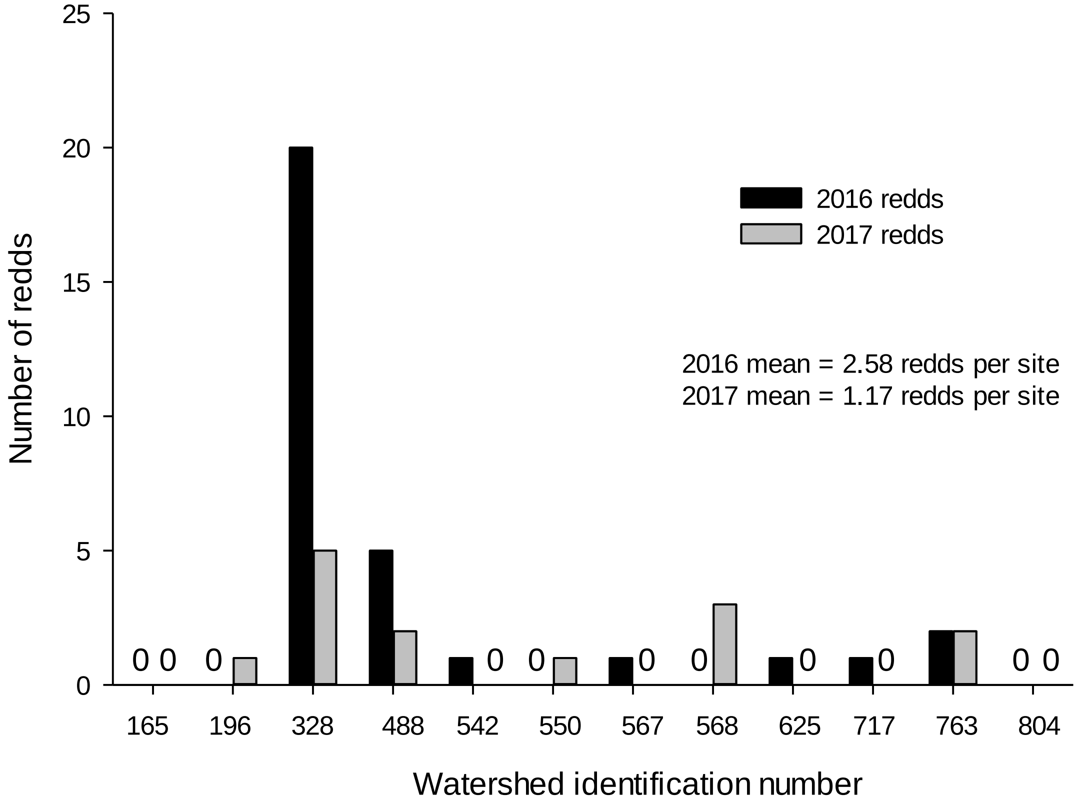

Figure 6. Number of Coho redds surveyed in 2016 (mean =2.58) and 2017 (mean = 1.17). Watersheds were sampled over the first 1,000 stream or until an anadromous fish block was discovered. Only watersheds sampled in the annual panel of watersheds sampled 2016 and 2017 were included in this graph.

Pre-removal culvert monitoring project

In 2017, population assessments of salmonids were completed above and below the culvert in Bear Creek. No coho were collected either above or below the culvert. Age-0 trout density and biomass were higher below the culvert than above, while age-1 or older cutthroat density and biomass were higher above the culvert than below (Figure 7). Overall, salmonid density and biomass were higher below the culvert than above.

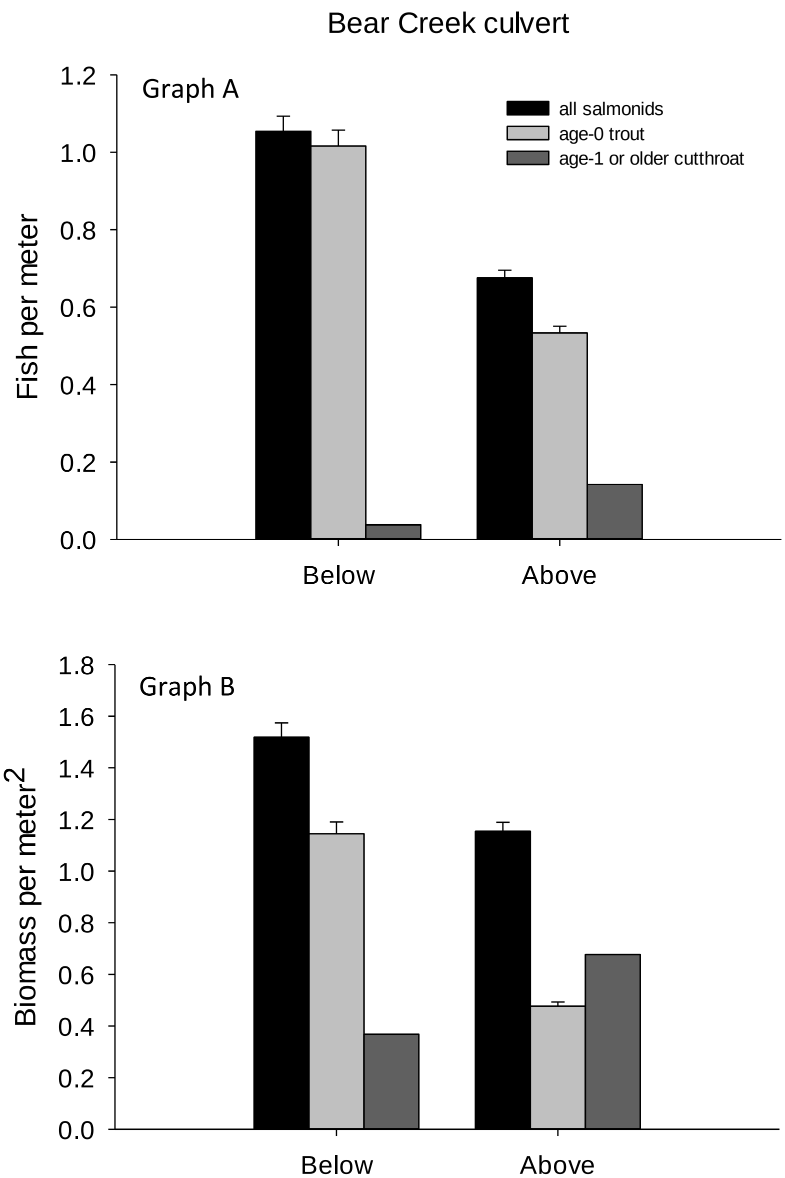

Figure 7. The first year of sampling above (treatment) and below (control) the Bear Creek culvert. Graph A contains fish densities (Fish per meter). Graph B contains biomass densities (biomass per meter^2). Both metrics will be evaluated for changes associated with culvert removal, scheduled for summer 2018.

Clearwater River snorkel and habitat survey

Snorkel and habitat surveys were completed over three and a half days in mid-September 2017 on DNR managed lands in the Clearwater River. The first half day was used to scout and flag potential put-in and take-out locations. Three to five kilometers of stream were sampled for three consecutive days resulting in a total of 12 kilometers sampled.

Mountain whitefish (*Prosopium williamsoni*) were only found in the upper and lower areas (Figure 8). Some studies have found that fish abundances fluctuate between areas with high and low abundance throughout streams (Gresswell et al. 2006; Welty et al. 2015; Le Pichon et al. 2017). Based on this information, mountain whitefish distributions were used to determine the length and number of the reaches. The new reach breaks corresponded with distribution breaks in juvenile coho and age-0 trout. This resulted in a clear separation of reaches for all species. Mountain whitefish were present in Reach 1, despite their absence in Reach 2. Reach 3 had the highest densities of mountain whitefish. Juvenile coho densities were highest in Reach 1 and were lowest in Reach 2 (Figure 9). Age-0 trout followed a more consistent distribution with the highest densities in Reach 1, followed by Reach 2 and finally Reach 3 (Figure 10). Cutthroat trout over 200 mm, rainbow trout over 200 mm, adult steelhead, and adult Chinook (*Oncorhynchus tshawytscha*) were present in low numbers (Table 1). Finally, longnose dace (*Rhinichthys cataractae*) were encountered but were not analyzed.

Table 1. Total number of fish encountered during a snorkel survey of 12 kilometers of the Clearwater River within DNR lands in 2017.

	Number of fish		
Species	Reach 1	Reach 2	Reach 3
Age-0 trout (cutthroat and steelhead)	1,231	239	171
Coho	2,376	53	1,468
Mountain whitefish	124	0	347
Cutthroat trout (> 200 mm)	16	3	40
Rainbow trout (>200 mm)	3	2	0
Adult steelhead	3	3	2
Adult Chinook	1	0	1

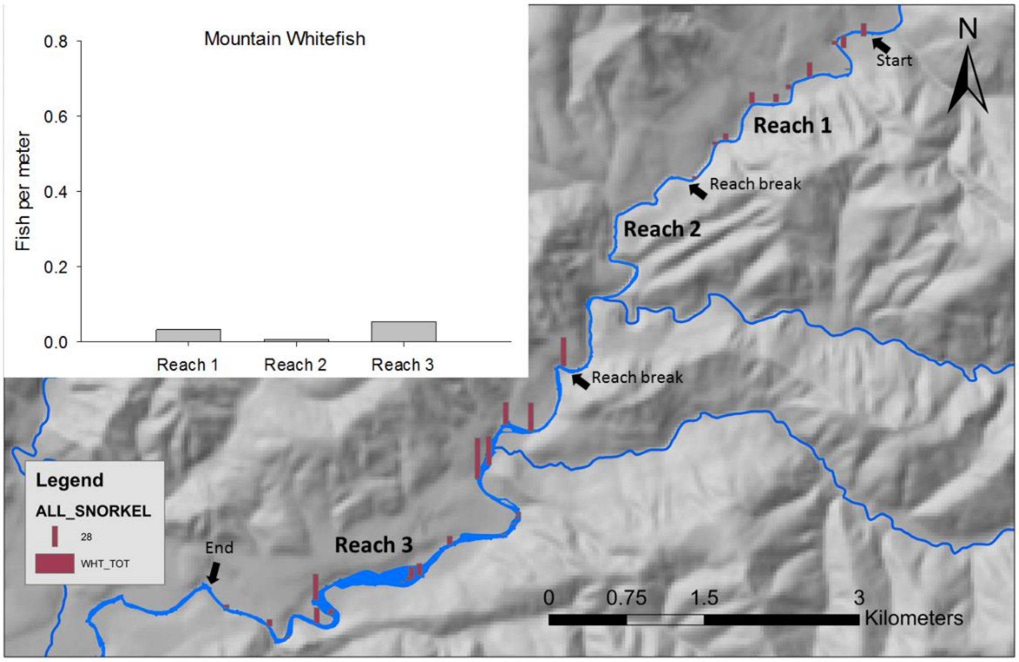

Figure 8. Mountain whitefish distribution over a 12 km section of the Clearwater River with reach comparison graph. Reach breaks were selected based on the presence and absence of whitefish. The red bars represent the number of mountain whitefish counted with each habitat unit.

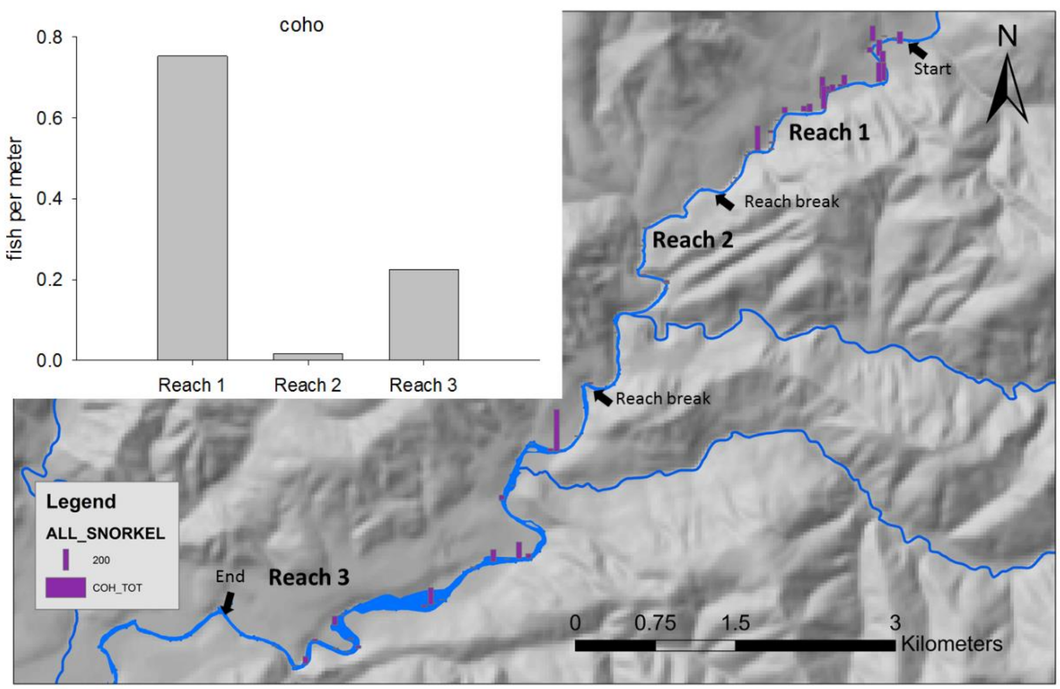

Figure 9. Juvenile coho distribution over a 12 km section of the Clearwater River with reach comparison graph. Purple bars represent the number of juvenile coho encounter per habitat unit.

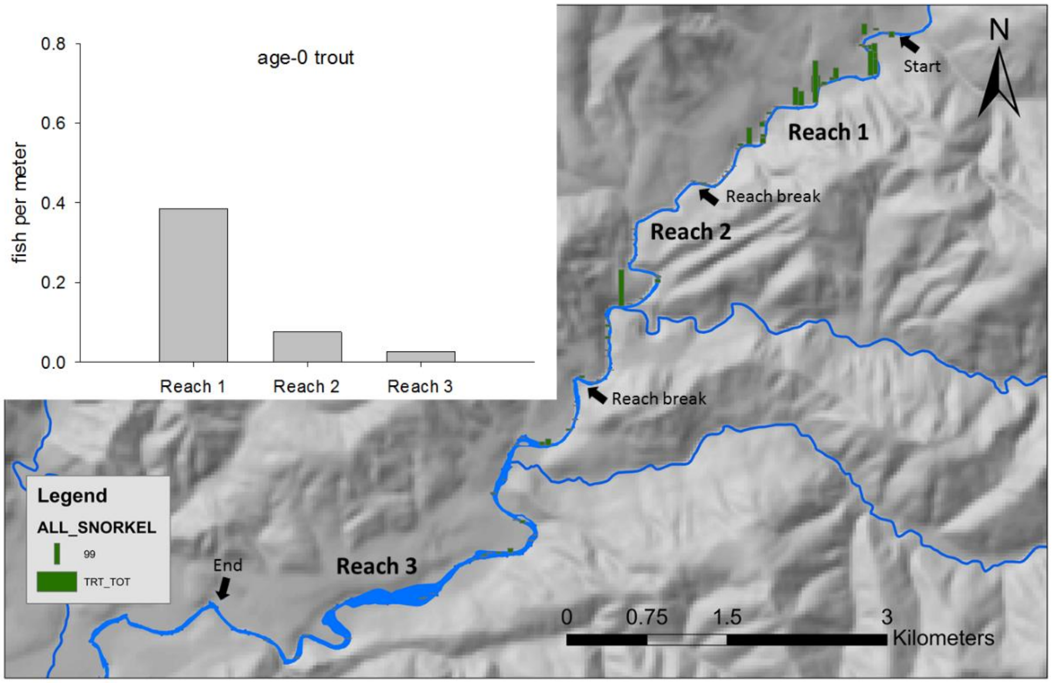

Figure 10. Age-0 trout (steelhead and cutthroat trout <200 mm) distribution over a 12 km section of the Clearwater River with reach comparison graph. Green bars represent the number of juvenile trout encountered per habitat unit.

Reach 1 contained the largest percentage of cobble (Figure 11). Boulder and bedrock were highest in Reach 2. This reach also contained the lowest percentage of cobble and gravels, but the largest percentage of sand. Reach 3 was dominated by cobble and gravel concentrations. Reach 1 contained the highest densities of instream wood (>10 cm diameter and > 2 m length) and key pieces of instream wood (>45 cm diameter and >2 m length), while Reach 2 had the lowest concentrations of instream wood, with most of the wood classified (77 percent) as key pieces (Figure 12).

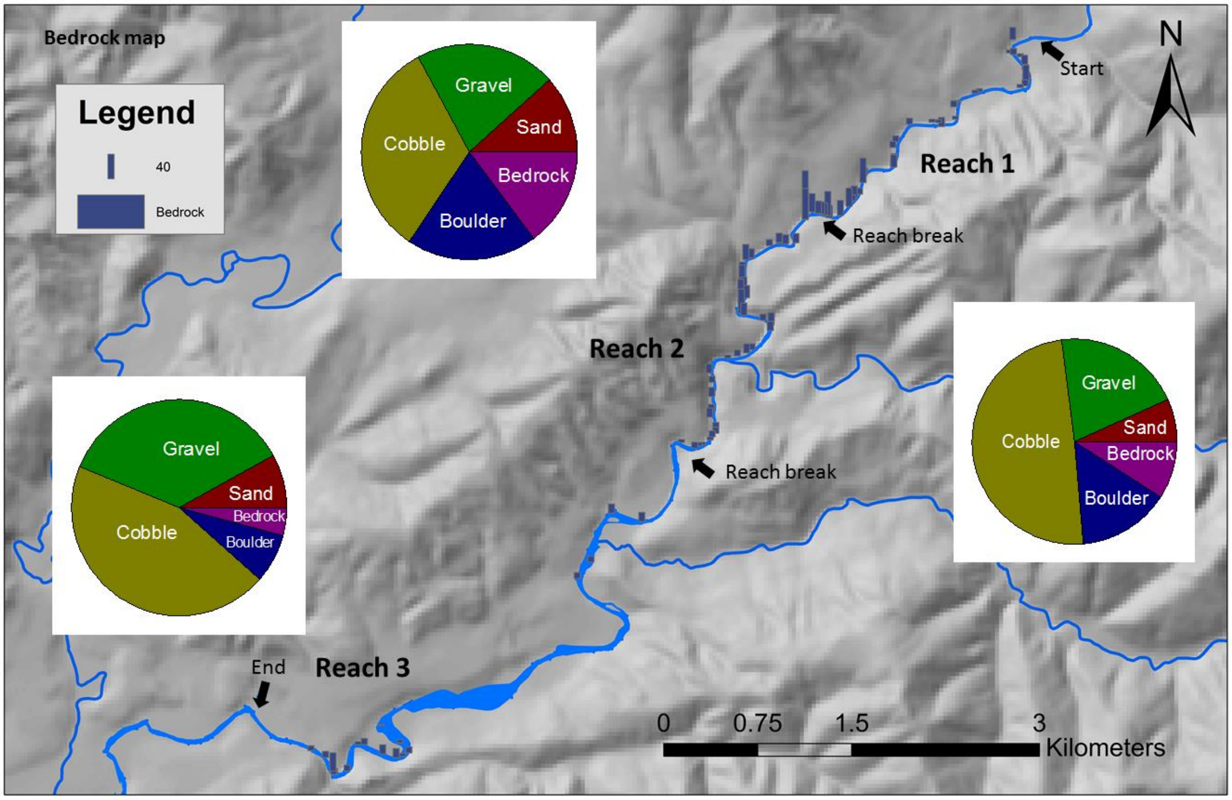

Figure 11. Bedrock distribution over a 12 km section of the Clearwater River with pie graphs of substrate distributions per reach. The blue bars represent the percentage of bedrock within each habitat unit.

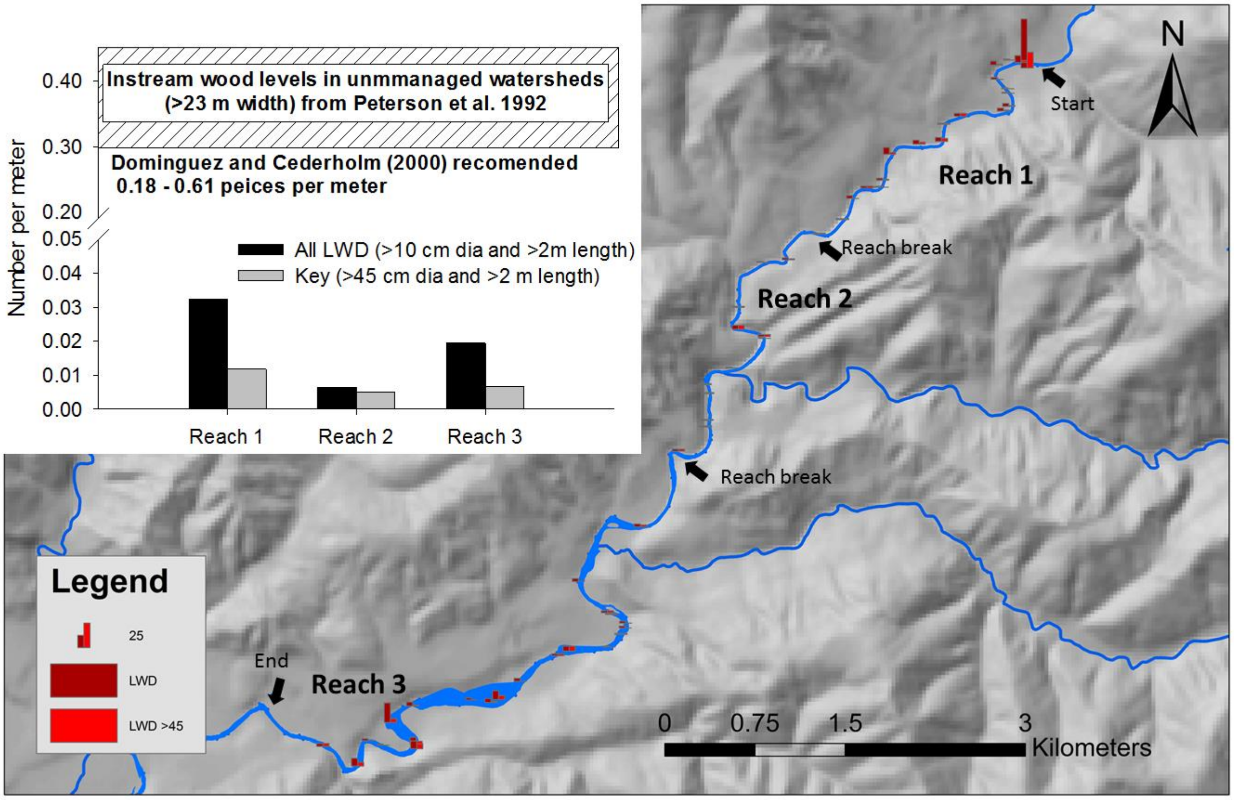

Figure 12. Instream wood (LWD) distribution of all (dark red; >10 cm diameter and > 2 m length) and key pieces (pink; >45 cm diameter and >2 m length) of instream wood over a 12 km section of the Clearwater River. The graph shows the densities of instream wood by reach as well as the recommended densities of instream wood from Peterson et al. (1992) and Dominguez and Cederholm (2000). The dark redd bars represent the number of pieces of wood and the bright redd bars represent the number of key pieces of wood per habitat unit.

While not significantly different, higher concentrations of all species and age groups of fish were observed in slow-water habitat that contained at least one key piece of instream wood (Figure 13). In the slow-water habitat of Reach 3, both coho ($t = 259.0$, $P = 0.005$) and age-0 trout ($T = 230.5$, $P = 0.044$) densities were significantly higher in units that contained at least one key piece of instream wood.

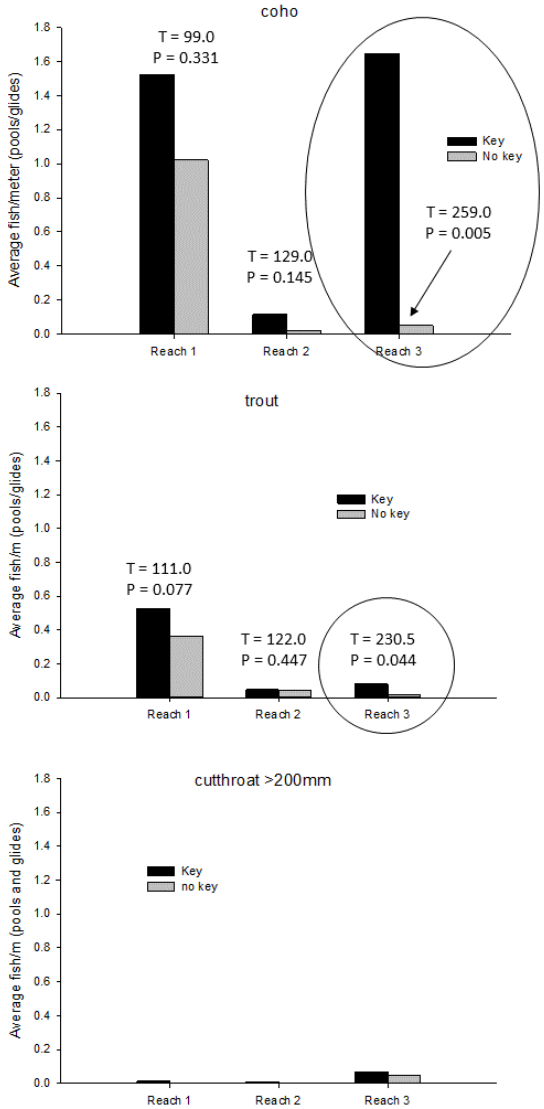

Figure 13. Comparison of fish densities in slow-water (pool and glides) habitats with and without key pieces of instream wood (>45 cm diameter and >2 m length) by reach. The circled comparisons had significant differences between fish densities in slow-water habitat when at least one key piece of instream wood was present. Reaches were determined by mountain whitefish distributions that allowed for identification of three biologically different reaches with the sampled area.

Clearwater River habitat and UAV survey comparison

UAV flights were conducted a week after habitat surveys and used a two-person crew to cover around three kilometers of stream in one day. The area covered by the UAV was limited due to battery life of the UAV and legal restrictions that mandate visual observation of the UAV. A large portion of the imagery was unusable for identifying instream wood, habitat units, or substrate size due to excessive shading (Figure 14). In places where the imagery was free of shadows, we were able to identify pieces of instream wood and areas of slow- and fast-moving water (Figure 15). No efforts were made to categorize substrate because of the shading and time requirements.

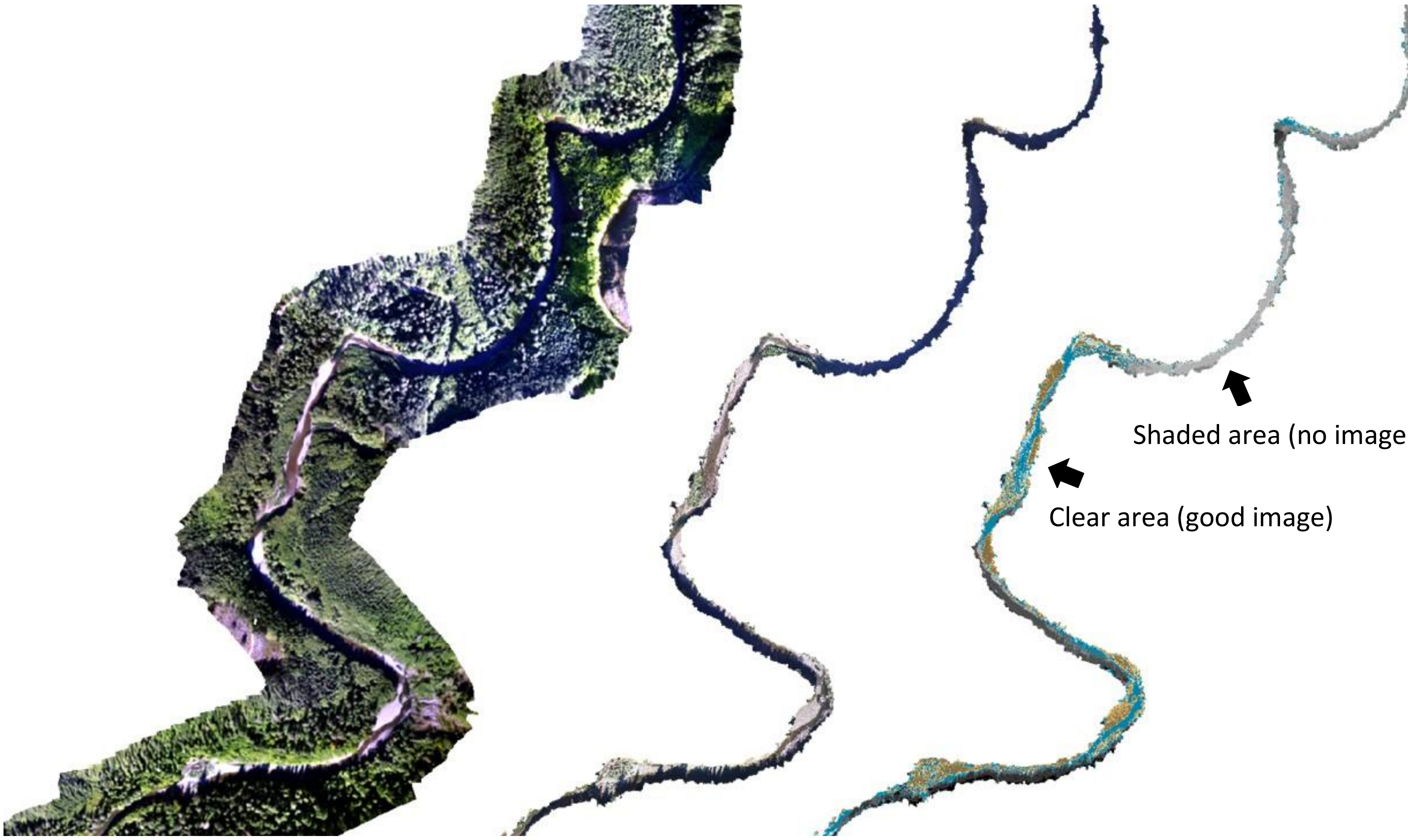

Figure 14. Processed Images taken from UAV flight over a three km section of the Clearwater River a week after snorkel and habitat survey. The image on the left is unprocessed. The middle image was clipped to include only the bankful area of a stream. The image on the right has been digitally converted after processing through ESRI's Arc Map. In the digital image greys and black represents shaded images, while blues are water and brown colors represent substrate.

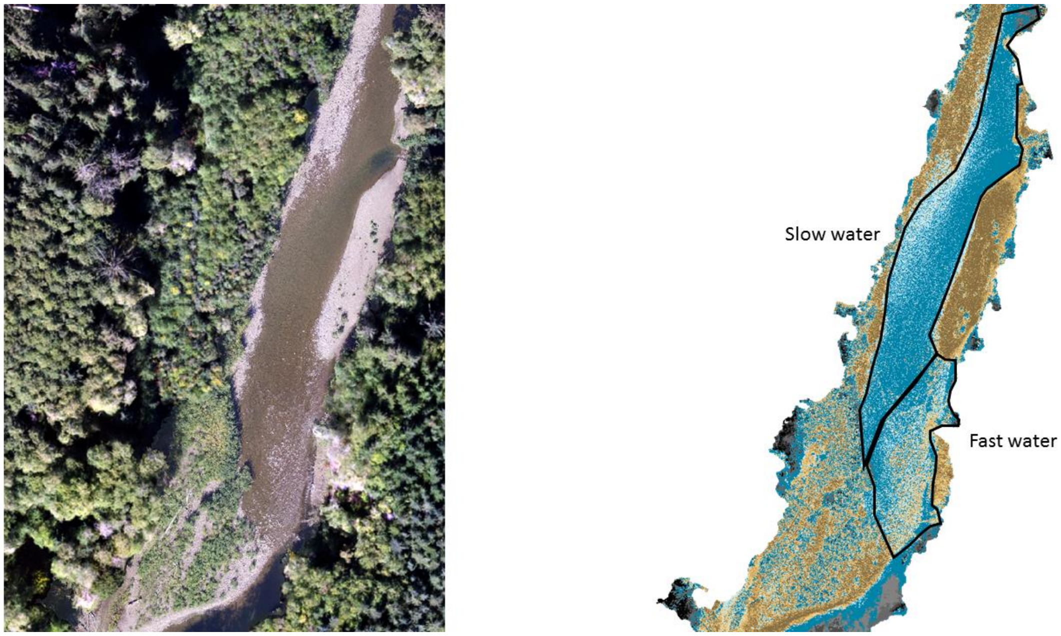

Figure 15. Classified images of slow and fast water habitat from UAV flight in the Clearwater River. The image on the left was taken from the drone while the image on the right was classified through Arc Map. Brown colors represent substrate and blue colors represent water.

Discussion and Recommendations

Fish population monitoring

RVMP juvenile fish monitoring has sampled the annual panel (n=20) for two years and the first rotating panel (n=15) once. In 2018, the third year of sampling will be completed for the annual panel and the first year of sampling completed for the second rotating panel. At the end of 2018, all of the watersheds included in the RVMP will have been sampled, allowing for the first analysis on the status of salmonids in the OESF, an assessment on the relationships between riparian habitat and DNR management practices, and temporal variability in the annual panel of watersheds. Based on 2017 field activities, it was determined that the crew may not be able to sample more than 100 meters of reach within a day if large densities of fish are present. The protocol will be updated so that reaches over 100 meters will be shortened to less than or equal to 100 meters. Fish sampling in 2017 demonstrated that enough watersheds could be sampled within a summer to use a two-year rotation among the rotating watersheds (15 watersheds per year; sampling schedule). This will increase the sampling frequency of watersheds and allow all watersheds to be sampled three times within six years (reporting schedule) and increase the ability to detect effects from management practices. Due to the lack of coho in both of the new potential unharvested watersheds (566 and 744), investigations should be taken to identify any potential downstream barriers to fish passage. Watershed 820 was found to be completely dry during the attempted survey in August 2017 and will be removed from the sample. Data exploration based on the thermograph data revealed that this site is expected to be dry for a large majority of the summer and there were no likely times during the sampling schedule when water is likely to be present. Watershed 433 was removed from the sample after it was discovered that the Pacific Coast Salmon Coalition was conducting coho carcass additions in the stream, and any fish response in the watershed would be difficult to attribute to either carcass addition or DNR management.

Pre-removal culvert monitoring project

Due to the unknown fish passage capabilities of the Bear Creek culvert, the greatest chance of detecting a difference before or after replacement would be if coho or any other anadromous species were found below but not above the culvert before replacement. During initial sampling in 2017, no coho were found below or above the culvert, limiting the ability to detect changes in species occupancy and range expansion following barrier removal. Since differences in the densities and biomass of age-0 and age-1 or older cutthroat trout were detected below and above the culvert, there is still a possibility of detecting differences between salmonid populations as a result of culvert replacement. More sampling will be needed to determine if temporal fish variability will be low enough or the effects of culvert removal will be large enough to detect a response from this culvert replacement. As such, monitoring will continue in 2018 before the culvert is replaced to further assess the likelihood of detecting a response. In addition, we will continue to search for other culverts scheduled for replacement on DNR land to better understand culvert replacement effectiveness.

Clearwater River snorkel and habitat survey

Snorkel and habitat surveys on the Clearwater River showed distinct differences between the three defined reaches. Instream wood levels were low over the entire area snorkeled. The upper reach (Reach 1) contained the highest densities of juvenile fish throughout the reach, despite instream wood levels below the suggested wood densities of Peterson et al. (1992) and Dominquez and Cederholm (2000). There was no significant relationship with juvenile fish densities and the presences of key pieces of wood in the slow-water habitat in Reach 1. This may be due to better overall habitat over the entire reach (Morris et al. 2006), close proximity to redds (Foldvik et al. 2010), or greater immigration from nearby tributaries (Erős 2017). Morris et al. (2006) hypothesized that areas with higher habitat diversity are not as sensitive to instream wood as areas with lower habitat diversity and found that the impact of instream wood additions would vary by reach. The middle reach (Reach 2) had the lowest densities of fish. The reach was mostly contained in a canyon (Figure 16) and had comparatively more boulders and bedrock. Instream wood and smaller substrate could be flushed through this reach during periods of high flow (Montgomery and Buffington 1997; Naiman et al. 2002), which may limit fish rearing capabilities. As such, Reaches 1 and 2 should not receive the highest priorities when planning stream restoration projects.

Reach 3 has the most potential for increasing salmonid production over the area snorkeled. Slow-water habitat within Reach 3 (the lowest reach) with at least one key piece of wood had significantly higher juvenile fish densities than slow-water habitat with no key pieces of wood. In addition, instream wood densities (0.02 pieces per meter) are below the recommended levels from Peterson et al. (1992; 0.30 to 0.46 pieces per meter) and Dominguez and Cederholm (2000; 0.18 to 0.61 pieces per meter). Instream wood additions could increase the current low densities in the reach until riparian forests, through passive restoration, start recruiting enough wood to restore and maintain higher levels (Kauffman et al. 1997). Wood addition projects have been successful for increasing salmon productivity at the site of implementation (Roni and Quinn 2002; Johnson et al. 2005; Pess et al. 2012).

If wood addition projects occur within these sample reaches, ideally they would include a monitoring aspect to evaluate the fish response. As DNR monitoring is planned over the same area in future years, current monitoring efforts could be used to evaluate the effectiveness of instream wood additions. Roni et al. (2014) found that while the positive effects of wood placements on habitat and at-site fish abundances are well known, more information is needed on the effects of wood additions at the reach level. The planned DNR snorkeling efforts would create a no-cost opportunity to evaluate potential changes in abundance at both the site and reach level. This monitoring would attempt to answer questions on whether wood addition projects increase fish populations at the reach level or if they accumulate existing fish. Any wood addition projects would ideally take place in 2020 or later when DNR monitoring has collected at least three years of pre-treatment monitoring.

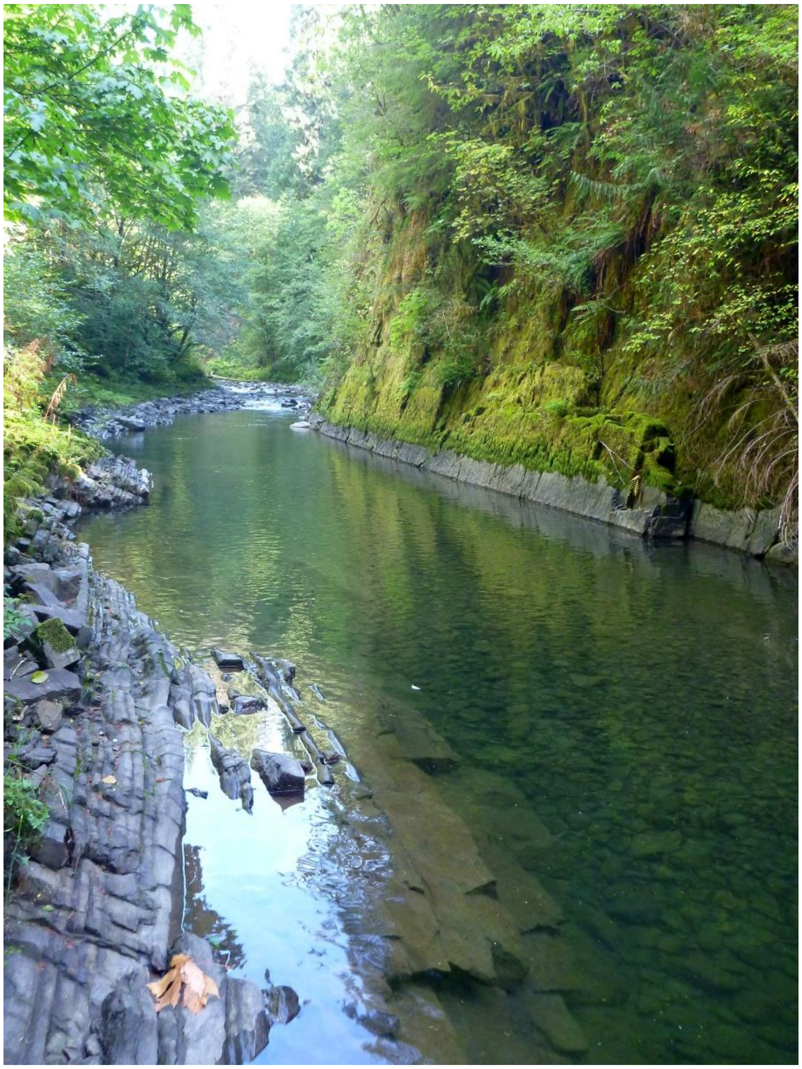
Figure 16. Picture of Reach 2 taken during snorkel surveys in the Clearwater River.

Clearwater River habitat and UAV survey comparison

Aerial imagery from the UAV over the Clearwater River contained too much shading to make comparisons to the ground-based habitat surveys. Counts of instream wood and delineating areas of fast and slow water were possible in areas without shading. One method for reducing shading may be to lower the altitude of the UAV, but this would likely increase the sampling time of the survey. Ground-based surveys were completed over 12 kilometers using one person over a three-day period while the UAV completed an approximately 3-kilometer section in one day with two people. Ground-based habitat data were processed and analyzed in one day while drone data was converted to orthophotos overnight and data were digitally classified in ArcMap in a day. If the drone was able to collect more useable imagery, processing of substrate, wood, and fast- and slow-water areas would have required additional time. The similar sampling time and presumably reduced accuracy from the UAV surveys compared with ground surveys do not justify the switch to aerial surveys at this time. However, the use of UAV imagery over time would provide a more precise method for documenting year-to-year changes within a reach. The use of UAVs should be revisited if advancements in image quality and collection are made.

Summary of Recommendations for the Riparian Validation Monitoring Program

- Sample all Type-3 watersheds over a two-year period (sampling schedule).
- Shorten population surveys in larger reaches to 100 meters or less.
- Continue to evaluate the two potential new unharvested watersheds (566 and 744) on DNR-managed lands.
- Remove watersheds 433 and 820 from the sample.
- Continue DNR redd surveys over the anadromous distribution or 1,000 meters.
- Continue to assess the Bear Creek culvert removal.
- Encourage the development of instream wood addition projects in the Clearwater River.
- Monitor the literature for advancements in UAV monitoring and analysis.

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Appendix 1. WADNR annual bull trout collection permit to U.S. Fish and Wildlife

Washington Department of Natural Resources' Salmonid Validation Monitoring Program for the Olympic Experimental State Forest - 2017 Annual Report.

Washington Department of Natural Resources
Kyle D. Martens, Fish Biologist
Olympia, WA.

Introduction

Washington Department of Natural Resources (DNR) conducted fish sampling across the Olympic Experimental State Forest (OESF) in 2017 under Section 10, Endangered Species Act Permit No. TE-64608B-0. The OESF contains areas that are protected in Unit 1 of U.S. Fish and Wildlife Services' Critical Habitat for bull trout (*Salvelinus confluentus*), though the exact extent of bull trout across the OESF is largely unknown. Fish sampling was conducted under DNR's salmonid validation monitoring program. The salmonid validation monitoring program is described in the 2016 study plan (http://file.dnr.wa.gov/publications/lm_oesf_riparian_monitor_salmonids_2016_plan.pdf) and follows the guidance from the state's Habitat Conservation Plan (HCP). The validation monitoring program will be used to assess the HCP's riparian conservation strategy in the OESF by developing cause and effect relationships between DNR management activities, habitat, and salmonid populations.

Methods

In 2017, sampling was attempted in 33 smaller headwater watersheds of the OESF (Figure 1). The watersheds were located in small fish baring tributaries of the Hoko River, Clallam River, Quillayute River (including the Sol Duc River, Dickey River and Calawah River), Goodman Creek, Mosquito Creek, Hoh River, and the Queets River (including the Clearwater River; http://file.dnr.wa.gov/publications/lm_oesf_long_term_monitoring_stations.pdf).

Backpack electrofishing was conducted to estimate fish densities at the reach level using multiple-pass removal electrofishing**.** Multiple-pass removal closely followed the methods of Martens and Connolly (2014) with all sampling occurring from mid-July through October. In addition, a snorkel survey was conducted over a 12 km section of the upper Clearwater River in September (Figure 2).

Results

During the 2017 field season, no bull trout were encountered.

Discussion

No bull trout were encountered from 2015-2017 and may not be present in the smaller headwater streams of the OESF. Bull trout are thought to use the larger portions of the Clearwater River but were not present in the areas snorkeled in 2016 or 2017. This may be due to low abundance, detection efficiency, or timing of our surveys. In 2018, we plan to resample the 20 annual watersheds, 15 watersheds in our 2nd rotating panel, and the 12 km section of the upper Clearwater River.

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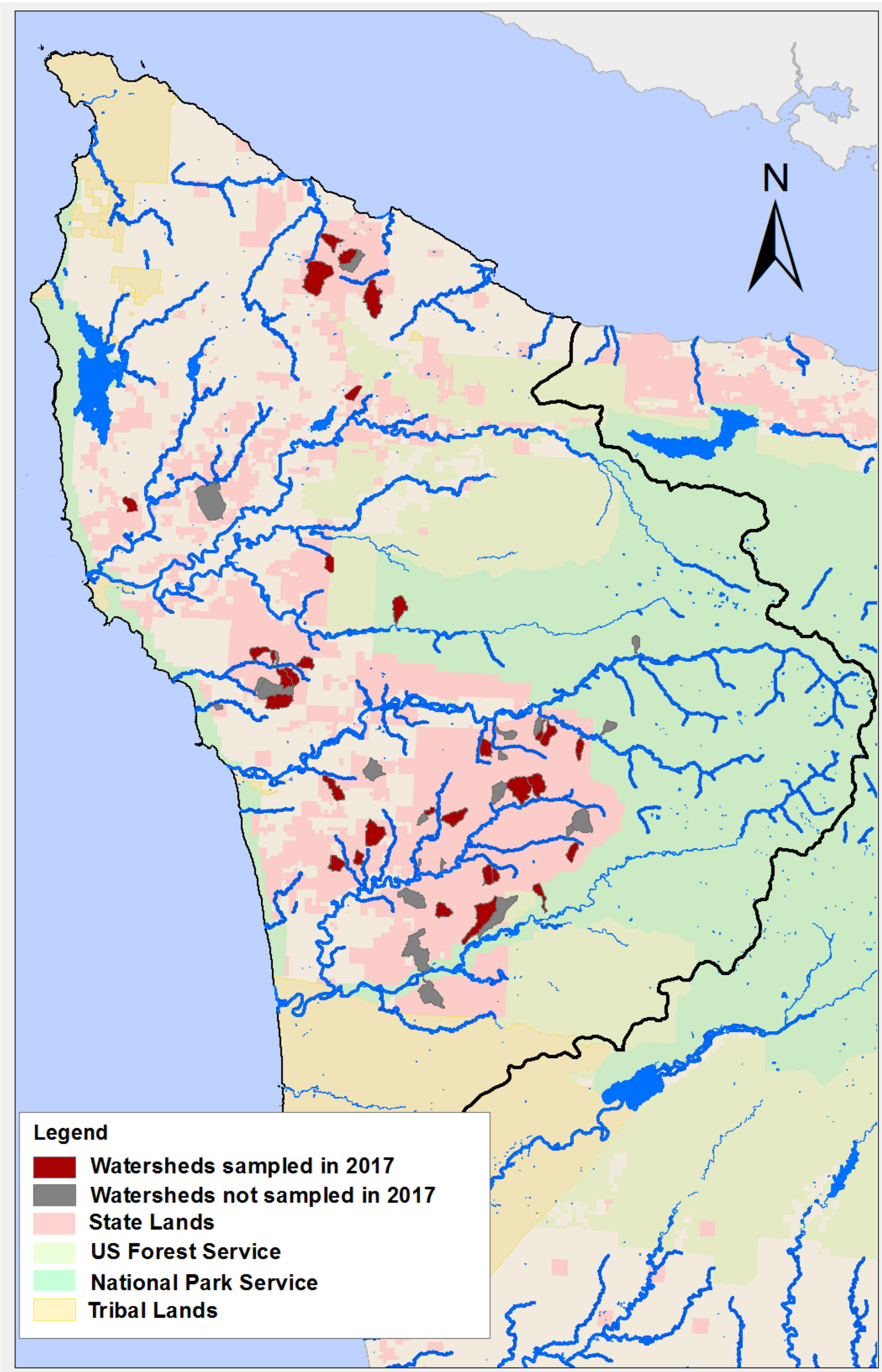

Figure 1. Map of electrofishing sites sampled in the 2017 field season across the Olympic Experimental State Forest.

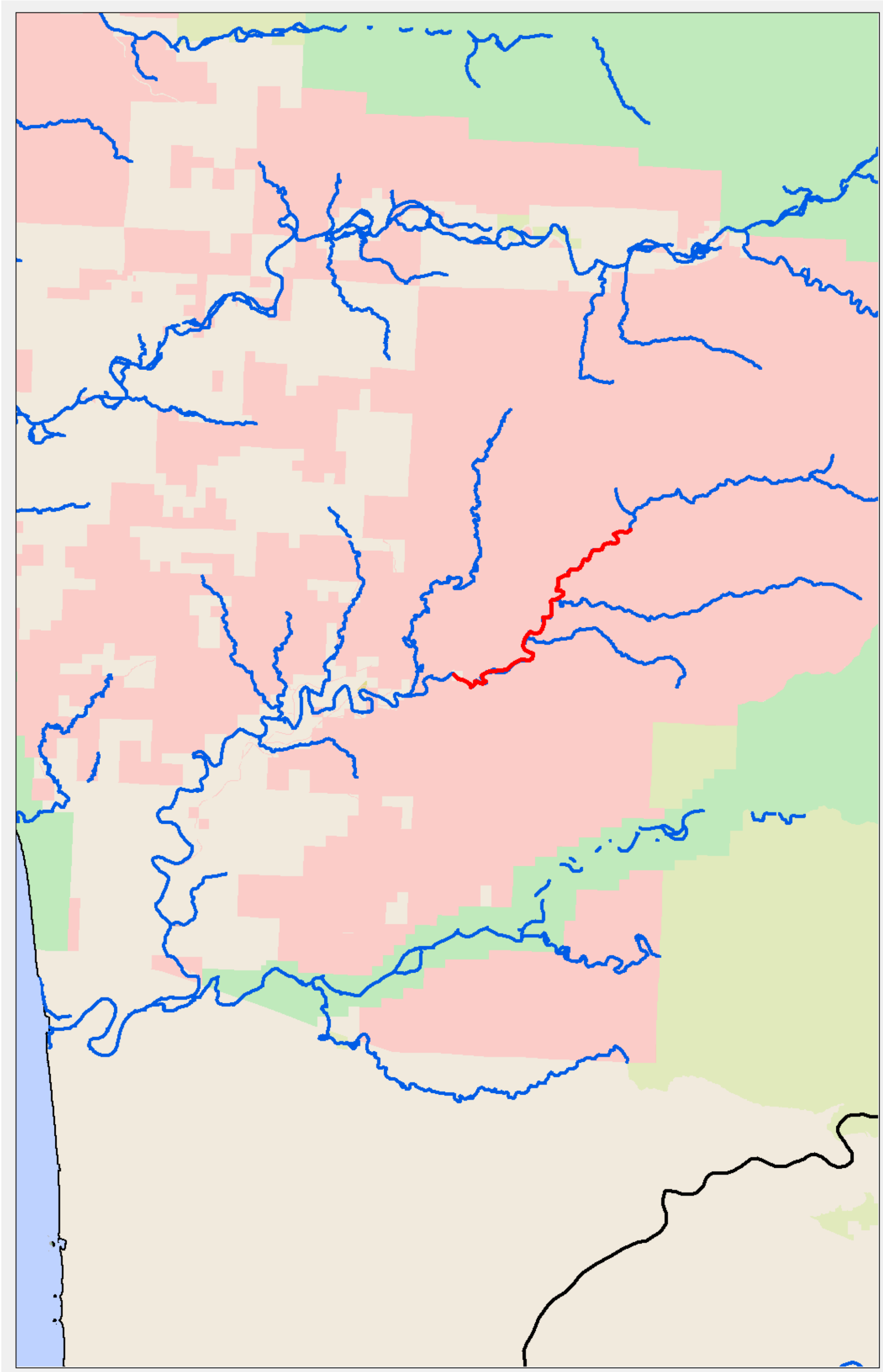

Figure 2. Map of the 12 km snorkel area in the 2017 field season in the Clearwater River. The red highlighted stream section represents the area snorkeled.

Appendix Table 1. Watershed locations and fish species encountered during Washington Department of Natural Resources' fish sampling on the OESF in 2017. COH = coho; CTT = coastal cutthroat; COT = Cottus species; OMY = steelhead or rainbow trout; TRT = unknown juvenile trout species (CTT or OMY); LMP = juvenile lamprey; UNK = DNR did not sample; and None = no fish were collected at site.

Basin	Latitude	Longitude	Fish Species
145	48.230597	-124.330753	COH, CTT, COT
157	48.22385192	-124.2948482	CTT
165	48.21168359	-124.3569823	COH, CTT, STH
196	48.19762618	-124.2741879	CTT,STH
328	48.091938	-124.2994254	COH,CTT
443	47.982793	-124.583603	COH, CTT, LMP, COT
488	47.94543555	-124.311738	COH,CTT,LMP,COT
542	47.84627504	-124.4061643	CTT,STH
544	47.8429896	-124.3812407	CTT,COT
550	47.8433088	-124.3491807	COH,CTT
567	47.84378017	-124.3631071	COH,CTT,COT
568	47.84201489	-124.3753559	COH,CTT
582	47.825944	-124.397975	COH, CTT, LMP, COT
597	47.811372	-124.370912	COH, STH, LMP, COT
621	47.79513	-124.017193	CTT
625	47.80673077	-124.0082626	COH,CTT,STH
639	47.79260891	-123.9626384	CTT,STH
642	47.78772853	-124.0953962	CTT,COT
687	47.747204	-124.01884	CTT, STH
688	47.735903	-124.290812	COH, COT
690	47.742588	-124.04108	COH, CTT, STH
717	47.71952839	-124.1531565	COH, CTT
718	47.713129	-124.125936	COH, CTT, LMP, COT
730	47.695933	-124.234346	COH, CTT, LMP, COT
750	47.6970612	-123.9609047	CTT, STH
760	47.672657	-124.252894	COH, CTT, LMP, COT
763	47.66614737	-124.2697792	COH,CTT,STH,LMP
773	47.67320626	-124.0761112	CTT,STH
776	47.6638	-124.068889	CTT
796	47.62141	-124.086913	COH, CTT, STH, LMP, COT
804	47.63644366	-124.1426444	CTT,STH,COT
BOG	47.901242	-124.214975	CTT, STH, COT
QUE	47.643235	-124.004597	COH, CTT, COT