2020

Riparian Validation Monitoring Program (RVMP)

2019 Annual Report

Washington State Department of Natural Resources, Forest Resources Division

1111 Washington Street SE
Olympia, WA 98504

WASHINGTON STATE DEPARTMENT OF
NATURAL RESOURCES
HILARY S. FRANZ | COMMISSIONER OF PUBLIC LANDS

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Executive Summary

The Riparian Validation Monitoring Program (RVMP) was designed to meet the Washington State Department of Natural Resources (DNR) commitment to the state trust lands Habitat Conservation Plan (HCP). This effort combined with the Status and Trends Monitoring of Riparian and Aquatic Habitat (STRAH) program represents DNR's largest riparian and salmonid monitoring program and the best indication of riparian forest, stream, and salmonid conditions on DNR-managed lands. The 2019 RVMP annual report contains two chapters: Chapter 1 is a progress report on the activities conducted in 2019 and Chapter 2 is an in-depth look at a habitat restoration project - the Bear Creek culvert removal.

In 2019, DNR conducted population abundance surveys to estimate juvenile salmonid densities (fish/meter) and biomass (grams/meter^2) in 41 watersheds from the annual panel (n=20) and the odd-year rotating panel (n=21) of 62 monitored watersheds, adult coho salmon redd surveys, monitoring of the Bear Creek culvert replacement project, and snorkel and habitat surveys in the Clearwater River. Monitoring has shown that fish populations have been trending upward within our annual panel of watersheds, primarily driven by age-0 trout. Overall, there have been large yearly and site variations in juvenile salmonid populations showing the need for continuous (both annual and long-term) sampling to help separate fish responses between these natural variations and habitat responses. Since its implementation in 2016, the RVMP has published two peer-review journal articles and its first status report. Early findings from these works also helped to develop a treatment for the new T3 watershed experiment (initiated in 2020), and to continuously improve the STRAH program.

To assess the impact of DNR culvert removal efforts, we initiated a case study around one of the remaining culverts. Sampling of the Bear Creek culvert removal began in 2017 and had two years of pre-treatment monitoring before the removal in 2018. The Bear Creek culvert was considered a partial barrier to salmonids with healthy populations of cutthroat trout both above and below the culvert. While it was considered possible for coho salmon to be found below the culvert, no coho salmon were found above or below the culvert either before or after removal. Without a change in species presence the likelihood of identifying changes resulting from culvert removal is significantly lower and identifying a response to culvert removal will ultimately depend on the amount of change in cutthroat trout abundance and the amount of yearly variation. While initial sampling has identified increased fish abundances both above and below the site one year after culvert removal, it is too early to attribute these changes to the culvert removal. Post-treatment monitoring will likely continue for at least three years (through 2021).

Acknowledgements

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Acronyms and Abbreviations

AIC – Akaike's Information Criterion

COH – Coho Salmon

CTT – Cutthroat Trout

DNR – Washington Department of Natural Resources

HCP – Habitat Conservation Plan

MS222 – Tricaine mesylate

OESF – Olympic Experimental State Forest

ONP – Olympic National Park

RVMP – Riparian Validation Monitoring Program

STH – Steelhead/rainbow trout

STRAH – Status and Trends Monitoring of Riparian and Aquatic Habitat in the Olympic Experimental State Forest Program

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Chapter 1: 2019 progress report for the Riparian Validation Monitoring Program (RVMP)

Kyle D. Martens

Introduction

The Riparian Validation Monitoring Program (RVMP) was designed to meet the Department of Natural Resources' (DNR) commitment for Riparian Validation Monitoring as described in the state trust lands Habitat Conservation Plan (HCP; WADNR 1997). The HCP allows for long-term certainty of forest management (primarily timber harvest) by allowing incidental take of federally listed species in exchange for mitigation and minimization of environmental impacts on state lands. The objective of Validation Monitoring, as described 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" (WADNR 1997). Validation Monitoring is the most complex and difficult of the three types of monitoring (implementation, effectiveness, and validation) in the HCP. It aims to test the hypothesis that forest management practices implemented under the HCP will restore and maintain habitat capable of supporting viable salmonid populations. If negative trends are detected or suspected in salmonid condition (abundance, biomass, species composition, age structure, and number of spawning redds), monitoring will then seek to evaluate the cause-and-effect relationships between DNR management activities, riparian habitat, and salmonids. Once the underlying mechanisms are understood, DNR may use this information to adapt its management practices.

The Olympic Experimental State Forest (OESF) is a working forest designated to use research and monitoring to better integrate revenue production (primarily through timber harvesting) and ecological values (primarily habitat conservation; WADNR 2016). The HCP designated the OESF as the place for Riparian Validation Monitoring, which was initiated in 2016. The RVMP samples the same sites and utilizes data from the Status and Trends Monitoring of Riparian and Aquatic Habitat (STRAH) program, established in 2012, to avoid collecting costly and redundant information. While the RVMP was primarily designed to meet the department's commitment to the HCP, this program has many other uses (documented below) including the only continuous field-based monitoring and assessment of riparian forest, fish, and stream habitat conditions on DNR-managed lands that provides evidence on whether DNR riparian management is working as intended.

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 predictive models of future habitat conditions and impacts on fish under different management alternatives. DNR uses these models in planning documents such as the OESF Forest Land Plan and Sustainable Harvest Calculation.
- Monitors the effects of climate change on salmonids in the Pacific Northwest.
- Complies with the HCP monitoring expectations.
- Establishes stronger relationships with other natural resource agencies, research organizations, academia, and tribal nations.

This report covers activities performed by the RVMP from January through December 2019. DNR conducted 1) population surveys to determine juvenile salmonid densities (fish/meter) and biomass (grams/meter^2) estimates in 41 watersheds from the annual panel (n=20) and the odd-year rotating panel (n=21) of 62 monitored watersheds; 2) adult coho salmon (*Oncorhynchus kisutch*) redd surveys; 3) monitoring of the Bear Creek culvert replacement project; 4) snorkel and habitat surveys in the Clearwater River.

Study Area

The OESF includes approximately 110,000 ha of state lands on the western Olympic Peninsula (Figure 2). The boundaries follow the Olympic Mountain crest, the West Twin Creek and Lake Crescent watersheds to the east, the Strait of Juan de Fuca to the north, the Pacific Ocean to the west, and the Quinault River Watershed to the south. Elevations within the OESF range from sea level to 1,155 m. The OESF is a coastal rain forest that receives heavy precipitation (203 to 355 cm per year) with the majority falling in the winter. It contains a diversity of the forests within three vegetation zones (Franklin and Dyrness 1988). The majority of the OESF is within the western hemlock zone (*Tsuga heterophylla*; 150 to 550 m elevation), while the lower elevations (0 to 150 m) are in the Sitka spruce zone (*Picea sitchensis*) and the upper elevations (550 to 1,155 m) are in the Pacific silver fir zone (*Abies amabilis*). DNR-managed forests within the OESF mostly consist of second- and third-growth forests as a result of prior timber harvests, with less than 10% of the forests being older than 140 years (WADNR 2016). After intensive timber harvest in the 1970s and 1980s, forest management under the 1997 HCP included landscape conservation strategies for upland and riparian species and harvest at an annual rate of about 0.5% of the OESF. The current sustainable harvest level for the OESF is 739 mmbf per decade or about 0.2% of the land base harvested through thinning and about 0.7% harvested through variable retention harvest annually (WADNR 2019).

DNR-managed lands contain over 4,300 km of streams including portions of several major rivers such as the Queets, Clearwater, Hoh, Bogachiel, Calawah, Sol Duc, Dickey, Hoko, and Clallam (WADNR 2013). The smallest fish-bearing streams (stream order 1-3; Strahler 1957) typically have some combination of juvenile coho salmon, rainbow trout/steelhead (*O. mykiss*), coastal cutthroat trout (*O. clarkii clarkia*), lampreys (*Lampetra spp.*) and/or sculpins (*Cottus spp.*).

Coastal cutthroat trout are the most commonly found salmonid species within these smaller streams (Martens 2016).

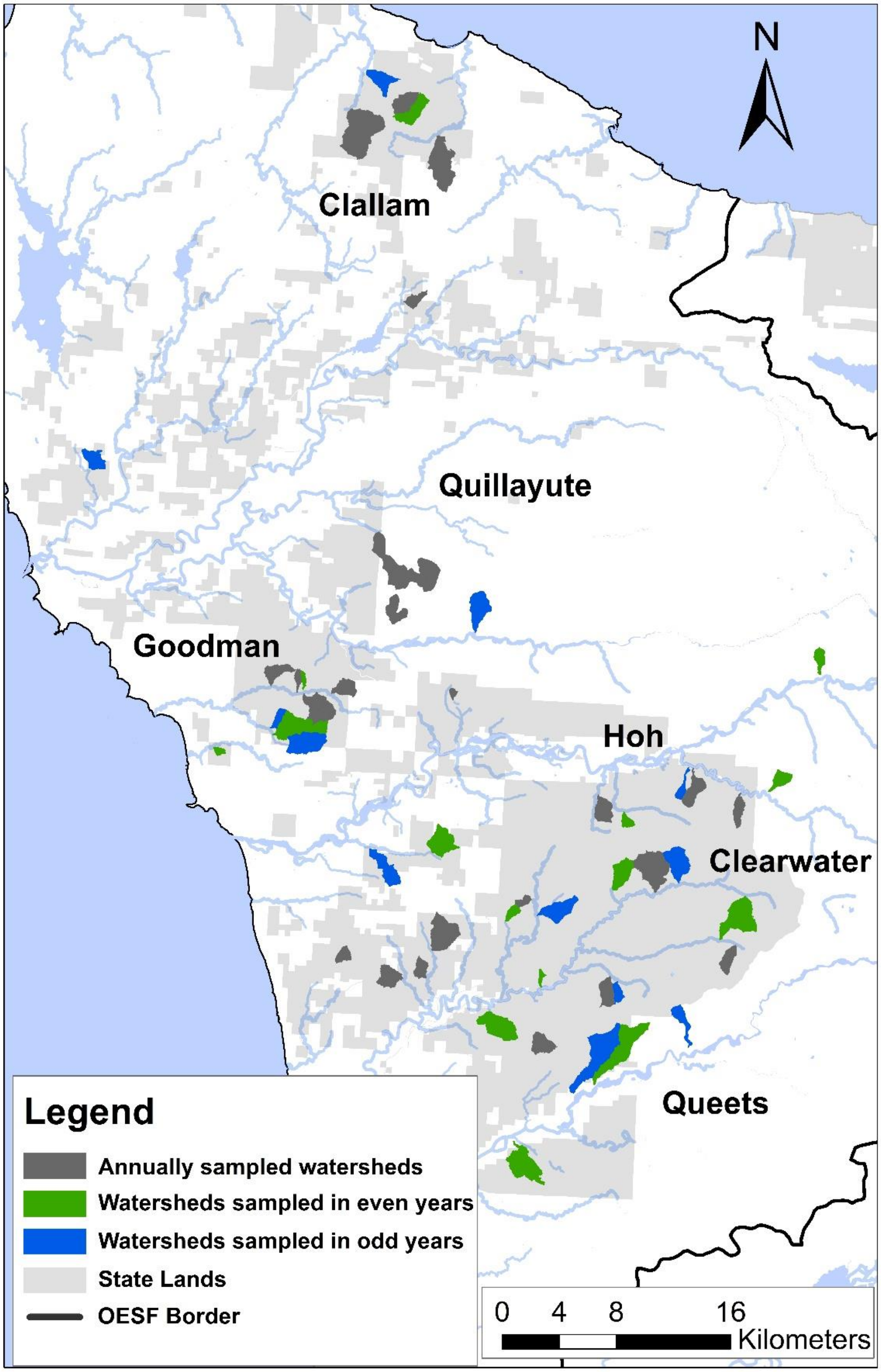

Figure 1. Map of OESF state managed lands and sample watersheds.

Methods

Study Design

The RVMP was designed to first use an observational approach to monitor 50 Type-3 watersheds[a] on state lands managed by DNR and 12 reference watersheds located on state lands (n=2), Olympic National Park (n=4), and Olympic National Forest (n=6; Martens 2016). The 50 managed watersheds were selected through a stratified random design under the STRAH program (Minkova et al. 2012). The 12 reference watersheds were selected based on their environmental condition (similar to the 50 managed watersheds), management history (> 95% of the watershed area never harvested), and location (reasonably easy access). As not all of the 62 watersheds could be sampled within a field season (summer), the RVMP calls for 20 watersheds to be sampled annually (annual panel), and an additional 21 watersheds per year to be sampled on a two-year rotation (even and odd years; Martens 2016). Stream habitat, juvenile fish, and redd surveys (adult fish) were monitored in 41 watersheds in 2019. Sampling reaches were located near the watershed outlet just above the floodplain of its confluencing stream and are 20 times the bankfull width or a minimum of 100 meters in length. In addition, a section of the Clearwater River, a Type-1 stream, was snorkel-surveyed to assess the effects of DNR management on a larger stream of the OESF.

[a]Type 1 water - "all waters, within their ordinary high-water mark, inventoried as "shorelines of the state" under Chapter 90.58 RCW and the rules promulgated pursuant to Chapter 90.58 RCW, but not including those waters' associated wetlands as defined in Chapter 90.58 RCW."

Type 2 water - "segments of natural waters that are not classified as Type 1 Water and have a high fish, wildlife, or human use. (i) Stream segments having a defined channel 20 feet or greater in width between the ordinary high-water marks and having a gradient of less than 4 percent.

Type 3 water - "segments of natural waters that are not classified as Type 1 or 2 Water and have a moderate to slight fish, wildlife, and human use. (A) Stream segments having a defined channel of 2 feet or greater in width between the ordinary high-water marks in western Washington and having a gradient 16 percent or less; (B) Stream segments having a defined channel of 2 feet or greater in width between the ordinary high-water marks in Western Washington and having a gradient greater than 16 percent and less than or equal to 20 percent; and having greater than 50 acres in contributing basin size in western Washington".

Type 4 water - "segments of natural waters which are not classified as Type 1, 2 or 3, and for the purpose of protecting water quality downstream are classified as Type 4 Water upstream until the channel width becomes less than 2 feet in width between the ordinary high-water marks".

Type 5 water - "natural waters not classified as Type 1, 2, 3, or 4; including streams with or without well-defined channels, areas of perennial or intermittent seepage, ponds, natural sinks and drainage ways having short periods of spring or storm runoff".

Juvenile Fish Sampling in Type-3 streams

Juvenile fish surveys were conducted using multiple-pass removal electrofishing of each sample reach. Sample reaches over 120 meters long were reduced to 100 meters or less to ensure all sampling could be completed within a day. Before sampling, seine nets were placed at the top and bottom of a reach to block fish movement. After a reach was blocked, a Smith-Root model 24b backpack electrofisher (https://www.smith-root.com) was used to collect fish with a forward and backward pass through the reach. Electrofishing was typically conducted using a frequency of 20 hertz with 10% duty cycle and voltage ranging from 300 to 600 volts. Fish sampling used a variable pass (3 to 6 passes) form of multiple pass-removal electrofishing. The number of passes were determined through the charts of Connolly (1996) and used as described in Martens and Connolly (2014). After electrofishing, all salmonids were anesthetized with MS-222, visually inspected, measured and weighed, and released. Fish collection activities were permitted through Washington State Department of Fish and Wildlife (permit # 20-157) and the U.S. Fish and Wildlife (permit # TE64608B-1). Fish population estimates were calculated using the program CAPTURE (Cooch and White 2012) and extrapolated over the length and area of the reaches. After all passes were completed, a stream habitat survey was conducted. The habitat survey identified habitat units based on the field guide of Minkova and Vorwerk (2015) and measured the lengths, widths, and depths of each unit, pool depth, pool-forming mechanism, and instream wood.

Redd Surveys in Type-3 streams

DNR redd surveys were conducted over the first 1,000 meters or the end of anadromous fish for each RVMP watershed with known coho salmon occurrences (coho salmon were found in 62 percent of the basins during initial sampling in 2015; Martens 2016). Surveys identified the presence of redds, any adult fish present, and marked locations with GPS. All scheduled watersheds were sampled three times over the sampling season. Surveys began in November and ended in mid-January, following the methods of Gallagher et al. (2007).

Snorkel Surveys on the Clearwater River

Snorkeling surveys were used to help understand the distribution of larger resident, anadromous adult, and juvenile salmonids in larger streams. The 12 km sampled section (starting near river kilometer 46 [downstream of Kunamakst Creek] and ending near river kilometer 33 [upstream of Bull Creek]) of the Clearwater River was chosen because it is fully contained within DNR managed lands and any impacts could only be attributed to DNR management practices. This section was subsequently separated into three reaches based on the distribution of Mountain Whitefish (which were absent in the middle section; Martens 2018). This middle reach is dominated by bedrock with steep banks creating a canyon stretch of river. Methods closely followed the protocols of Thurow (1994) with a two to three person crew snorkeling in a downstream direction counting fish of each species per habitat unit (e.g. pools, riffles, and glides). Habitat surveys were conducted simultaneously with the snorkel surveys.

This survey collected information on habitat units, instream wood, and substrate. Habitat units were separated into pool, glides, and riffles measured with a laser rangefinder. Instream wood pieces were segregated into two groups (pieces 10-45 cm diameter and > 2 m length, and “key pieces” >45 cm diameter and >2 m length). The percentage of channel substrate by categories (sand, gravel, cobble, boulder and bedrock) were visually estimated for each habitat unit. Snorkel surveys on the Clearwater River began in 2017 and have taken place for three years. Reach 2 was not surveyed in 2018 due to heavy rain that reduce visibility and ultimately the number of sampling days.

Results

Forty-one watersheds were sampled for juvenile salmon, 12 watersheds were surveyed three times for coho salmon redds and all three reaches of mainstem Clearwater River were snorkeled, completing all planned activities for 2019. DNR crews handled 476 coastal cutthroat trout, 1210 coho salmon, 1335 juvenile trout (a combination of age-0 coastal cutthroat trout and steelhead/rainbow trout), and 98 steelhead/rainbow trout during juvenile abundance surveys within 41 Type-3 watersheds. Sculpin were found often but were not collected (sculpin lack a swim bladder and are not as easily collected as juvenile salmon, and the HCP only calls for salmonid monitoring). Juvenile lamprey were also found in 12 of the 41 watersheds. In addition to the species found in the smaller Type-3 watersheds, mountain whitefish and longnose dace were found during snorkel surveys in the Clearwater River.

There was a high amount of variability among the watersheds sampled in 2019. Two of the three watersheds with the highest abundances were located in the Clearwater watershed. These two streams did not contain coho salmon and were primarily driven by age-0 trout (Figure 2 and 3; Appendix 1).

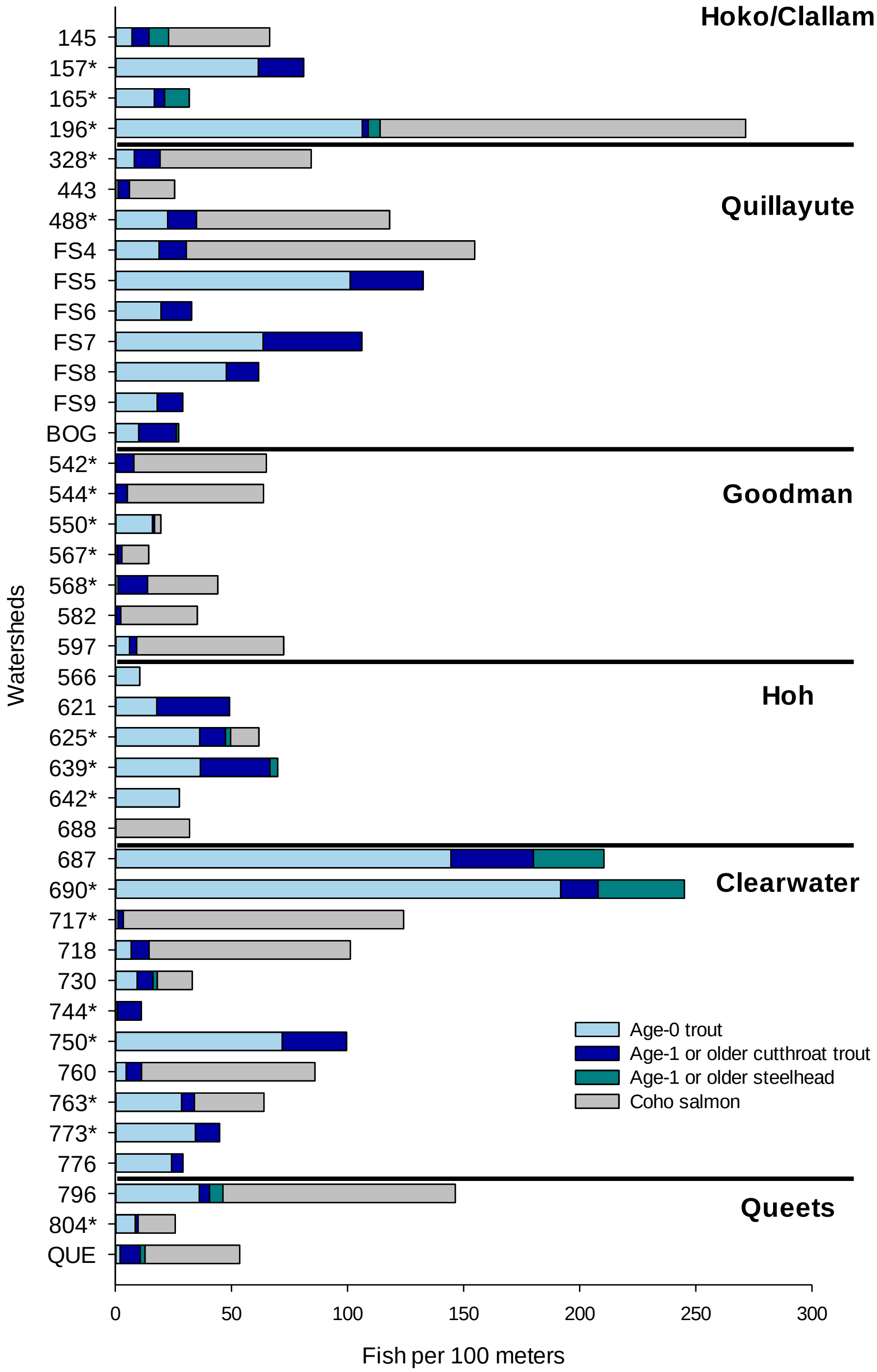

*Figure 2. Fish per 100 meters of reaches sampled during the summer of 2019 under the Department of Natural Resources' Riparian Validation Monitoring Program (RVMP). *Annual sampling reaches*

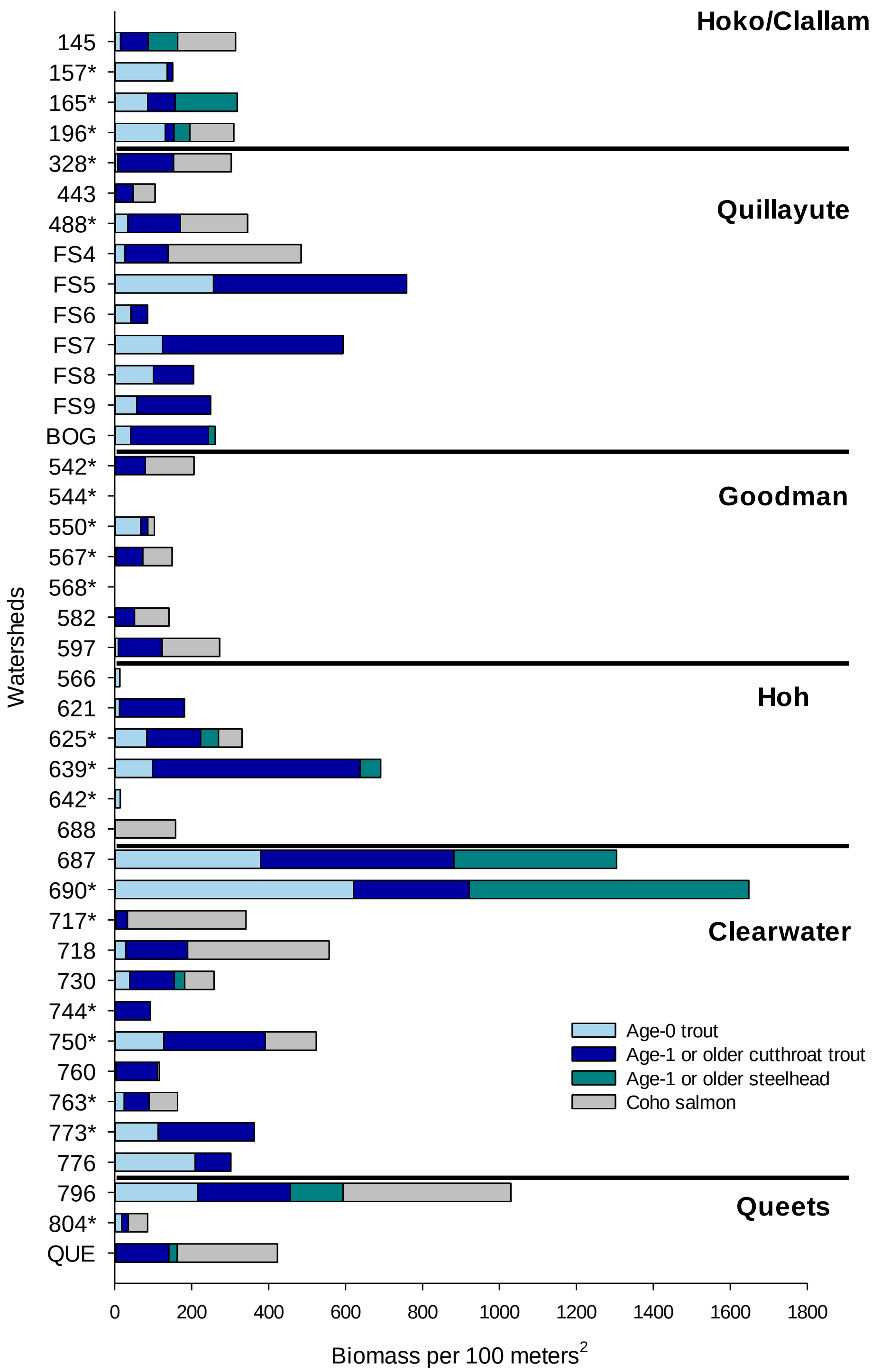

*Figure 3. Fish Biomass per 100 meters^2 of reaches sampled during the summer of 2019 under the Department of Natural Resources' Riparian Validation Monitoring Program (RVMP). *Annual sampling reaches*

Altogether, fish numbers in the annually sampled watersheds have increased from 2016. However, fish numbers slightly decreased from 2018 to 2019, the first decrease since sampling began. Juvenile coho salmon numbers have increased every year from 2016 through 2019. Age-0 trout have shown the most variability and appear to be driving the overall trend. Age-1 and older coastal cutthroat trout and steelhead numbers have been mostly stable (Figure 4).

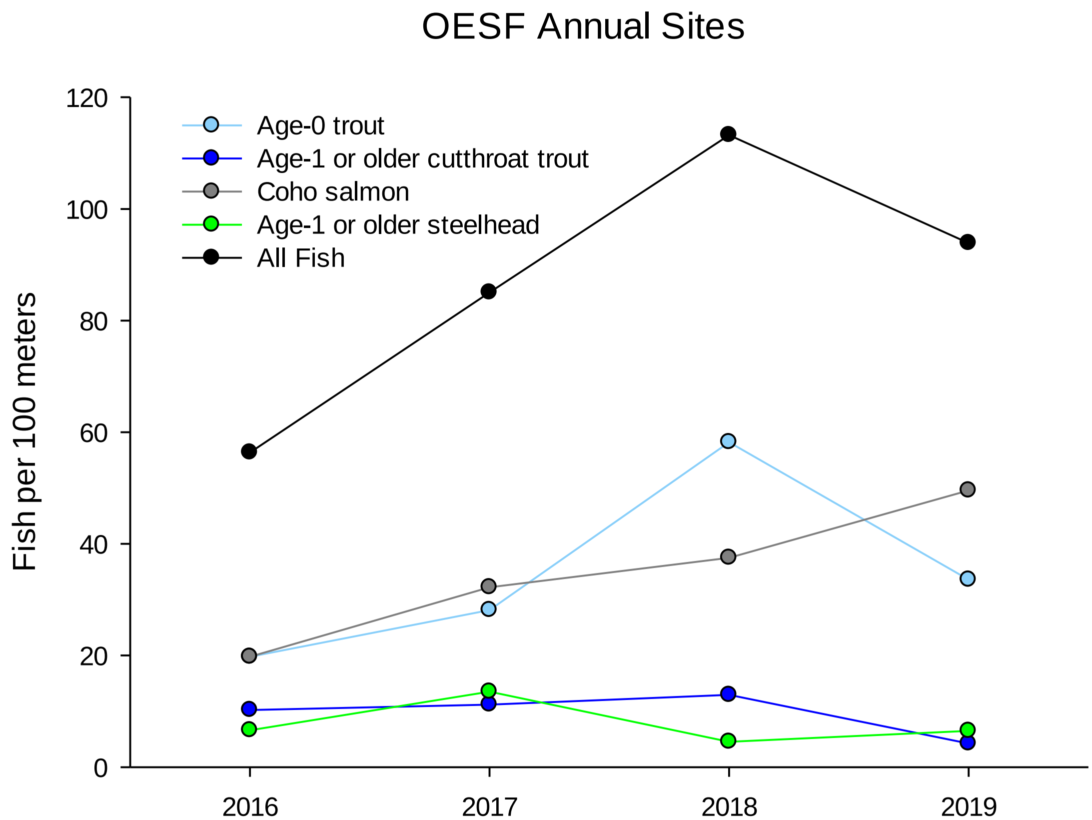

Figure 4. Average fish per 100 meters of stream for the annual panel of sampling sites (n=20) under the Riparian Validation Monitoring Program (RVMP) on the Olympic Experimental State Forest.

Fish Biomass in the annually sampled watersheds has followed a similar pattern as fish density with the highest biomass in 2018. The high level of biomass in 2018 was driven primarily through age-1 or older cutthroat trout. While most fish biomass levels have shown high variability over the four years, juvenile coho salmon have slowly increased every year (Figure 5).

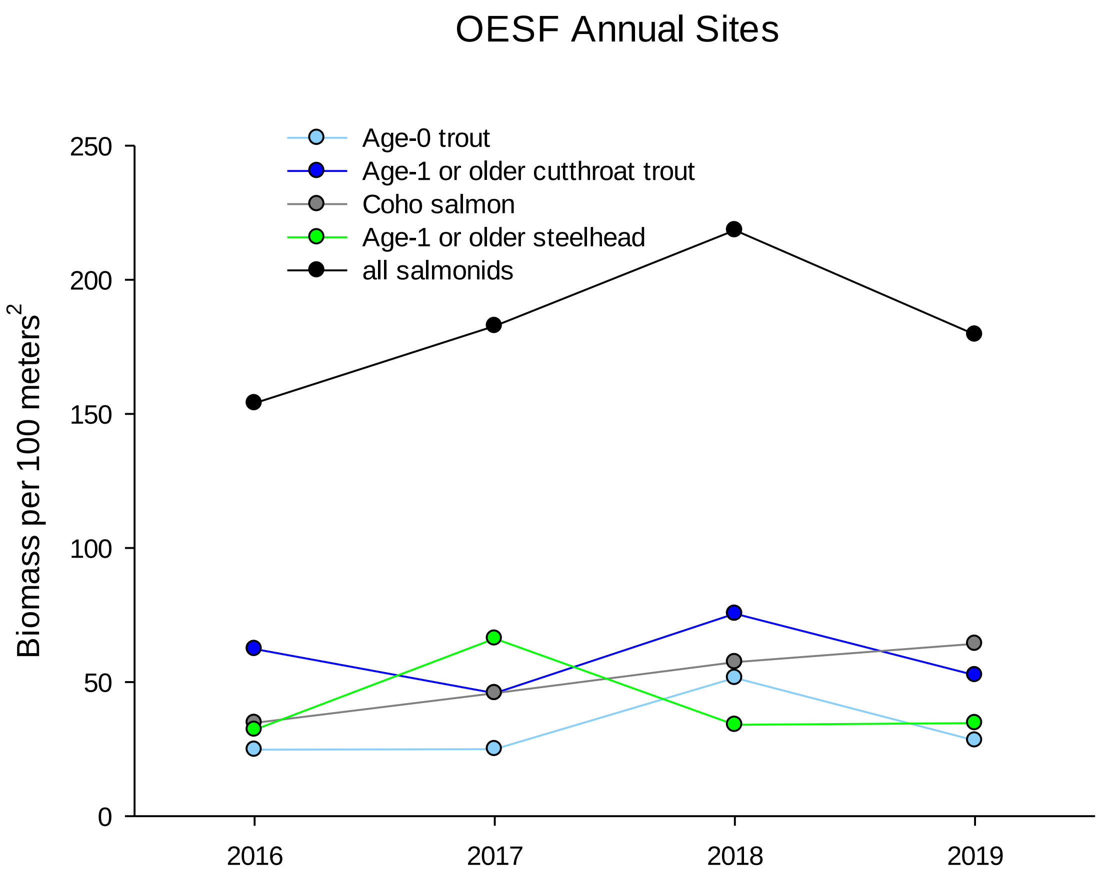

Figure 5. Average Biomass (g) per 100 meters^2 for the annual panel of sampling sites (n=20) under the Riparian Validation Monitoring Program (RVMP) on the Olympic Experimental State Forest.

Redd surveys were conducted in 18 streams in 2019 including the 12 streams sampled annually for redds from 2016 through 2019. Watershed 328 has contained the most amount of redds every year sampled and contained a record 26 redds in 2019. This stream appears to be an anomaly as most streams have ranged from 0 to 5 redds. Overall, several of these streams, that typically contain coho salmon, seem to consistently have few to no redds (Figure 6).

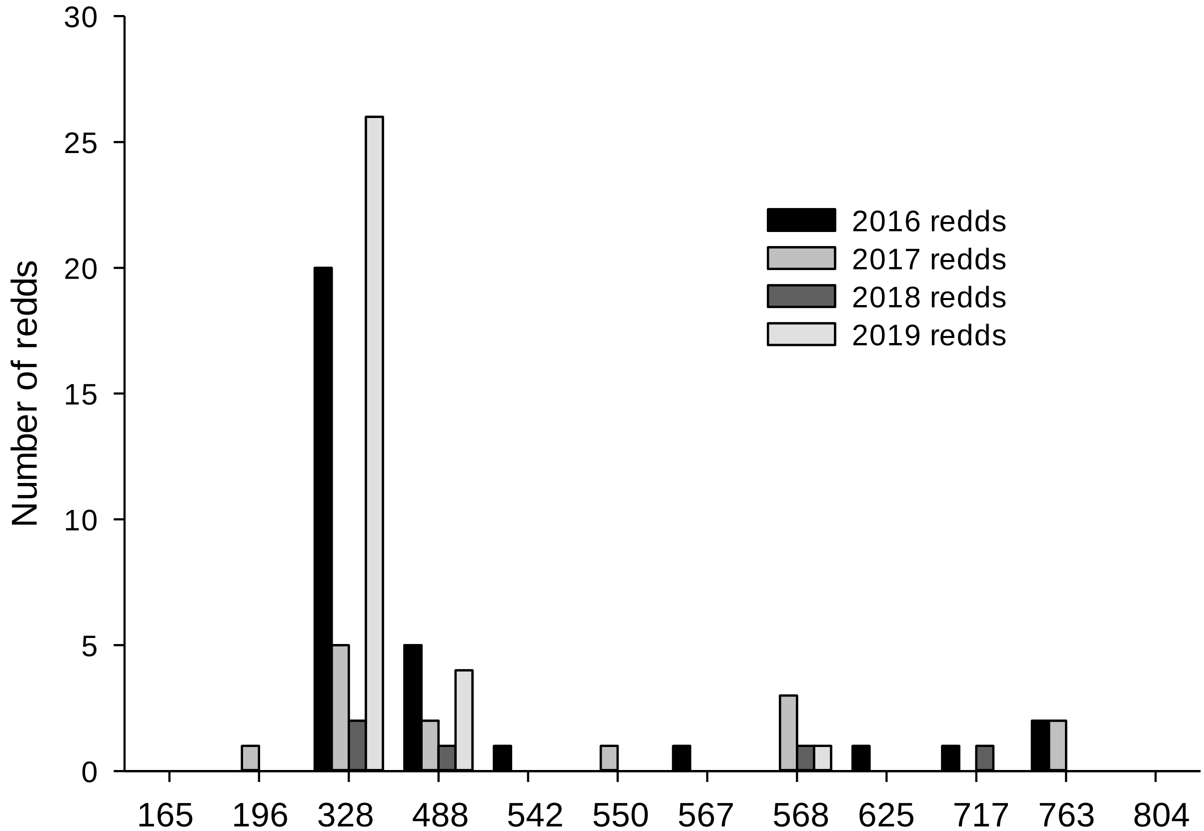

Figure 6. Coho salmon redd surveys conducted in the annual panel of watersheds from 2016 through 2019.

In 2019 Clearwater River snorkel survey, juvenile coho salmon numbers have been highest in the upper most reach (Reach 1) with the lowest number of juvenile coho salmon in 2018 (Figure 7). Age-0 trout (a combination of juvenile steelhead and coastal cutthroat trout) had the highest numbers in the upper most reach (Reach 1) and the lowest numbers in the most downstream reach (Reach 3; Figure 7), while mountain whitefish numbers have been highest in the lowest reach and have decreased from 2017 through 2019 (Figure 8).

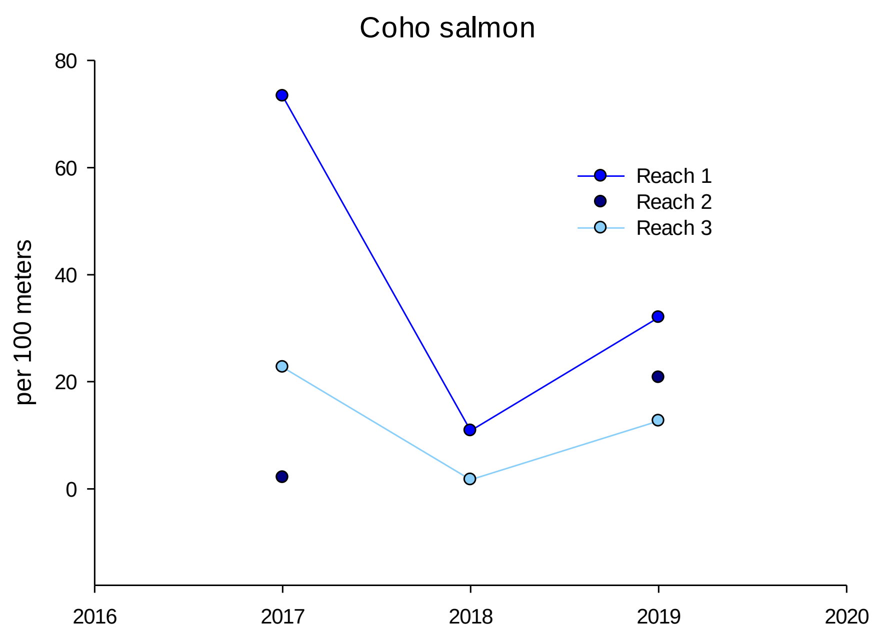

Figure 7. Coho salmon in the Clearwater River during snorkel surveys from 2017 through 2019. Reach 2 was not snorkeled in 2018 due to higher than usual rain accumulations that led to poor visibility.

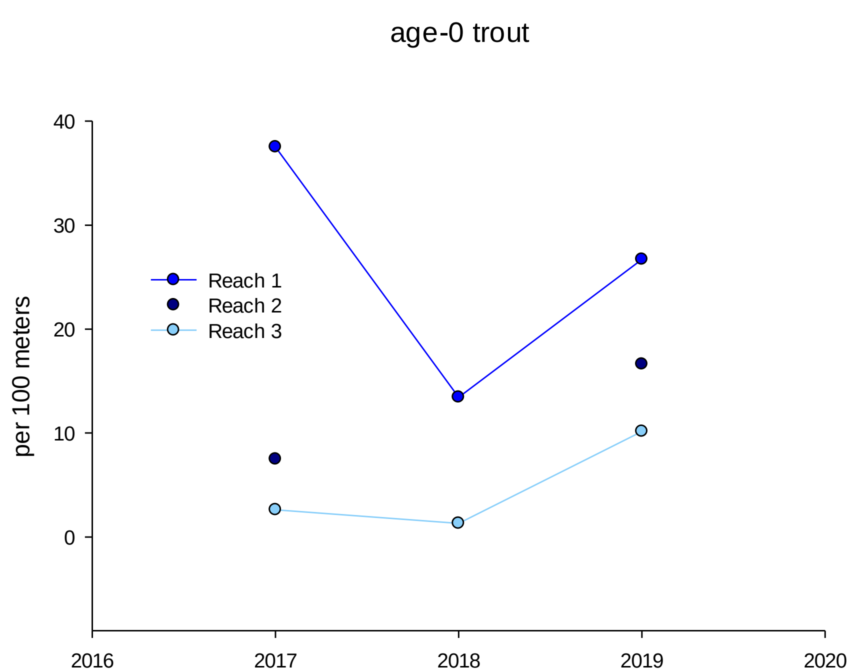

Figure 8. Age-0 trout in the Clearwater River during snorkel surveys from 2017 through 2019. Reach 2 was not snorkeled in 2018 due to higher than usual rain accumulations that led to poor visibility.

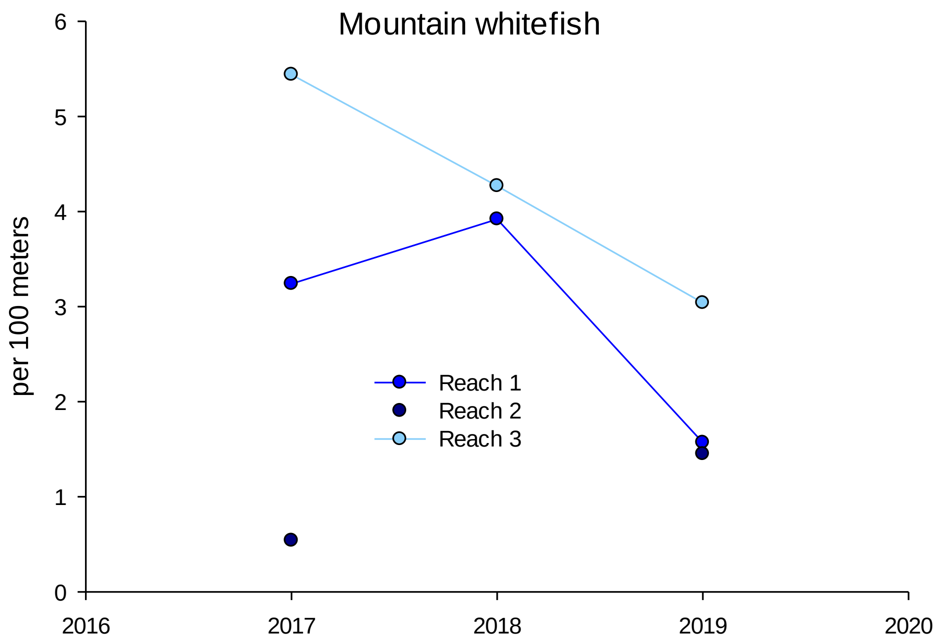

Figure 9. Mountain whitefish in the Clearwater River during snorkel surveys from 2017 through 2019. Reach 2 was not snorkeled in 2018 due to higher than usual rain accumulations that led to poor visibility.

Discussion

The lack of an obvious spatial pattern between watersheds highlights the need to continue sampling a large number of watersheds. The OESF contains diverse landscapes that result in diverse fish communities and abundances. Relatively stable age-1 or older populations of coastal cutthroat trout and coho salmon provide hope that potential habitat changes can be identified. Increases in juvenile coho salmon numbers over the four years of sampling is encouraging, however these numbers may be influenced by ocean conditions and adult returns, and not necessarily the result of improving habitat on DNR lands.

The lack of consistent coho salmon redd counts in watersheds with relatively consistent numbers of juvenile coho salmon could be attributed to two sources: 1) upstream spawning and downstream movement or 2) upstream juvenile coho salmon movement from larger streams. In many of these streams, the 1,000 meter surveys make up all or the majority of anadromous access. As such, most juvenile coho salmon in watersheds without coho salmon redds are likely the result of juvenile fish movement into the watersheds. Juvenile coho salmon movement into tributary streams has been well documented and allows for habitat expansion beyond areas with coho salmon spawning (Kahler et al. 2001; Bramblett et al. 2002; Wigington et al 2006).

Clearwater River snorkel surveys have consistently found lower numbers of juvenile fish in Reach 3 (River kilometer 40 to 33) when compared to Reach 1. Reach 3 has also been found to lack instream wood (Martens 2018), which has been found to be detrimental towards salmonids (Roni et al. 2015). Reach 2 also suffers from low amounts of instream wood and salmonids numbers. This reach is contained within a canyon making stream restoration and instream wood placements more complicated and less likely to persist over the long term (canyon reaches often have more concentrated flows and narrower floodplains that tend to move wood easier than areas with wider flood plains). Based on initial findings, Reach 3 provides the greatest opportunity to increase salmonid production within the study area. Due to the ongoing monitoring, stream restoration within this area would provide a no cost opportunity to evaluate the effectiveness of any restoration actions. This type of monitoring is uncommon and needed to ensure that restoration actions are working (Palmer et al. 2005).

As sampling continues and more data becomes available, we are better suited to distinguish differences in management-related habitat changes from natural year-to-year variability in fish abundance and biomass (possibly associated with adult returns or seasonal weather trends). Understanding this annual variability will help to separate yearly differences from long-term shifts in habitat. These patterns will be crucial for understanding the effects of DNR management on fish populations. In the meantime, we are constantly learning more about the status of fish and habitat across the OESF. This work has led to an ever-increasing number of publications. These publications include information comparing past conditions on the OESF to current conditions (Martens et al. 2019), coastal cutthroat trout conditions on the OESF (Martens 2019), and a review assessing how forest conditions affect the amount of instream wood (Martens et al. 2020). In addition, early indications on two limiting factors (low amounts of instream wood and high stream shading) led to the development of an alternative management strategy in the new T3 watershed study. This study began pre-treatment monitoring in 2020 and will test two alternative management strategies against current management practices. Several watersheds in the RVMP (488, 730, and 760) are scheduled for Variable Retention Harvests over the next few years. These watersheds have been prioritized for annual sampling and contain at least three years of pre-treatment monitoring that will allow us to effectively monitor any potential response of salmonids using one of the most recommended designs (Before, After, Control, Impact or BACI) for these types of studies. This work will create a better understanding of DNR forest management and its impact on the surrounding environment and will give managers and other stakeholders some of the first information on whether the guidelines within the HCP are working.

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Appendix 1. Abundance and Biomass estimates for watersheds sampled in 2019. OESF = Olympic Experimental State Forest, REF = reference, CTT = Coastal cutthroat trout, TRT = age-0 coastal cutthroat trout and rainbow trout/steelhead, STH = steelhead, RBT = rainbow trout, COH = coho salmon

Watershed	Type	Panel	Species	Abundance (fish/m)	Biomass (biomass/m^2)
145	OESF	ODD	CTT	0.0726	0.2853
			TRT	0.0726	0.0602
			STH/RBT	0.0846	0.3010
			COH	0.4353	0.5946
157	OESF	ANNUAL	CTT	0.1951	0.0615
			TRT	0.6160	0.5880
165	OESF	ANNUAL	CTT	0.0442	0.2330
			TRT	0.1680	0.2797
			STH/RBT	0.1061	0.5255
196	OESF	ANNUAL	CTT	0.0255	0.0711
			TRT	1.0638	0.4182
			STH/RBT	0.0511	0.1308
			COH	1.5745	1.1412
328	OESF	ANNUAL	CTT	0.1118	1.1411
			TRT	0.0813	0.0640
			COH	0.6504	1.1795
443	OESF	ODD	CTT	0.0487	0.3470
			TRT	0.0122	0.0200
			COH	1.0764	0.4280
488	OESF	ANNUAL	CTT	0.1243	0.7750
			TRT	0.2253	0.1977
			COH	0.8314	0.9940
542	OESF	ANNUAL	CTT	0.0800	0.4379
			COH	0.5700	0.6936
544	OESF	ANNUAL	CTT	0.0523	NA
			COH	0.5860	NA
550	OESF	ANNUAL	CTT	0.0089	0.0499
			TRT	0.1601	0.1842
			COH	0.0267	0.0456
566	REF	ODD	TRT	0.1052	0.1268
567	OESF	ANNUAL	CTT	0.0192	0.1196
			TRT	0.0096	0.0060
			COH	0.1152	0.1290
568	OESF	ANNUAL	CTT	0.1261	NA
			TRT	0.0126	NA
			COH	0.3026	NA
582	OESF	ODD	CTT	0.0236	0.1971
			COH	0.3298	0.3386
597	OESF	ODD	CTT	0.0306	0.3628
			TRT	0.0613	0.0303
			COH	0.6333	0.4753

621	OESF	ODD	CTT	0.3130	1.0463
			TRT	0.1789	0.0792
625	OESF	ANNUAL	CTT	0.1104	0.4886
			TRT	0.3642	0.2925
			STH/RBT	0.0221	0.1629
			COH	0.1214	0.2130
639	OESF	ANNUAL	CTT	0.2997	2.4524
			TRT	0.3663	0.4469
			STH/RBT	0.0333	0.2410
642	OESF	ANNUAL	TRT	0.2757	0.1208
687	OESF	ODD	CTT	0.3560	1.6634
			TRT	1.4450	1.2558
			STH/RBT	0.3037	1.4004
688	OESF	ODD	COH	0.3197	0.3973
690	OESF	ANNUAL	CTT	0.1609	0.8513
			TRT	1.9183	1.7590
			STH/RBT	0.3713	2.0583
717	OESF	ANNUAL	CTT	0.0232	0.2034
			TRT	0.0116	0.0302
			COH	1.2065	2.1679
718	OESF	ODD	CTT	0.0772	0.3693
			TRT	0.0686	0.0672
			COH	0.8662	0.8473
730	OESF	ODD	CTT	0.0563	0.3573
			TRT	0.0938	0.1198
			STH/RBT	0.0188	0.0828
			COH	0.1501	0.2348
744	OESF	ANNUAL	CTT	0.1024	0.5792
			TRT	0.0093	0.0070
750	OESF	ANNUAL	CTT	0.2765	0.9828
			TRT	0.7190	0.4809
760	OESF	ODD	CTT	0.0661	0.5430
			TRT	0.0472	0.0230
			COH	0.7460	0.6730
763	OESF	ANNUAL	CTT	0.0544	0.2829
			TRT	0.2860	0.1109
			COH	0.2993	0.3250
773	OESF	ANNUAL	CTT	0.1037	0.6661
			TRT	0.3456	0.3011
776	OESF	ODD	CTT	0.0486	0.3610
			TRT	0.2430	0.8180
796	OESF	ODD	CTT	0.0435	0.4350
			TRT	0.3623	0.3901
			STH/RBT	0.0580	0.2478
			COH	1.0000	0.7890
804	OESF	ANNUAL	CTT	0.0123	0.0612
			TRT	0.0860	0.0647
			COH	0.1597	0.1770

BOG	REF	ODD	CTT	0.1618	0.8113
			TRT	0.1010	0.1669
			STH/RBT	0.0101	0.0720
FS4	REF	ANNUAL	CTT	0.1170	0.4597
			TRT	0.1890	0.1116
			COH	1.2421	1.4139
FS5	REF	ANNUAL	CTT	0.3146	2.9140
			TRT	1.0112	1.4921
FS6	REF	ANNUAL	CTT	0.1315	0.4307
			TRT	0.1972	0.1510
FS7	REF	ANNUAL	CTT	0.4248	1.2850
			TRT	0.6372	0.3390
FS8	REF	ANNUAL	CTT	0.1394	0.3125
			TRT	0.4781	0.3009
FS9	REF	ANNUAL	CTT	0.1101	0.3640
			TRT	0.1018	0.1084
QUE	REF	ODD	CTT	0.0857	0.7496
			TRT	0.0214	0.0157
			STH/RBT	0.0236	0.1190
			COH	0.4069	1.4129

Chapter 2: Bear Creek Culvert Removal

Alexandra Howell and Kyle D. Martens

Introduction

The construction of roads, bridges or culverts are typically designed and used to enable vehicle passage over streams. In the past, many streams crossings were designed to allow water passage without regard to fish presence or migration patterns, often using cheaper small-diameter culverts over more expensive bridges. These culverts often fully blocked fish passage or created conditions that reduced passage for some species or life stages of fish. This led to a large number of culverts that negatively affected fish by creating impassable water drops, accelerated stream velocities, or otherwise altered stream flows that disrupt or isolate fish populations (Goodrich et al. 2018; Baker and Votapka 1990). Impassable culverts can have an especially negative impact on anadromous fish, such as salmon, because they can reduce the amount of available spawning and rearing habitat. Conroy (1997) found that >7,500 km of otherwise-appropriate spawning habitat in Washington state was inaccessible due to impassable culverts. For example, impassible culverts were estimated to reduce coho salmon (*Oncorhynchus kisutch)* smolt production in the Stillaguamish and Skagit river basins by 30–58% (Beechie et al. 1994; Pess et al. 1998). This loss of spawning and rearing habitat has been identified as one of the causes of salmon declines (Roni et al. 2002).

Partial and/or seasonal barriers that allow some—but not all—fish to pass can also negatively impact fish populations. Culverts may allow adult fish to pass, but pose a barrier to smaller fish, such as juveniles and/or small resident fish (Baker and Votapka 1990). Similarly, a culvert that is passable at some flows may become impassable at others. For example, when flow is high, water velocities can exceed a fish's maximum burst speed, and when water levels are low there can be insufficient water for fish to swim up through culverts (Davis and Davis 2010; Evans and Johnson 1980). While these barriers may allow adult fish to reach spawning habitat upstream of the culvert, they may still reduce available rearing habitat for juveniles and affect their ability to respond to changing hydraulic and climatic conditions (Baker and Votapka 1990; Furniss et al. 1991).

Due to concerns over the negative impacts of culverts on salmonid populations in Washington, in 2001 the Washington Forest Practices Rules included the Road Maintenance and Abandonment Plan rules for all large forest landowners. All large forest landowners must bring their roads into compliance with forest practices rules, including fixing fish passage barriers, by 2016 or by 2021 with an approved extension. In addition, newly identified barriers must also be fixed. Currently, DNR is more than 99% complete in fixing known fish barriers and has fixed over 2500 barriers since 2001.

State agencies not under the Forest Practices Rules were mandated to remove or repair all fish barrier culverts by 2030. In 2001, twenty-one tribes joined by the United States sued the state of Washington, arguing that the use of impassable culverts prevented the tribes from fishing in their "usual and accustomed fishing places" (United States v. Washington, No. CV 70-9213 [W.D. Wash. March 29, 2013]; Blumm 2017). In 2013, the courts issued an injunction stating that Washington's state agencies were obligated to fix or remove all culverts "in order to pass all species of salmon at all life stages at all flows where the fish would naturally seek passage" (United States v. Washington, No. CV 70-9213, [W.D. Wash. March 29, 2013]). The 2013 injunction applied to approximately 1,000 culverts "west of the Cascade Mountains and north of the Willapa and Columbia River drainages" and required the state to repair, replace, or remove all fish-barrier culverts by 2030 (Kanzler et al. 2019). The goal of the injunction was to help salmon populations recover by opening up more habitat. Models have determined that one of the most effective ways to aid salmon population recovery is to increase their available habitat (Rieman et al. 2001; Wilson 2003). Similarly, field studies have found that opening up more habitat through barrier removal can facilitate salmon recovery (Roni et al. 2008; Zimmerman 2020).

Successful barrier removal can be determined through changes in fish presence or abundance. Fish have the ability to recolonize newly available habitat relatively quickly (Roni et al. 2008). One study found that 90% of spawning coho salmon used habitat upstream of a removed barrier within a year of completion (Beamer et al. 1998). Similarly, after the installation of a fish passage facility at Washington's Landsburg dam, Chinook salmon (*O. tshawytscha*) spawned upstream within a year of completion (Burton et al. 2013). Another study on the removal of a fish-blocking culvert in British Columbia, found that bull trout (*Salvelinus confluentus*) spawned in the newly-accessible habitat within a year (Shrimpton et al. 2008). The use of reconnected habitat can also facilitate salmon population increases. Shrimpton et al. (2008) found that bull trout returned to spawn upstream of a replaced culvert within a year, resulting in a population increase when compared to a control stream. In addition, Pess et al. (2003 and 2005) found that the removal of barrier culverts was followed by increases in juvenile salmon population densities by "one to two orders of magnitude" over the course of several years with the largest increases occurring when reconnected habitats had higher levels of pools and large instream wood. Another study found that barrier removal was the most effective means of restoration and responsible for 70% of the observed population increases (Scully et al. 1990). Overall, culvert removal projects can produce positive results within a year and can create sustained positive impacts (Roni et al. 2002, Beechie et al. 2003).

Washington State Department of Natural Resources (DNR) routinely replaces or removes problematic culverts that are newly discovered to meet the Forest Practices RMAP rules. While the majority of culvert removal projects are expected to provide substantial benefits for anadromous salmonid populations, questions remain on how much benefit can be derived from improving partial barrier culverts or culverts that allow access to only minimal amounts of upstream habitat. Monitoring these culvert removals can provide more information on the importance of partial barrier culvert removals and improve our understanding of restoration activities. In this study, we monitored the fish response to a culvert removal in Bear Creek in state trust lands located on Washington's Olympic Peninsula.

Study Area

The Bear Creek culvert was selected because it was 1) scheduled to be replaced in the near future, and 2) had potential for juvenile coho salmon below the culvert. All of the other culverts evaluated for monitoring were determined to be very unlikely to have juvenile coho salmon below the culvert prior to removal, reducing the chance to identify a change in species composition (the most obvious passive sign of fish passage improvement). Bear Creek is located on Washington's Olympic Peninsula with portions flowing through state lands managed by the DNR. Bear Creek is a second-order (DNR Type-3) stream that flows into the Hoko River. The Hoko River watershed is home to Chinook salmon, chum salmon (*O. keta*), coho salmon, steelhead (*O. mykiss*), and coastal cutthroat trout (*O. clarkii clarkii*; WDFW 2020). In 2018, a culvert, meeting the guidelines as a fish passage barrier (WDFW 2009), was removed (Figure 1 and 2). The culvert was located on an abandoned road (E1400) 7.4 km upstream from the stream's confluence with the Hoko River. The culvert was a 40 ft long corrugated metal tube with a gradient of 4.5%. Prior to removal only coastal cutthroat trout and sculpin were found both above and below the culvert.

Figure 1. Bear Creek culvert prior to removal.

Figure 2. Bear Creek culvert after removal.

Methods

This study uses a Before After Control Impact (BACI) design to evaluate the removal of the Bear Creek culvert. A BACI design is one of the more robust designs and often recommended to evaluate stream restoration. Monitoring began in 2017 and included two years of pre-removal monitoring before the culvert was removed after the 2018 sampling. 2019 was the first year of three planned years (2019-2021) of post-removal sampling. The study sampled two reaches: one above the culvert and one below. The above-culvert reach is considered the treatment reach with any changes in salmonids expected to take place in this reach after removal. The downstream reach is considered the control and expected to show no response after the treatment. Initial sampling in the spring of 2017 found only coastal cutthroat trout and sculpin above the culvert prior to removal. No sampling was done below the culvert, but it was expected that anadromous fish could access the area below the culvert.

Fish surveys were conducted using multi-pass removal electrofishing. Electrofishing was conducted over 100 meter reaches with a minimum of three and up to six forward and backward passes per survey. Prior to electrofishing, seine nets were placed at the top and bottom of reach to block fish movement. Electrofishing was conducted using a Smith-Root model 24b backpack electrofisher (https://www.smith-root.com) using a frequency of 20 hertz with 10% duty cycle and voltage ranging from 300 to 600 volts. The number of passes was determined through the charts of Connolly (1996) and used as described in Martens and Connolly (2014). Sculpin were not actively collected during the survey since they are not as easily collected as salmonids with electrofishing (sculpin do not have a swim bladder and are not as effectively captured by electrofishing as other fish). Using a variable-pass method reduces underestimation resulting from insufficient passes, and improves the quality of the estimates by increasing the number of passes when needed (Rosenberger and Dunham 2005, Connolly 1996). Captured salmonids were anesthetized with MS-222, visually inspected, measured, weighed, and released (Martens 2019).

Once electrofishing was complete, a habitat survey was conducted over the sampled reach to determine the amount of instream wood; characterize habitat units (riffle, pool, etc.); and measure each unit's length, width, and depth. Finally, using the sample reach length and width; number of salmonids captured; and salmonid weight and lengths, the fish density per 100 meters of reach and fish biomass per square meter of reach surface area for each year were calculated. Population estimates were conducted by species and age class.

Results

Fish Density

In both reaches, coastal cutthroat trout and sculpins were the only fish species collected over the entire study. Overall, coastal cutthroat trout density in both reaches increased after culvert removal. For age-0 coastal cutthroat trout, density prior to culvert removal averaged 72.31 fish per 100 meters (fish/100m) below the culvert, and 70.51 fish/100m above the culvert. The year after the culvert was removed (2019), these values increased to 111.41 fish/100m below the culvert, and 109.30 fish/100m above the culvert. These increases observed in 2019 resulted in an overall increase in age-0 coastal cutthroat trout after culvert removal from an average of 71.41 fish/100m to 110.36 fish/100m in Bear Creek.

Age-1 and older costal cutthroat trout populations followed a similar trend. Coastal cutthroat trout density prior to culvert removal averaged 13.25 fish/100m below the culvert and 18.37 fish/100m above the culvert (Figure 3). The year after the culvert was removed (2019), these values increased to 21.00 fish/100m below the culvert, and 31.22 fish/100m above the culvert. This resulted in an overall increase in age-1 and older coastal cutthroat trout after culvert removal from an average of 15.81 fish/100m to 26.118 fish/100m in Bear Creek.

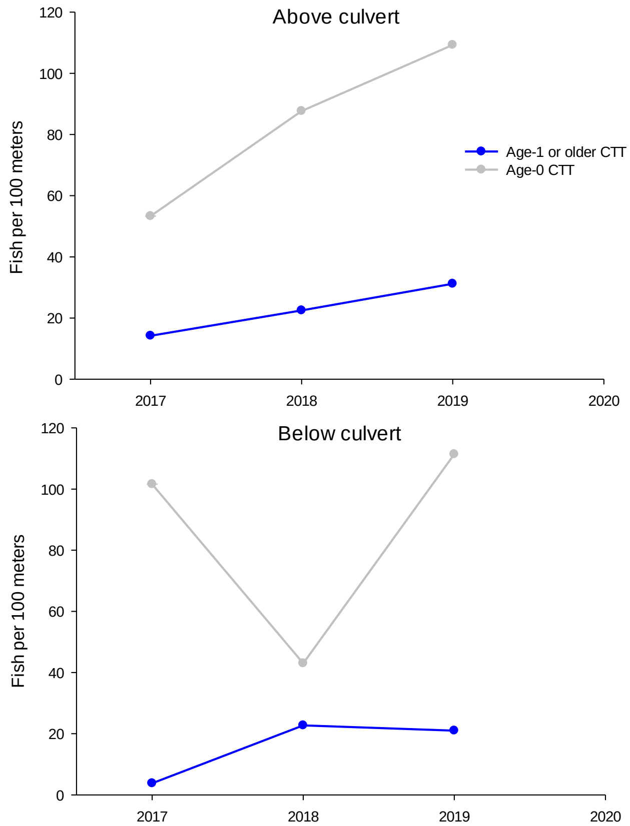

Figure 3. Fish density in Bear Creek above and below the culvert from 2017 through 2019.

Biomass

Examining the stream as a whole, coastal cutthroat trout biomass throughout the stream did not change dramatically after culvert removal. For age-0 coastal cutthroat trout, fish biomass remained at about 0.7122 g biomass per square meter (g/m^2) throughout the stream, and age-1 and older coastal cutthroat trout biomass remained at about 1.1095 biomass/m^2 (Figure 4).

However, both age groups did see a change when assessing fish biomass above and below the removed culvert. Age-0 coastal cutthroat trout biomass increased above the culvert after removal from 0.6025 biomass/m^2 to 0.7842 biomass/m^2, and decreased below the culvert after removal from 0.7975 biomass/m^2 to 0.6647 biomass/m^2. Age-1 and older coastal cutthroat trout saw a similar trend. Their biomass increased above the culvert after removal from 0.8512 biomass/m^2 to 1.2748 biomass/m^2, and decreased below the culvert after removal from 1.3800 biomass/m^2 to 0.9320 biomass/m^2.

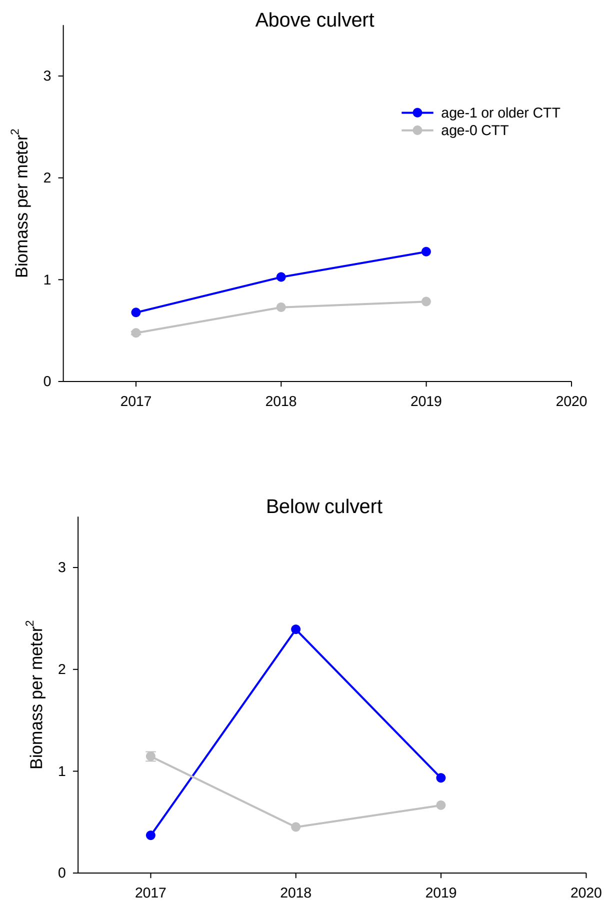

Figure 4. Fish Biomass in Bear Creek above and below the culvert from 2017 through 2019.

Discussion

One year after culvert removal, coastal cutthroat trout abundances in Bear Creek were higher than they were prior to culvert removal both above and below the culvert. However, more years of monitoring are required before we can attribute this increase to culvert removal. For example, the fact that both the above and below sites had similar increases may indicate a yearly fluctuation rather than a response to culvert removal. Salmon recruitment and abundances can fluctuate from year to year, even without restoration efforts (Platts and Nelson 1988, Kratzer and Warren 2012, Dauwalter et al 2009). To better understand the effects of culvert removal more post-treatment monitoring will be needed to accurately convey the impact of the Bear Creek's culvert removal project.

The only way to definitively identify a response a year after removal, without expensive tracking equipment, would be to discover a change in species presence. Unfortunately, there were no changes in fish species either above or below the site after removal. Since coastal cutthroat trout exist in both resident and anadromous forms, coho salmon would be the most likely species to occupy the area and provide evidence of anadromous fish passing above the former barrier. As is, it is unclear if there is a downstream barrier or if reduced populations of coho salmon are preventing expansion into the newly open habitat. Future sampling may determine if coho salmon are capable of reaching the newly assessable habitat, but will not inform if the removed culvert was a barrier to anadromous species prior to removal.

The preliminary findings suggest coastal cutthroat trout densities and biomass are higher in 2019 after culvert removal than they were before culvert removal. These findings align with the findings of previous barrier-removal studies, which have found that salmonid populations increase in reaches where barriers are removed as early as a year after removal (Beamer et al. 1998, Roni et al. 2002, Roni et al. 2008, Shrimpton et al. 2008). However, due to the dynamic nature of salmonid populations—as well as the inherent variability that comes with conducting research in natural systems—one year of post-removal monitoring is not enough to make definitive conclusions. In order to determine if changes are resulting from culvert removal, a minimum of three years of post-removal monitoring will be needed.

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