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Fish and Habitat Assessment in Rock Creek, Klickitat County, Southeastern Washington, 2018

Open-File Report 2020–1051

U.S. Department of the Interior
U.S. Geological Survey

Cover:
Background photograph: Electrofishing sample reach showing block nets to define sample area, Rock Creek,southeastern Washington (Photograph by Jill Hardiman, Fisheries Biologist, U.S. Geological Survey, October 2017).
Inset photograph: *Oncorhynchus mykiss* captured during electrofishing in Rock Creek, southeastern Washington (Photograph by Rachel Ohnemus, Biological Technician, U.S. Geological Survey, October 2017).

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
meter (m)	1.094	yard (yd)
kilometer (km)	0.6214	mile (mi)
	Area	
square centimeter (cm^2)	0.1550	square inch (ft^2)
square centimeter (cm^2)	0.001076	square foot (ft^2)
square meter (m^2)	10.76	square foot (ft^2)
square meter (m^2)	0.0002471	acre
square kilometer (km^2)	247.1	acre
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
cubic meter (m^3)	35.31	cubic foot (ft^3)
cubic meter (m^3)	1.308	cubic yard (yd^3)
cubic meter (m^3)	0.0008107	acre-foot (acre-ft)
	Flow rate	
meter per second (m/s)	3.281	foot per second (ft/s)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32.$$

Datum

Vertical coordinate information is referenced to the, North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the, North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Abbreviations

AIC_c	Corrected Akaike's Information Criterion
DPS	Distinct Population Segment
ESA	Endangered Species Act
FL	fork length
GPS	geographic positioning system
MCR	Middle Columbia River
MS-222	tricaine methanesulfonate
MUX	Multiplexing Transceiver System (Destron-Fearing 1001M)
PIT	passive integrated transponder
PTAGIS	Columbia Basin PIT Tag Information System
PTIS	passive tag interrogation system
RCL	Rock Creek Longhouse
RCS	Rock Creek Squaw
rkm	river kilometer
SE	standard error
USGS	U.S. Geological Survey
YN	Yakama Nation

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Executive Summary

Native steelhead (anadromous form of rainbow trout [*Oncorhynchus mykiss*]) and bridgelip sucker (*Catostomus columbianus*) were historically used by the Kah-miltpah (Rock Creek) Band for sustenance, trade, and traditional practices in Rock Creek, a tributary to the Columbia River in southeastern Washington State. Rock Creek flows south to the Columbia River at river kilometer (rkm) 368 and is an intermittent stream of great significance to the Yakama Nation and to the Kah-miltpah Band in particular. Concern over declines in the abundance of these fish in Rock Creek prompted a research and monitoring program to better understand habitat conditions, population status, and limiting factors. In addition to steelhead and bridgelip sucker, coho salmon (*Oncorhynchus kisutch*) and resident rainbow trout are also present and monitored. Rainbow trout and steelhead will be collectively referred to as *O. mykiss*. Streamflow is a limiting habitat factor in this system, but steelhead and coho salmon still successfully return to spawn, rear, outmigrate, and survive over summer in many of the isolated pools that provide important refuge for juvenile rearing.

We completed a habitat survey during autumn 2018 to assess the perennial pools during low-flow conditions. In Rock Creek, the overall percentage of habitat recorded as dry was 41, non-pool wet was 42, and pool was 17. The number of pools (*n*=93) recorded was less than during previous years' survey efforts (2015–17). The percentage of non-pool wet habitat was generally higher in 2018 than in previous years. This is a likely result of habitat reaches, which in the past, were considered pools but have become shallower and smaller and are now categorized as non-pool wet habitat. However, the fewer habitat reaches categorized as pools in 2018 now have an average length, area, and depth that are generally greater than in past years. In Walaluuks Creek, the percentage of habitat recorded as dry was 53, non-pool wet was 40, and pool was 7. The percentage of pool habitat was the lowest of all years surveyed since 2015.

Fish sampling occurred during autumn after habitat surveys were completed from October 1 to November 9. Fish species distribution, relative abundance, length-frequency distribution, and pool fish density were determined using backpack electrofishing in stratified, systematically selected pools. During fish sampling, 855 *O. mykiss* were handled and 662 were tagged with a passive integrated transponder (PIT) tag, and 718 coho salmon were handled and 567 were PIT tagged. A total of 536 bridgelip suckers and largescale suckers (*Catostomus macrocheilus* [*n*=6]) were handled and 294 were PIT tagged. In Rock Creek, pool abundance estimates were calculated for six pools for both *O. mykiss* age classes (age 0 and age 1 or older [age 1+]) and one additional pool for age 1+. For pools where age-0 *O. mykiss* were present, the average pool population abundance was 0.144 (*n*=6; range: 0.052–0.208) fish per square meter. For age-1+ *O. mykiss*, the average pool population abundance was 0.045 (*n*=7; range: 0.002–

0.179) fish per square meter. For age-0 *O. mykiss* in Walaluuks Creek, the average pool abundance was 0.207 fish per square meter (*n*=7; range: 0.038–0.416), and for age-1+ fish, the average pool abundance was 0.382 fish per square meter (*n*=6; range: 0.009–0.761). In Rock Creek, coho salmon were more abundant than *O. mykiss* in pools except for three pools upstream from rkm 20. The average pool abundance for coho salmon was 0.256 fish per square meter (*n*=8; range: 0.019–0.756) in Rock Creek pools. In Walaluuks Creek, coho salmon were captured in four pools and were not captured in the upstream pools sampled. The average pool abundance for coho salmon in the four lower pools was 0.488 fish per square meter (*n*=4; range: 0.417–0.548). Bridgelip suckers were captured in all pools in Rock Creek except the pool sampled at rkm 21.8. The average pool abundance for bridgelip suckers was 0.552 fish per square meter (*n*=7; range: 0.015–1.554) in Rock Creek. Bridgelip suckers were captured in three downstream pools in Walaluuks Creek, and the average abundance was 0.044 fish per square meter (*n*=3; range: 0.024–0.085).

Overwinter and reach survival probabilities were estimated for *O. mykiss* and coho salmon using a Cormack-Jolly-Seber modeling approach. The best fit survival model for the *O. mykiss* and coho salmon was a reach only model. The upstream reach includes overwinter survival probability because fish are tagged and released in autumn and primarily migrate the following spring. During 2018, coho salmon (0.568, standard error [*SE*]=0.027) had a significantly higher probability of overwinter survival than *O. mykiss* (0.276, *SE*=0.019). The reach survival probability was higher for *O. mykiss* than coho salmon in the downstream migratory reaches. Survival was not modeled for bridgelip suckers. For bridgelip suckers, 147 were detected of 294, that were PIT tagged and released in the Rock Creek subbasin (50.0 percent).

Information provided in this report increases our understanding of the status and trends of these populations. It further documents how intermittent streams can support salmonid populations. It also provides insight into potential management and restoration actions that could be beneficial and timing and allocation of resources. Ongoing monitoring work of this population will inform progress towards Rock Creek species recovery goals and contribution to recovery goals for the steelhead Middle Columbia River Distinct Population Segment.

Introduction

The U.S. Geological Survey (USGS) collaborated with the Yakama Nation (YN) starting in autumn of 2009 to study fish populations in Rock Creek. Rock Creek is an intermittent stream of great significance to the YN and to the Kah-miltpah (Rock Creek) Band in particular. This work began as a Bonneville Power Administration Monitoring and Evaluation project (project number: 2007–156–00) to gather baseline environmental and biological data throughout the subbasin. The project focus was to understand the current status of native salmonid populations and associated habitat conditions and to identify opportunities for habitat restoration. Bridgelip suckers have been added as a species of concern for the YN Kah-miltpah Band in the Rock Creek subbasin. The overall goal of this project is to improve habitat conditions for native fish of concern and for salmonids listed under the Endangered Species Act (ESA) in the Rock Creek subbasin to support sustainable populations.

Historically, native steelhead (anadromous form of rainbow trout [*Oncorhynchus mykiss*]) and bridgelip sucker (*Catostomus columbianus*) were used by the Kah-miltpah Band for sustenance, trade, and traditional practices (Northwest Power Planning Council, 2004). Low-flow habitat surveys during late summer have consistently shown an intermittent streamflow pattern with disconnected perennial pools (Harvey, 2014, 2015; Hardiman and Harvey, 2019). Large sections of Rock Creek dry completely during summer, and flow connectivity does not return until late autumn to early winter. During 2015, a drought year, 46 percent of the surveyed stream length (from rkm 2 to rkm 22) was dry and 20 percent consisted of pools (Harvey, 2015). High water temperature during summer and early autumn (range: 17–25 degrees Celsius [°C], depending on location and year) further challenges survival of juvenile salmonids in lower Rock Creek sections (Harvey, 2015). Rock Creek lacks instream complexity. Shallow bedrock and boulder subarmor contribute to infrequent and shallow pool structure that lacks cover, and large woody debris is generally absent from the low-flow channel and is not a habitat forming agent (Conley, 2015). Despite these challenging conditions, salmonids continue to persist, adding to recent research documenting intermittent streams as important and productive salmonid habitat (Wigington and others, 2006; Ebersole and others, 2009; Woelfle-Erskine and others, 2017; Hwan and others, 2018).

Anadromous salmonid populations currently present and being monitored in the Rock Creek subbasin include coho salmon (*Oncorhynchus kisutch*) and steelhead. Resident rainbow trout are also present and monitored; rainbow trout and steelhead will be collectively referred to as *O. mykiss* throughout this report because it is difficult to distinguish between them as juveniles. Streamflow is a limiting habitat factor in this system, but *O. mykiss* and coho salmon still successfully spawn, rear, outmigrate, and survive over summer in many isolated pools (Harvey, 2014, 2015; Hardiman and Harvey, 2019). Smolt-to-adult return rates for the 3,039 steelhead smolts tagged with passive integrated transponder (PIT) tags in the Rock Creek subbasin during 2009−12 ranged from 2.2 to 5.5 percent (Harvey, 2015). During this time, coho salmon were only abundant in larger numbers in the Rock Creek subbasin in 2011, during which 151 fish were PIT tagged and, of these, 2 were detected in Rock Creek as adults (Harvey, 2014). The smolt-to-adult return rates fall within the steelhead Middle Columbia River Distinct Population Segment (MCR DPS) recovery goals of 2–6 percent as set by the Comparative Survival Study Oversight Committee (Comparative Survival Study Oversight Committee and Fish Passage Center, 2018). During, 2016–17, coho salmon were captured throughout the Rock Creek subbasin and were in abundance like that of *O. mykiss* in many of the pools sampled (Hardiman and Harvey, 2019).

The native steelhead population within Rock Creek is considered an independent population of the steelhead MCR DPS, which was listed as ESA threatened on January 5, 2006 (National Marine Fisheries Service, 2009a, b; National Oceanic and Atmospheric Administration, 2016). The Rock Creek population is within the Cascade Eastern Slopes Tributaries major population group. The National Marine Fisheries Service has a recovery goal for the Rock Creek population to reach a maintained population status, defined as 25-percent or less risk level (Northwest Fisheries Science Center, 2015; National Marine Fisheries Service, 2016). Ongoing monitoring work on this population will inform progress towards this recovery goal and contribute to the larger recovery goals for the MCR DPS.

Bridgelip suckers are a culturally significant species of concern to the YN and the Kah-miltpah ~~Band.~~ The bridgelip sucker was historically abundant throughout the Rock Creek subbasin. In the last decade, Tribal members have observed that suckers are less abundant for ceremonial and subsistence harvest. Little information is currently known about the movement, distribution, and abundance of bridgelip suckers in Rock Creek nor in populations within the central Columbia River, southeastern Washington (Dauble, 1980). In previous years, the presence of bridgelip suckers was documented during juvenile salmonid abundance and population surveys (Harvey, 2014; Hardiman and Harvey, 2019). During 2016–18, sampling for bridgelip suckers included PIT-tagging and mark-recapture techniques to assess fish distribution, pool abundance, and movement.

This assessment focuses on juvenile fish monitoring and habitat work completed during 2018 in Rock Creek subbasin. This is a continuation of monitoring efforts from 2016−17 and allows for comparisons to past work (2009−12); furthermore, it increases our understanding of current status and trends of fish distribution, abundance, and survival of fish species of concern within the Rock Creek subbasin (Harvey, 2014, 2015; Hardiman and Harvey, 2019). Continued monitoring of salmonids within this subbasin will provide population status and trends needed to assess progress towards reaching ESA recovery goals. It further contributes to restoration planning within the subbasin by identifying reaches where salmonids are more abundant and will provide a basis for effectiveness monitoring of future restoration projects. This work shows the importance of intermittent streams and local species adaptation and persistence in the face of challenging environmental conditions.

This report fulfills collaborative agreements with YN and Bonneville Power Administration annual reporting requirements for monitoring and evaluation of fish and habitat assessments within Rock Creek subbasin during 2018. It provides status and abundance metrics for juvenile *O. mykiss*, coho salmon, and bridgelip suckers in Rock Creek subbasin. This information adds to a multiyear monitoring and evaluation program to assess fish use, water quality/quantity, and habitat conditions to determine areas of high fish productivity and survival and limiting factors. Long term species and habitat monitoring is needed to assess effects of changes in climate conditions and landscape use, and successful strategies used in restoration projects.

Study Area

The Rock Creek watershed encompasses an area of 578 square kilometers (km^2; fig. 1). Rock Creek, in southeastern Washington, flows south to the Columbia River at river kilometer (rkm) 368. The mouth of Rock Creek at an altitude of 81 meters (m) is inundated up to 2 kilometers (km) by Lake Umatilla, the reservoir behind John Day Dam, which impounds the Columbia River. The headwaters of Rock Creek originate in the Simcoe Mountains, which are the watershed’s northern border at an altitude of 1,433 m, on the southern border of the YN Reservation. The average annual precipitation in Rock Creek varies from about 24 centimeters (cm) at the mouth to 65 cm near the headwaters (Conley, 2015). Major tributaries to Rock Creek include Walaluuks Creek (formerly named Squaw Creek) at rkm 13, Luna Creek at rkm 18.5, and Quartz Creek at rkm 27. From June through October each year, the streamflow in Rock Creek and its tributaries decreases, becoming intermittent until the autumn rains resume (generally in October or November). The fish habitat in Rock Creek is spatially diverse (“patchy”) with varied suitability as salmonid habitat during the low-flow period, particularly in the more downstream reaches. The primary limiting habitat factor is instream flow during the low-flow period. This is characterized by reduced connectivity and isolated pools, which can have direct and indirect effects on fish survival through predation, thermal stress, disease/parasite infestation, and competition for resources.

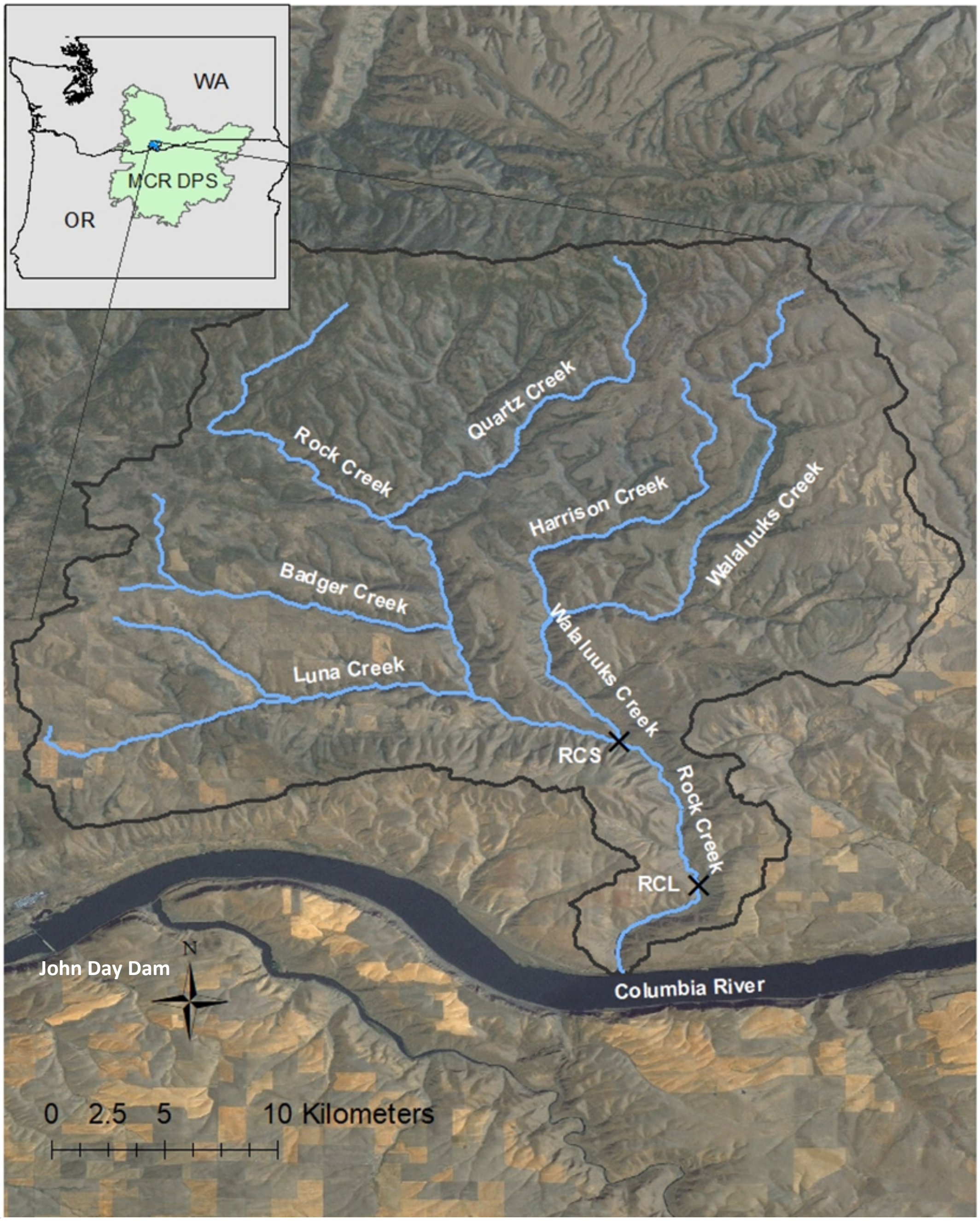

Figure 1. Map of the Rock Creek subbasin (indicated by black outline) and locations of tributary streams and passive tag interrogation systems (X) Rock Creek Squaw (RCS, river kilometer [rkm] 13) and Rock Creek Longhouse (RCL, rkm 5), Rock Creek, Washington and John Day Dam (rkm 347), Columbia River. Smaller map inset shows the location of the subbasin within the steelhead Middle Columbia River Distinct Population Segment (MCR DPS).

The Kah-miltpah Band lived in the Rock Creek subbasin for thousands of years and survived on historically abundant sources of fish, wildlife, and plants present there. Salmon, steelhead, Pacific lamprey (*Entosphenus tridentatus*), and bridgelip suckers are all culturally significant species that were once abundant in main stem Rock Creek before John Day Dam induced inundation of the lowest 2 km by Lake Umatilla. The Yakama Nation Longhouse is at rkm 6, and the primary land ownership within the study area is either YN or private.

Methods

Stream Pool Habitat Surveys

Habitat surveys were completed to assess fish habitat and identify perennial pools during low-flow conditions, autumn 2018. Methods used were like those used during 2015–17 habitat surveys (Harvey, 2015; Hardiman and Harvey, 2019). The survey started where Rock Creek and the backwater caused by John Day Dam converge (rkm 2) and continued upstream to about rkm 22. Walaluuks Creek was surveyed from the confluence with Rock Creek upstream to about rkm 8. During the survey, we measured the lengths (in meters) of habitat reaches categorized as dry and non-pool wet. For habitat reaches categorized as pools, additional variables were measured. These included the length (in meters) of the pool, wetted width (in meters) at the middle of the pool, average residual depth (in centimeters), maximum residual depth (in centimeters), and temperature (in degrees Celsius). Lengths were recorded using a range finder and measuring tape for sections that were highly vegetated. A geographic positioning system (GPS) point was taken at the start of each habitat reach, and associated survey data were recorded using an iPad with GIS Pro software. Additionally, a hard paper format was recorded in the field for subsequent data proofing. A photograph was taken at each habitat unit. A streamgage was maintained and monitored at the Old Highway 8 bridge (rkm 12.9) by YN and USGS personnel. The streamgage recorded stage height (in feet) every 15 minutes.

Fish Sampling and Tagging

Fish sampling was focused primarily on capturing juvenile salmonids and bridgelip suckers to investigate distribution, relative abundance, life history characteristics, and population dynamics. Sampling occurred during autumn from October 1 to November 9, after habitat surveys were completed. Sampling methods included electrofishing surveys, fish handling for measuring fork lengths and weights, and implanting PIT tags. Information on fish movement, timing, and detection histories to calculate survival estimates was determined using instream passive tag interrogation system (PTIS) sites. There are two PTIS sites in Rock Creek subbasin. The upstream site located at rkm 13 near the confluence with Walaluuks Creek (formerly named Squaw Creek), is referred to as Rock Creek Squaw (RCS), and the downstream site located at rkm 5, near the Rock Creek Longhouse referred to as Rock Creek Longhouse (RCL) site. The Columbia Basin PIT Tag Information System (PTAGIS) detection sites located at hydroelectric projects in the main stem Columbia River were also used.

The sample design for fish abundance focused on pool habitats in which mark-recapture techniques could be used to estimate abundance. Additional sampling occurred in non-pool habitats (that is, riffles and glides) and pools selected outside the sample design to obtain additional fish for PIT tagging. This allowed us to increase sample sizes for improving survival estimates, smolt travel time estimates, and smolt-to-adult return estimates in the future. Habitat survey data were used to determine pools available for electrofishing based on depth criteria. Selection criteria for pool abundance sampling was limited to pools with a maximum depth less than 140 cm and greater than or equal to 70 cm for Rock Creek and 55 cm for Walaluuks Creek. A stratified, systematic sample design with a randomly selected start pool was used to determine which pools to sample within a study year, like methods used in past study years (Harvey, 2014; Hardiman and Harvey, 2019). The pools available for sampling based on depth criteria were ordered by approximate river kilometer from downstream to upstream. The total number of pools was divided such that 10 pools would be identified within Rock Creek and 8 pools in Walaluuks Creek that would span the length of the study area for that creek. A number was selected randomly for the starting pool, and pools were systematically (for example, every third pool) selected after that. The goal for pool abundance sampling was to achieve estimates for at least eight pools in Rock Creek and six pools in Walaluuks Creek; however, extra pools were selected in the sample design, with the understanding that some pools may not be sampled. Reasons for not completing pool abundance sampling included the following: the pool location was too close to PTIS sites, a high proportion of the pool depths were equal to or greater than 100 to 120 cm and the crew could not safely and efficiently electroshock, the water temperature was greater than 17°C on the day of sampling with poor water quality, or too few fish were captured to complete mark-recapture analysis. Some legacy pools (perennial for multiple years and sampled in past years) were also selected for comparison to past results (2009−12 and 2016−17). Alternate pools were chosen as needed by sampling the next pool systematically selected or the nearest pool that was suitable for sampling. For Walaluuks Creek, fewer pools fit sampling criteria for depth, so more emphasis was placed on sampling legacy pools where we already had numerous years of data collected.

Pools were electrofished using a battery-powered Smith-Root model 12-B backpack electrofisher (Smith-Root, Inc., Vancouver, Washington). The electrofisher settings for voltage, frequency, and duty cycle were determined by the physical characteristics of the site (water conductivity, creek size, water volume). The lowest effective electrofisher settings were used to minimize fish injury. The electrofisher settings were typically 60 hertz, 6 milliseconds, and 300 volts (V). Two to three crew members with dip nets remained downstream from the electrofisher and netted stunned fish. Fish sampling consisted of single-pass electrofishing upstream from pool tail out to pool head and a single-pass downstream from head to tail out within each pool. We attempted to capture all juvenile salmonids, suckers (primarily bridgelip), and about 15 of any other fish species observed while electrofishing to determine fish species composition in each pool. One exception for fish collection procedures occurred for the pool near rkm 4 in lower Rock Creek, in which smallmouth bass (*Micropterus dolomieu*) and northern pikeminnow (*Ptychocheilus oregonensis*) were also collected and marked with a fin clip to do mark-recapture analysis. All captured fish were immediately placed into dark-colored, plastic buckets filled with ambient stream water and fitted with aerators. Fish were held until the pool had been electrofished and fish were recovered from handling procedures.

Fish processing procedures included anesthetizing, measuring, implanting PIT tags, and recovery. Fish were anesthetized with the tricaine methanesulfonate (MS-222) before physical handling (dosage of about 50 milligrams per liter MS-222). Because the effectiveness of MS-222 as an anesthetic varies with factors such as temperature and fish density, the concentration of anesthetic was adjusted if needed. Adjustment of the anesthetic concentration was based on the amount of time for a group (three to five) of fish to lose equilibrium. The goal was for the time to lose equilibrium to be between 1 and 5 minutes. After anesthetizing, fish were identified to the species level; scanned for PIT tags; measured for fork length (FL) to the nearest millimeter; weighed to the nearest 0.1 gram; and inspected for external signs of disease, parasite infection, or injury. The presence of disease or injury was noted on the datasheets. If fish were deemed to be in poor condition, at the tagger's discretion, a PIT tag would not be implanted, and a fin clip would be used as a mark instead. Tissue samples (a fin clip) for about 10–15 *O. mykiss* per pool were preserved for genetic analysis. Genetic samples were submitted to the Columbia River Inter-Tribal Fish Commission for analysis. To individually mark fish to track movements, estimate pool abundance (mark recapture), and estimate the probability of survival, we inserted PIT tags (12 mm; 134.2 kilohertz [kHz]) in the peritoneal cavity of salmonids and bridgelip suckers that exceeded 70-mm FL. All PIT tagging followed the procedures outlined by the Columbia Basin Fish and Wildlife Authority (1999). All PIT-tag data were entered into the PTAGIS database, maintained by the Pacific States Marine Fisheries Commission (accessed September 2019 at https://www.ptagis.org/home). To mark fish less than 70-mm FL, a fin clip was used on the caudal fin. During the recapture pass the following day, unmarked salmonids captured exceeding 70-mm FL were PIT tagged, but unmarked salmonids less than 70 mm were returned to the stream unmarked. After handling, fish were placed in a 5-gallon recovery bucket fitted with aerators and filled with ambient stream water where they were held until they fully regained equilibrium. After the fish recovered, they were released back to the pool from where they were captured.

Fish metrics such as length-frequency distribution and weight-length regressions were calculated for salmonids and bridgelip suckers captured throughout the study area. Length-frequency distribution was graphed for fish counts within 2-mm intervals for a range of lengths from 30 to 240 mm (appendix 1). Fish were categorized by tagged or not tagged and capture location (Rock Creek or Walaluuks Creek). Weight-length data were graphed and fit with a power function (appendix 2).

Pool Population Estimates

We estimated fish population density using mark-recapture methods detailed in Temple and Pearsons (2007). We anchored block nets, with each spanning the creek, at the upstream and downstream end of each pool. The nets were constructed of 3-mm knotless nylon mesh. The weighted line of each net was secured to the stream bottom with cobble and boulders. Sticks or other material were used to prop up each net at least 0.5 m above the water surface. This was done to ensure that fish did not enter or leave the site (that is, closed population) during data collection. Each pool was electrofished via a single-pass upstream from tail out to head, followed by a downstream pass. All captured salmonids and bridgelip suckers were marked (that is, PIT tagged or fin clipped) and returned to the sampled pool, block nets were cleaned and left overnight, and the pool was electrofished to recapture marked fish the following day. This allowed for a minimum recovery period of 18 hours.

For our mark-recapture data analysis, we used length-frequency histograms to assign ages to age-0 (less than or equal to 104 mm FL) and age-1 or older (age-1+; greater than 104 mm FL) *O. mykiss* (appendix 1). To estimate fish abundance in sample pools we used the Chapman modification of the Lincoln-Peterson estimator as follows (Chapman 1951; Seber 1982):

$$\hat{N} = \frac{(M+1)(C+1)}{(R+1)} - 1 \qquad (1)$$

where

$\hat{N}$	is the abundance estimate of fish in the sample area,
M	is the number of fish marked in the first sample,
C	is the number of fish captured in the second sample, and
R	is the number of marked fish captured in the second sample.

Variance was calculated as:

$$v(\hat{N}) = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)} \qquad (2)$$

where

v	is the variance of the abundance estimate, and 95-percent confidence interval is calculated as:

$$\hat{N} \pm 1.96\sqrt{v(\hat{N})} \qquad (3)$$

Population abundance estimates were converted to densities (fish per square meter) for each pool for a standardized comparison across pools because pool size was highly variable. Additional pool measurements were made at the time of sampling for population abundance to estimate the surface sample area. Measurements included the pool length and wetted width measurements at the pool tail out, head of the pool, and at one-quarter, one-half, and three-quarter lengths of the pool. The sample area was then calculated using the pool length multiplied by the average wetted width measurements.

Completing pool population abundance estimates provides an index over time to detect potential trends in pool abundance and species diversity for salmonids within the Rock Creek subbasin. This also provides current status data and improved understanding of the variability of species abundance and diversity within pools throughout the study area. Because of high variability in pool abundance and limitations on sampling efforts based on time and budget constraints, the expansion of population estimates throughout the study area has not been done.

Passive Integrated Transponder Tag Interrogation

Two multiplexing PTISs were installed in Rock Creek in autumn 2009 to evaluate timing and degree of PIT-tagged fish movement, survival, adult stray rate, and other life history attributes. These PTISs were built and installed by USGS and maintained and downloaded by the YN. One PTIS was installed near the Rock Creek Longhouse at rkm 5 and powered by connecting directly to a local power source near the longhouse, with three arrays in an upstream to downstream orientation where each consisted of two side-by-side antennas. All antennas were about 6.1 m long and 1 m wide and were attached to flat substrate with a variety of anchoring methods. The upstream PTIS was installed at the confluence with Walaluuks Creek at rkm 13 and was powered by a solar panel array (fig. 1). The RCS PTIS was installed with one array composed of two antennas 40 m upstream from the confluence of Walaluuks Creek, a single array of two antennas installed 20 m downstream from the confluence of Walaluuks Creek, and two arrays with single antennas in Walaluuks Creek about 3 m apart and 5 m upstream from the confluence. All antennas at both sites were 6.1 m long and 1 m wide and were anchored in pass-by orientation (flat to the substrate). The PTIS transceivers were Destron-Fearing 1001M Multiplexing Transceiver Systems (MUXs) that can power as many as six 6.1-m-long antennas. These transceivers were designed to detect 134.2-kHz full-duplex tags, a common PIT tag implanted into salmonids in the Columbia River Basin. To reduce electrical interference within the PITSs, local power or solar panels were connected to a charging circuit that contained two banks of batteries (each bank consisted of two 12-V batteries wired in series for 24 V) and a switching mechanism to alternately charge one bank of batteries while the other bank was isolated from the charging circuit and powering the MUX. The MUXs were removed from July through October when the pools were disconnected to protect them from high summer air temperatures, thus eliminating the opportunity for tracking fish movement. MUX units were reconnected in autumn when water levels rise in Rock Creek. A log is maintained to describe breaks in monitoring at the instream PTIS sites throughout the study periods (appendix 3).

Survival Estimates and Travel Times

Survival estimates were calculated for PIT-tagged fish using individual capture history detections at PTIS interrogation sites. Individual capture histories were created by assigning a 1 to each detection site in which an individual fish was detected and a 0 if it was not detected. Estimates were calculated using PTIS detections over time and a Cormack-Jolly-Seber approach (Cooch and White, 2010), with the RMARK package in the program R (R Core Team, 2008). In the context of survival estimation, the passive detection of PIT-tagged smolts at any other PTIS downstream from the tagging location was considered a "recapture." Recapture data on fish tagged in Rock Creek were downloaded using the PTAGIS database. Interrogation sites downstream from John Day Dam were combined, such that a detection at any interrogation site would be assigned a 1. PIT-tagged fish were analyzed separately by species. A suite of survival models were compared using corrected Akaike's information criterion (AICc) analysis and ranked based on delta AICc (Burnham and Anderson, 2002). We used the corrected version, AICc, because of small sample sizes.

To estimate the probability of survival for salmonids, three models were considered. The models include reach only, an additive model with reach and release group, and an interaction model with reach and release group. For estimating probability of detection, only reach was modeled. Reaches were separated by PTIS interrogation sites. The upstream reach, RCS, included habitat upstream from the RCS (rkm 13) PTIS starting from the locations in which fish were tagged and released. This included fish releases up to about rkm 21 on Rock Creek and rkm 8 on Walaluuks Creek. The RCL reach includes the habitat between RCS and RCL (rkm 5). The John Day Dam reach includes the area downstream from RCL in Rock Creek to the juvenile PIT tag interrogation sites at John Day Dam on the Columbia River. Release groups were defined by location in which tagging and release occurred in the following manner: fish tagged and released in Rock Creek upstream from RCS (Rock Creek) and fish tagged and released in Walaluuks Creek. Coho salmon had an additional release group defined as salmon that were tagged and released downstream from the RCS PTIS and upstream from the RCL PTIS (Rock Creek Lower). This release group was modeled separately with reach only because the capture history format had one less detection array. A small number (31) of *O. mykiss* was tagged within this reach, with few detections (7) at the RCL PTIS site, and no detections in the Columbia River interrogation sites; therefore, it was not feasible to model survival probability for this group. It was assumed that any salmonids detected at RCS and RCL migrating downstream would continue to migrate downstream to the Columbia River. Any *O. mykiss* that stop to rear and cease migration (potadromous *O. mykiss*, for example) would be evaluated as mortalities for these survival estimates. Potadromous *O. mykiss* may remain in an area of suitable habitat (that is, the pool in which they were tagged and released) for multiple years and would not be detected at downstream PTIS sites.

For bridgelip suckers, probability of survival was not modeled. Suckers PIT-tagged in Rock Creek have not been contacted outside of the instream PTISs and determining probability of detection is difficult because many of the suckers only pass one PTIS. Therefore, results for suckers are focused on percentage of recapture detections at Rock Creek PTIS arrays. The percentage of detections is the number of PIT tagged suckers that have been detected at least once at either PTIS after the initial mark-recapture release event divided by the total number of suckers PIT tagged during autumn sampling events.

Individual detection history information at interrogation sites was used to investigate travel time between interrogation sites for PIT-tagged fish. Travel times were calculated as the time difference between first detection date and time at RCS and first detection date and time at RCL for PIT-tagged fish within Rock Creek. For salmonids that outmigrated to the Columbia River, travel times for this reach were calculated as the difference between first detection date and time at RCL and first detection date and time at John Day Dam.

Results

Stream Pool Habitat Surveys

Surveys were completed from August 17 to October 5, covering about 20.3 rkm in Rock Creek and 8.7 rkm in Walaluuks Creek. A map was created from the survey data, using GPS point locations to create habitat reach classifications (fig. 2). Surveys were a continuation of work done in 2015–17 (Harvey, 2015; Hardiman and Harvey, 2019) and are presented for comparison (tables 1 and 2). During the 2018 Rock Creek survey, the overall percentage of habitat recorded as dry was 41, non-pool wet was 42, and pool was 17. The number of pools (n=93) recorded was less than during previous survey efforts (table 1). This resulted in the lowest percentage of pool habitat by length for all years surveyed. The percentage of non-pool wetted habitat was generally higher in 2018 than in previous years. Of the habitat categorized as pools in 2018, the average length, area, and depths were generally greater than past years. Other multiyear trends are that the lower river section (rkm 2–13) had a higher percentage of dry habitat than the upper river section (rkm 14–22). Generally, recorded water temperatures were consistently higher in the lower river than the upper river. The maximum pool temperatures recorded during the autumn survey exceeded 16 °C in all river sections.

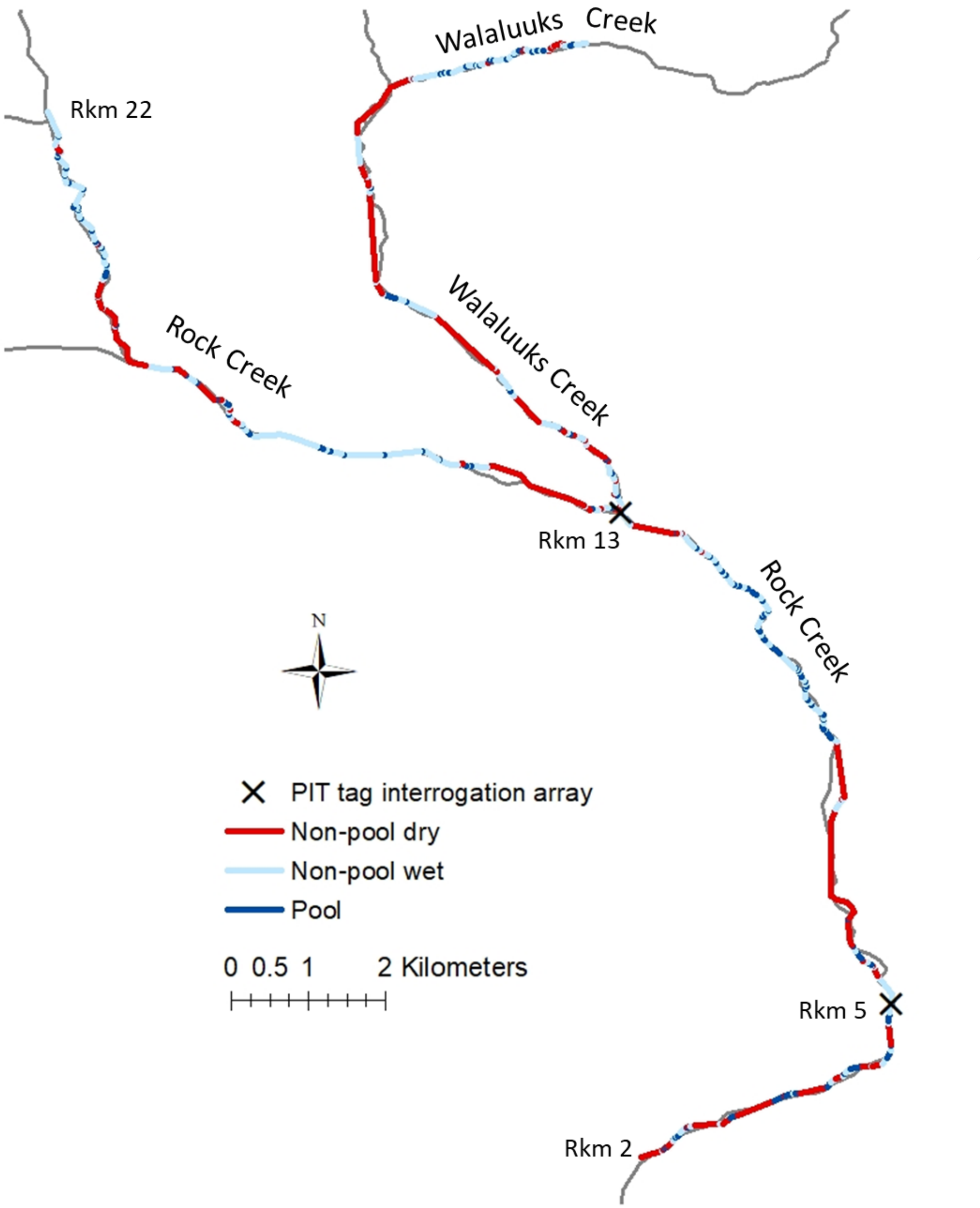

Figure 2. Schematic showing the location and streambed sections that were non-pool dry, non-pool wet, and pool habitats during surveys, Rock Creek and Walaluuks Creek, Washington, autumn 2018. [rkm, river kilometer; PIT, passive integrated transponder]

Table 1. Length of stream that was dry, non-pool wet, or pool, along with the average maximum depth, and mean depth of pools in Rock Creek, Washington, during surveys done in late August and September of 2015–18.

[**Abbreviations:** rkm, river kilometer; m, meter; m^2, square meter; cm, centimeter; °C, degrees Celsius]

Survey metrics	Rkm 2–13				Rkm 14–22				Rkm 2–28		Rkm 2–22[1]	
	2015	2016	2017	2018	2015	2016	2017	2018	2015	2016	2017	2018
Total stream length surveyed (m)	12,030	12,377	11,567	12,488	8,822	8,991	7,758	7,856	27,324	28,190	20,062	20,344
Length dry (m)	6,786	6,350	5,110	6,243	2,860	3,046	2,813	2,037	10,549	10,817	8,660	8,280
Percentage dry	57	51	44	50	33	34	36	26	38	38	43	41
Length of non-pool wet (m)	2,691	3,089	3,705	3,855	4,432	4,453	3,911	4,826	11,674	12,191	7,616	8,681
Percentage of non-pool wet	22	25	32	31	50	49	51	61	43	43	38	42
Number of pools	62	83	70	53	60	70	46	40	172	206	116	93
Total length of pools (m)	2,553	2,938	2,752	2,390	1,530	1,492	1,034	993	5,101	5,182	3,786	3,383
Percentage of pools by length	21	24	24	19	17	17	13	13	19	19	19	17
Average pool length (m)	41	35	39	45	26	21	23	25	30	25	33	36
Average pool area (m^2)	381	311	340	391	153	113	123	170	224	182	254	296
Average maximum depth of pools (cm)	68	65	72	79	55	51	58	65	58	54	66	73
Average mean depth of pools (cm)	36	35	32	39	25	27	28	41	29	29	31	40
Average temperature of pools (°C)[2]	18	17	20	19	15	14	17	15	15	15	19	17
Maximum pool temperature (°C)[2]	23	24	25	25	18	24	20	19	23	24	25	25

[1]Surveys were not done upstream from rkm 22 in 2017 and 2018.

[2]Temperature was recorded in all pools during August and September survey dates.

Table 2. Length of stream that was dry, non-pool wet, or pool, along with the average maximum depth, and mean depth of pools in Walaluuks Creek (formerly Squaw Creek), Washington, during surveys done in 2015–18.

[**Abbreviations:** rkm, river kilometer; m, meter; m^2, square meter; cm, centimeter; °C, degrees Celsius]

Survey metrics	Walaluuks Creek rkm 0–9			
	2015	2016	2017	2018
Survey dates	9/24–9/29	9/15–9/19	9/11–9/15	9/13–9/21
Total stream length surveyed (m)	9,066	9,303	8,215	8,672
Length dry (m)	5,596	5,350	3,725	4,626
Percentage dry	62	57	45	53
Length of non-pool wet (m)	2,257	3,051	3,424	3,427
Percentage of non-pool wet	25	33	42	40
Number of pools	45	51	60	36
Total length of pools (m)	1,213	903	1,067	619
Percentage of pools by length	13	10	13	7
Average pool length (m)	27	18	18	17
Average pool area (m^2)	133	81	83	77
Average maximum depth of pools (cm)	49	52	54	63
Average mean depth of pools (cm)	25	27	27	35
Average temperature of pools (°C)[1]	14	14	16	17
Maximum temperature of pools (°C)[1]	17	17	19	17

[1]Temperature was recorded in pools during September survey dates.

For Walaluuks Creek, the percentage of habitat recorded as dry was 53, non-pool wet was 40, and pool was 7 during the 2018 survey (table 2). The percentage of pool habitat was the lowest of all survey years. The 2018 results for dry and non-pool wet habitat fell within the range of the 2016 and 2017 survey results.

Fish Sampling and Tagging

During 2018, the number of *O. mykiss* handled and tagged was higher than the number of coho salmon. A total of 855 *O. mykiss* were handled, and 662 were PIT tagged. For coho salmon, 718 were handled and 567 were PIT tagged (table 3). As of December 12, 2019, 175 *O. mykiss* and 289 coho salmon were detected at the Rock Creek PTISs (RCS and RCL) and other downstream Columbia River PIT tag interrogation sites (table 3). A total of 536 bridgelip and largescale (*C. macrocheilus*) suckers; *n*=6) were handled, and 294 were PIT tagged, of these 147 were detected at Rock Creek PTISs (table 4). Most of the suckers handled and PIT tagged were in Rock Creek, only 13 were PIT tagged in Walaluuks Creek.

Table 3. Summary of *Oncorhynchus mykiss* (*O. mykiss*) and coho salmon (coho; *Oncorhynchus kisutch*) passive integrated transponder (PIT) tagged in Rock Creek and Walaluuks Creek, during autumn 2018, and detections at PIT tag interrogation systems in Rock Creek and the Columbia River, Washington.
[Walaluuks Creek confluence is located at Rock Creek river kilometer (rkm) 13. The Rock Creek sites are RCL (Rock Creek Longhouse) at rkm 5 and RCS (Rock Creek Squaw) at rkm 13. Downstream detection sites (outmigration) in the Columbia River were JDJ (John Day Dam juvenile bypass, rkm 347), B2J (Bonneville Dam juvenile bypass, rkm 234), BCC (Bonneville Dam corner collector, rkm 234), and TWX (PIT tag detection trawl operated at the Columbia River estuary, rkm 75). Detection information is up to date to December 12, 2019.]

	Release site, species					
	Rock Creek		Walaluuks Creek		Totals	
	O. mykiss	Coho	*O. mykiss*	Coho	*O. mykiss*	Coho
	Number of fish					
Handled	530	451	325	267	855	718
PIT tagged	404	312	258	255	662	567
Detected	102	154	73	135	175	289
Detection sites	Number of fish detected					
RCS	51	73	51	87	102	160
RCL	93	142	66	110	159	252
JDJ	20	13	20	16	40	29
B2J	1	7	5	7	6	14
BCC	18	15	10	17	28	32
TWX	2	1	2	4	4	5

Table 4. Summary of bridgelip suckers *(Catostomus columbianus*) and largescale suckers *(Catostomus macrocheilus*) passive integrated transponder (PIT) tagged in Rock Creek, and Walaluuks Creek, during autumn 2018, and detections at PIT tag interrogation systems (PTIS) in Rock Creek, Washington.
[Walaluuks Creek confluence is located at Rock Creek river kilometer (rkm) 13. The two Rock Creek PTIS sites are RCL (Rock Creek Longhouse) at rkm 5 and RCS (Rock Creek Squaw) at rkm 13. Detection information is up to date to December 12, 2019.]

	Release site				
	Rock Creek			Walaluuks Creek	Totals
	Release rkm				
	0–4	5–13	14–22	0–4	
	Number of fish				
Handled	68	222	233	13	536
PIT tagged	54	121	106	13	294
Detected	3	66	72	6	147
PTIS site	Number of fish detected				
RCS	0	2	42	3	47
RCL	3	64	63	5	135

Nontarget Fish Species Distribution

Species distribution for nontarget species was also documented. Speckled dace (*Rhinichthys osculus*), red sided shiners (*Richardsonius balteatus*), and sculpin (*Cottidae*) were found throughout the sampling area, with dace being abundant in most pools. Additional species handled included northern pikeminnow, smallmouth bass, and bluegill (*Lepomis macrochirus*). All but one of the northern pikeminnow (*n*=32) were captured from the pool at rkm 4.5; the other one was captured near rkm 9. Northern pikeminnow FL ranged from 45 to 120 mm. All smallmouth bass (*n*=4) were captured in the pool at rkm 4.5, and their FL ranged from 50 to 157 mm. One bluegill (FL of 95 mm) was captured in a pool near rkm 6.

Pool Population Estimates

During 2018, 93 habitat units were categorized as pools in Rock Creek, of which 39 had a maximum depth greater than or equal to 70 cm and less than 140 cm. From these, 11 pools were selected for population estimates using a systematic design with a random start and additional legacy pools (fig. 3). Two pools selected in the systematic design, located at about rkm 10 and 10.9, were sampled for 1 day because too few salmonids were captured to complete a mark-recapture analysis. A total of nine pools were sampled and analyzed using mark-recapture efforts to estimate population abundance in Rock Creek. For Walaluuks Creek, 36 habitat reaches were categorized as pools, of which maximum depths were greater than or equal to 55 cm and less than 120 cm. A total of seven pools were sampled and analyzed using mark-recapture analysis for population abundance in Walaluuks Creek (fig. 3).

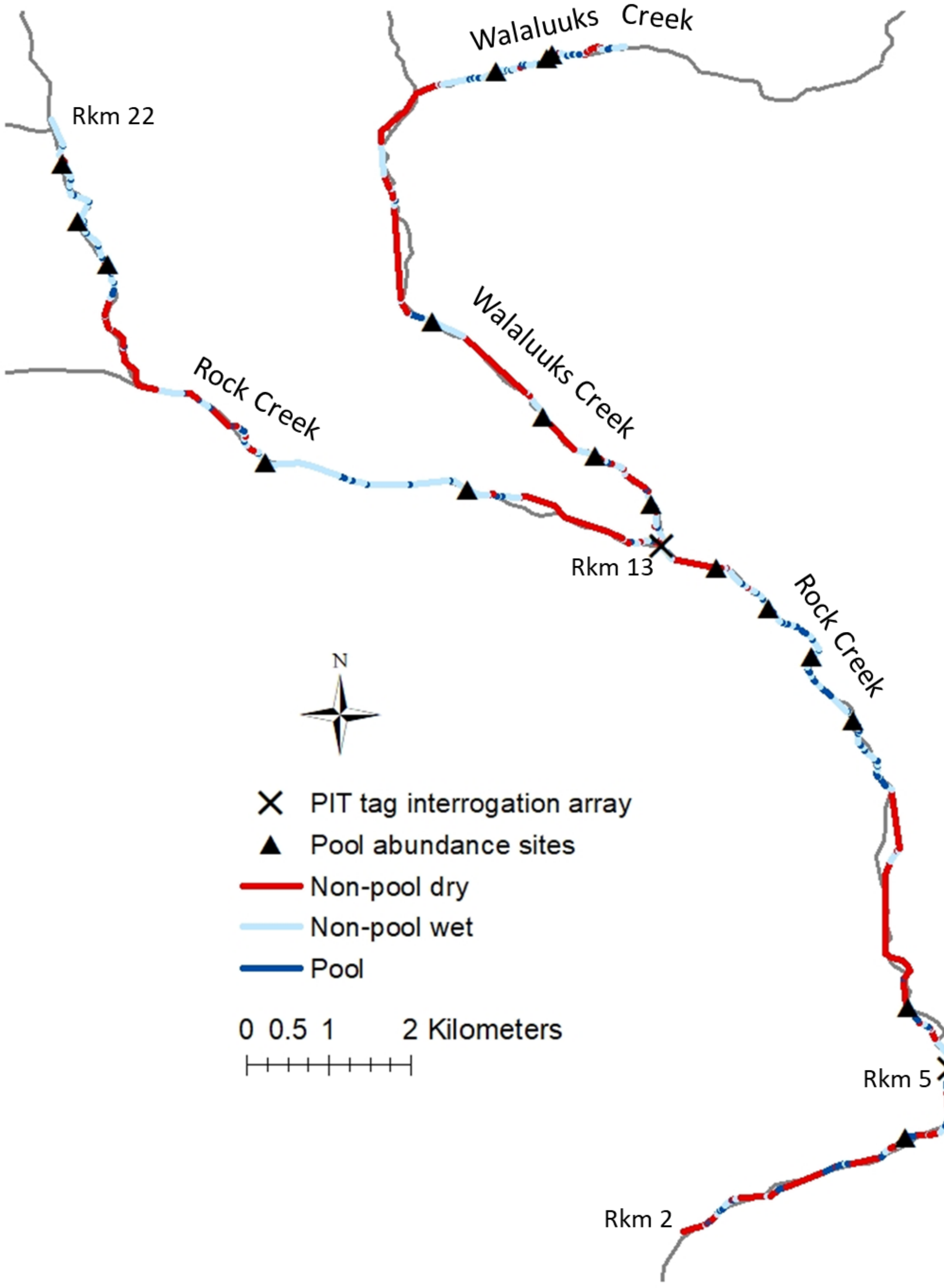

Figure 3. Schematic showing the location and stream sections that were non-pool dry, non-pool wet, and pool habitats during late August to September and pool abundance sites sampled during 2018, Rock Creek and Walaluuks Creek, southeastern Washington. [rkm, river kilometer; PIT, passive integrated transponder]

For *O. mykiss,* pool abundance estimates were generally higher in pools farther upstream in Rock Creek (fig. 4). Few *O. mykiss* were found in pools downstream from rkm 15. Mark-recapture sampling efforts resulted in zero *O. mykiss* captured at pools at about rkm 4.4 and 12.5, and too few age-0 *O. mykiss* captured at about rkm 6.3 to estimate abundance. Pool abundance estimates were calculated for six pools for both age classes and one additional pool (rkm 6.3) for age 1+. Generally, age-0 *O. mykiss* were more abundant than age 1+ in pools sampled in Rock Creek during autumn. For pools where age-0 *O. mykiss* were present, the average pool population abundance was 0.144 (*n*=6; range: 0.052–0.208) fish per square meter. For age-1+ *O. mykiss*, the average pool population abundance was 0.045 (*n*=7; range: 0.002–0.179) fish per square meter (fig. 4).

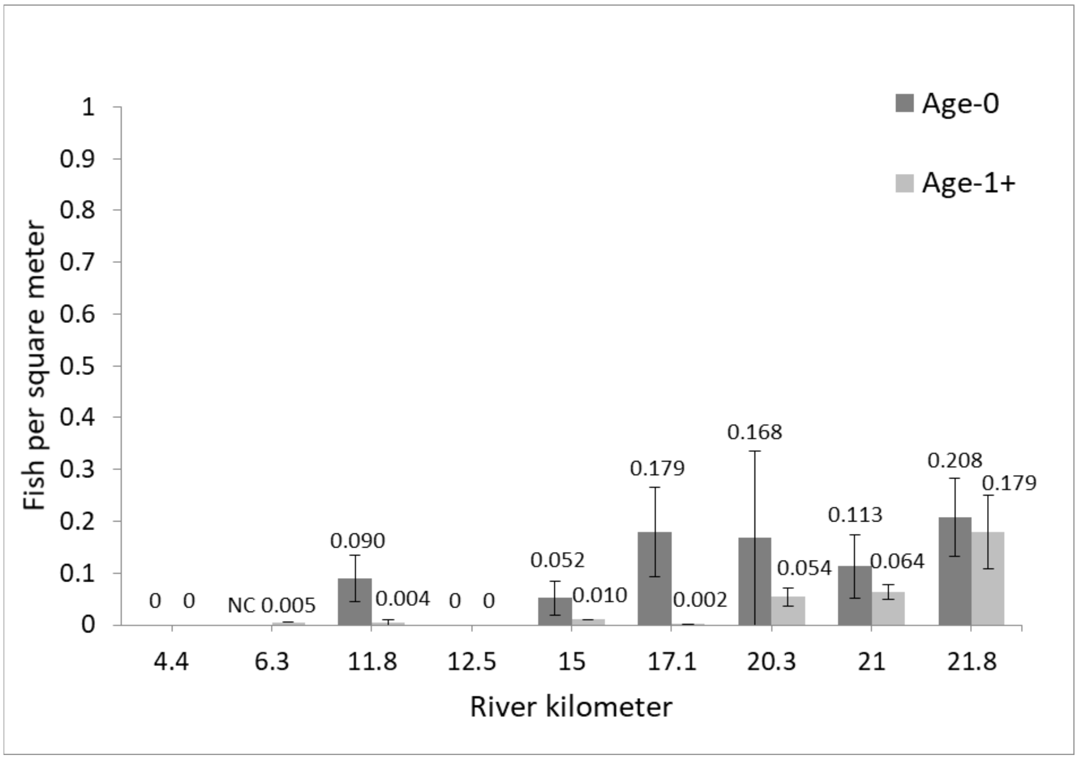

Figure 4. The number of age-0 and age-1 or older (fork length greater than 104 millimeters) *Oncorhynchus mykiss* per square meter in pools, Rock Creek, Washington, autumn 2018. Error bars indicate 95-percent confidence intervals. NC indicates too few fish were captured to estimate abundance.

In Walaluuks Creek, *O. mykiss* were captured in all pools and were found in higher densities than in Rock Creek (fig. 5). The age-0 fish were more abundant in pools downstream from rkm 3.6. The age-1+ fish were more abundant in the upstream pools. For age-0 *O. mykiss* in Walaluuks Creek, the average pool abundance was 0.207 fish per square meter (*n*=7; range: 0.038–0.416 [fig. 5]). For age 1+, the average pool abundance was 0.382 fish per square meter (*n*=6; range: 0.009–0.761 [fig. 5]).

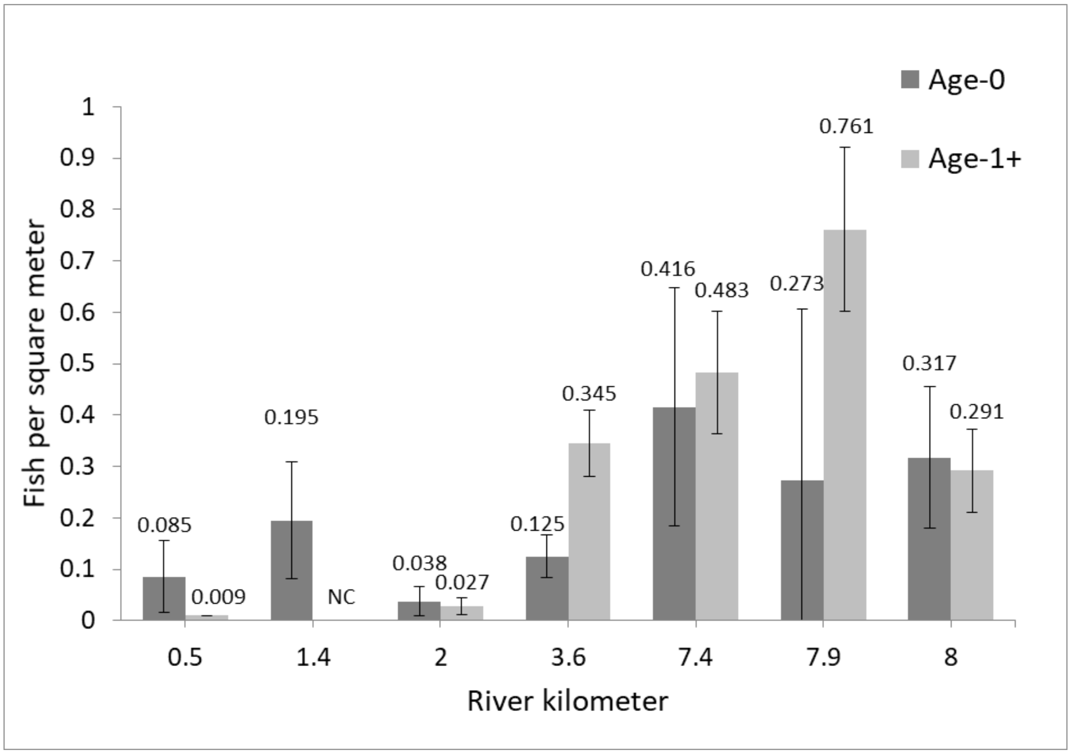

Figure 5. The number of age-0 and age-1+ (fork length greater than 104 mm) *Oncorhynchus mykiss* per square meter in pools, Walaluuks Creek, Washington, autumn 2018. Error bars indicate 95-percent confidence intervals. NC indicates too few fish were captured to estimate abundance.

Coho salmon were captured throughout Rock Creek, except in the pool near rkm 4.4 (fig. 6). They were most abundant in pools from rkm 6.3 to 17.1. Coho salmon were more abundant than *O. mykiss* in pools except for the three upstream pools at rkm 20.3, 21, and 21.8. The average pool abundance for coho salmon was 0.256 fish per square meter (*n*=8; range: 0.019–0.756 [fig. 6]) in Rock Creek pools. In Walaluuks Creek, coho salmon were captured in four pools and were not captured in the most upstream pools sampled (fig. 7). The average pool abundance for coho salmon in the four lower pools was 0.488 fish per square meter (*n*=4; range: 0.417–0.548 [fig. 7]).

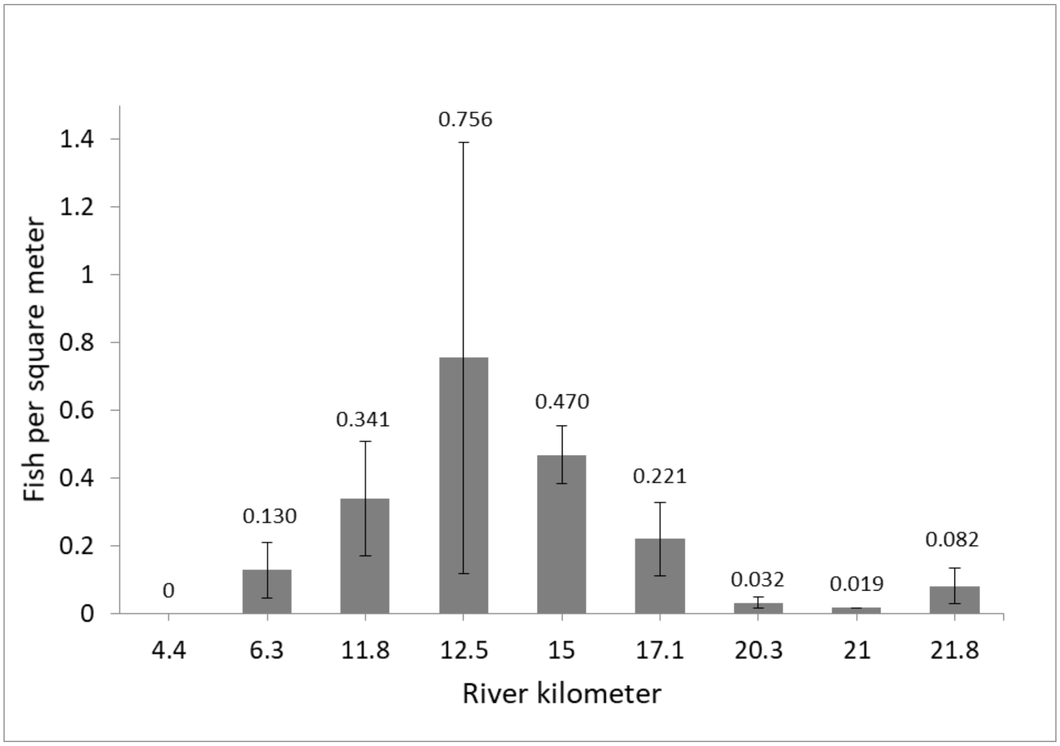

Figure 6. The number of coho salmon (*Oncorhynchus kisutch*) per square meter in pools, Rock Creek, Washington, autumn 2018. Error bars indicate 95-percent confidence intervals.

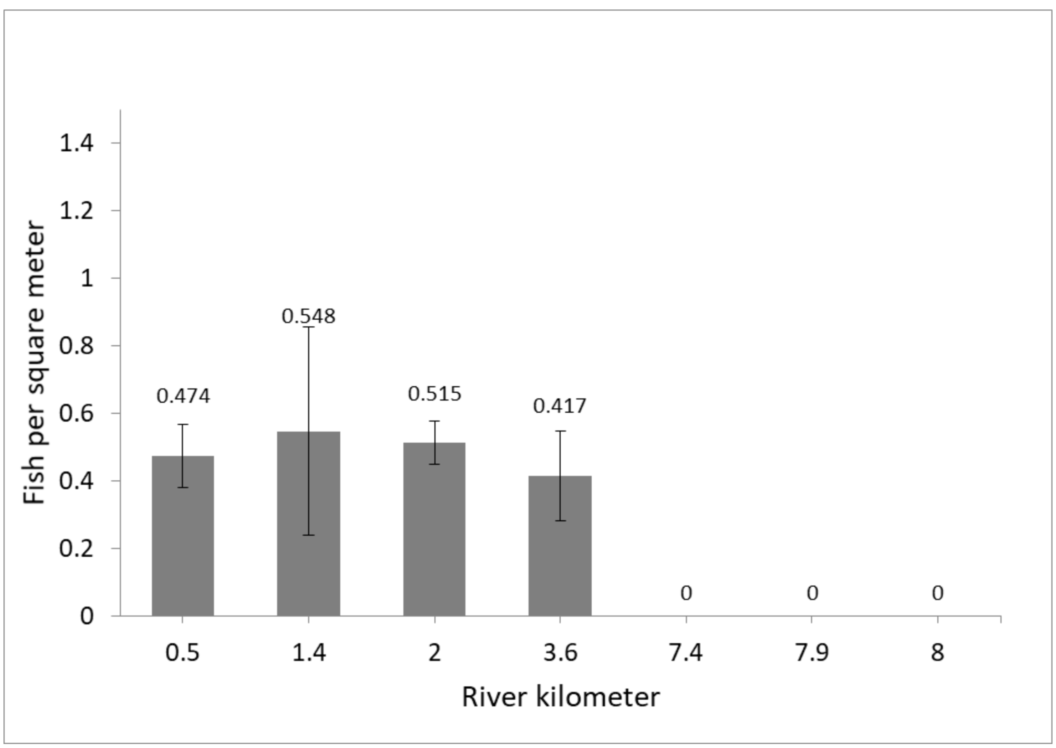

Figure 7. The number of coho salmon (*Oncorhynchus kisutch*) per square meter in pools, Walaluuks Creek, Washington, autumn 2018. Error bars indicate 95-percent confidence intervals.

Bridgelip suckers were captured in all pools in Rock Creek except the most upstream pool at rkm 21.8 (fig. 8). Largescale suckers were only captured at rkm 4.4 in low abundance. The average pool abundance for bridgelip suckers was 0.552 fish per square meter (*n*=7; range: 0.015–1.554 [fig. 8]) in Rock Creek pools. Bridgelip suckers were captured in the three downstream pools in Walaluuks Creek (fig. 9). The average abundance was 0.044 fish per square meter (*n*=3; range: 0.024–0.085 [fig. 9]).

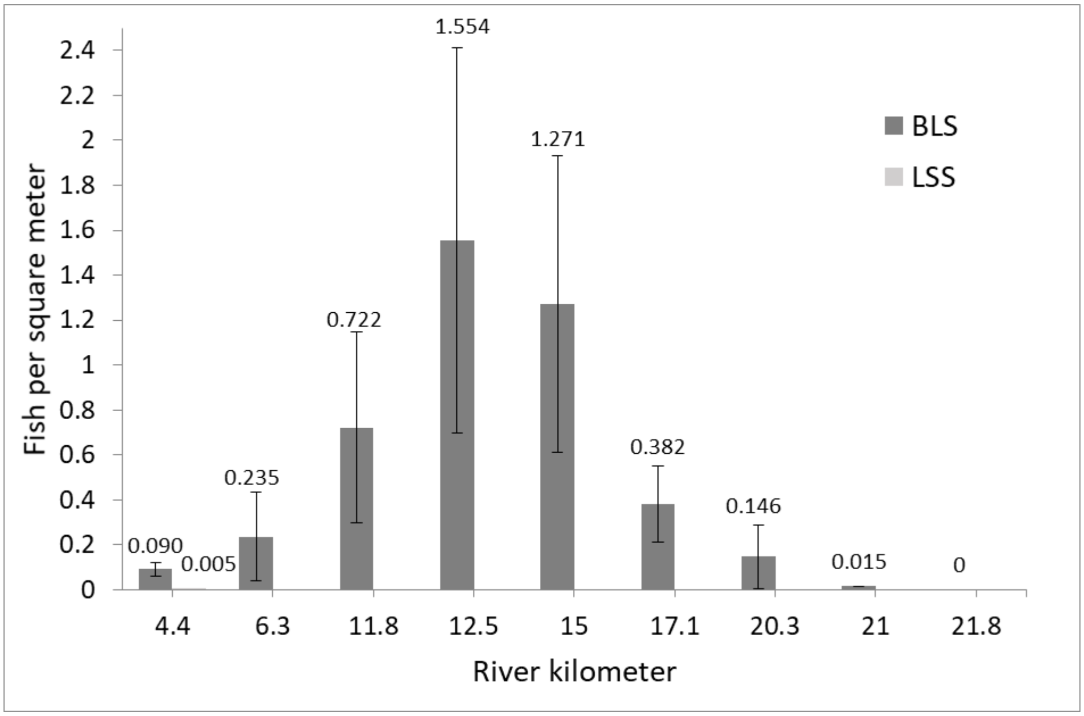

Figure 8. The number of bridgelip (*Catostomus columbianus*, BLS) and largescale suckers (*C. macrocheilus*, LSS) per square meter in pools, Rock Creek, Washington, autumn 2018. Error bars indicate 95-percent confidence intervals.

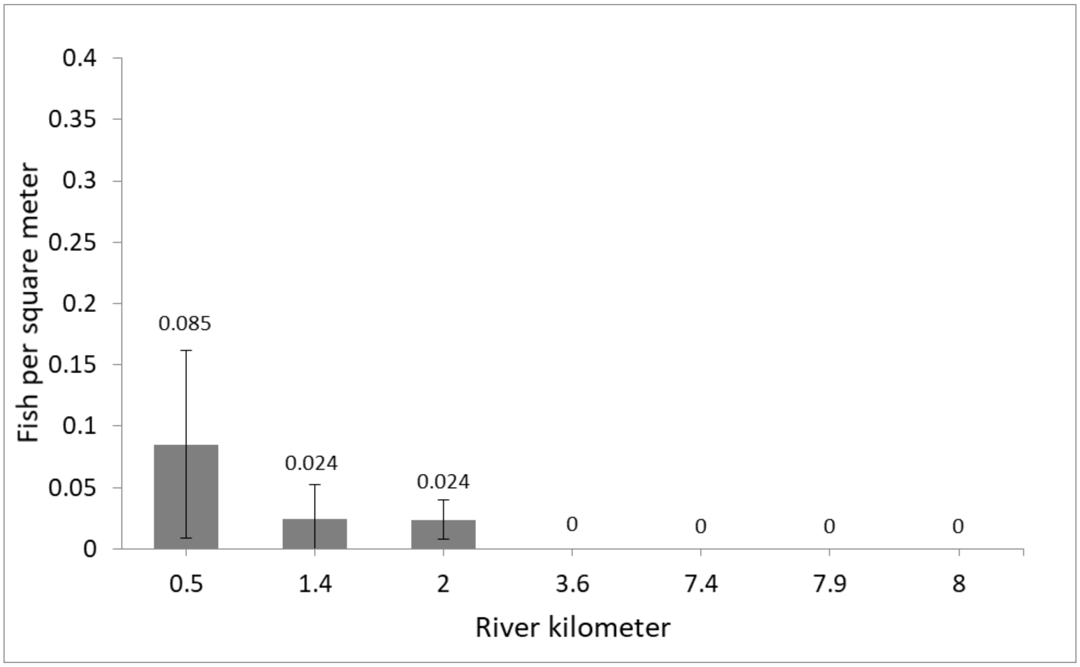

Figure 9. The number of bridgelip suckers (*Catostomus columbianus)* per square meter in pools, Walaluuks Creek, Washington, autumn 2018. Error bars indicate 95-percent confidence intervals.

Pool population abundance estimates were opportunistically calculated for northern pikeminnow and smallmouth bass at rkm 4.4 in Rock Creek. This pool has been a legacy site and allows for status and trend abundance assessment of data on piscivorous and nonnative species in this location. During 2018, few smallmouth bass were captured for an estimated pool population of five fish (*SE*=2.041; 95-percent confidence interval 1–9) and a density of 0.005 fish per square meter (95-percent confidence interval 0.001–0.009). For northern pikeminnow, the pool population estimate was 39 fish (*SE*=7.201; 95-percent confidence interval 25–53) and a density of 0.039 fish per square meter (95-percent confidence interval 0.025–0.053).

Fish abundance densities were combined for all species and plotted by pool for comparison. Bridgelip suckers were the most abundant species in many of the pools in Rock Creek (fig. 10). In the three most upstream pools (upstream from rkm 20), *O. mykiss* was the most abundant species. Of the salmonid species, coho salmon were more abundant in pools downstream from rkm 20. In Walaluuks Creek, salmonids were more abundant than bridgelip suckers (fig.11). Coho salmon were most abundant in the three most downstream pools sampled. *O. mykiss* was the dominant species in the upstream pools (fig. 11).

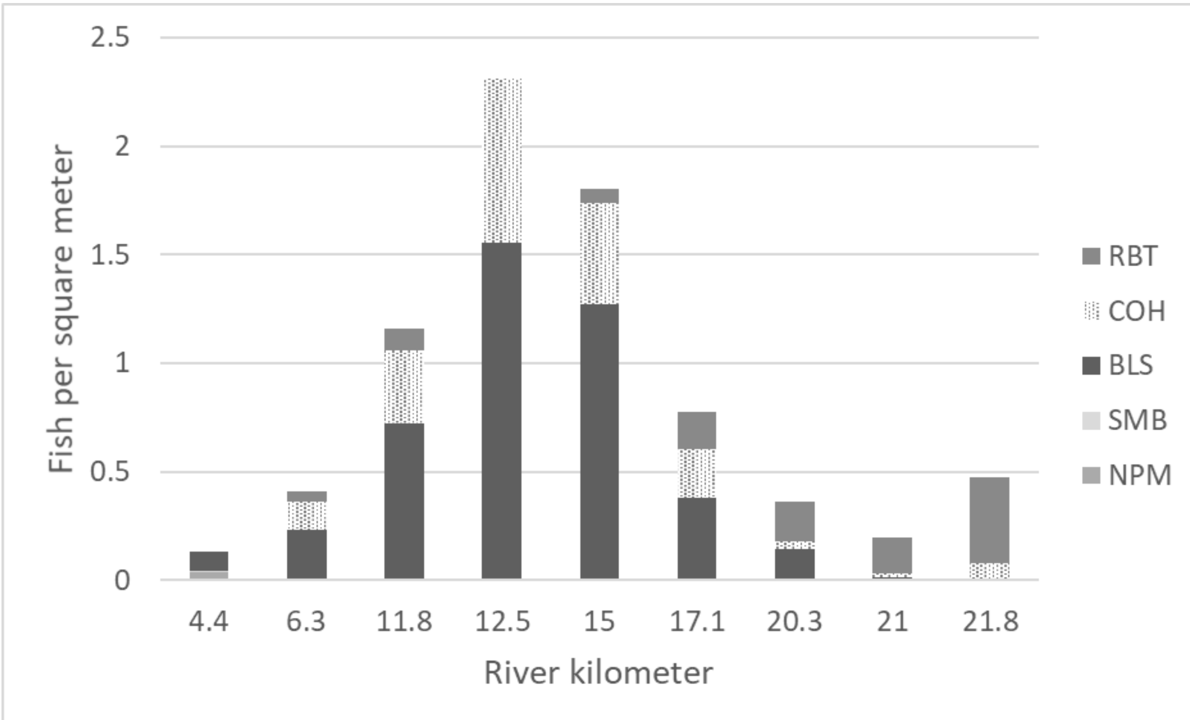

Figure 10. Number of fish per square meter in pools, Rock Creek, Washington, autumn 2018. [RBT, *Oncorhynchus mykiss*; COH, coho salmon (*O. kisutch*); BLS, bridgelip suckers (*Catostomus columbianus*); SMB, smallmouth bass (*Micropterus dolomieu*); NPM, northern pikeminnow (*Ptychocheilus oregonensis*)].

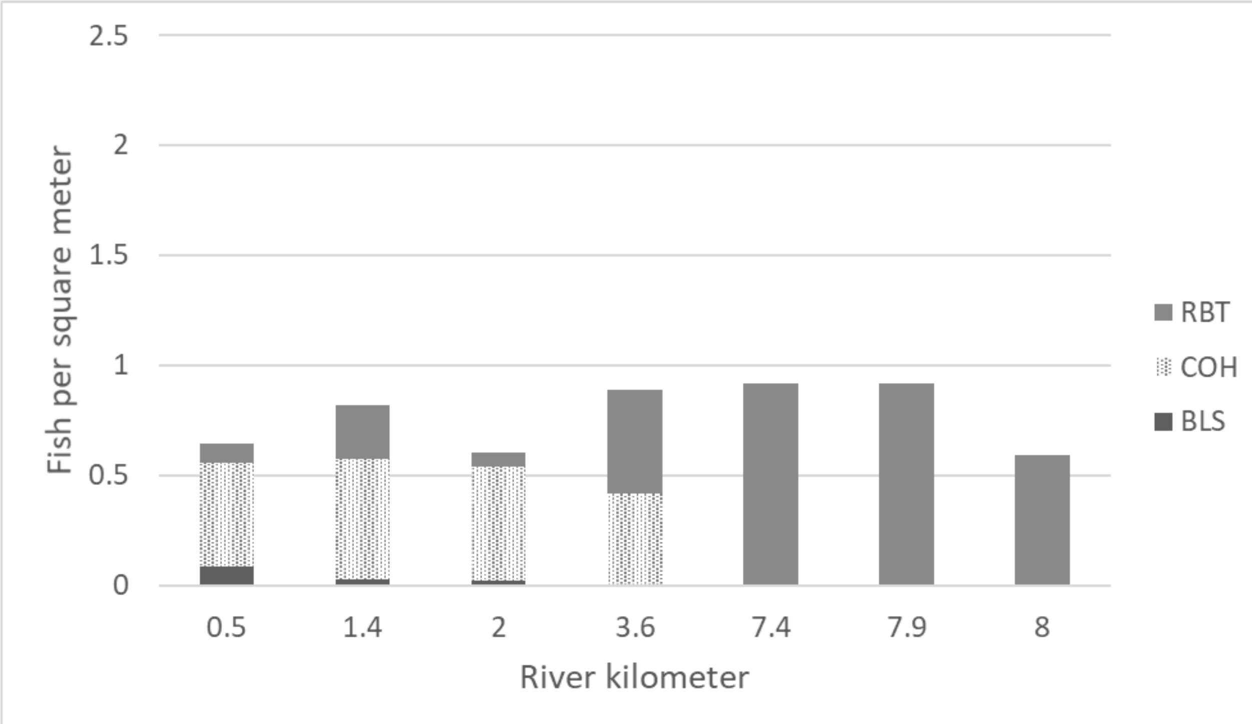

Figure 11. Number of fish per square meter in pools, Walaluuks Creek, Washington, autumn 2018. [RBT, *Oncorhynchus mykiss*; COH, coho salmon (*O. kisutch*); and BLS, bridgelip suckers (*Catostomus columbianus*)].

Fish Movement, Travel Times, and Survival Estimates

Juvenile *O. mykiss* and coho salmon PIT tagged in the autumn typically migrated downstream in April and May the following year (figs. 12, 13). Most of the downstream fish movement occurred on the descending arm of spring peak flow events. Release location in Rock Creek or Walaluuks Creek did not affect outmigration timing. A few salmonids were detected at the instream PTISs in the winter months, indicating some rearing during winter is occurring in reaches downstream from RCS. More coho salmon were detected moving downstream in winter months than *O. mykiss*. PIT-tagged salmonids that migrated past RCS in winter did not typically migrate past RCL until the spring (March–April); this resulted in some long maximum travel times between RCS and RCL (table 5). The overall median travel time from RCS to RCL for *O. mykiss* was 0.91 day, which was faster than that of coho salmon (1.73 days, table 5). The overall travel rate between RCS and RCL for *O. mykiss* was two times faster than for coho salmon (0.11 versus 0.22 day per rkm). Travel times and rates also differed between species from RCL to John Day Dam, with *O. mykiss* migrating faster (table 5). The median travel time between RCL and John Day Dam was 5.53 days for *O. mykiss* and 9.31 days for coho salmon. Travel rates were 0.21 day per rkm and 0.36 day per rkm for *O. mykiss* and coho salmon, respectively (table 5).

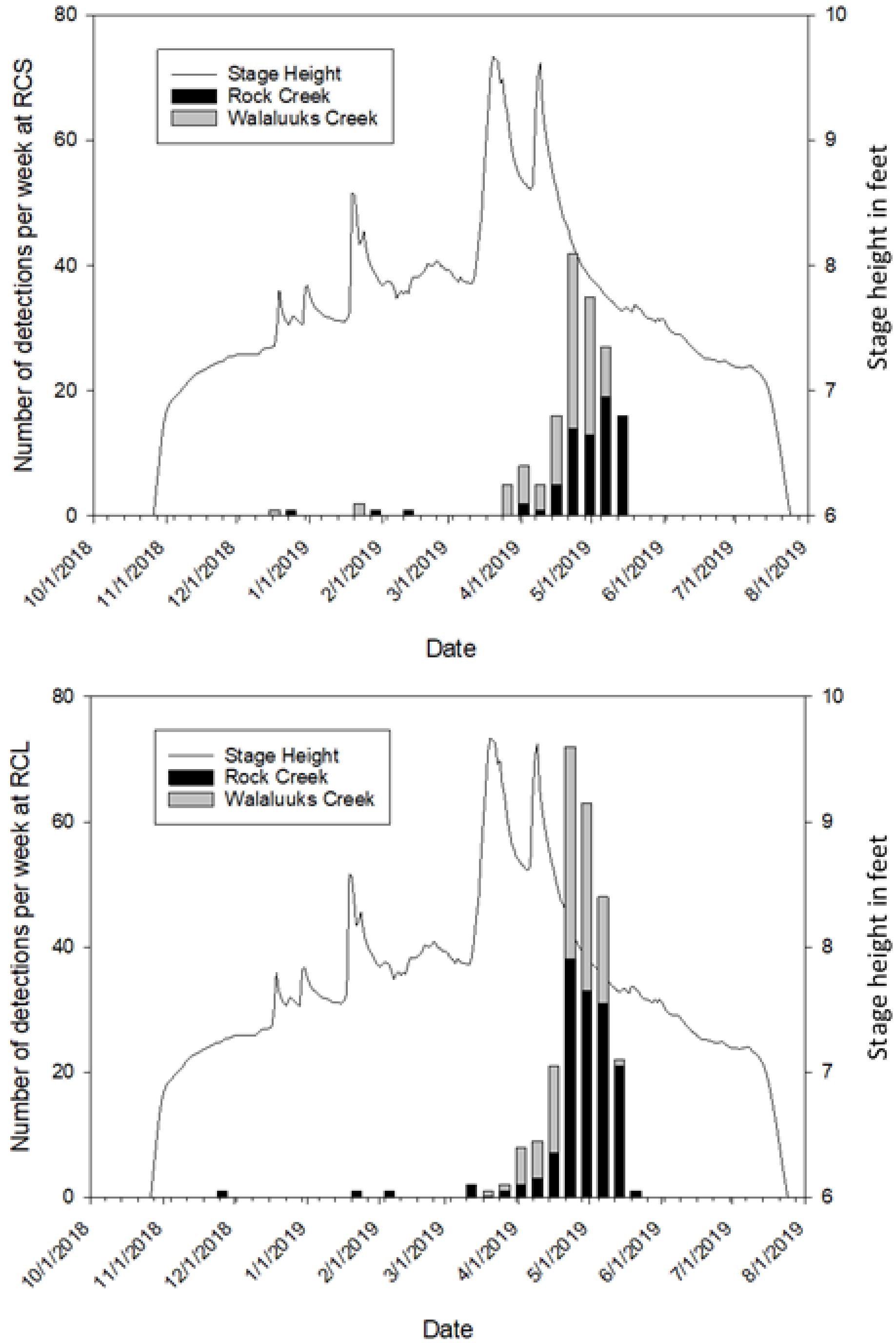

Figure 12. Graphs of first detections of passive integrated transponder (PIT) tagged *Oncorhynchus mykiss* at PIT interrogation systems Rock Creek Squaw (RCS, river kilometer [rkm] 13) and Rock Creek Longhouse (RCL, rkm 5) by date and Rock Creek streamgage (Stage height) at rkm 12.9, Rock Creek, Washington, 2018–19. Bars indicate the release location either in Rock Creek or Walaluuks Creek.

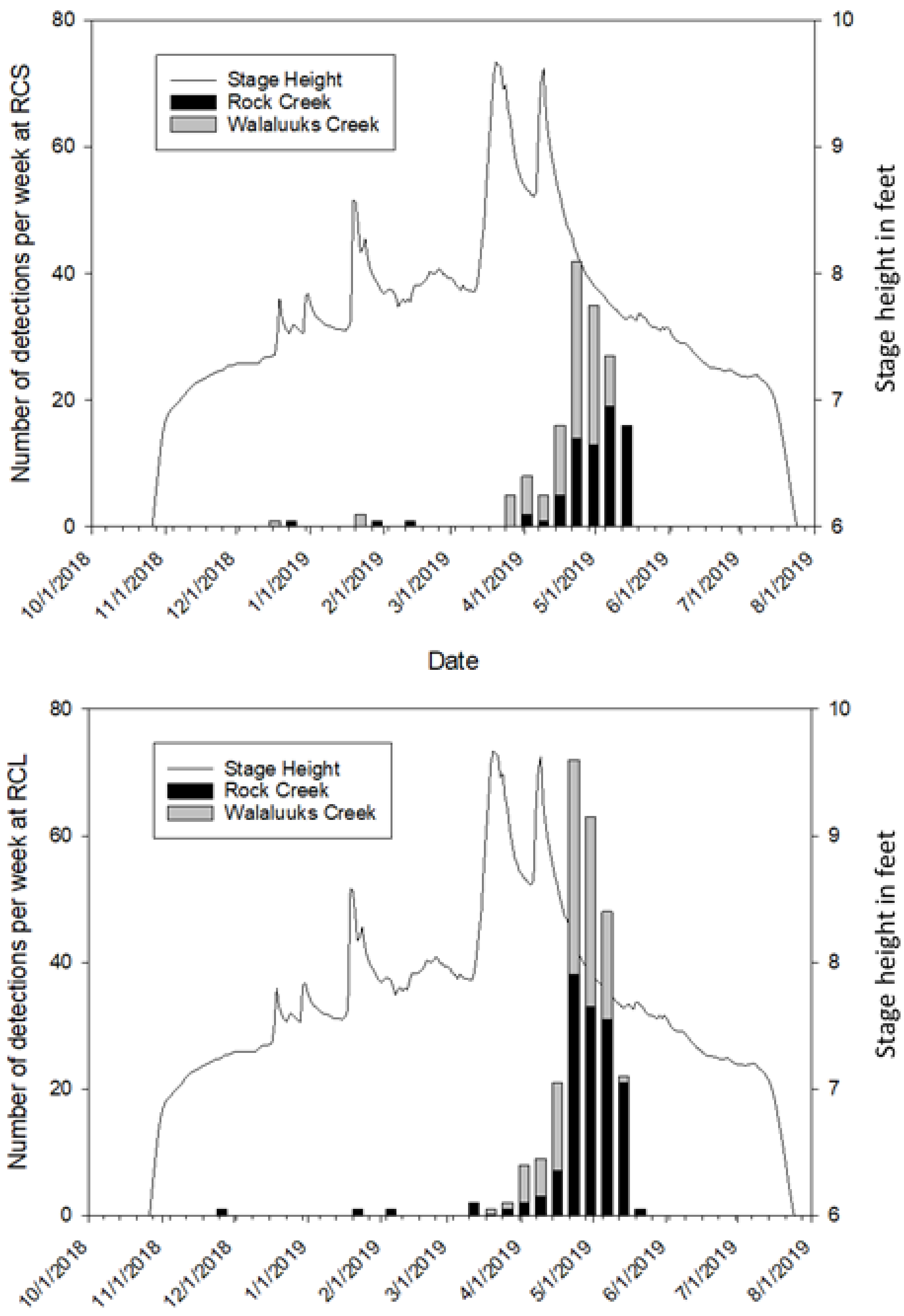

Figure 13. Graphs of first detections of passive integrated transponder (PIT) tagged coho salmon (*Oncorhynchus kisutch*) at PIT interrogation systems Rock Creek Squaw (RCS, river kilometer [rkm] 13) and Rock Creek Longhouse (RCL, rkm 5) by date and Rock Creek streamgage (Stage height) at rkm 12.9, Rock Creek, Washington, 2018–19. Bars indicate the release location either in Rock Creek or Walaluuks Creek.

Table 5. Summary statistics for travel time (in days) and travel rate (in days per river kilometer) for passive integrated transponder tagged steelhead (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*) first detections between passive tag interrogation systems during autumn 2018.

[**Abbreviations:** RCS, Rock Creek Squaw at river kilometer (rkm) 13; RCL, Rock Creek Longhouse at rkm 5; combined, Rock and Walaluuks Creeks combined; d/rkm, day per river kilometer; pct, percentile; d, day; JDJ, John Day Dam juvenile bypass at Columbia River rkm 347; n, number of fish]

Metric	Release site and species					
	Rock Creek		Walaluuks Creek		Combined	
	O. mykiss	Coho	*O. mykiss*	Coho	*O. mykiss*	Coho
RCS to RCL (8 rkm)						
n	47	64	43	64	90	128
Median rate (d/rkm)	0.10	0.16	0.23	0.23	0.11	0.22
Median (d)	0.82	1.27	1.84	1.86	0.91	1.73
25−75th pct (d)	0.21–1.92	0.98–2.83	0.53–9.94	1.01–4.99	0.24–5.38	0.99–3.89
10−90th pct (d)	0.16–5.29	0.46–8.77	0.18–14.90	0.76–9.93	0.16–12.14	0.62–9.87
Range (d)	0.12–26.38	0.16–87.17	0.06–27.78	0.12–21.06	0.06–27.78	0.12–87.17
RCL to JDJ (26 rkm)						
n	14	12	19	13	33	25
Median rate (d/rkm)	0.17	0.42	0.24	0.30	0.21	0.36
Median (d)	4.47	11.04	6.22	7.81	5.53	9.31
25−75th pct (d)	2.55–7.33	7.26–15.38	4.19–15.47	5.98–15.90	3.82–12.80	5.98–15.90
10−90th pct (d)	2.15–11.42	4.02–17.84	3.14–25.01	5.10–21.23	2.51–22.32	4.32–20.48
Range (d)	1.88–20.86	3.14–24.03	2.54–28.18	3.07–27.76	1.88–28.18	3.07–27.76

During 2018, bridgelip suckers were monitored for movement at PTIS arrays. A few suckers were observed moving upstream (*n*=5), but most detections indicated downstream movement. Downstream movement and the timing of the detections at RCS and RCL seemed to be correlated with winter and spring freshet flow patterns (fig. 14). A few fish were detected moving downstream during winter, but most were detected downstream during April–June. It should also be noted that tracking fish movement during the summer months (June–October) is not possible because the stream becomes disconnected and the PTIS arrays are deactivated until flows return in October–November (appendix 3). No bridgelip suckers were detected at interrogation arrays outside of the Rock Creek subbasin. The median travel time for suckers from RCS to RCL was 5.07 days (range: 0.04–140.85); the median travel rate was 0.20 day per rkm. The 25th to 75th percentile travel times were 1.88–17.38 days, and the 10th to 90th percentile travel times were 1.08–100.07 days. Bridgelip suckers spent more time (days) within the RCS to RCL reach than salmonid species.

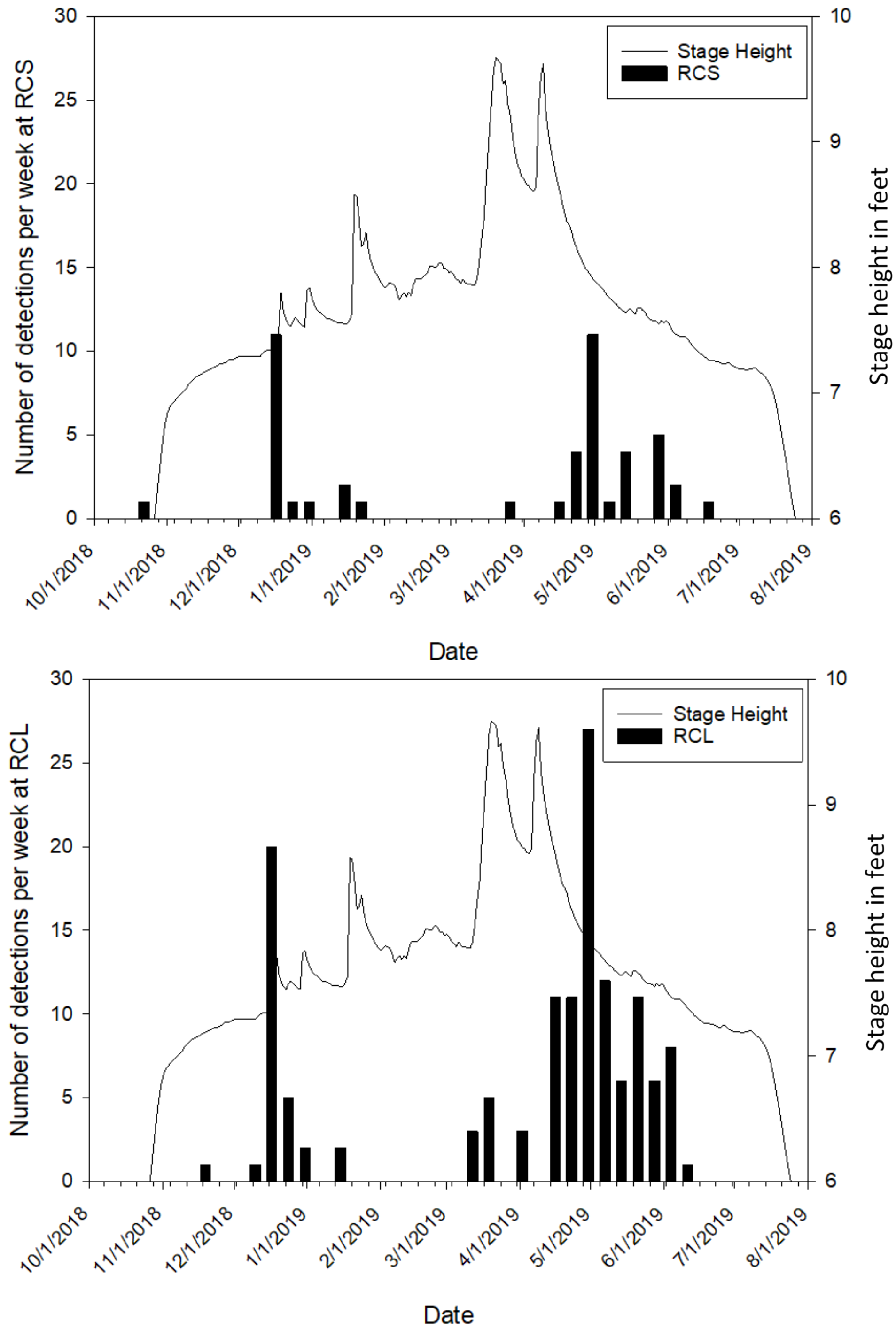

Figure 14. Graphs of first detections of passive integrated transponder (PIT) tagged bridgelip suckers (*Catostomus columbianus*) at PIT tag interrogation systems Rock Creek Squaw (RCS, river kilometer [rkm] 13) and Rock Creek Longhouse (RCL, rkm 5) by date and Rock Creek streamgage (Stage height) at rkm 12.9, Washington, 2018–19.

The best fit survival model for both the *O. mykiss* and coho salmon was the reach only model (table 6). Thus, results are presented by species for all salmonids PIT tagged upstream from RCS (table 7, fig. 15). The RCS reach includes overwinter survival probability because fish are tagged and released in the autumn and primarily migrate the following spring. During 2018, coho salmon (0.568, *SE*=0.027) had a significantly higher probability of overwinter survival in the RCS reach than *O. mykiss* (0.276, *SE*=0.019 [table 7, fig. 15]). The reach survival probability was higher for *O. mykiss* than coho salmon in both downstream reaches RCL and John Day Dam.

Table 6. Models of survival probability for reach survival of juvenile *Oncorhynchus mykiss* and coho salmon (*O. kisutch*) released in Walaluuks Creek and Rock Creek (release group) upstream from the confluence with Walaluuks Creek during autumn 2018.

[Survival reaches were from release sites to next downstream location of detection and between. This included the two Rock Creek sites at river kilometer (rkm) 13 and rkm 5 and main stem Columbia River sites at John Day Dam juvenile bypass, rkm 347, and other interrogation sites downstream to the estuary. **Abbreviations:** K, number of parameters; AICc, corrected Akaike's information criterion; Delta AICc, difference from model with smallest AICc; AIC, Akaike's information criterion; phi, survival probability; p, detection probability; rel, release]

Model	K	Deviance	AICc	Delta AICc	AIC weight
O. mykiss					
phi (reach) p (reach)	8	37.45	1,432.77	0.00	0.64
phi (reach + rel group) p (reach)	9	36.91	1,434.26	1.49	0.30
phi (reach*rel group) p (reach)	12	34.24	1,437.73	4.97	0.05
Coho salmon					
phi (reach) p (reach)	8	24.85	1,491.99	0.00	0.61
phi (reach + rel group) p (reach)	9	24.68	1,493.87	1.87	0.24
phi (reach*rel group) p (reach)	12	19.46	1,494.81	2.82	0.15

Table 7. Survival modeling results for juvenile *Oncorhynchus mykiss* and *Oncorhynchus kisutch* (Coho) tagged and released in Rock Creek and Walaluuks Creek, southeastern Washington during autumn of 2018.

[**Abbreviations:** %, percent; CI, confidence interval; release groups: all, fish released in Rock Creek upstream from rkm 13 and in Walaluuks Creek; RLO, fish released in Rock Creek between rkm 13 and 5; reach: RCS, from release location to the passive integrated transponder (PIT) tag interrogation array Rock Creek Squaw (rkm 13); RCL, from rkm 13 to 5 at Rock Creek Longhouse PIT tag interrogation array; JDA, from RCL to John Day Dam on the Columbia River, rkm 347]

Species/release group	Reach	Survival estimate	Standard error	Lower 95% CI	Upper 95% CI	Detection probability
O. mykiss/all	RCS[1]	0.276	0.019	0.241	0.314	0.585
Coho/all	RCS[1]	0.568	0.027	0.515	0.618	0.613
O. mykiss/all	RCL	0.972	0.039	0.689	0.998	0.897
Coho/all	RCL	0.877	0.044	0.763	0.940	0.913
Coho/RLO	RCL[1]	0.569	0.118	0.340	0.772	0.700
O. mykiss/all	JDA	0.897	0.214	0.085	0.999	0.263
Coho/all	JDA	0.883	0.043	0.771	0.944	0.913
Coho/RLO	JDA	0.272	0.147	0.080	0.615	0.286

[1]Reach estimates include overwinter survival.

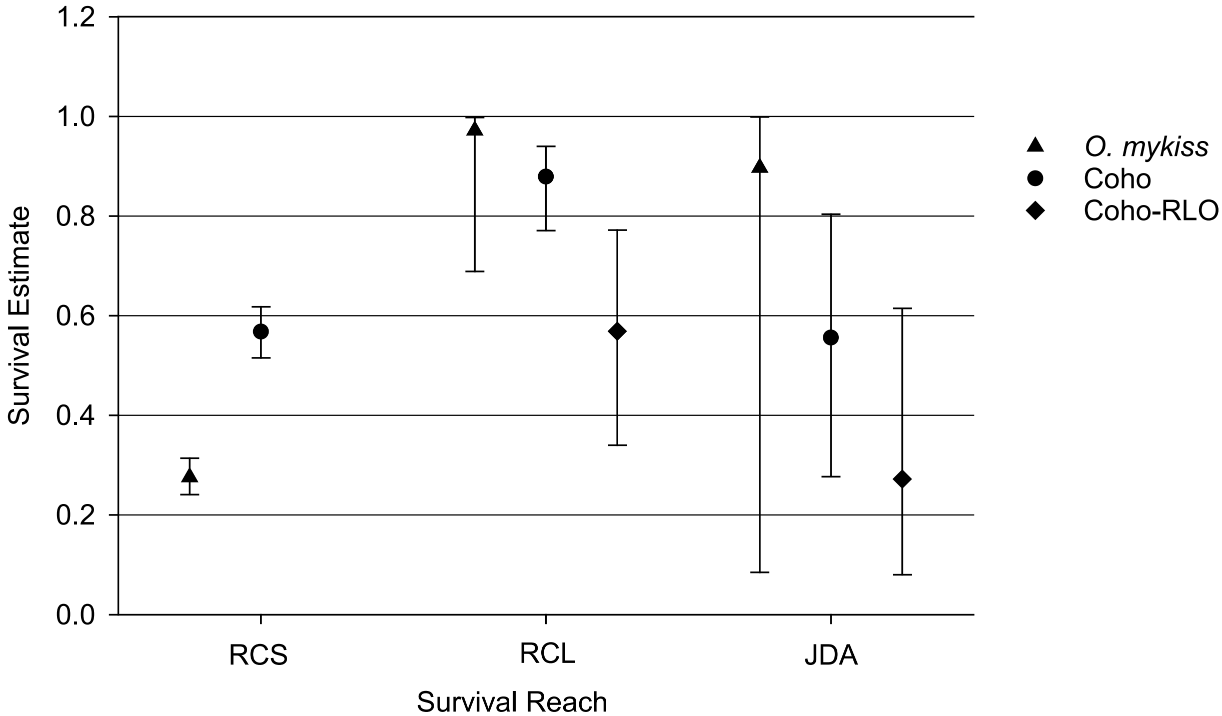

Figure 15. Graph of steelhead (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*) reach probability of survival estimates with 95-percent confidence intervals for fish tagged with passive integrated transponders (PITs) during autumn of 2018 in Rock Creek and Walaluuks Creek, Washington. [Survival reaches include: RCS, from release location to the PIT tag interrogation array Rock Creek Squaw at river kilometer (rkm) 13; RCL from rkm 13 to rkm 5 Rock Creek Longhouse PIT tag interrogation array; and JDA, from RCL to John Day Dam on the Columbia River, rkm 347. Release groups include fish released in Walaluuks Creek and Rock Creek upstream from rkm 13 and fish released in Rock Creek between rkm 13 and 5 (RLO).]

Survival probability estimates for coho salmon PIT tagged and released downstream from RCS and upstream from RCL were modeled separately. The survival probability estimate (0.569, *SE*=0.118) for this release group, reach RCL, also included overwinter survival like the overwinter RCS reach survival estimate for coho salmon released upstream of RCS. For *O. mykiss*, few fish were PIT tagged and released between RCS and RCL and later detected at RCL (7 out of 31 tagged and detected; 22.6 percent); thus, survival was not modeled for this release group.

Reach survival estimates were not modeled for bridgelip suckers. Although, suckers do migrate downstream during flow events, fewer detections occur at both instream PTIS sites, and no detections have occurred outside of Rock Creek subbasin. Therefore, modeling to estimate probabilities of detection and survival are more difficult and less reliable. Using instream PTIS detections for bridgelip suckers PIT tagged and released in Rock Creek subbasin, 50 percent were recaptured (147 detected out of 294 tagged and released).

Discussion

Salmonid pool abundance in Rock Creek subbasin varies by pool and species but generally has followed a downward trend as seen in Columbia River Basin runs. Adult counts of salmon and steelhead at Columbia River dams have generally decreased in the last 10 years (Columbia Basin Fishery Agencies and Tribes, 2019); however, adult coho salmon counts have been more variable at the lower Columbia River dams. During 2009 and 2014, higher adult coho salmon counts occurred at Bonneville and John Day Dams (Columbia Basin Fishery Agencies and Tribes, 2019), which correlated with a higher abundance of coho salmon juveniles in Rock Creek during autumn of 2011 and 2016 (Harvey, 2014; Hardiman and Harvey, 2019). Juvenile *O. mykiss* pool abundance estimates have demonstrated a steady decline since estimates were calculated in 2011–12 and 2016–18 (Harvey, 2014; Hardiman and Harvey, 2019). The only exception was a higher average pool abundance (0.38 fish per square meter) during 2018 for age-1+ *O. mykiss* in Walaluuks Creek compared to 2016–17 (0.20 and 0.13 fish per square meter [Hardiman and Harvey, 2019]). Juvenile coho salmon abundance has been more variable. During sampling efforts from 2009 to 2012, coho salmon were only abundant during 2011 (Harvey, 2014; Hardiman and Harvey, 2019). Since 2016 sampling in Rock Creek, coho salmon have been found in abundances similar to and often higher than *O. mykiss*. The average pool abundance for coho salmon was highest in 2016, followed by 2011 (0.82 compared to 0.52 fish per square meter), since then, pool abundance has been lower (0.24 and 0.26 fish per square meter for 2017 and 2018 [Hardiman and Harvey, 2019]). The average coho salmon pool abundance in Walaluuks Creek was also high in 2011 (2.40 fish per square meter; Harvey, 2014); however, since then, average pool abundance estimates have been lower (0.42 and 0.49 fish per square meter in 2017 and 2018, respectively [Hardiman and Harvey, 2019]). For both salmonid species, many pools in Walaluuks Creek had higher pool abundances than those in Rock Creek. For coho salmon, this was true for the four lowest pools sampled in Walaluuks Creek, and for *O. mykiss*, it was the uppermost pools. During 2018, the average coho salmon pool abundances were considerably higher than those of *O. mykiss*; furthermore, preliminary data from fish surveys in 2019 found this trend persists and coho salmon are found higher in the Rock Creek subbasin than in previous years.

The presence and increased abundance of coho salmon may have increased competition for resources (habitat and food) and potentially lowered *O. mykiss* autumn condition and reduced overwinter survival (Young, 2004). In 2018, the probability of overwinter survival for *O. mykiss* was the lowest estimated since 2016 and was almost one-half that of coho salmon (0.276 compared to 0.568). For coho salmon, the 2018 survival probability fell within the range of results from 2016 to 2017 (Hardiman and Harvey, 2019). This could indicate density-dependent (combined salmonid species) reduced fitness and (or) asymmetric competition, where age-0 and some age-1 *O. mykiss*, being smaller than coho salmon, may not compete as well for resources (Young, 2004; Sogard and others, 2009; Pess and others, 2011). Larger coho salmon may occupy mutually preferred low-velocity pools and displace smaller *O. mykiss* into high-velocity riffles (asymmetric competition). A negative effect of fish density on growth has been observed in small coastal California streams, particularly for age-0 *O. mykiss* populations during summer (Sogard and others, 2009). This may result in reduced growth and fitness going into winter and potential reduction in survival. Conversely, coho salmon may have increased their fitness by being larger heading into winter and increased their overwinter survival probability, or coho salmon may have a survival advantage over *O. mykiss* (Quinn and Peterson, 1996; Young, 2004; Ebersole and others, 2006; Sogard and others, 2009; Pess and others, 2011; Hwan and others, 2018). In other systems, juvenile coho salmon in newly established populations have outnumbered resident salmon species by 40 percent within 5 years of colonization (Pess and others, 2011). The effects of the increased distribution and abundance of juvenile coho salmon on *O. mykiss* in the Rock Creek subbasin need further investigation.

As seen in previous study years, salmonid abundance is limited and variable in the lower section of Rock Creek up to rkm 13 (Harvey, 2014, 2015; Hardiman and Harvey, 2019). The consistent absence of salmonids in the pool near rkm 4 may be indicative of poor habitat (rearing and spawning, water quality) and poor oversummer survival. Reaches that are consistently unproductive for salmonid capture are likely poor habitat and have high potential for indirect and direct mortality during summer months, thus resulting in few to no salmonids captured in these pools during autumn sampling. Furthermore, this pool tends to have piscivorous species such as smallmouth bass and northern pikeminnow, which also have higher temperature tolerances than salmonids. In the lower river sections, average pool temperatures during the autumn surveys exceeded the 16 °C limit for surface water that has been set by the Washington Department of Ecology as an indicator of stream health for salmonid habitat and a 20 °C limit for nonsalmonid habitat (Washington Department of Ecology, 2019). Rock Creek habitat quality is variable and patchy between rkm 4 and 13. There are long (greater than 1,000 m) stretches of seasonally dry reaches, frequent bedrock pools, and little stream complexity and cover for fish. The increased abundance of salmonids upstream is indicative of more suitable habitat and water quality (that is flows and temperature). Consistent salmonid abundance in pools differs between the two species, indicating potential differing exploitation of habitats. Reaches that consistently have salmonids but with varying abundances across years would be areas warranting potential restoration actions to improve habitat quality.

Low oversummer survival combined with poor overwinter survival, particularly in 2018 for *O. mykiss,* is likely a limiting factor to Rock Creek population recovery and sustainability. Poor survival can be exacerbated by changing climate conditions, such as more frequent and prolonged droughts, drier winters, and reduced snowpack (Hwan and Carlson, 2015; Hwan and others, 2018). Local adaptation to the existing environmental conditions could be a factor in maintaining species persistence over the years and increasing spatial and genetic diversity through continued connectivity to the greater MCR steelhead population. Previous tagging efforts (2009–12) resulted in steelhead smolt-to-adult return rates ranging from 2.2 to 5.5 percent (Harvey, 2015). Rock Creek still supports salmonid productivity, as seen in other intermittent streams (Wigington and others, 2006; Hwan and others, 2018; Obedzinski and others, 2018), and continues to contribute to the MCR steelhead population. Resilience of Rock Creek steelhead combined with straying as a common life history behavior in steelhead can contribute to population genetic diversity (Keefer and Caudill, 2012, 2014). Some Rock Creek PIT-tagged steelhead are likely straying based on the higher observed smolt-to-adult return rates to Bonneville Dam (2.4 to 10.4 percent) versus Rock Creek, and a percentage of fish observed upstream at McNary Dam (Harvey, 2015; Hardiman and Harvey, 2019). Furthermore, out-of-basin (tagged outside of Rock Creek subbasin) PIT tagged steelhead are also detected by the Rock Creek PTISs. Smolt-to-adult return rates will be calculated for salmonids tagged during 2016–18, when more time has passed to detect most of the adult returns to the Rock Creek subbasin.

Juvenile bridgelip suckers are well distributed in Rock Creek; however, we typically observed higher abundance in Rock Creek downstream from rkm 20, where bridgelip suckers were often the most abundant of the three species in pools in which mark-recapture population analysis was completed. Although these species eat mainly periphyton, small individuals (46–149 mm) also include chironomid larvae and pupae, zooplankton, and miscellaneous aquatic invertebrates in their diet (Dauble, 1980). It should be noted, in many of these same pools, dace are abundant as well, which may increase the level of feeding by small bridgelip suckers on a food base other than periphyton and detritus. The presence and abundance of both these species may affect limited resources, especially over summer when pools become isolated from flow, limiting feeding opportunities and potentially lowering fish growth for all species present (Harvey and others, 2006).

In Rock Creek, it can be difficult to distinguish bridgelip suckers from sympatric largescale suckers because of variability of taxonomic characters (Dauble, 1980). Some suckers were identified as largescale suckers but numbers were few. Hybridization between the two species has been documented in several localities in the Columbia River Basin (Dauble, 1980). During autumn sampling, we capture primarily age-0 and age-1 suckers, of which we have begun to observe patterns in movement (primarily downstream during spring) and obtain a 50-percent recapture, detection rate at our instream PTISs.

Bridgelip suckers and steelhead continue to be important to the Rock Creek Band of the YN. Information provided in this report increases our understanding of the status and trends of these populations. It also provides insight into potential management and restoration actions. The intermittent nature of Rock Creek, combined with low summer flows, warrants protection of spring inputs and actions to protect and enhance current instream flows. Some potential management and land use actions could include limiting cattle grazing within the stream, reduction of water withdrawals, and new land development (such as roads or new wells). Other restoration actions to potentially increase stream flows could be considered such as protect and enhance headwater meadows to increase water table storage, and beaver analogs, or beaver introduction to increase instream water storage (Beechie and others, 2013). Restoration projects that focus on restoring flow regimes, increasing connectivity, restoring riparian function, and increasing instream complexity may benefit salmonids.

Adaptive Management and Lessons Learned

Future study results could be enhanced by increasing the numbers of fish tagged. This would likely increase the precision on estimates for survival, smolt-to-adult returns, and residence and travel times. This could be completed by using smaller sized PIT tags (9 mm), which would increase the size range in which salmonids could be tagged down to 55-mm FL. Increasing the range of fish sizes would improve information around life history behaviors for age-0 *O. mykiss*. An increase in the overall number of fish tagged and size ranges may allow for some size dependent survival and behavior analysis as well.

Increasing our understanding of what habitat attributes are contributing to or limiting survival could help identify potential restoration actions. Identifying attributes that affect fish survival at the reach scale (such as instream fish cover, riparian cover, water temperature), and at the landscape scale (such as drought years, dry winters, wet winters, shifts in snowpack, and hydrologic regimes, including frequency and duration of events), would help target potential restoration actions, timing, and allocation of resources to ameliorate effects. Limited water quantity and quality could be affected by water restoration actions, such as limiting land development, agricultural practices in the riparian corridor, water withdrawals, and conservation and protection of perennial springs that support salmonid protection, especially during limited low-flow summer periods (Grantham and others, 2012).

Additional information could be gained with the installation of a PTIS array at the mouth or inundated part of Rock Creek near its confluence with the Columbia River. This would improve instream survival estimates by improving overall detection efficiencies and provide an additional reach to estimate survival through; furthermore, it would provide more information on timing of stream entry by adults, which could be correlated to flow timing and run timing. This could provide insight into behavioral adaptations on migration timing of salmonids to spawn in this subbasin as well as out-of-basin fish use. The instream PTIS sites provide information on the use of Rock Creek for both in-basin and out-of-basin fish. This information is available to the public and resource managers through the PTAGIS website (accessed January 2020 at https://www.ptagis.org/).

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Appendixes

Appendix 1. Length-Frequency Distribution

Length-frequency distribution data were graphed for each species (Oncorhynchus mykiss, coho salmon, and bridgelip suckers) of interest in Rock Creek subbasin during electrofishing sampling in autumn, 2018. Graphs are presented by species for the main stem Rock Creek, Walaluuks Creek, and both creeks combined. Fish are categorized as tagged, inserted passive integrated transponder into the body cavity, or not tagged. Individual fish forklengths were grouped into 2 mm increments.

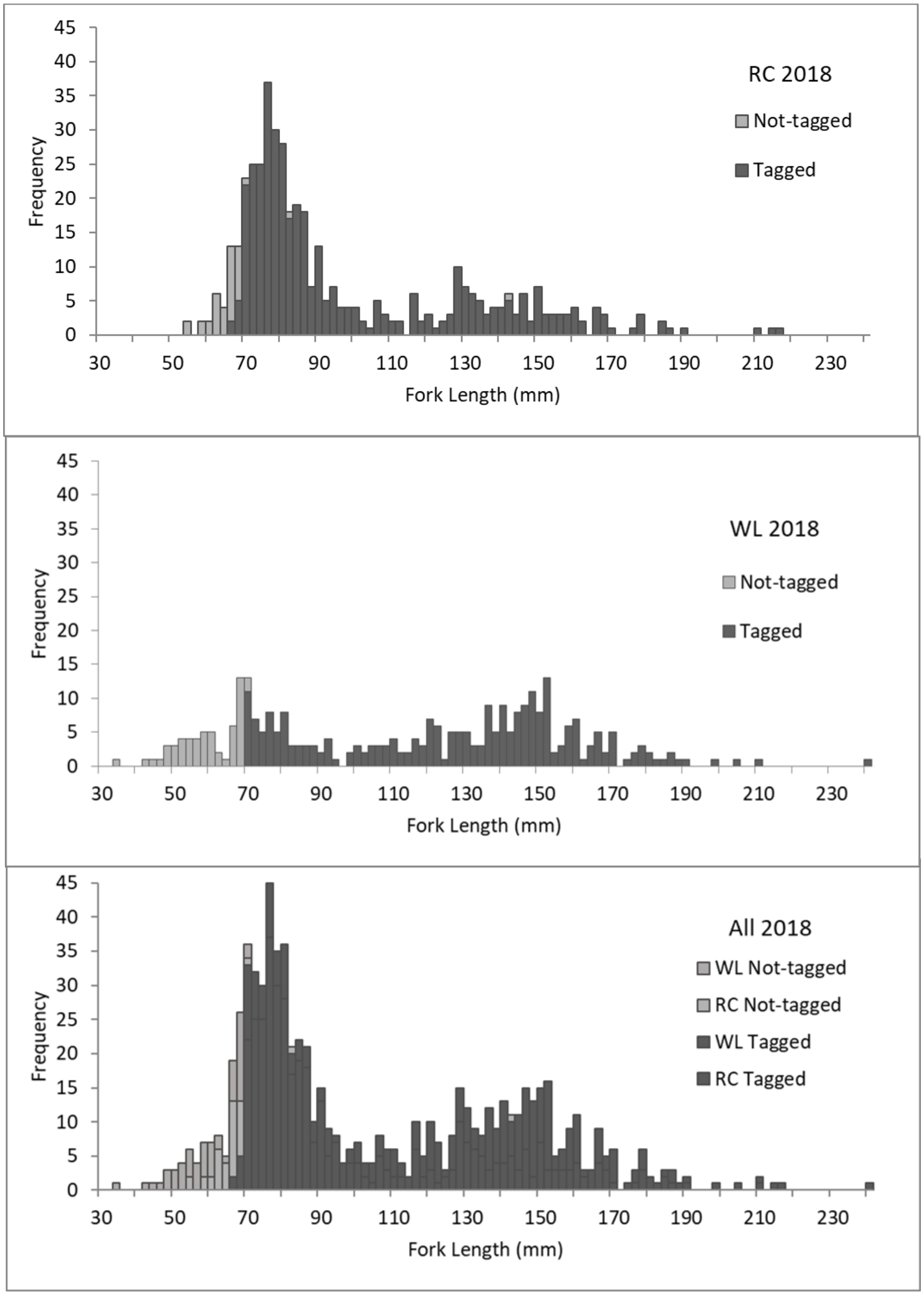

Figure 1.1. Length-frequency histograms for *Oncorhynchus mykiss* sampled in Rock Creek (RC, top panel), Walaluuks Creek (WL, middle panel), and both creeks combined (all, bottom panel) in southeast Washington, autumn 2018. Passive integrated transponder tags were inserted into tagged fish.

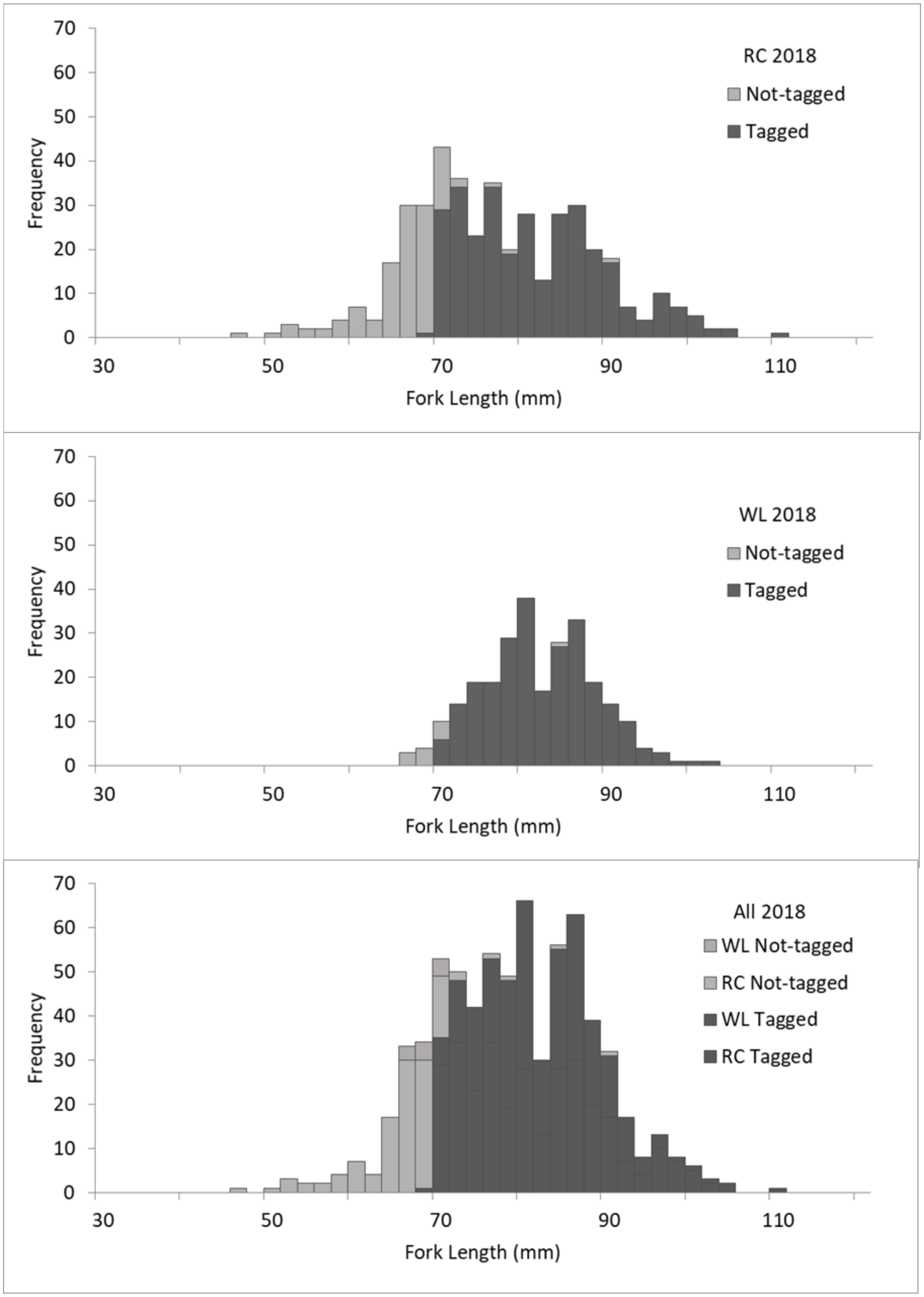

Figure 1.2. Length-frequency histograms for coho salmon (*Oncorhynchus kisutch*) sampled in Rock Creek (RC, top panel), Walaluuks Creek (WL, middle panel), and both creeks combined (all, bottom panel) in southeast Washington, autumn 2018. Passive integrated transponder tags were inserted into tagged fish.

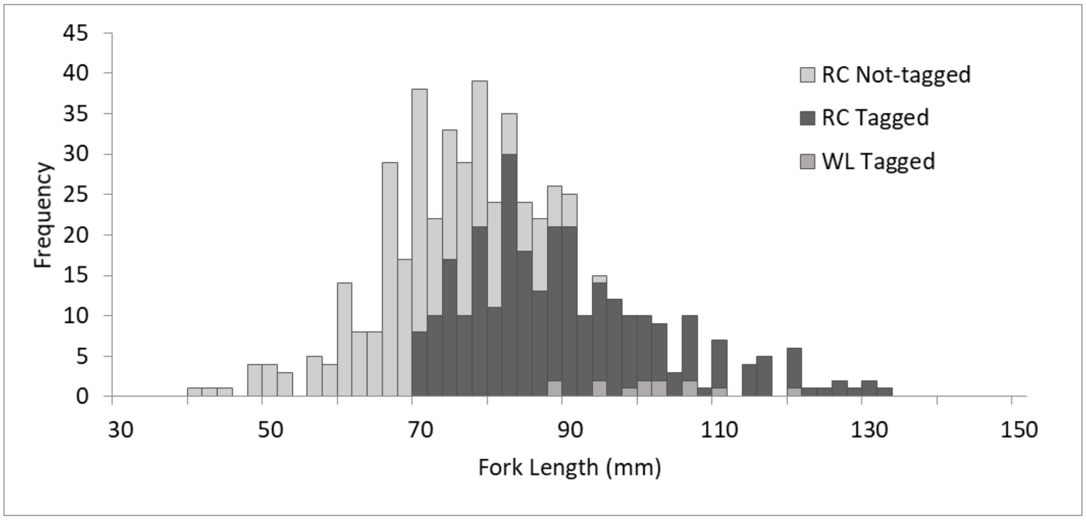

Figure 1.3. Length-frequency histograms for bridgelip suckers (*Catostomus columbianus*) sampled in Rock Creek (RC) and Walaluuks Creek (WL), in southeast Washington, autumn 2018. Passive integrated transponder tags were inserted into tagged fish.

Appendix 2. Length-Weight Regression

Individual fish fork length and weights were graphed for each species (*Oncorhynchus mykiss*, coho salmon, and bridgelip suckers) of interest in Rock Creek subbasin during electrofishing sampling in autumn, 2018. A best fit regression equation was fitted to each plot.

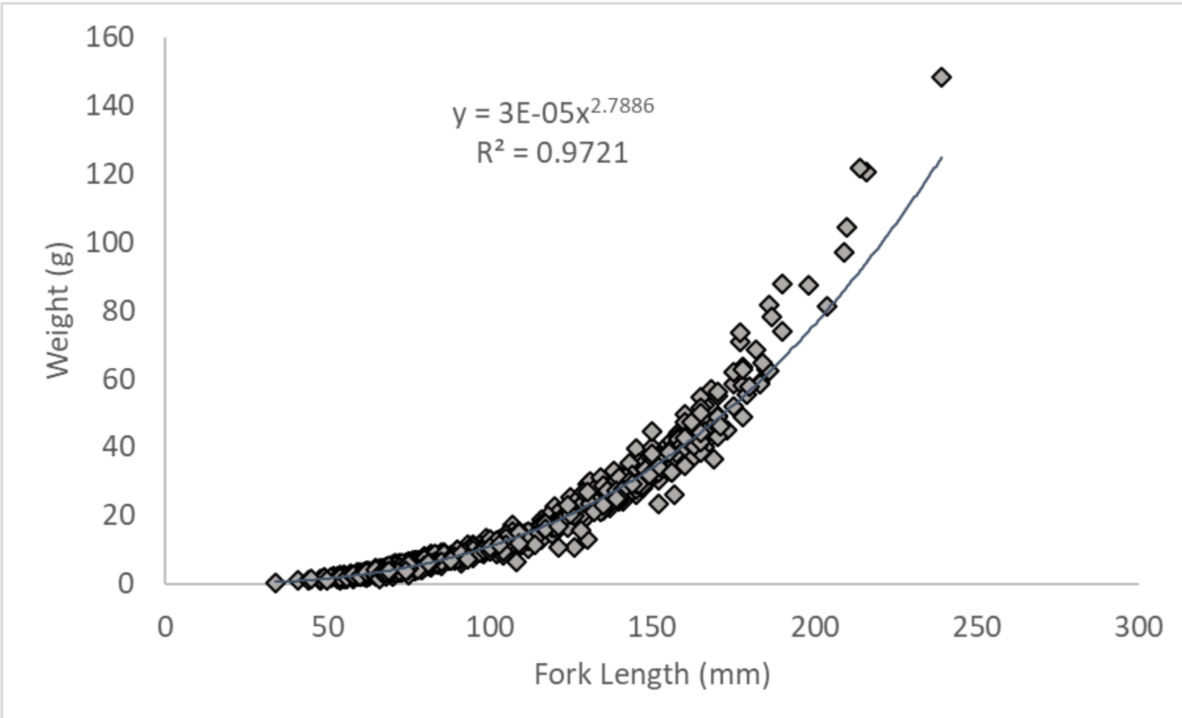

Figure 2.1. Length-weight relationship for *Oncorhynchus mykiss* captured in Rock and Walaluuks Creeks, southeastern Washington, during electrofishing in autumn of 2018. [R^2, coefficient of determination]

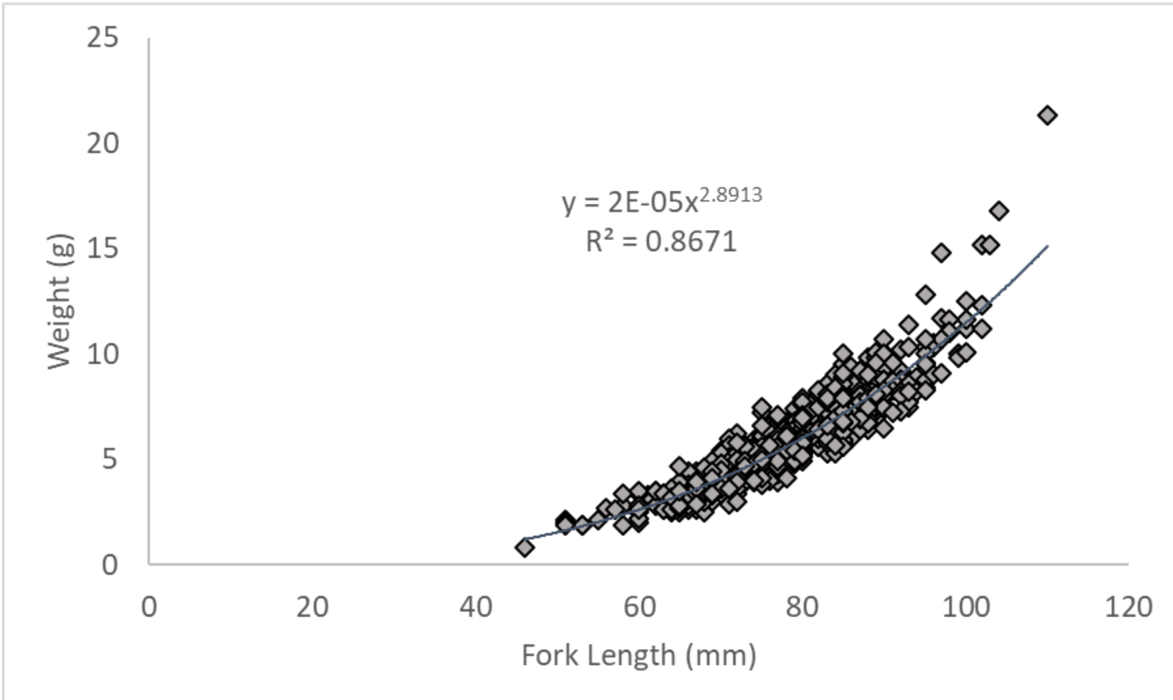

Figure 2.2. Length-weight relationship for coho salmon (*Oncorhynchus kisutch*) captured in Rock and Walaluuks Creeks, southeastern Washington, during electrofishing in autumn 2018. [R^2, coefficient of determination]

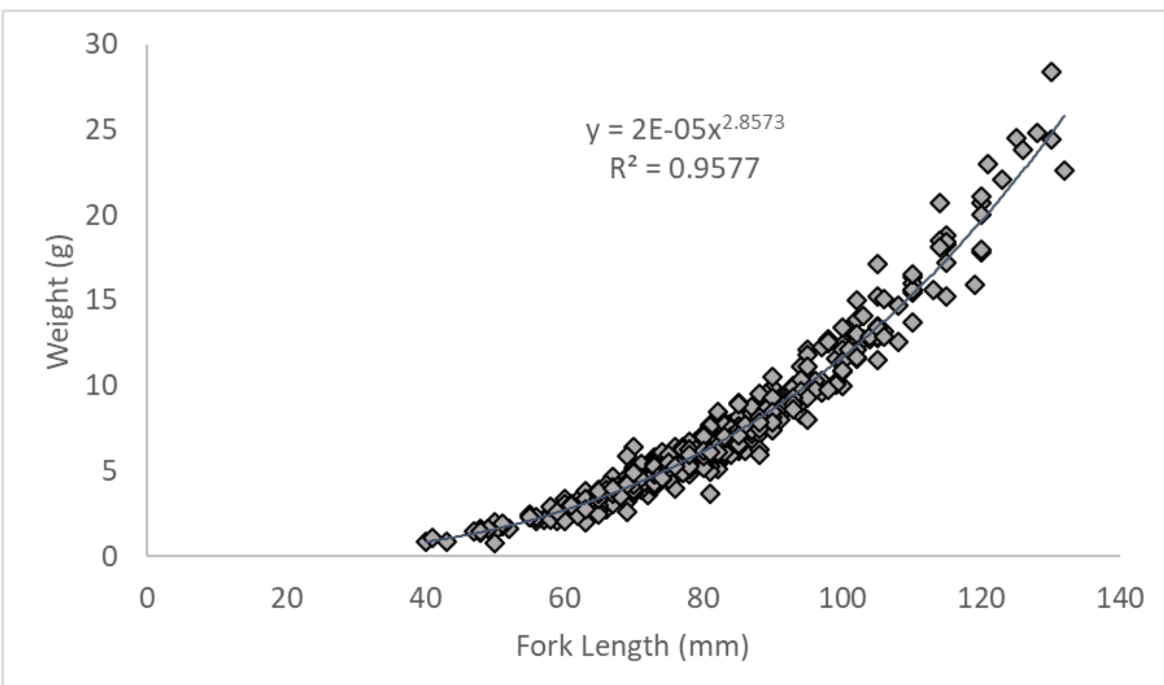

Figure 2.3. Length-weight relationship for bridgelip suckers (*Catostomus columbianus*) captured in Rock and Walaluuks Creeks, southeastern Washington, during electrofishing in autumn 2018. [R^2, coefficient of determination]

Appendix 3. Passive Integrated Transponder Interrogation System Operation Log

Table 3.1. Summary of dates for passive integrated transponder interrogation system operations for Rock Creek Squaw and Rock Creek Longhouse sites on Rock Creek, Washington.

[RCL, Rock Creek Longhouse; rkm, river kilometer; RCS, Rock Creek Squaw]

Dates	Operating status	Action
	RCL (rkm 5)	
10/24/18–7/1/18	Operating	Activated for fish monitoring.
7/1/18–10/24/18	Not operating	Deactivated for summer because of intermittent flow.
10/24/18–7/1/19	Operating	Activated for fish monitoring.
7/1/19–10/29/19	Not operating	Deactivated for summer because of intermittent flow.
10/30/19–12/27/19	Operating	Activated for fish monitoring.
12/28/19–1/3/19	Not operating	Problem in breaker box, power loss.
1/3/19	Operating	Operating at 1600 hours.
	RCS (rkm 14)	
10/24/18–12/11/18	Operating	Activated for fish monitoring.
12/11/18–12/14/18	Not operating	Power outage.
1/1/19–2/28/19	Operating intermittently	Power loss due to snow on solar panels.
3/1/19–6/3/19	Operating	Fish monitoring.
7/1/19–11/4/19	Not operating	Deactivated for summer because of intermittent flow.
11/4/19–12/2/19	Operating intermittently	No data recorded.
12/2/19	Operating	Reset and tuned.

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For more information concerning the research in this report, contact the
Director, Western Fisheries Research Center
U.S. Geological Survey
6505 NE 65th Street
Seattle, Washington 98115-5016
https://www.usgs.gov/centers/wfrc

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