Rock Creek Fish and Habitat Assessment
for
Prioritization of Restoration and Protection Actions

Yakama Nation Fisheries Resource Management

BPA Project # 2007-156-00

Report covers work performed under BPA contracts #(s) 56662 Rel 32, 56662 Rel 57

Report was completed under BPA contract # 56662 Rel 136

6/1/2013 – 12/31/2015

Elaine Harvey

Yakama Confederated Tribes, Goldendale, WA 98620

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

This report should be cited as follows:

Elaine Harvey, Rock Creek Fish and Habitat Assessment for Prioritization of Restoration and Protection Actions, 6/1/2013 - 12/31/2015 Annual Report, 2007-156-00

Contents

Executive Project Summary/Abstract

The overall goal of this project is to improve habitat conditions for steelhead trout (*Oncorhynchus mykiss*), listed under the Endangered Species Act (ESA), in the Rock Creek subbasin in southeastern Washington in order to support sustainable populations. This report describes results of the monitoring and evaluation activities, salmonid populations adult movement, smolt-to-adult return rate, spawner abundance, redd distribution, and habitat conditions in the Rock Creek subbasin. The project also addresses information gaps identified in the National Oceanographic and Atmospheric Administration (NOAA)-Fisheries' *Recovery Plan for the Rock Creek Population of Middle Columbia River Steelhead* and the Northwest Power & Conservation Council's (NPCC) *Rock Creek Subbasin Plan*, which state that ongoing monitoring and evaluation within the Rock Creek subbasin is a high priority. This report summarizes progress and results for the following major objectives under this contract:

1. Monitoring and Evaluation -- to assess current habitat conditions, limiting factors and status of salmonid populations in the subbasin, including: salmonid populations movement, habitat use, life history, survival to adulthood and adult distribution, relative abundance, spawning behavior (e.g. kelting), and perennial habitat type mapping. Geomorphic survey and mapping was conducted to identify site specific locations with the watershed for restoration (Final draft submitted to BPA December 2017). A co-authored journal article on the life history of Rock Creek steelhead was submitted to multiple fisheries journals for publishing.
2. Conservation and Protection of Riparian Corridor – Lease 200 acres to exclude cattle grazing and promote a healthy ecological functioning riparian zone.
3. Spring Enhancement and Revegetation -- Riparian revegetation and invasive weed removal along the stream corridor to increase stream shading and lower stream temperatures at several sites. Native tree and shrub species were chosen for the revegation in the spring enhancement and revegetation sites.

Introduction

The Rock Creek subbasin encompasses an area of approximately 223 square miles of southeastern Washington. Rock Creek flows south to the Columbia River at river mile (RM) 230, approximately 12 miles upstream of John Day Dam (Appendix A). The lowermost portion (1.2 mi.) is inundated by the backwaters of the John Day Dam. Elevations range from 200 feet at the confluence to over 3,200 feet in the Simcoe Mountains. Annual precipitation ranges from approximately 8 inches at the confluence to 24 inches in the headwaters. From June through September, the stream flow in Rock Creek and its tributary streams decreases, becoming intermittent until the fall rains resume (generally in October or November). Major tributaries to Rock Creek include Walaluuks Creek (previously known as Squaw Creek with legal name change in May 2017), Quartz Creek, Badger Creek, Luna Creek, and Harrison Creek.

Anadromous salmonid populations present in the Rock Creek subbasin include fall Chinook (*O. tshawytscha*) and coho (*O. kisutch*) salmon, summer steelhead (*O. mykiss*), as well as resident rainbow trout (*O. mykiss*). Rock Creek steelhead are listed as “threatened” under the Endangered Species Act (ESA), originally listed as part of the Middle Columbia River steelhead Evolutionarily Significant Unit (ESU) on March 25, 1999. Other native and non-native fish species are found primarily in the lower reaches of the subbasin.

The Rock Creek subbasin is of great significance to the Yakama Nation, and to the Kahmiltpah (Rock Creek) Band in particular. The Kahmiltpah Band lived in the subbasin for thousands of years and survived on the historically abundant source of fish, wildlife, and plants in the subbasin. Salmon, steelhead, Pacific lamprey, and bridgelip suckers are all culturally significant species that were once abundant prior to the John Day Dam inundation to the lowest two miles of the mainstem Rock Creek. Oral history describing historic runs of anadromous and resident fish and perennial flows in the subbasin indicate that fish populations and habitat have been significantly altered from historic conditions. The subbasin has been identified as a potentially productive watershed for steelhead, but with significant habitat limitations (low flow, high stream temperatures, and riparian, channel and floodplain degradation).

The full suite of assessments conducted in Rock Creek primarily focused on salmonid genetics, spawning and rearing behaviors, abundance and distribution, and habitat conditions have all contribute to fulfilling the data gaps identified in the subbasin plan and the recovery plans. Low flow habitat surveys were initiated in 2010 and continued till 2012 in the mainstem Rock Creek (rkm 2- 29) and tributary streams (rkm 2-9). Habitat surveys resumed during the lowest flow periods of 2015 with extended areas surveyed in Quartz, Walaluuks, and Harrison creeks. We found that an average of 38% of the surveyed streambed length was dry (rkm 2-29), 19% remained as perennial pools with low habitat complexity, and 43% was non-pool wet. Overall the results from the 2015 reflected having a higher proportion dry in the lower river (57%) than the upper section (33%). The maximum water temperature recorded in those pools for the most part did not exceed lethal limits for salmonids, and most pools had a maximum temperature that was lower than 18°C.

The fish habitat in Rock Creek is spatially diverse ("patchy") and variably suitable during the low-flow period, particularly in the more downstream reaches. Therefore, the most limiting habitat factor is instream flows during the low-flow period.

A total of 82 out-of-basin PIT-tagged fish have been detected at the Rock Creek passive integrated transponder systems (PITSs) since monitoring began in 2009 (see Report A). About 27% of the 3,088 passive integrated transponder (PIT) -tagged *O. mykiss* and 38% of the 151 PIT-tagged coho were detected outmigrating as smolts, of which 92% migrated in April and May. As of November 2013, 9 *O. mykiss* and 4 coho that were tagged in Rock Creek as juveniles have returned as adults to Bonneville Dam on the Columbia River mainstem (RM 146). There is evidence that adult steelhead entering Rock Creek to spawn (February-March) have traveled in the mainstem Columbia River past McNary Dam (RM 292) throughout the winter, when the mainstem dams do not provide downstream passage except through turbines (see Report A). Continued operation of the PIT-tag detection units will allow us to estimate smolt-to-adult return rates for fish tagged in Rock Creek.

Access to fall Chinook and coho salmon spawning habitat is inconsistent and limited to years when there is enough instream flow during their spawning period to connect Rock Creek to the mainstem Columbia River. Neither of those stocks appear to have viable populations in Rock Creek. Steelhead redds were observed in the mainstem Rock Creek from RM 1- RM 13.5, and in Walaluuks Creek from RM 0 – RM 5.5; i.e., virtually everywhere surveyed. Steelhead distribution in the basin may be more widespread; however, difficult access and lack of permission limited the range of surveys.

Prior to the efforts described in this report, very little was known about the threatened Mid-Columbia River steelhead population or the fish habitat conditions in Rock Creek, though some data gaps remain. We did not assess the fish population in the inundated portion of Rock Creek (RM 0-1.2). Estimates for survival of smolts passing from lower Rock Creek to the John Day Dam could be refined through additional PIT-tagging of juvenile salmonids and the installation of a PIT- interrogation system at the Highway 14 bridge (RM 0). A focused assessment of the influence of altered hydrologic and other habitat conditions and introduced predator species on salmonid survival within the inundated portion of Rock Creek would be needed to better understand to what extent this reach is a source of mortality for Rock Creek salmonids.

Through the efforts outlined in this report, we have determined that there is habitat available to consistently support salmonids throughout the basin, though the habitat in the lowermost 6 miles is less consistently suitable (depending on the water year and weather conditions) than farther upstream. Out-of-basin steelhead spawn in Rock Creek and appear to have overwhelmed the endemic population; however, genetically distinct populations of *O. mykiss* persist higher in the basin above likely passage barriers. Additional information from a separately funded geomorphic assessment (in progress) should help refine restoration opportunities. We anticipate the results of these combined efforts will support the priority actions and reaches for restoration and habitat protection.

1. Monitoring & Evaluation

The overall objective of the Monitoring and Evaluation effort was to gather baseline environmental and biological data throughout the subbasin to understand the current conditions of native salmonids and associated habitat conditions, and to identify opportunities for habitat restoration. This fish and habitat assessment was the first comprehensive assessment to be conducted in the Rock Creek subbasin originating in 2009 and continuing into 2015. Fish movement, smolt-to-adult return rate (SAR), out-of-basin steelhead straying into the Rock Creek subbasin, and perennial habitat type mapping is covered in this document titled, *Fish and Habitat Assessment in Rock Creek, Klickitat County, Washington* (Report A). Adult salmon and steelhead abundance and redd distribution results, geomorphic survey and mapping, and co-authored journal article status are included in the report titled, *Adult Fish Assessments* (Report B). Report A: Fish and Habitat Assessment in Rock Creek, Klickitat County, Washington.

Report A: Fish and Habitat Assessment in Rock Creek, Klickitat County, Washington

June 2013 – December 2015

Prepared by:

Jill M. Hardiman[1] and Elaine Harvey[2]

1U.S. Geological Survey
Western Fisheries Research Center
Columbia River Research Laboratory
5501-a Cook-Underwood Rd.
Cook, WA 98672
Phone: 509-538-2299 x201 Email: *jhardiman@usgs.gov*

2Yakama Nation Fisheries
Goldendale Field Office
P.O. Box 655
Goldendale, WA 98620
Phone: 509-773-3147 Email: elaine@ykfp.org

Prepared for:

U.S. Department of Energy

Bonneville Power Administration

Environment, Fish, and Wildlife Department

Project Number 2007-156-00

Contract Number 56662 Rel 32 & 57

Table of Contents

List of Tables

List of Figures

Abstract

The U.S. Geological Survey (USGS) and the Yakama Nation have collaborated in the Rock Creek subbasin, southeastern, Washington since 2009 to assess steelhead (*Oncorynchus mykiss*) populations and habitat conditions. Rock Creek, flows south to the Columbia River at river kilometer (rkm) 368. During 2015, a habitat survey was conducted, and monitoring of Passive Integrated Transponder (PIT)-tagged salmonids in the Rock Creek subbasin continued. Two multiplexing PIT-tag interrogation systems (PTISs) were installed in Rock Creek in the fall of 2009 to evaluate timing and degree of salmonid movement, smolting success, stray rates, and other life history attributes. These have been monitored every year since, during the spring, fall, and winter months. Returning adult steelhead detection histories are summarized from past Rock Creek PIT-tagging efforts. Detection histories and detection efficiencies were used to estimate a smolt-to-adult return rate (SAR) for Rock Creek PIT-tagged steelhead (tagged from 2009 to 2012) that ranged from 2.2% to 5.5%. Additionally, a SAR was also estimated for Rock Creek

PIT-tagged steelhead returning to Bonneville Dam, Columbia River (rkm 235). The SAR rate to Bonneville Dam was always higher (2.4% to 10.4%), indicating straying of adults to other sites for spawning potentially further upstream or in other tributaries, or pre-spawn mortality. Twenty-two Rock Creek PIT-tagged steelhead were detected returning to Rock Creek and 35 were detected at Bonneville Dam from past tagging efforts (2009 – 2012). Monitoring of the Rock Creek PTISs [Rock Creek Lower (RCL) and Rock Creek Squaw (RCS)] provide evidence for PIT-tagged salmonid use from fish tagged outside of Rock Creek subbasin (out-of-basin) origins. A total of 82 out-of-basin PIT-tagged fish have been detected at the Rock Creek PTISs since installation.

The habitat survey was conducted in Rock Creek from September 16 to October 7, 2015. The survey started at rkm 2 and continued upstream to rkm 29.3, and included portions of the major tributaries, ranging from 1 to 9 rkm survey length upstream from their confluence. During the survey, we measured the lengths of all dry and non-pool wet sections, and for pools: the length, wetted width, average residual depth, maximum residual depth, and temperature. During the 2015 survey of Rock Creek, 38% of the river between rkm 2 and 29 was classified as dry, with a higher relative proportion (57%) of dry being in the lower river section (rkm 2-13) than the upper river section (33%, rkm 14-22). This was higher than during survey years 2010 to 2012, which ranged from 29% to 43% in the lower river. As a result of the increase in dry area the percent of non-pool wet habitat was less (22%) than previous years (range 34% to 43%), as well as the percent of pools (21%). However, more river kilometers were surveyed in the lower river section (rkm 2-13) than previous years. For the 2015 survey length (rkm 2 to 29), 19% was classified as pools and 43% was non-pool wet. This work informs potential restoration actions by identifying the persistent pools across years and in years of low water flow (i.e., 2015). This work also provides a baseline to evaluate effectiveness of future restoration actions. Potential restoration actions could include headwater and upland restoration to improve base flows and pool habitat enhancement, through increased structure and vegetation plantings for increased cover.

The Rock Creek steelhead population remains to be an important cultural resource for the Rock Creek Band of the Yakama Nation Tribe. The Rock Creek steelhead population is part of the Cascades Eastern Slope major population group (MPG), one of four MPGs contributing to the Middle Columbia steelhead distinct population segment (DPS). The National Marine

Fisheries Service recovery plan for Rock Creek (NMFS 2009a) identifies an overall biological recovery goal for Rock Creek steelhead to contribute to recovery of the Mid-Columbia DPS by reaching a moderate risk rating (maintained status 25% or less risk level; NWFSC, 2015). The SAR results will help inform recovery goals and population status assessments for the Rock Creek population.

Introduction

This project was initiated in 2008 to assess habitat conditions for steelhead (the anadromous form of Rainbow Trout, *Oncorhynchus mykiss*), in the Rock Creek subbasin to support sustainable populations (Harvey 2014). The native steelhead population within Rock Creek is considered an independent population of the Middle Columbia River steelhead distinct population segment (DPS), which was listed as threatened under the Endangered Species Act (ESA) on March 25, 1999 and reconfirmed on January 5, 2006 (71 FR 834; National Marine Fisheries, 2009a and 2009b). The Rock Creek subbasin located in southeastern, Washington (Figure 1), is of great significance to the Yakama Nation and to the Rock Creek Band in particular. Historically, steelhead were presumed to have used the major streams and tributaries of Rock Creek and were used by the Rock Creek Band members for both sustenance and trade (NPPC, 2004). Oral history describing historic runs of anadromous and resident fish and perennial flows in the subbasin, indicate that fish populations and habitat have been significantly altered from historic conditions. Rock Creek was identified as critical habitat for the Middle Columbia River steelhead DPS (NOAA, 2005). The subbasin has been identified as a potentially productive watershed for steelhead, but with significant habitat limitations (e.g., low flow, high stream temperatures, and riparian, channel and floodplain degradation; Harvey, 2014).

This assessment builds on the first comprehensive assessment conducted in the Rock Creek subbasin, from June 1, 2008 to May 31, 2013 (Harvey, 2014), and it provides a comparison of habitat conditions across multiple years, including 2015, a low water year. It further addresses the need for ongoing monitoring and evaluation within the Rock Creek watershed, stated as a high priority in the National Marine Fisheries' (NMFS) *Recovery Plan for the Rock Creek Population of Middle Columbia River Steelhead Distinct Population Segment* (NMFS 2009b) and the Northwest Power & Conservation Council's (NPCC) *Lower Mid-Columbia Mainstem Including Rock Creek Subbasin Plan* (NPCC, 2004). The overall objective of this monitoring and evaluation effort was to gather baseline environmental and biological data to better understand life history traits and distribution of native salmonids and associated habitat conditions. Furthermore, the results can help identify opportunities for habitat restoration to support a sustainable steelhead population. It also provides baseline information towards effectiveness monitoring of future restoration management actions.

Updated information is available from past tagging efforts on Rock Creek PIT-tagged adult steelhead returning to the Columbia River and the Rock Creek subbasin. Mainstem Columbia River PIT tag adult interrogation sites are located at Bonneville, The Dalles, John Day and McNary dams. Maintaining and monitoring PIT-tag interrogation systems (PTIS) within Rock Creek allowed for estimation of smolt-to-adult return rates for Rock Creek PIT-tagged fish returning to Rock Creek. Additionally, we provide information on the numbers of adult Rock Creek PIT-tagged fish that overshoot Rock Creek and either stray into other areas for spawning or pass upstream of McNary Dam and fall back to eventually return to Rock Creek. Overshoot behavior has been observed in PIT-tagged steelhead from the John Day and Umatilla rivers as well (Carmichael et al., 2012). This is a concern since spill is terminated late August to April at McNary Dam forcing downstream passage through the turbines for fish to return to natal streams. Adult steelhead survival for fish passing through the turbines at McNary Dam was significantly lower than for fish passing via the surface spillway weir (Normandeau Associates, Inc., 2014). Fall back rates for steelhead at McNary Dam were monitored in a radio telemetry study from 1996 to 2001, which ranged from 7.6 % to 12.9 % (Boggs et al., 2004). Many questions arise from the upstream straying of fish from their natal stream origins such as the level of mortality at hydroelectric projects as they attempt to migrate back downstream, what the bioenergetics effects on survival and reproductive fitness are, and what the impacts on genetic population structure within and out of Rock Creek subbasin are. Additionally, there could be phenotypic selection occurring which could influence population viability. Furthermore, evidence of the numbers of fish falling back through McNary Dam and the presence of kelt life history traits suggest alternate downstream passage routes may be warranted through Columbia River mainstem dams during the winter months.

Out-of-basin fish use by hatchery-origin strays has been a concern in Rock Creek subbasin and other nearby rivers such as the John Day and Deschutes (Northwest Fisheries Science Center, 2015). This report provides updated information on non-Rock Creek origin (out-of-basin) PIT-tagged fish use straying into Rock Creek. Straying is a natural trait of many salmon populations, however the degree of occurrence and the impact of this behavior on the Rock Creek population is not fully understood.

This report describes the results to date of the cooperative study between Yakama Nation and the U.S. Geological Survey (USGS) to assess salmonid fish populations and habitat conditions in the Rock Creek subbasin. Specific objectives include: 1) habitat survey to document persistent pools during the low flow period in 2015, 2) comparison of past habitat survey results across multiple years, 3) continue monitoring of Rock Creek origin PIT-tagged adult salmonids returning to the Columbia River and Rock Creek subbasin, and 4) continue monitoring for non-Rock Creek origin (out-of-basin) PIT-tagged fish use in the Rock Creek subbasin.

Study Site Description

Rock Creek, a Washington State tributary that flows south to the Columbia River at river kilometer (rkm) 368, is 21 km upstream of John Day Dam (Harvey, 2014). The watershed encompasses an area of 578 km^2 (Figure 1). Lake Umatilla, the reservoir behind John Day Dam, inundates the lower 2 km of Rock Creek and is at 81 m in elevation. The headwaters of Rock Creek originate in the Simcoe Mountains, which are the watershed’s northern border at 1,433 m, on the southern border of the Yakama Nation Reservation. The average annual precipitation in Rock Creek varies from about 25 cm at the mouth to 71 cm near the headwaters. Major tributaries to Rock Creek include Walaluuks Creek (formerly named Squaw Creek) at rkm 13, Luna Gulch at rkm 18.5, and Quartz Creek at rkm 27. There is a Yakama Nation longhouse at rkm 6, and the primary land ownership within the study area was either Yakama Nation or private.

Methods

Habitat surveys were used to assess the perennial pools during low flow conditions and PIT interrogation sites on the mainstem Columbia River and in the Rock Creek subbasin were used for monitoring of previously PIT-tagged Rock Creek steelhead and Coho Salmon, *O. kisutch* as described in Harvey 2014. To track movements of PIT-tagged fish within Rock Creek subbasin, we continued to operate two PTISs to detect Rock Creek origin returning adults and out-of-basin PIT-tagged salmonid use.

Stream Pool Habitat Surveys

Surveys were conducted from September 16 through October 7, 2015 in Rock Creek from rkm 2 upstream to rkm 29.3 and in four major tributaries including Walaluuks (formerly named Squaw Creek), Luna, Harrison, and Quartz creeks. Tributary survey lengths ranged from 1 to 9 rkm upstream from their confluence with Rock Creek or another tributary (Harrison Creek to Walaluuks Creek, Figure 1). During the survey, we measured the lengths of all dry and non-pool wet sections, and for pools: the length, wetted width, average residual depth, maximum residual depth, and temperature. Data were recorded using an iPad with GIS Pro software for a digital version in addition to hard paper format. A photo was taken at each habitat unit.

A flow gage was maintained and monitored at highway 8 bridge (rkm 12.9) by Yakama Nation and USGS personnel and temperature was monitored thoughout the watershed. The flow gage recorded stage height and water temperature every 15 minutes during periods of continuous stream flow. Air and stream temperature were monitored by Eastern Klickitat Conservation District in Walaluuks Creek at rkm 0.3 (RC7), and in Rock Creek at rkm 2.4 (RC9), 12.8 (RC8), and 22.1 (RC6) using Onset Corporation Hobo temperature probes that recorded temperatures every 30 minutes.

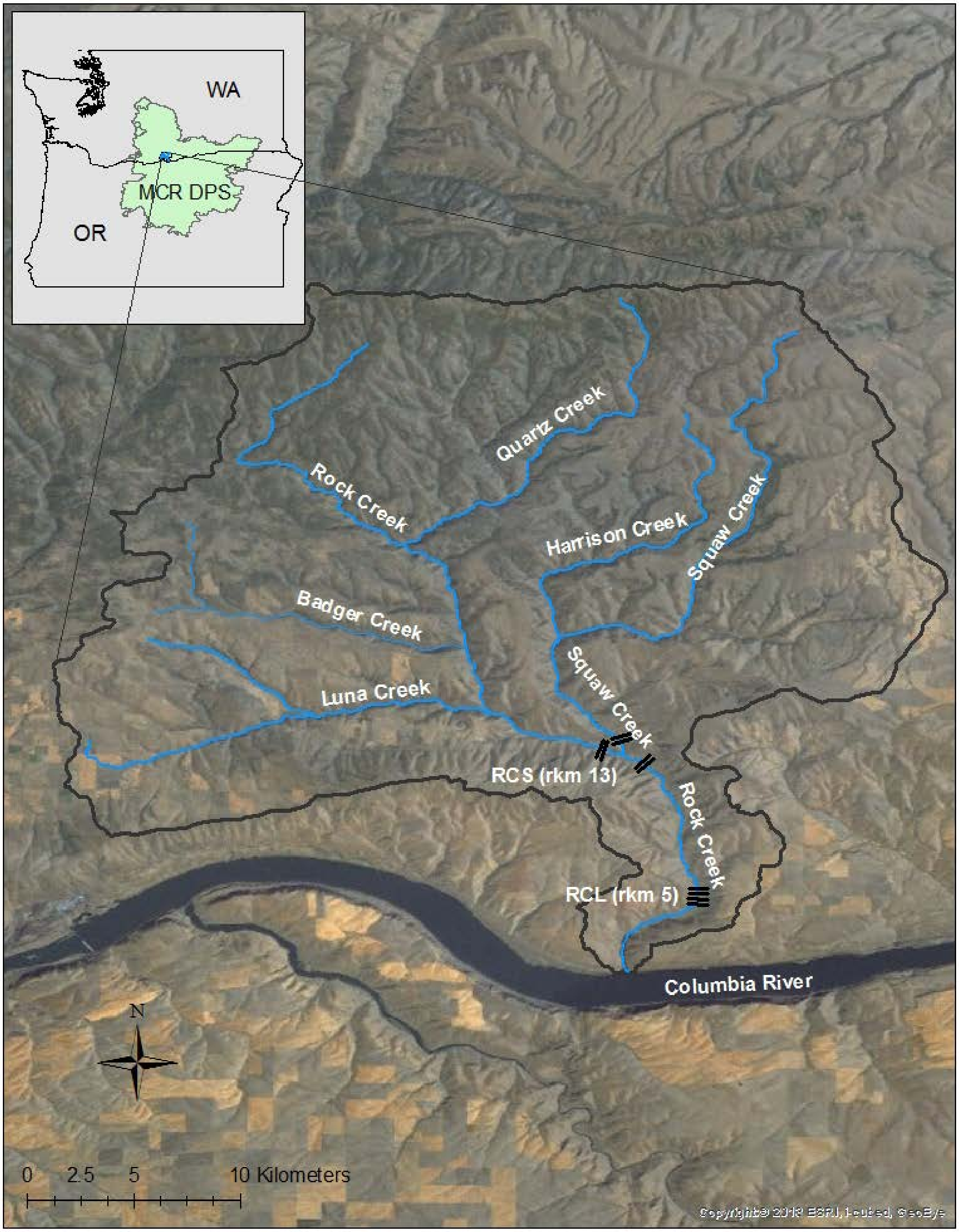

Figure 1. A map of the Rock Creek subbasin (indicated by black outline) and locations of tributary streams and PIT-tag interrogation systems (double black lines) Rock Creek Squaw (RCS) and Rock Creek Lower (RCL) in Rock Creek, Washington. Smaller map inset shows the location of the subbasin within the Middle Columbia River Steelhead Distinct Population Segment (MCR DPS). Squaw Creek has recently been re-named Walaluuks Creek in Washington State.

PIT-tag Interrogation

Two multiplexing PTISs were installed in Rock Creek in the fall of 2009 to evaluate timing and degree of salmonid movement, survival, adult stray rate, and other life history attributes. These PTISs were built and installed by USGS and maintained and downloaded by the Yakama Nation. One PTIS was installed near the Rock Creek Longhouse at rkm 5 (RCL) and powered by grid power, with three arrays in an upstream to downstream orientation where each consisted of two side-by-side antennas. The other PTIS was installed at the confluence with Walaluuks Creek at rkm 13 (RCS) and was powered by a solar panel array (Figure 1). The RCS PTIS was installed with one array composed of two antennas at 40 m upstream of Walaluuks Creek. A single array of two antennas was installed at 20 m downstream of Walaluuks Creek, and two arrays with single antennas in Walaluuks Creek about 3 m apart and 5 m upstream of the confluence. All antennas at both sites were 6.1-m long, were 1-m wide, and were anchored in pass-by orientation (flat to the substrate). The PTIS transceivers were Destron-Fearing 1001M (MUX) that can power up to six 6.1 m long antennas. These transceivers were designed to detect 134.2 kHz full-duplex tags, the standard PIT tag type used in salmonids in the Columbia River basin. To reduce electrical interference within the PITSs, grid power or solar panels were connected to a charging circuit that contained two banks of batteries (each bank consisted of two 12V batteries wired in series for 24V) 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. To protect the MUXs from the high summer air temperatures, they were removed from July through October when the pools were disconnected, thus eliminating the opportunity for fish movement.

Fish movement and SAR

Juvenile steelhead and Coho Salmon were PIT-tagged during previous study years (2009 - 2012) and their movement was monitored at the RCS and RCL sites and other interrogation sites in the Columbia River (Harvey 2014). We summarized adult detection histories from all Rock Creek PIT-tagged fish by number detected (upstream detections as adults), days between out-migration detection at RCL and return detection at RCL, and months of entry to Rock Creek (RCL site). Additionally, other fish contacts (non-Rock Creek tagged) were summarized at RCS and RCL to assess out-of-basin fish use.

Detection histories were used to estimate detection efficiencies at interrogation sites RCL and Bonneville Dam for both smolt out-migration and adult in-migration. A tagged smolt detection list was generated by out-migration year, for all Rock Creek PIT-tagged fish that were dectected at any of the mainstem Columbia River interrogation sites downstream of RCL, including mortalities found at East Sand and Little Miller islands. Using this list, the number of smolts that had passed undetected at RCL could be determined. A smolt was defined as a PIT-tagged *O. mykiss* contacted at the lowest PTIS site (RCL) and characterized as actively migrating downstream for a given migration year. *O. mykiss* were typically tagged (tag year) in the fall and migrated out of Rock Creek the following spring (out-migration year). Thus, the RCL downstream smolt detection efficiency was calculated using the following forumula:

$$DE_{RCLs} = \frac{S}{s} \quad (1)$$

where,

DE_{RCLs} = estimate of detection efficiency of out-migrating PIT-tagged smolts at RCL,

S = number of PIT-tagged smolts detected at RCL and downstream interrogation sites, and

s = number of PIT-tagged smolts detected at downstream interrogation sites.

The DE_{RCLs} was then used to estimate the number of out-migrating PIT-tagged smolts missed by multiplying the proportion of smolts not detected (1- DE_{RCL}) times the number of smolts detected at the interrogation site (RCL). This number was then added to the number of smolts detected at RCL for a total estimate of out-migrating PIT-tagged smolts (Table 5). A similar methodology was used for adult detection efficiency estimation for RCL and Bonneville Dam interrogation sites. For adult detection efficiency at RCL, an adult detection list was generated for detections occurring at RCS, the interrogation site located upstream of RCL. Adult detection efficiency was calculated at RCL using both Rock Creek PIT-tagged adults and out-of-basin PIT-tagged adults that were detected at RCS (upstream site). Adult returns from known out-migration years often spanned multiple years, returning during the months of December to March. Thus, it was more difficult to use a one year in-migration detection efficiency that aligned completely with the smolt out-migration year. Because of this detection efficiencies for adults in-migrating past RCL were calculated by summing known detections across a two year period. It is known that the detection efficiencies at a given site vary on a yearly basis. The number of missed adults was calculated using the RCL adult detection efficiency and the number of known RCL adult detections.The following equation was used:

$$DE_{RCLA} = \frac{A}{a} \quad (2)$$

where,

DE_{RCLA} = estimate of detection efficiency of in-migrating PIT-tagged adults at RCL,

A = number of returning PIT-tagged adults detected at RCL and upstream at RCS, and

a = number of returning PIT-tagged adults detected at RCS.

For Bonneville Dam an adult detection efficiency was estimated for Rock Creek PIT-tagged adult steelhead for all years combined. Detection histories of Rock Creek PIT-tagged adults occurring at any interrogation site upstream of Bonneville Dam, including RCL and RCS were used to generate an adult detection list. The following equation was then used:

$$DE_{BONA} = \frac{AB}{ab} \quad (3)$$

where,

DE_{BONA} = estimate of detection efficiency of in-migrating Rock Creek PIT-tagged adult steelhead at Bonnevile Dam (BON),

AB = number of returning Rock Creek PIT-tagged steelhead adults detected at BON and at RCL, RCS, or any mainstem interrogation sites upstream of BON, and

ab = number of returning Rock Creek PIT-tagged steelhead adults detected at RCL, RCS, or any mainstem interrogation sites upstream of BON.

Adult return estimates for Rock Creek PIT-tagged steelhead were calculated by adding the number of missed adult PIT-tagged steelhead to the number of detected adult steelhead returns for Bonneville Dam and RCS. Smolt-to-adult return rates were estimated using known fish detections and adjustments made for detection efficiencies for smolts and adults at RCL, and for adults at Bonneville Dam. Smolt-to-adult return (SAR) rates were calculated as the number of estimated returning PIT-tagged adults divided by the number of estimated PIT-tagged out-migrating smolts from Rock Creek.

Results

Stream Pool Habitat Surveys

We surveyed about 27.3 rkm of Rock Creek, 9 rkm of Walaluuks Creek, 1.5 rkm of Harrison Creek, 0.8 rkm of Luna Creek, and 3.8 rkm of Quartz Creek during September 16 to October 7, 2015 (Tables 1, 2, and 3). This was a greater stream length than in surveys in 2010-2012. The differences in surveyed lengths were due to changes in private property access, thalweg changes, and increased survey efforts in 2015. The 2015 survey data are presented in the context of the past (2010-2012) survey sections of Rock Creek (lower, rkm 2-13 and upper, rkm 14-22), as well as for the entire survey length (rkm 2-29; Table 1). During 2015, 38% of the Rock Creek stream bed between rkm 2 and 29 was classified as dry, with a higher proportion (57%) of the dry habitat found in the lower river (rkm 2-13, Table 1) than the upper river section (33%, rkm 14-22). This was a higher proportion than during the years 2010 to 2012, which ranged from 29% to 43% dry in the lower river. As a result of the increase in dry area, the percent of non-pool wet habitat was less (22%) than previous years (range 34% to 43%), as well as the percent of pools (21%) in the lower river. However, more river kilometers were surveyed in the lower river section than past years. In the upper river section (rkm 14-22), the survey results were similar to previous years' (Table 1). The overall percentage of streambed length that was pool was 19% during 2015 (rkm 2 to 29). Most other pool metrics fell within the ranges of past years' results for the upper and lower sections, except that the average pool area, maximum depths, and mean depths were less in the upper river section in 2015. Average pool temperature during 2015 was higher in the lower river, 17.5 °C (range of 14.1 – 22.8 °C) versus the upper river section, 15.1 °C (range of 11.9 – 18.2 °C). The range of pool temperatures for the entire survey length was 11.5 °C to 22.8 °C (median = 15.2 °C).

The 2015 survey data for Walaluuks Creek (rkm 0 to 9) are presented with previous data from 2010-2012, in Table 2. For Walaluuks Creek, the percent of stream length surveyed as dry increased to 62%, higher than previous years (range 29% to 53%; Table 2). The percent non-pool wet decreased to 25% from 37% to 56% in past years. The percent total length classified as pools (13%) was similar to past years (10% to 14%). The number of pools recorded was 45, the same as in 2012, but less than in 2011 and 2010 (56 and 72, respectively). During 2015, the average pool length (27 m; range = 5.2 – 86.8 m) and area (133 m^2; range = 10.4 – 557.6 m^2) were higher than past years (length range = 16-21 m; area range = 65-78 m^2), the average maximum depth was less (49 cm; range = 53-59 cm), and the average mean depth (25 cm; range = 27-32 cm) was also lower than previous annual surveys. The average temperature of pools during the survey was 13.5 °C (median = 13.0 °C) with a range of 10.5 °C – 17.0 °C.

Table 1. Length of stream that was dry, non-pool wet, or pool, the average maximum depth, and mean depth of pools in Rock Creek, WA during surveys in late September of 2010-2012 and late September to early October 2015.

	rkm 2-13[a]				rkm 14-22				rkm 2-29
	2010	2011	2012	2015	2010	2011	2012	2015	2015
Total stream length surveyed (m)	7,542	11,001	9,541	12,030	8,484	8,930	8,895	8,822	27,324
Length dry (m)	2,166	3,513	4,102	6,786	2,337	3,271	3,726	2,860	10,549
Percent dry	29	32	43	57	27	37	42	33	38
Length non-pool that was wet (m)	3,302	4,743	3,281	2,691	4,551	4,304	4,002	4,432	11,674
Percent non-pool that was wet	43	43	34	22	53	48	45	50	43
Number of pools	54	58	60	62	68	49	45	60	172
Number of pools/100 m	0.72	0.53	0.63	0.52	0.80	0.55	0.51	0.68	0.63
Total length of pools (m)	2,074	2,745	2,158	2,553	1,596	1,355	1,167	1,530	5,101
Percent pools by length	28	25	23	21	19	15	13	17	19
Average pool length (m)	39	47	36	41	23	28	26	26	30
Average pool area (m^2)	302	387	260	381	136	144	125	153	224
Average max depth of pools (cm)	69	78	75	68	62	62	64	55	58
Average mean depth of pools (cm)	34	38	43	36	32	28	36	25	29
Average temperature of pools (°C)[b]				18				15	15

[a] Surveys were not done downstream of rkm 4.8 in 2010. In 2012, surveys were not done between rkm 3 and 4.8.
[b] Temperature was recorded in all pools during 2015 and not the other years.

Table 2. Length of stream that was dry, non-pool wet, or pool, the average maximum depth, and mean depth of pools in Walaluuks Creek, WA during surveys in late September of 2010-2012 and late September to early October 2015.

	Walaluuks Creek rkm 0-9			
	2010	2011	2012	2015
Total stream length surveyed (m)	8,438	8,888	8,567	9,066
Length dry (m)	3,512	2,599	4,550	5,596
Percent dry	42	29	53	62
Length non-pool that was wet (m)	3,753	5,114	3,158	2,257
Percent non-pool that was wet	44	58	37	25
Number of pools	72	56	45	45
Number of pools/100 m	0.85	0.63	0.53	0.50
Total length of pools (m)	1,172	1,175	859	1,213
Percent pools by length	14	13	10	13
Average pool length (m)	16	21	19	27
Average pool area (m^2)	65	75	78	133
Average max depth of pools (cm)	53	54	59	49
Average mean depth of pools (cm)	31	27	32	25
Average temperature of pools (°C) [b]				13.5

[b] Temperature was recorded in all pools during 2015 and not the other years.

During 2015 short sections (1 to 4 rkm) of Luna, Harrison, and Quartz creeks were surveyed starting at their confluence with Rock Creek or another tributary (Table 3). No pools were observed in either Luna Creek (rkm 0-1) or Harrison Creek (rkm 0-1.5), and high percentages (98%) of both creeks were dry during the survey period. In contrast, most of the section of Quartz Creek was classified as either non-pool wet (86.2%) or pool (13.6%). The pool lengths ranged from 8 - 63 m, with a median length of 18.4 m, the pool areas ranged from 42.4 – 277.1 m^2, the median was 90.7 m^2, the pool mean depths ranged from 20 – 75 cm, and the median was 50 cm. Pool temperatures in Quartz Creek ranged from 13 °C - 15 °C and the median temperature was 14 °C.

Table 3. Length of stream that was dry, non-pool wet, or pool, the average maximum depth, and mean depth of pools in tributary creeks to Rock Creek, WA during late September to early October, 2015. Rkm are the approximate river kilometers surveyed from the confluence with Rock Creek walking upstream.

	Harrison Creek	Luna Creek	Quartz Creek
	rkm 0-1.5	rkm 0-1	rkm 0-4
Total stream length surveyed (m)	1,529	869	3,752
Length dry (m)	1,492	856	7
Percent dry	98	98	0.2
Length non-pool that was wet (m)	37	13	3,224
Percent non-pool that was wet	2	2	85.9
Number of pools	0	0	24
Number of pools/100 m	na	na	0.63
Total length of pools (m)	na	na	521
Percent pools by length	na	na	13.9
Average pool length (m)	na	na	22
Average pool area (m^2)	na	na	103
Average max depth of pools (cm)	na	na	86
Average mean depth of pools (cm)	na	na	53
Average temperature of pools (°C)	na	na	14

The 2015 habitat survey results were mapped as in the past, to compare habitat type (non-pool dry, non-pool wet, and pool) and location (Figures 2 and 3). Pool locations were fairly consistent across years, but non-pool dry segments were greater (in number and length) in the lower Rock Creek section in 2015. This was particularly apparent downstream of rkm 5 (Figure 3). Linear survey results also showed persistent pools across years (Figures 4 and 5). The habitat type river kilometer shifts across years, was probably due to thalweg changes. The 2015 survey section above rkm 26 had more dry sections than were observed in the 2010 surveys (rkm 26-28, Figure 6). Quartz Creek was surveyed in 2015 up to rkm 4 and was almost entirely non-pool wet (85.9%) or pool habitat (13.9%, Table 3 and Figure 7). In Walaluuks Creek, the pool location patterns were relatively consistent among years, however the segments observed as dry had greater lengths in 2015 (Figure 8 and Table 2). The number of pools present was the same as in 2012, and though the pool lengths and areas were greater, the pools were shallower (Table 2). The number of pools observed in 2010 and 2011 were higher than in 2015, this could indicate a consolidation of pools or a loss of pools over time. Pool depths for the lower and upper Rock Creek sections were shallower in 2015 (Figure 9).

A flow gage was maintained at highway 8 bridge (rkm 12.9) by Yakama Nation and USGS personnel, although data were collected intermittently due to battery and equipment memory constraints and environmental conditions (pool location becomes dry). Data were collected intermittently from April 10, 2015 to December 30, 2015 with a maximum of 9.51 ft (2.90 m), minimum stage height of 3.84 ft (1.17 m), and an average of 7.02 ft (2.14 m). Data were not collected from May 9 to June 9, June 24 to July 7, July 23 to November 8, and November 24 to December 7, 2015. Previous data were also collected from November 25, 2013 to November 14, 2014, with missing values during August 4 to October 22, 2014. During this period, maximum stage height was 11.68 ft (3.56 m), minimum of 4.19 ft (1.28 m), and an average of 7.10 ft (2.16 m). Typically Rock Creek has two freshet pulses, one in winter (late November to December) and again during February to April.

Maximum daily water temperature data at four locations in Rock Creek were obtained from Eastern Klickitat Conservation District (Figure 10). Three of the four logger locations probably became isolated pools or went dry entirely in late June early July. Surface flow stopped about July 7 at the Walaluuks Creek (RC7), rkm 0.3 location and resumed in late October. At Rock Creek location RC8 (rkm 12.8), surface flow stopped about June 26 and at RC9 (rkm 2.4) on about July 11th, the stream became isoloated and almost went dry by September. The upper most site (RC6) at rkm 22.1, was the only site with apparent flow for the entire logging time, although the depth became too low to measure in August. At this site, the average maximum daily temperature was 16.7 °C and remained below 20 °C for the recording period.

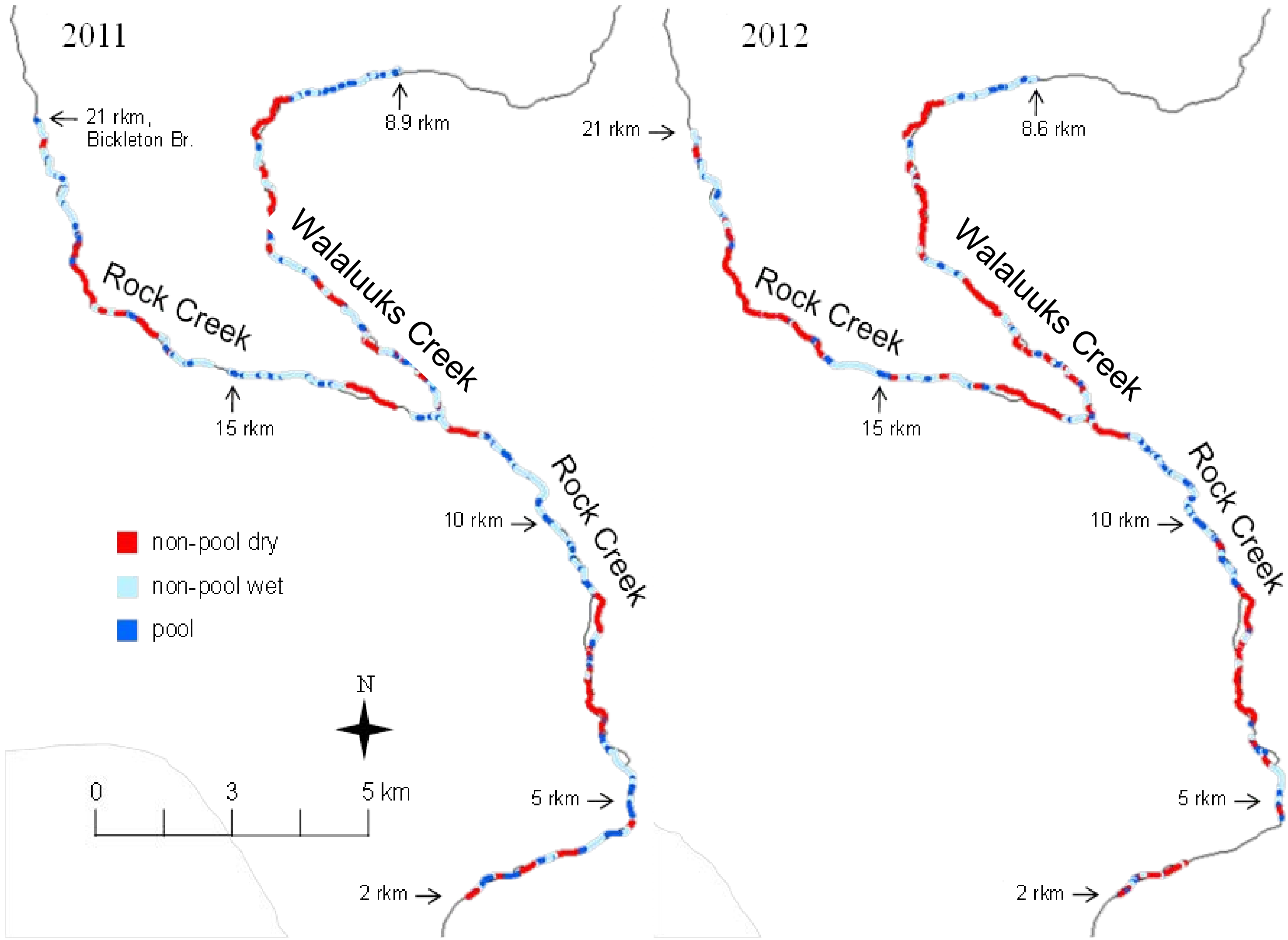

Figure 2. Maps of Rock Creek from river kilometer (rkm) 0 to 21, and Walaluuks (formerly Squaw) Creek to rkm 9 showing the location and lengths of streambed sections that were non-pool dry, non-pool wet, or pools during early September 2011 and 2012. Maps courtesy of A. Matala and D. Graves (Columbia River Inter-Tribal Fish Commission), excerpted from Harvey et al. 2014.

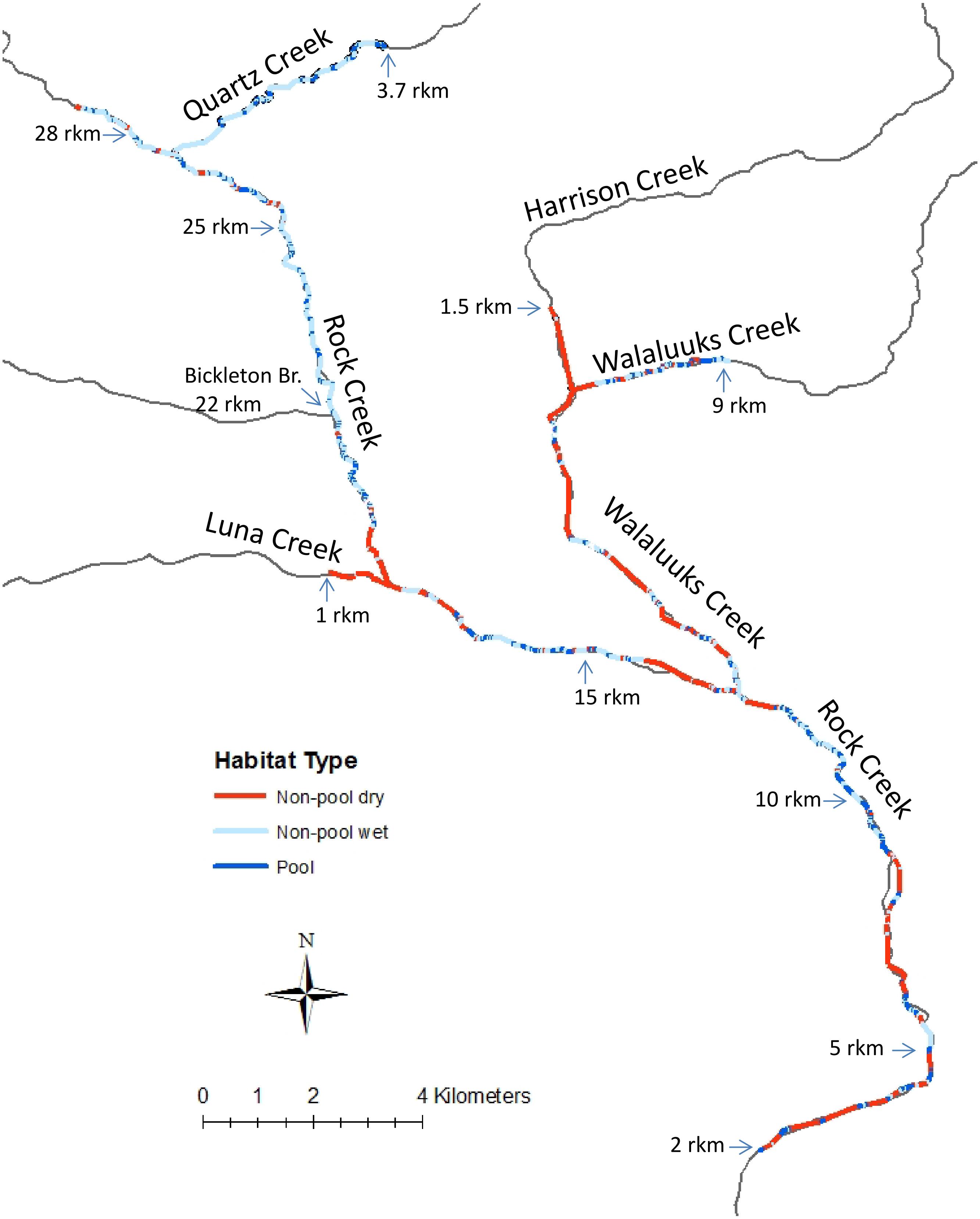

Figure 3. Maps of Rock Creek from river kilometer (rkm) 0 to 29, Walaluuks (formerly Squaw) Creek, Quartz Creek, Harrison Creek, and Luna Creek showing the location and lengths of streambed sections that were non-pool dry, non-pool wet, and pool habitats during late September to early October 2015.

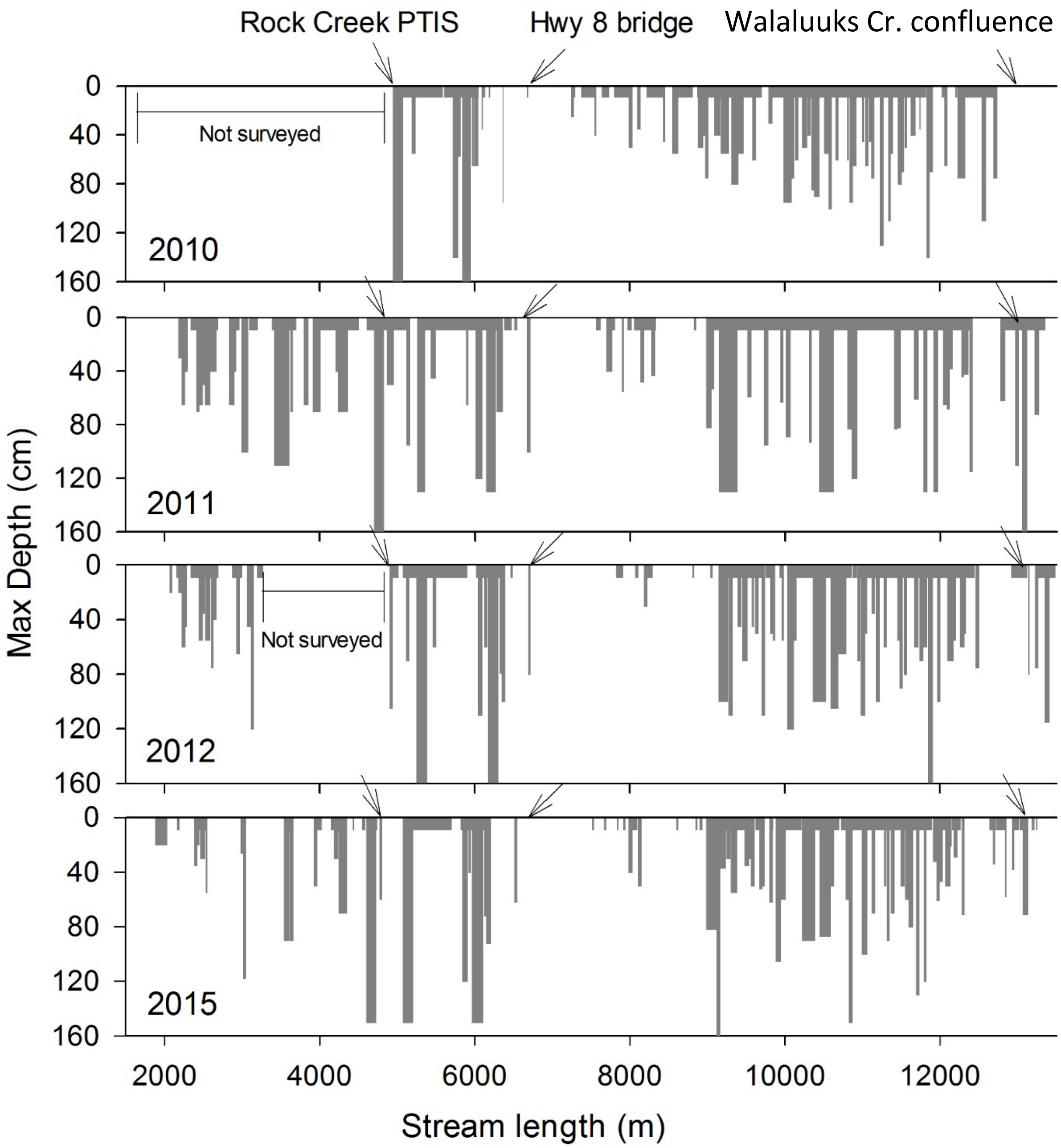

Figure 4. The length of thalweg that was dry (blank), non-pool wet (bars of equal height), and pool (variable bar showing maximum depth of each pool) from river kilometer 2 to 13 of Rock Creek, WA during September to October of 2010, 2011, 2012, and 2015. Arrows indicate approximate reference locations along the thalweg each year. Walaluuks Creek was formerly named Squaw Creek.

Walaluuks Cr. confluence

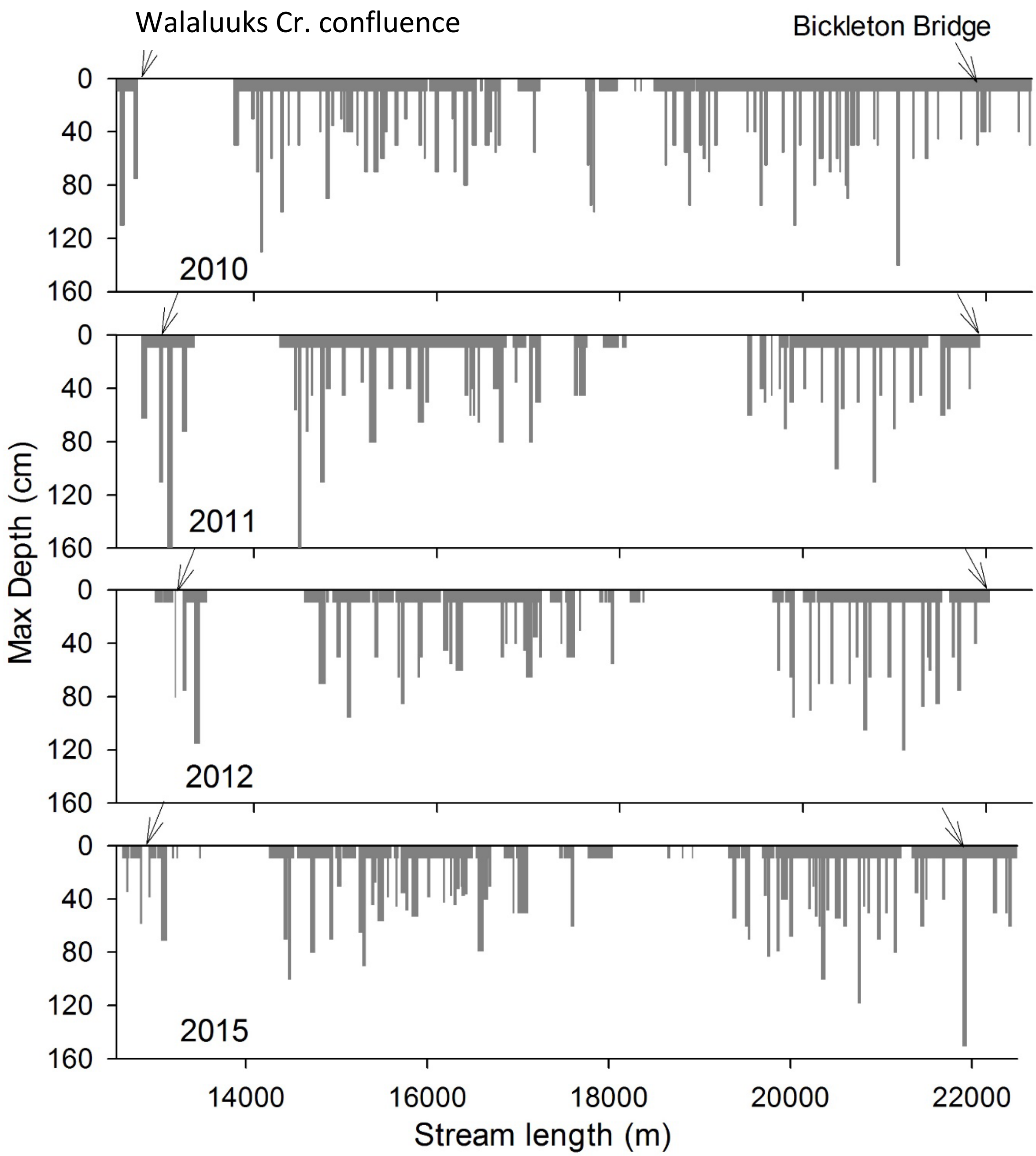

Figure 5. The length of thalweg that was dry (blank), non-pool wet (bars of equal height), and pool (variable bar showing maximum depth of each pool) from river kilometer 13 through 22 of Rock Creek, WA during September to October for years 2010, 2011, 2012, and 2015. Arrows indicate approximate reference locations along the thalweg during each survey year. Walaluuks Creek was formerly named Squaw Creek.

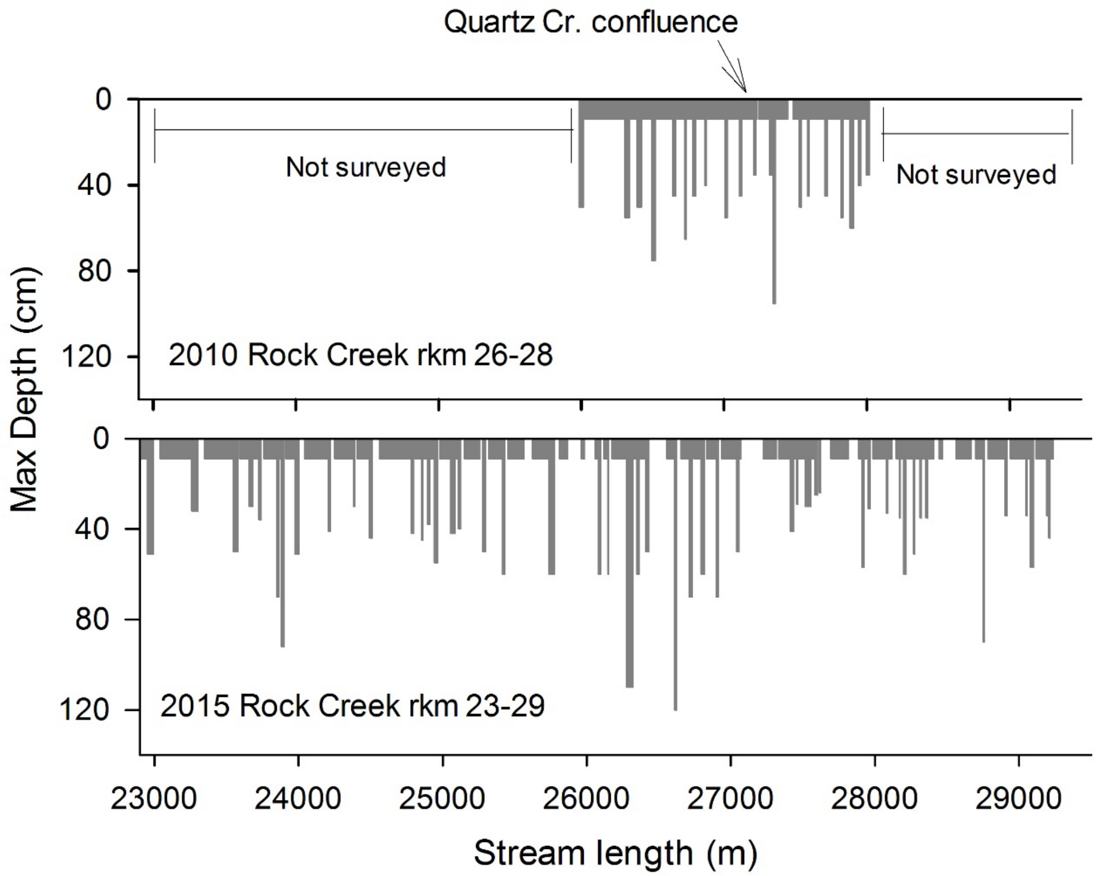

Figure 6. The length of thalweg that was dry (blank), non-pool wet (bars of equal height), and pool (variable bar showing maximum depth of each pool) from river kilometer 23 through 29 of Rock Creek, WA during September to October for years 2010, and 2015.

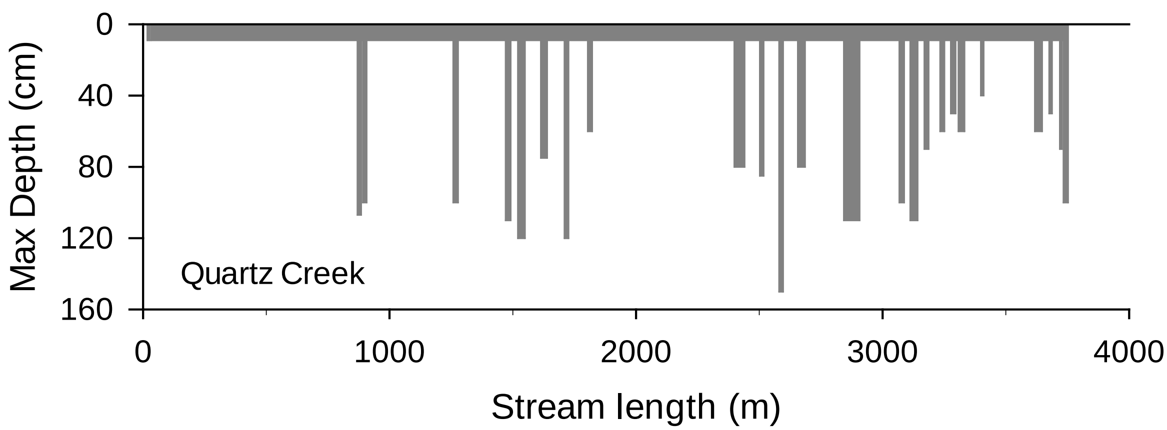

Figure 7. The length of thalweg that was dry (blank), non-pool wet (bars of equal height), and pool (variable bar showing maximum depth of each pool) from river kilometer 0 to 4 of Quartz Creek, WA during late September to October, 2015

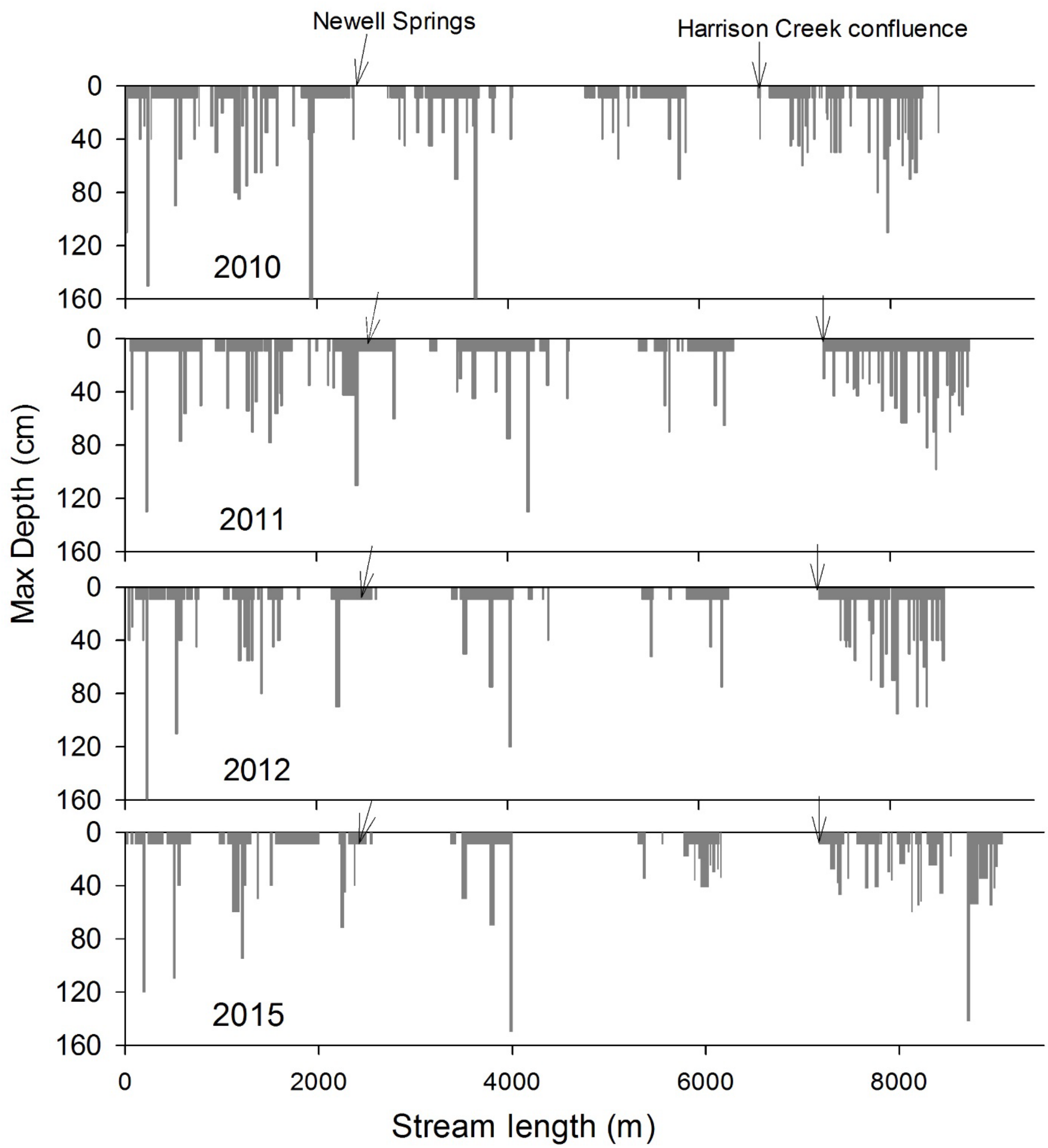

Figure 8. The length of thalweg that was dry (blank), non-pool wet (bars of equal height), and pool (variable bar showing maximum depth of each pool) from river kilometer 0 up to 9 of Walaluuks (formerly Squaw) Creek, WA during September to October for years 2010, 2011, 2012, and 2015. Survey length varied between years. Arrows indicate approximate reference locations along the thalweg during each survey year.

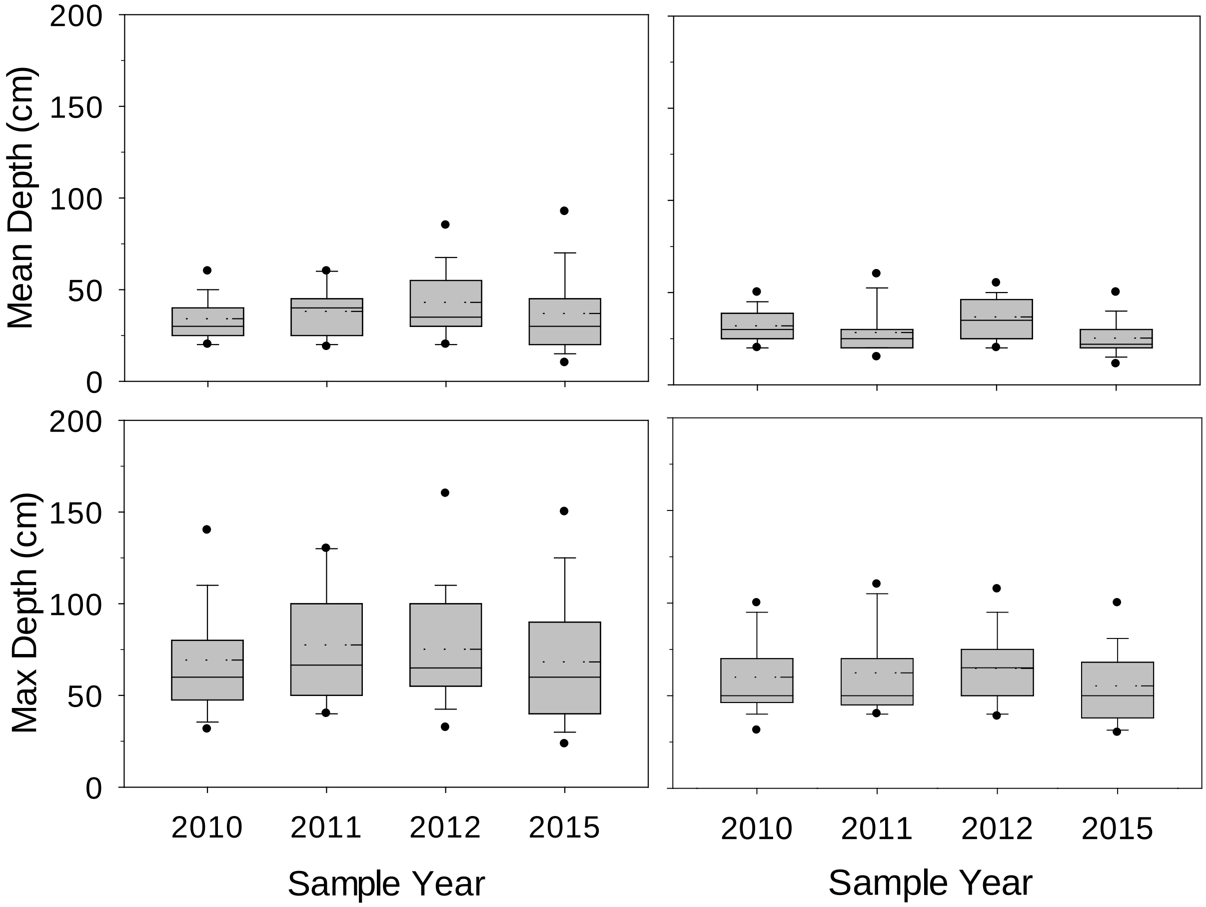

Figure 9. Mean and maximum depths plots for Rock Creek, WA during late September to October, 2015. The dots represent the 5th and 95th percentiles, the whisker lines indicate the 10th and 90th percentiles and the box lines represent the 25th, 50th, and 75th percentiles for the mean and maximum pool depths in lower Rock Creek (rkm 5 to 13) and the upper Rock Creek (rkm 14 to 23) survey sections. The dashed line indicates the mean.

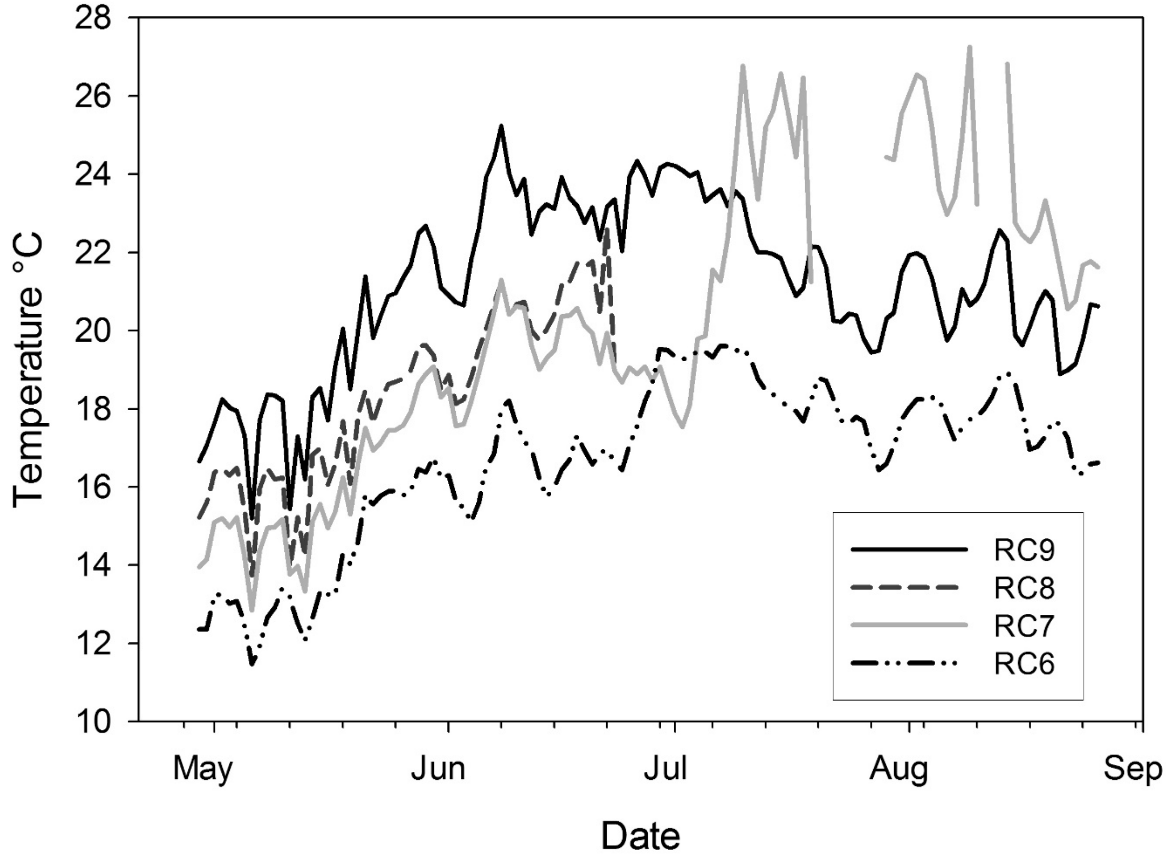

Figure 10. Daily maximum stream temperatures for May to September 2015 at four locations in Rock Creek subbasin, WA from thermographs maintained by the Eastern Klickitat Conservation District. The thermograph locations in Rock Creek are: RC9 = rkm 2.4, RC8 = rkm 12.8, and RC6 = rkm 22.1, and in Walaluuks (formerly Squaw) Creek, RC7 = rkm 0.3. Locations RC7, RC8, and RC9 became pooled or dry in late June early July.

Fish movement and SAR

Steelhead adult return data from previous PIT tagging efforts in Rock Creek subbasin from 2009 – 2012 (Harvey, 2014) have been updated. No *O. mykiss* were tagged in Rock Creek basin since 2013, when 49 fish were tagged from a pool directly upstream of "Ekone Falls" (rkm 33; potential seasonal or partial barrier) and a pool 40 m downstream, in the upper Rock Creek basin. These fish were not detected at any downstream interrogation sites. A detailed account of the out-migration of juveniles from the past tagging efforts (2009 – 2012) was presented in Harvey (2014) and detection results are briefly summarized in Table 4. Detection queries on the Columbia Basin PIT Tag Information System (PTAGIS) database have been performed through May 2017 and likely include all potential detections from the previous tagging efforts.

Smolt out-migration detection efficiencies at RCL were calculated by out-migration year, and ranged from 54.6% to 97.8% from 2010 to 2013 (Table 5). Adult detection efficiencies at RCL, using both out-of-basin and Rock-Creek PIT-tagged steelhead, ranged from 70% to 91.7% from 2012 to 2016 (Table 5). Smolt-to-adult return rates are presented using the smolt detection efficiency to estimate smolt out-migrants only and using the smolt detection efficiency and the adult detection efficiency to estimate adult returns for comparison. The SAR rate estimate for PIT-tagged steelhead smolts within Rock Creek (from 2009 to 2012) and returning to Rock Creek, ranged from 1.7% to 4.9% using detection efficiencies for out-migrating smolts (Table 5). The SAR rate to Bonneville Dam was always higher (2.2% to 9.8%; Table 5), at least partially owing to over shooting of adults, past the mouth of Rock Creek and passing above McNary Dam (detected at MCN) or other sites (i.e., Ice Harbor Dam), for spawning potentially upstream or in other tributaries (e.g., Deschutes, John Day, and Umatilla rivers), or possible pre-spawn mortality. A total of 22 steelhead have been detected returning to Rock Creek, from the 3,039 juveniles tagged in Rock Creek and 35 were detected passing upstream at Bonneville Dam. The SAR rate estimate for Rock Creek using detection efficiencies for both the out-migrating smolts and in-migrating adults ranged from 2.2% to 5.5% (Table 5). For returning Rock Creek PIT-tagged steelhead, estimated SAR to Bonneville Dam ranged from 2.4% to 10.4% (Table 5).

Of the 35 adult steelhead that were detected at Bonneville Dam adult fish ladders, 19 (54%) were also contacted at McNary Dam, with 14 (74% of the 19) returning downstream and detected in Rock Creek. Rock Creek PIT-tagged steelhead were detected returning to Rock Creek from December through March, with one fish returning in April. Of the 22 steelhead returning to Rock Creek, 21 of these had both out-migration and in-migration detections on RCL, with which to calculate days between the last RCL (juvenile out-migration) and the first RCL (adult in-migration) detection. The average time between last and first detections was 859 days (range = 626 - 1072 days), indicating these steelhead were spending 1- 3 years in the ocean before returning to Rock Creek. At least 3 of the 22 (13.6%) returning adult steelhead exhibited kelt life history behaviors and were detected out-migrating in the spring through the lower Columbia River (final detections were at John Day Dam Juvenile bypass or Bonneville Dam). Three other fish detection histories indicated possible kelt life history behaviors. These three fish were detected moving downstream in Rock Creek at RCL in late March or April (typical kelt out-migration period) after returning earlier in the winter, but no further downstream detections were confirmed for out-migration through the Columbia River.

Juvenile and adult steelhead and Coho Salmon from out-of-basin enter and reside in Rock Creek for various periods of time. A total of 82 out-of-basin PIT-tagged fish have been detected at the Rock Creek PTISs, since monitoring began in 2009. Of these, 33 (40%) were tagged as adults (25 steelhead and 8 Coho Salmon) and were of unknown juvenile origin. All but four of these adults were tagged and released at or downstream of Bonneville Dam. The other four steelhead adults were tagged and released during late summer months at Priest Rapids Dam (rkm 639) into the left bank (facing downstream) adult fish ladder. Two of the four steelhead released at Priest Rapids Dam had final detections in Rock Creek (during the following January and April), the third was detected in Rock Creek and then continued downstream (last detection at Bonneville Dam corner collector), and the fourth was detected in Rock Creek before moving upstream for a last detection at Lower Granite Dam. This fourth fish passed at least five dams going upstream or downstream. The Coho Salmon were detected at the Rock Creek PTISs in late-November and early December during the years of 2012 and 2013.

Five of the 21 (24%) steelhead adults tagged below Bonneville Dam exhibited potential kelt behavior, with detections in Rock Creek, followed by final detections downstream at John Day Dam or Bonneville Dam. One fish tagged (August 2009) at Bonneville Dam was detected upstream at McNary Dam (September 2009), then moved downstream into Rock Creek (February 2010). This same fish was later detected downstream at Bonneville Dam corner collector (April 2010), then again upstream at Bonneville Dam adult ladder (August 2010), and at McNary Dam (September 2010), returning back to Rock Creek in February 2011. The final detection for this steelhead was at the Bonneville corner collector in April 2011. A second steelhead tagged at Bonneville Dam (August 2009), was detected upstream at John Day Dam juvenile bypass (November 2009), and entered Rock Creek in January 2010. This fish was detected at RCL in March 2010, then downstream at the Bonneville corner collector (April 2010). It moved upstream again, being detected at Bonneville fish ladders in August 2010, returning to Rock Creek, with detections occurring at RCL from February 6 through February 22, 2011. The last detection for this fish occurred downstream at the Bonneville corner collector in April 2011. The other three kelts were tagged at Bonneville Dam during July, August, and September, and were detected in Rock Creek (RCL) during the following January and February, with all three having last detections downstream at either John Day Dam juvenile bypass or Bonneville corner collector during April of that same year.

Of the remaining out-of-basin fish detected in Rock Creek, 15 were of unknown origin (i.e., incomplete information in the PTAGIS database), 33 were *O. mykiss* tagged as juveniles, and 1 was a juvenile Chinook salmon, *O. tshawytscha* tagged and released at Lower Granite Dam. Three of the unknown origin fish were last detected outside of the Rock Creek subbasin, including two downstream at Bonneville Dam (juvenile bypass and corner collector) and one upstream at Lower Granite Dam. Of the 33 *O. mykiss* tagged as juveniles of known origin, 22 were from the Snake River Basin, 5 were tagged within the John Day River Basin, 3 were from smaller tributaries to the Columbia River (i.e., Umatilla River, Deschutes River, and Fifteen Mile Creek), and 3 were from the Columbia River between rkm 347-522 (including part of the Snake River). Two of the juveniles tagged within the Snake River basin entered Rock Creek on the downstream migration, including the one juvenile Chinook salmon. The majority of the Snake River Basin origin *O. mykiss* detected at Rock Creek (13 of the 22) as adults were tagged at Lower Granite Dam as juveniles and transported downstream of Bonneville Dam and released. These fish were typically detected migrating upstream in the fall 1 to 2 years later. Ten of these adult *O. mykiss* were detected in the fall at McNary Dam prior to their last detections occurring the following winter or early spring in Rock Creek. Of the other nine Snake River Basin PIT-tagged fish (tagged in tributaries to the Snake River), six of these were also detected at McNary Dam 1 to 2 years later in the fall, before being detected in Rock Creek during February to April. Two of these fish were detected as far upstream as Ice Harbor Dam, in which both returned to Rock Creek and one was last detected downstream at John Day Dam, as a potential kelt. The majority (75%) of the out-of-basin adult steelhead detected in Rock Creek were initially detected upstream of Rock Creek at McNary Dam.

Table 4. Summary of *O. mykiss* PIT- tagged in Rock Creek, WA and its tributaries from 2009 to 2012 and detections at PIT-tag interrogation systems in Rock Creek and the Columbia River. Rock Creek is a Columbia River tributary located at river kilometer (rkm) 368, the two sites on Rock Creek are RCL at rkm 5 and RCS at rkm 13. Downstream detection sites (steelhead out-migration) 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), TWX (PIT tag detection trawl operated at the Columbia River estuary, rkm 75), ESANIS (East Sand Island bird colony, rkm 8), LMILIS (Little Miller Island bird colony, rkm 331). Adult detection sites (steelhead in-migration) in the Columbia River were BON (Bonneville Dam adult fish ladders), TD1 (The Dalles Dam adult fish ladders, rkm 308), and MCN (McNary Dam adult fish ladders, rkm 470). Detection information was updated May 2017.

	Tag year			
Number of Steelhead	**2009**	**2010**	**2011**	**2012**
Tagged	551	97	1179	1212
Morts (tag/handle)	0	0	4	7
Detected	197	26	250	374
Out-migration detection sites	**Number of Steelhead Detected**			
RCS	182	19	122	306
RCL	175	14	189	336
JDJ	58	9	72	97
B2J	9	0	1	23
BCC	30	2	7	28
TWX	4	0	2	6
ESANIS/LMILIS (morts)	16	2	10	25
In-migration detection sites	**Number of Steelhead Detected**			
BON	4	2	12	17
TD1	1	2	12	18
RCL	3	1	8	10
RCS	3	1	4	5
MCN	2	1	6	10

Table 5. Summary of *O. mykiss* PIT- tagged in Rock Creek (RC), WA smolt and adult detections, detection efficiency at the PIT-tag interrogation site, RCL and Bonneville Dam (BON) , estimated total smolt out-migrants and adult returns, and smolt-to-adult return rates for fish tagged and released from 2009 to 2012 in Rock Creek to Rock Creek and Bonneville Dam.

Tag year	**2009**	**2010**	**2011**	**2012**
Number tagged	551	97	1179	1212
Out-migration year	**2010**	**2011**	**2012**	**2013**
RCL smolt detections (out)	175	14	189	336
RCL smolt detection efficiency (%)	97.8	54.6	65.1	95.3
Estimated number of smolts missed	4	6	66	16
Total estimated RC smolts	179	20	255	352
In-migration years	**2012-2013**	**2013-2014**	**2014-2015**	**2015-2016**
RCL adult detections (in)	3	1	8	10
RCL adult detection efficiency (%)	75.0	86.4	84.2	81.3
Estimated number of adults missed	1	0	1	2
Total estimated adult returns to RC	4	1	9	12
In-migration years 2012-2016				
BON adult RC-tagged detections (in)	4	2	12	17
BON adult detection efficiency (%)	94.1	94.1	94.1	94.1
Estimated number adults missed	0	0	1	1
Total estimated RC adults to BON	4	2	13	18
Smolt to adult returns (using smolt detection efficiency)				
Rock Creek	1.68	4.91	3.14	2.84
Bonneville Dam	2.24	9.82	4.71	4.83
Smolt to adult returns (using smolt and adult detection efficiency)				
Rock Creek	2.18	5.46	3.63	3.38
Bonneville Dam	2.37	10.40	4.98	5.12

Discussion/Conclusion

Rock Creek, although intermittent, maintains a persistent steelhead population with adults returning to spawn in their natal stream. The SAR rate for Rock Creek PIT-tagged steelhead, ranged from 2.2% to 5.5%, which is within the mainstem Columbia and Snake rivers NPCC recovery goals of 2-6%. These numbers are also similar to SARs calculated for Deschutes, John Day, and Yakima rivers wild steelhead populations to mainstem dams (Bonneville, John Day, and McNary) available at the Fish Passage Center website (http://www.fpc.org/web/apps/jquerymobile/demos/cssoverallsarsdataquery_step8_tableoutput.php) as part of the Comparative Survival Study of PIT-tagged Steelhead (McCann et al., 2015). The SAR estimates for Rock Creek will help inform recovery goals for the Rock Creek population and the Mid-Columbia (MCR) steelhead population. The MCR steelhead populations have met regional SAR goals in most recent years, particularly nearby populations from the John Day, Deschutes, and Yakima rivers (McCann et al., 2015). The overall SARs for Upper Columbia (UCR) and Snake rivers populations of salmon and steelhead are not meeting the 2%–6% regional goal (McCann et al., 2015). The higher SAR rates for Rock Creek PIT-tagged *O. mykiss* at Bonneville Dam, could be a result of error in detection efficiency for the RCS and RCL sites, but also likely indicate Rock Creek fish are straying to other sites. Furthermore, mainstem Columbia River SARs are typically higher than SARs to natal streams and may result from prespawn mortality.

Straying is a natural trait of many salmon populations and has been documented in the nearby Oregon tributaries of John Day River and the Deschutes River (Keefer and Caudill, 2012; Keefer and Caudill, 2014; NWFSC, 2015). Juveniles PIT-tagged in the John Day River and nearby tributaries (Umatilla, Deschutes, and Fifteen Mile Creek) strayed into Rock Creek as adults (8 of 33 known origin tagged juveniles). Straying can be considered a desirable and 'natural' component of salmonid metapopulation biology, and can contribute to genetic resilience, spatial diversity, demographic stability and the potential for range expansion into unexploited habitats or less degraded habitats as necessary (Keefer and Caudill, 2012; Keefer and Caudill, 2014). Within the Rock Creek subbasin, what proportions of potential strays are MCR versus Snake River (and perhaps a higher proportion of these are from transported fish in this ESU) and their impact on the Rock Creek population are not fully understood. Adult straying is often associated with juvenile behavior, and transportation of juvenile salmon is likely to increase adult straying behaviors (Keefer et al., 2008; Keefer and Caudill, 2014). In this study, the majority of the Snake River Basin origin *O. mykiss* detected at Rock Creek as adults (13 of the 22) were tagged at Lower Granite Dam as juveniles and then transported downstream of Bonneville Dam and released. There is considerable variation among studies documenting straying estimates for steelhead likely attributable to life history traits and management or experimental practices (Keefer and Caudill, 2014). Initial genetic analyses of juvenile *O. mykiss* sampled in the Rock Creek drainage indicate a relatively high similarity to Snake River DPS, suggesting relatively high stray rates from that region into Rock Creek (Matala, 2014). In Rock Creek, 22 adults were detected with a known juvenile tagging origin being from the Snake River Basin from 2009 to 2016. The documentation of

Snake River Basin origin fish straying into Rock Creek, leads the question of how many are straying into other nearby tributaries as well. The juvenile origins of many of the out-of-basin PIT-tagged fish (48 of the 82; 59%) detected in Rock Creek were not known. Other questions remain, such as what contribution are the Rock Creek fish to the overall MCR population? And whether the influence of out-of-basin straying fish is a relatively new event, year specific, or if it has historically contributed to this population? The contribution of resident Rainbow Trout to the Rock Creek population is also not well known. The Yakama Nation is pursuing additional tagging and genetic sampling efforts to better inform this data gap.

Another potential cause of loss of returning adults is through overshoot of Rock Creek, including upstream of McNary Dam (Ham et al., 2012). This provides opportunity for increase in direct mortality or injury through, passage at mainstem dams. Downstream passage options are limited for adult salmon during winter months in the mainstem Columbia River as project spill does not typically occur. The majority of steelhead fall back through the powerhouse or through the juvenile bypass system, which has been shown to have an injury rate up to 50% at McNary Dam (http://www.dfw.state.or.us/fish/crp/mid_columbia_river_plan_WASTB_workshop.asp). Boggs et al. (2004) reported that an average of 21% of radio-tagged steelhead, between the years of 1996 - 2001 that passed a dam, fell back one or more times during upstream migrations at Columbia and Snake River dams. Many salmon and steelhead that fall back at dams enter tributaries or hatcheries downstream from the fallback location (Boggs et al, 2004). McNary Dam (the closest upstream dam to Rock Creek) had the highest overshoot and fall back rate at lower Columbia River dams, with a mean rate of 25.2% (Boggs et al., 2004). This study documented PIT-tagged adults that moved past the mouth of Rock Creek and were detected at McNary Dam; 64% of the Rock Creek PIT-tagged steelhead returning to Rock Creek were also detected at McNary Dam. Steelhead will enter nearby tributaries or hatcheries downstream of a dam after overshooting and falling back behavior. This has been documented through telemetry studies for steelhead atat Columbia River dams (mean of 59.6%) and at Snake River dams (mean of 57.4%; Boggs et al., 2004). It is currently unknown whether the additional travel and potential passage stress reduces the reproductive fitness of these fish. These fish may have higher physiological stress, reduced fat and energy stores, and lower productivity than fish that go directly to Rock Creek.

This study does not focus on the mechanisms effecting smolt to adult survival to Rock Creek, but does note that year to year variability is expected and observed throughout the Columbia River Basin and that many factors outside of the Rock Creek subbasin influence it. River and ocean conditions influence SAR by effecting both out-migration and in-migration life history stages, and harvest. Adult returns from PIT tagging efforts in Rock Creek, spanned out-migration years 2009-2012 and potential in-migration years 2010-2015. Higher mainstem temperatures during adult migration can result in thermoregulation delays into tributaries which can decrease survival to natal streams through a likely increase in harvest (Keefer et al., 2009). The 2015 water year produced the second lowest spring flows at McNary Dam since 1995. In 2015, temperatures at nearly all Federal Columbia River Power System projects exceeded the 20°C (68°F) standard for 35%–46% of the passage season (April–August). Steelhead adult annual fish passage numbers were lower at Bonneville, John Day, and McNary dams during 2012 and 2013, then during 2010, 2011, and 2014 (Fish Passage Center, Adult Steelhead Counts). Adult returns begin to trend downward for 2015 and 2016 for each of these dams to adult passage numbers below what was observed in 2012 and 2013. Another potential data gap for smolt mortality is predation that may occur in the inundated portion of Rock Creek at the mouth by piscine predators. This study does provide evidence of Rock Creek PIT tagged juveniles successfully, out-migrating to the ocean and returning 1-3 years later to their natal stream to spawn.

Habitat surveys were not conducted in Rock Creek during the years of 2013-2014, but were re-initiated in 2015, a low flow year. Rock Creek remains an intermittent stream with a higher proportion of dry reaches in the lower river sections, particularly during the 2015 survey year. The primary function of the Rock Creek habitat survey is to document the perennial pools from year to year. The identification of consistent perennial pools will aid in the selection of potential restoration projects. Low baseflows and lack of connectivity in late-summer and early-fall are considered the primary limiting habitat factors for fish production. Conley (2015) has completed an extensive fluvial assessment report for Rock Creek and its' tributaries and what implications it has for salmonid habitat management. The Conley (2015) report details many of the habitat forming processes within the subbasin and which are contributing to limiting salmonid habitat.

Although, temperatures can be limiting to summer survival in isolated pools, none of the surveyed pools were at the lethal level of 25 °C (Hokanson et al., 1977; Behnke, 1992; Thurow et al., 1997). However, seven (4.1%) pools located in the lower Rock Creek section had survey temperatures above 20 °C with a maximum temperature of 22.8 °C and 72 of 172 (41.9%) pools had temperatures greater than 16 °C. A 16 °C limit for surface water has been set by the Washington Department of Ecology as an indicator of stream health for salmonid habitat and a 20 °C limit for non-salmonid habitat (Washington Department of Ecology, Chapter 173-201A, Water Quality Standards for the Surface

Waters of the State of Washington). The maximum temperature surveyed in the 45 pools in Walaluuks Creek was 17 °C, of which 5 (11.1%) pools were recorded as. Over summer survival for juveniles is further complicated by the lack of connectivity between pools and vulnerability to predators, including non-piscine such as, raccoons, herons, etc..

The upper Rock Creek section generally had better salmonid habitat than the lower river section, with lower water temperatures, and lower proportions of dry stream. Persistent pools remain from year to year however, size and depths may vary. Additionally, percent of dry versus non-pool wet was variable across years and likely dependent on type of water year (i.e. drought or low flow years). The years with the highest percent of dry stream length were 2012 and 2015, both were low flow years. Low baseflows are still a primary limiting habitat component causing loss of connectivity and pool isolation. This is also a factor in Walaluuks Creek. During the 2015 survey, the percent of dry streambed increased over 2012, also a low flow year. Anecdotal discussions with tribal biologists, suggest that the existing pools are smaller and shallower than in the past. The average maximum and mean pool depths during 2015 were the lowest of any survey years. This could be a result of past flooding and fire events in the near vicinity, increasing sediment and cobble deposition within the streambed. Further compounding the lack of quality pool habitat is the lack of large wood recruitment and low instream complexity or cover within existing pools. There is woody debris present and even abundant throughout the Rock Creek subbasin however it is generally of small diameter and length and does not contribute to habitat formation processes (Conley, 2015). A number of invasive plants have also been noted throughout Rock Creek, including Himalayan blackberry, which was widespread (Conley, 2015). The blackberry in particular is likely inhibiting establishment of native plant species by out-competing native understory vegetation and preventing the establishment of native trees. Cattle grazing was also present within the Walaluuks Creek and portions of Rock Creek and may lead to further degradation of habitat (Belsky et al. 1999). Although a low proportion of the stream remains as perennial pools, Steelhead still persist.

This population remains an important cultural resource for the Rock Creek Band of the Yakama Nation Tribe. The National Marine Fisheries Service recovery plan for Rock Creek (NMFS 2009a) identifies an overall biological recovery goal for Rock Creek steelhead to contribute to recovery of the Mid-Columbia DPS by reaching a moderate risk status. The SAR results presented here will help inform the recovery goals and risk status. It is still unknown as to what extent the Rock Creek population is contributing to the Mid-Columbia DPS and will continue to contribute in the future. We do know that the Rock Creek steelhead still persist, under stressful environmental conditions and limiting habitat factors of lowbase flows and lack of connectivity. The NMFS recovery plan also identifies geographic subgroups (Major Population Groups or “MPG”) of the Mid-Columbia DPS and establishes goals for four “viable salmonid population” (VSP) criteria that include abundance, productivity, spatial structure, and diversity (McElhany et al., 2000). Rock Creek steelhead are grouped with the Cascades Eastern Slope Tributaries MPG which includes the Klickitat, White Salmon, Deschutes, and Fifteenmile subbasins (NMFS, 2009a). In order for the Mid-Columbia Sub-domain to meet recommendations for low risk populations at the MPG level, the ESA Steelhead Recovery Plan has identified a set of most likely scenarios to continue to achieve a maintained low to moderate risk status (Ford et al., 2011). The Cascades Eastern Slope Tributaries MPG recovery scenario recommendation for the Klickitat, Fifteenmile, and both the Deschutes east side and west side populations should reach at least viable status (Ford et al., 2011). One population within the MPG should be highly viable, consistent with the VSP criteria. The Rock Creek population should reach maintained status (25% or less risk level). Future PIT-tagging efforts and continued steelhed population monitoring in Rock Creek Steelhead will provide information to further inform these recovery goals and recommendations.

Adaptive Management & Lessons Learned

This work informs potential restoration actions by identifying the persistent pools across years and in years of low water flow (i.e. 2015). Potential restoration actions could include instream pool complexity enhancement, through increased structure and vegetation plantings for increased cover and beaver analogs. Increased habitat complexity in the perennial pools could increase the potential carrying capacity by providing protection from predators, reduced displacement by dominant fish, increased food availability, and isolation from competitors during low flow summer months (Dolloff and Warren, 2003). Increasing riparian cover and shade cover could decrease pool temperatures, keeping temperatures in a range that is optimal for salmonids longer. Flow to this intermittent stream continues to be an issue.

Rock Creek is also used by out-of-basin steelhead, some that have migrated upstream to McNary Dam and fallen back to return to Rock Creek. The timing of these fish entering into Rock Creek during the months of December to March is at a time when spill is not available as a downstream passage route at McNary Dam. Thus, turbine passage and a juvenile bypass system are typically the only passage route options. Evidence of overshoot behavior and kelt life history prompts the question as to whether there should be a non-turbine downstream passage option during the winter months on mainstem Columbia and Snake rivers dams. Some experimental studies have taken place at McNary Dam, investigating winter operation of the spillway weir and it's use as a downstream passage route by steelhead (Ham et al., 2012). This study further documents occurrences of downstream passage of PIT-tagged adult steelhead and kelts that would likely benefit from spillway weir operations during winter months at McNary Dam.

The continued documentation of out-of-basin adult fish use provides some insight to a basin wide data gap regarding straying of hatchery fish, particularly those transported as juveniles (Keefer and Caudill, 2012). Accounting for hatchery- and transport-related strays in the Columbia River system is not well documented, because few subbasins are routinely monitored for out-of-basin fish. The continued monitoring of the PTISs in Rock Creek subbasin provide a source of information to fill this data gap. Further, studies into the continued use of the Rock Creek system and the other nearby systems such as the John Day and the Deschutes may provide insight into the mechanisms affecting this behavior. The effect of out-of-basin strays on population-level impacts of reproductive fitness and genetics is not well understood in Rock Creek subbasin or for most Columbia River populations (Keefer and Caudill, 2012). An increase in PTISs at Columbia River tributary mouths would provide useful data to track stray rates.

The RCS and RCL PTISs will be maintained and monitored as long as funding is available to do so for the spring, fall, and winter months. These 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 (*http://www.ptagis.org/*). Future tagging efforts in Rock Creek will provide more information on SAR rates as well as distinctions between resident, out-migrant, and kelt life history traits all present in this system. Additional genetic sampling may provide further information on out-of-basin fish use and degree of mixing with resident populations of MCR fish versus Snake River or UCR populations.

Acknowledgements

We would like to thank the private landowners, especially Roscoe Imrie, that allowed access to their lands for habitat surveys and maintenance of the PTISs. We thank the Yakama Nation for partnering with USGS to conduct this work and Bonneville Power Administration for funding. We owe the success of this project to the work of Yakama Nation fisheries technicians and volunteers; Jeanette

Burkhardt, Joe Zendt, Seymour Billy, Macaw Howtopat, and David Lindley. We also thank the USGS fisheries biologists, technicians, interns, and volunteers for the work that they have done; Pat Connolly, Ian Jezorek, Brad Liedtke, Andy Wells, Matt Sholtis, and Joe Warren. As well as Brady Allen for his previous years of work on this project and discussions about current and future work in Rock Creek.

References

Behnke, R.J. 1992. Native trout of western North America. Monograph 6. American Fisheries Society, Bethesda, Maryland.

Belsky, A.J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. Journal of Soil and Water Conservation First Quarter 1999, 54(1): 419-431.

Boggs, C. T., M. L. Keefer, C. A. Peery, T. C. Bjornn, and L. C. Stuehrenberg. 2004. Fallback, Reascension, and Adjusted Fishway Escapement Estimates for Adult Chinook Salmon and Steelhead at Columbia and Snake River Dams. Transacations of the American Fisheries Society, 133:4,932-949.

Carmichael, Ruzycki, and Tatum. 2012. Potential Impacts to Oregon’s Middle Columbia River Steelhead Populations Resulting From Adult Entrapment Above Mainstem Columbia River Dams. Report available via the web accessed on December 13, 2016. (*http://www.dfw.state.or.us/fish/CRP/docs/mid_columbia_river/meetings/2014/Carmichael_et_al_2012_Mid_C_adult_Steelhead_trib_bypass.pdf*)

Dolloff, C.A., and M.L. Warren. Fish relationships with wood in small streams, 2003, in S.V. Gregory, K.L. Boyer, and A.M. Gurnell eds. The Ecology and management of wood in world rivers: American Fisheries Society, Symposium 37, Bethesda, Maryland, p. 179-194.

Ford, Michael J., A. Albaugh, K. Barnas, T. Cooney, J. Cowen, J. J. Hard, R. G. Kope, M. M. McClure, P. McElhany, J. M. Myers, N. J. Sands, D. Teel, and L. A. Weitkamp. 2011. Status review update for Pacific salmon and Steelhead listed under the Endangered Species Act: Pacific Northwest. *NOAA Technical Memorandum NMFS-NWFSC* 113.

Ham, K.D., P.S. Titzler, R.P. Mueller, and D. Trott. 2012. Hydroacoustic evaluation of adult Steelhead fallback and kelt passage at McNary Dam, Winter 2010-2011. Final Report. Prepared for U.S. Army Corps of Engineers, Wallla Walla District, Walla Walla, Washington, Biological Services Contract W912EF-08-D-0004.

Harvey, E., Rock Creek Fish and Habitat Assessment for Prioritization of Restoration and Protection Actions, 2014, Prepared for Bonneville Power Administration.

Hokanson, K. E., C. F. Kleiner, and T. W. Thorslund. 1977. Effects of constant temperatures and diel temperature fluctuations on specific growth and mortality rates and yield of juvenile rainbow trout, *Salmo gairdneri.* Journal of Fisheries Research Board of Canada. 34:639-648.

Keefer, M.L., C.C. Caudill, C.A. Peery, S.R. Lee. 2008. Transporting juvenile salmonids around dams impairs adult migration. Ecological Applications, 8(8):1888–1900.

Keefer, M.L., C.A. Peery, and B. High. 2009. Behavioral thermoregulation and associated mortality trade-offs in migrating adult Steelhead (*Oncorhynchus mykiss*): variability among sympatric populations. Canadian Journal of Fisheries and Aquatic Sciences, 66:1734-1747.

Keefer, M. L., and C. C. Caudill, 2014. Homing and straying by anadromous salmonids: a review of mechanisms and rates. Review of Fish Biology and Fisheries Journal. 24:333-368.

Keefer, M. L., and C. C. Caudill. 2012. A review of adult salmon and Steelhead straying with an emphasis on Columbia River populations. Technical Report 2012-6, prepared for U.S. Army Corps of Engineers, Walla Walla District, p. 78.

Matala, A. 2014. Genetic evaluation of Steelhead trout (*Oncorhynchus mykiss*) in the Rock Creek watershed of the middle Columbia River Basin. Report D *in* Harvey, E., ed., Rock Creek Fish and Habitat Assessment for Prioritization of Restoration and Protection Actions: July 1, 2008 – May 31, 2013. Prepared for Bonneville Power Administration, Portland, OR. Project # 2007-156-00.

McCann, J., B. Chockley, E. Cooper, H. Schaller, S. Haesaker, R. Lesard, C. Petrosky, E. Tinus, V. Dyke, R. Ehlke, and M. DeHart. 2015. Comparative Survival Study of PIT-tagged Spring/Summer/Fall Chinook, Summer Steelhead, and Sockeye, 2015, Prepared for Bonneville Power Administration, p. 496.

National Oceanic and Atmospheric Administration (NOAA). 2005. Updated Status of Federally Listed ESU’s of West Coast Salmon and Steelhead. NOAA Technical Memorandum NMFS-NWFSC-66.

National Marine Fisheries Service. 2009a. Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan. Prepared by the National Marine Fisheries Service Northwest Region.

National Marine Fisheries Service. 2009b. Recovery Plan for the Rock Creek Population of the Middle Columbia River Steelhead Distinct Population Segment. Prepared by the National Marine Fisheries Service Northwest Region, p 102.

Normandeau Associates, Inc. 2014. Direct injury and survival of adult steelhead trout passing a turbine and spillway weir at McNary Dam. Prepared for US Army Corps of Walla Walla District, Normandeau project number 20517.001, p 89.

Northwest Fisheries Science Center (NWFSC). 2015. Status review update for Pacific salmon and Steelhead listed under the Endangered Species Act: Pacific Northwest. Available at: https://www.nwfsc.noaa.gov/assets/11/8623_03072016_124156_Ford-NWSalmonBioStatusReviewUpdate-Dec%2021-2015%20v2.pdf

Northwest Power Planning Council (NPCC). 2004. Lower Mid-Columbia mainstem including Rock Creek subbasin plan. Prepared for the Northwest Power and Conservation Council, p. 391.

Thurow, R.F., D.C. Lee, and B. E. Rieman. 1997. Distribution and status of seven native salmonids in the interior Columbia River basin and portions of the Klamath River and Great Basins. North American Journal of Fisheries Management 17:1094–1110.

Washington Department of Ecology, Chapter 173-201A, Water Quality Standards for the Surface Waters of the State of Washington.

Appendices

A.1: How to access data for this project.

Data access will be maintained through the Yakama Nations Fisheries Program. If you would like to know more about data contained with in this report please contact Elaine Harvey.

Report B: Adult Fish Assessments

Contents

List of Tables

List of Figures

Spawning surveys

Spawning surveys provide a means of monitoring annual escapement as well as spawning distribution of adult anadromous fish. Spawning surveys were conducted to monitor spatial and temporal redd distribution of fall Chinook, coho, and steelhead, and to collect biological data from carcasses. Stream reaches were surveyed multiple times during the spawning seasons, with most reaches receiving at least 2-3 passes, conducted approximately two weeks apart in each reach. Subsequent survey passes generally continued in each reach until no live spawners were observed. Methods generally followed those of Gallagher et al. (2007). Scale samples were also taken from carcasses using methods outlined in Crawford et al. (2007).

One-man pontoon and foot surveys were conducted within the known geographic range for each target species where access was physically possible and permission was granted. Individual salmon or steelhead redds were counted and their locations recorded using handheld Global Positioning System (GPS) units. Counts of live fish and carcasses were also recorded. Carcasses were examined to determine sex, egg/milt retention (percent spawned), and presence of Coded Wire Tags (CWT) or external experimental marks. We attempted to cover as much as possible of the presumed spawning range of each species, although for steelhead, some gaps in survey coverage exist. Access to the headwaters of Rock (upstream of RM 20), Quartz (upstream of RM .5) and Walaluuks (upstream of RM 5) creeks is very challenging due to steep canyon walls and lack of roads, which limited the ability to conduct surveys upstream of those rivermiles during a regular work day. Spawning surveys in Luna Creek were limited to the lowest .5 rivermiles because one landowner did not provide access to their property. Fall Chinook surveys were conducted in December; coho surveys were conducted from December through late February; steelhead surveys began in January and continued through late May. The lower to middle reaches of Rock Creek have intermittent flow and there is no connectivity during the summer and early fall months. Fall Chinook and coho spawning habitat availability is limited to years when there is actual instream flow early in the spawning season.

Neither fall Chinook or coho spawning seems to be consistent enough year to year to lead to viable spawning populations of those stocks in Rock Creek. The low cumulative numbers of actual observed live adults, redds, and carcasses of fall Chinook and coho in Rock Creek are reflective of survey conditions; instream flow is variable year to year during the fall and early winter months, depending on fall precipitation. A tabular summary of spawning survey results by species in Rock Creek is presented in Tables B-1 to B-2.

Fall Chinook

Fall Chinook surveys were conducted in December, covering approximately 2.5 river miles in both 2013 and 2014. Typically fall Chinook surveys would start in November but there was insufficient instream flow and connectivity to allow fish passage upstream of the confluence of Rock Creek until December. Table B-1 shows results for fall Chinook redd counts in the Rock Creek subbasin for the 2008–2014 spawning seasons. The majority of observed spawning occurs adjacent to the Army Corps of Engineers' park at the Rock Creek confluence (where the flowing Rock Creek meets the inundated area backed up by the Columbia River behind John Day Dam, Lake Umatilla). In 2013, only one redd was observed and no live adults or carcasses were observed. For 2014, a total of 3 redds were observed and no live adults or carcasses found in the 2.5-mile reach. This will be the final year of monitoring fall Chinook since the actual numbers are low and it has been so variable that we come across redds or live adults during the survey.

Table B-1. Results of fall Chinook spawning surveys in Rock Creek subbasin, 2008 - 2014.

Results of Fall chinook spawner surveys in the Rock Creek Subbasin 2008 - 2014

			Surveyed	#	Reach Redds	Redds	Live Observed			Morts		
Year	Stream	Reach	Miles	Passes	Totals	/Mile	Floy Tag	No Floy	Unknown	Floy Tag	No Floy	Unknown
2008	Rock Creek	Rock Creek conflu. to gasline	2.5	2	2	0.8	0	0	2	0	0	0
2009	Rock Creek	Rock Creek conflu. to gasline	2.5	2	0	0	0	0	0	0	0	0
2010	Rock Creek	Rock Creek conflu. to Highway 8 bridge	2.5	3	6	2.4	0	0	2	0	2	0
2011	Rock Creek	Rock Creek conflu. to Highway 8 bridge	2.5	2	0	0	0	0	0	0	0	0
2012	Rock Creek	Rock Creek conflu. to Highway 8 bridge	2.5	3	0	0	0	0	0	0	0	0
2013	Rock Creek	Rock Creek conflu. to Highway 8 bridge	2.5	2	1	0	0	0	0	0	0	0
2014	Rock Creek	Rock Creek conflu. to Highway 8 bridge	2.5	3	3	1.2	0	0	0	0	0	0
		Mainstem Totals (surveyed reach)	2.5		12		0	0	4	0	2	0

Coho

Coho surveys were conducted between early December through late February, covering nearly 3.6 rivermiles (RM) in 2014 – 2015 and 16.7 rivermiles were covered in 2014 - 2015, with 2-3 passes at each reach. The majority of observed spawning occurs from RM 1 to RM 14 in the mainstem Rock Creek and RM 0 to RM 2 in Walaluuks Creek, shown in Figure B-1. For the 2014 spawning season, 16 coho redds, two live adults, and four carcasses were observed within the spawning reaches. During the 2015 spawning season, there was a total of 17 redds, 18 live coho adults, and 4 carcasses were enumerated in the Rock Creek mainstem RM 1–RM 14, and in Walaluuks Creek, 8 coho redds, one live adult, and no carcasses were found in the lowest 2 rivermiles. Coho access to spawning habitat is also limited in the fall and early winter season because of insufficient instream flow at the Rock Creek confluence. Surveys during both years were limited by high flow and turbidity during the spawning seasons with some ice limitations in December 2013. During juvenile population surveys, juvenile coho distribution and abundance varied from year to year in sampled pools in Rock Creek and Walaluuks Creek. This evidence corresponds with the variable number of redds observed in the subbasin year to year.

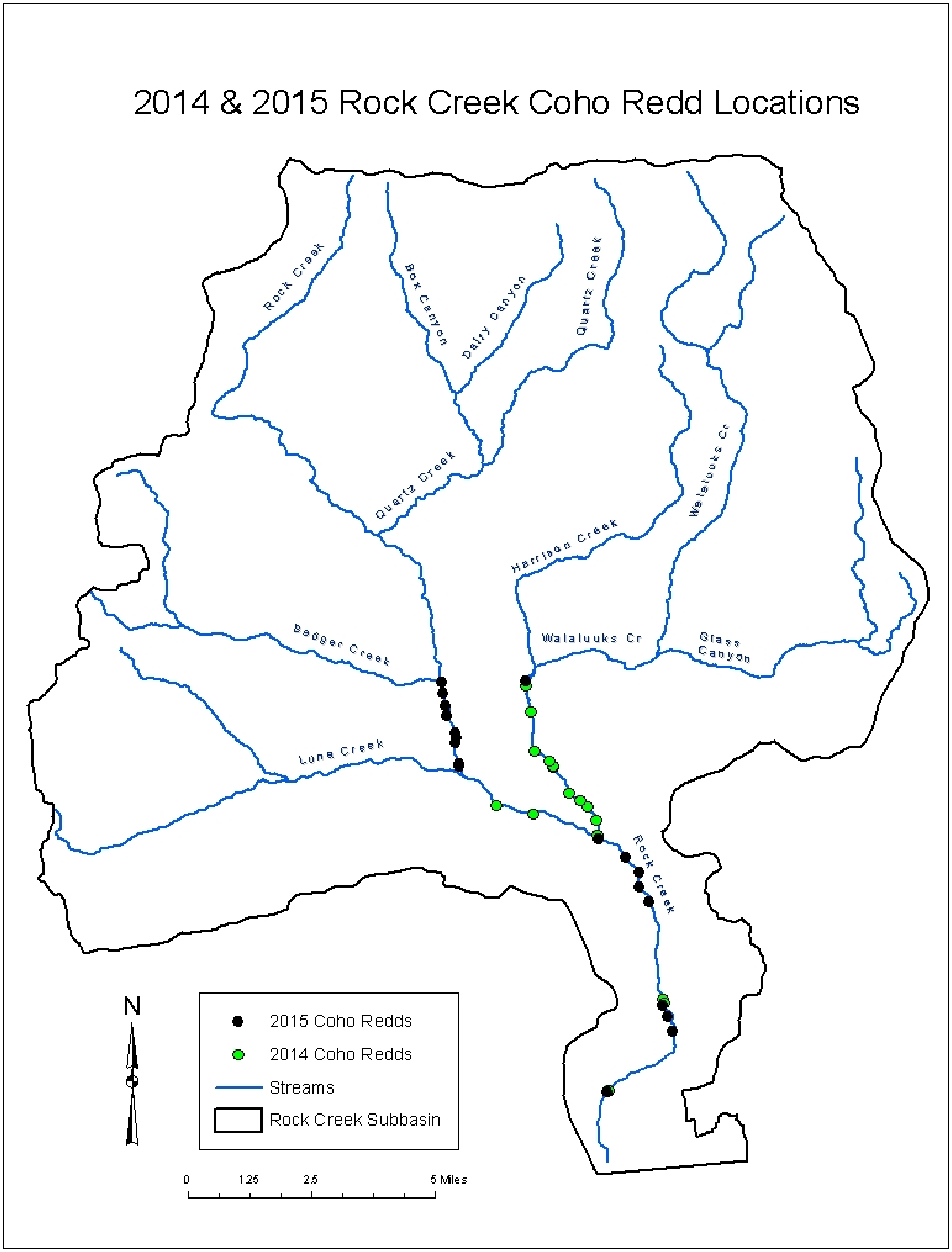

Figure B-1. Rock Creek coho redd distribution map, 2014 – 2015.

For each year surveyed, only a few (0 – 4) coho salmon carcasses were observed during spawning surveys in Rock Creek and none in Walaluuks Creek. During the two years surveyed, only one carcass was recovered and scale samples were collected from since the other carcasses were deteriorated at the time of sampling. The coho scale was aged as a 3-year-oldand the fork length was measured at 640 mm.

Steelhead

Steelhead spawning surveys were conducted between January and late May, covering approximately 24.97 rivermiles in 2014 and 24.72 rivermiles in 2015, with between 2-3 passes in each survey reach. Survey reach lengths varied based on accessibility and consent to cross private land. Spawning surveys were conducted in the mainstem Rock Creek (RM 1–RM 20.08), Walaluuks Creek (RM 0-RM 5), and Luna Creek (RM 0–RM .5). High spring flows and low visibility often limited the timing and safe access to survey reaches. Steelhead spawning is widespread in the lower to middle reaches of Rock Creek and Walaluuks Creek, as shown in Figure B-2. Steelhead have been observed spawning in similar locations each year in the subbasin.

The majority of steelhead redds observed in the mainstem Rock Creek were from RM 1-RM 13.5, and in Walaluuks Creek from RM 0–RM 5.5. We attempted to cover the entire presumed steelhead spawning range (80% coverage) in the subbasin in the 2014 - 2015 spawning seasons. In 2014, a total of 99 steelhead redds, 33 live adults, and 1 carcass were documented in the 24.97 rivermiles surveyed in the subbasin (Table B-2). A total of 160 redds, 35 live adults, and 4 steelhead carcass were documented during the 2015 season. In 2014, the number of survey days was limited because of high flow and low visibility conditions (Table B-2). Survey conditions most likely biased the 2014 redd counts low.

On an average year, only few steelhead carcasses were recovered on spawning surveys in Rock Creek, as steelhead could potentially survive the spawning process and migrate downstream as kelts. Based off recent PIT tag interrogation results, there is evidence of steelhead kelting life histories being exhibited in the subbasin (see Report A). During the two years reported here, a total of 5 steelhead carcasses were recovered, from five of which readable scale samples were collected. All five adults were aged as 3-year-olds and the fork lengths ranged from 550 mm to 800 mm.

We plan to continue conducting redd count and adult abundance surveys because they provide useful information on spawning distribution and they provide an opportunity for reconnaissance of critical steelhead spawning habitat. Genetic samples are collected from all adult carcasses found and archived for future genetic analyses of Rock Creek steelhead. Spatial information (GPS coordinates) collected during redd count surveys using the same protocol over multiple years have been used to identify reaches where spawning habitat should be protected or restored. Adult abundance surveys coupled with PIT tag interrogation are valuable research methods in evaluating restoration efforts, managing fisheries resources and in determining if recovery goals for this species are being met.

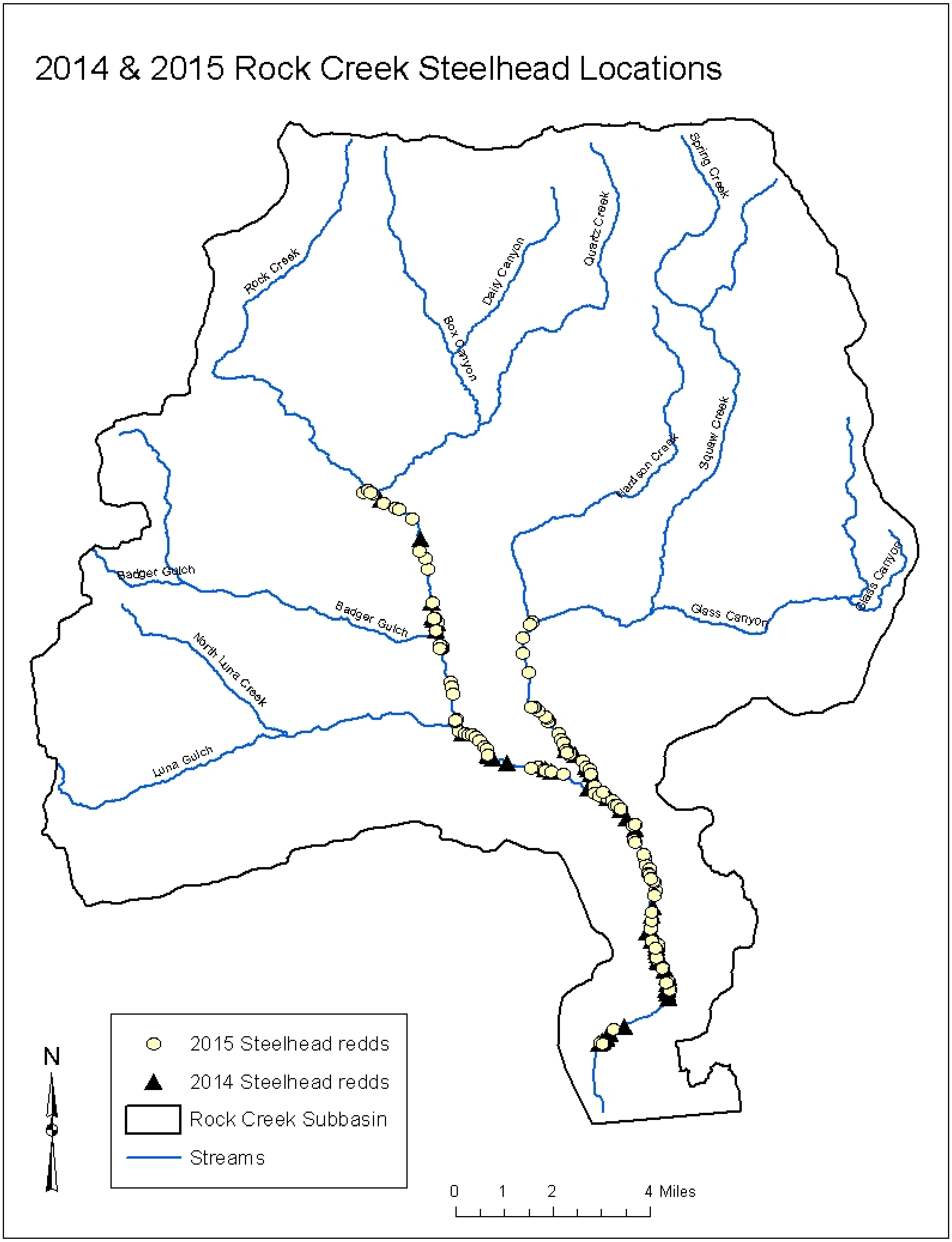

Figure B-2. Rock Creek steelhead redd distribution map 2014 – 2015.

Table B-2. Results of steelhead spawning surveys in Rock Creek subbasin, 2014 - 2015.

Results of 2014 Steelhead spawning surveys in the Rock Creek Subbasin

Stream	Reach	Miles	# Passes	Reach Redds Totals	Redds /Mile	Live Observed			Morts		
						Floy Tag	No Floy	Unknown	Floy Tag	No Floy	Unknown
Mainstem	Rock Creek Boat Launch to Hwy 8 Bridge	3.6	3	11	3.06	0	3	0	0	1	0
	Hwy 8 Bridge to Squaw Cr. confluence	5.6	3	12	2.14	0	7	0	0	0	0
	Squaw Cr. confluence to Unnamed Trib.	7.02	3	39	5.56	0	7	0	0	0	0
	Unnamed Trib. to Quartz Confluence	3.59	2	13	3.62	0	0	8	0	0	0
	Mainstem Totals (surveyed reaches)	19.81		75	14.38	0	17	8	0	1	0
Tributaries	Luna Creek	0.5	3	0	0.00	0	0	0	0	0	0
	Squaw Cr. at confluence to end of survey	4.16	3	24	5.77	0	0	8	0	0	0
	Badger Gulch at confluence	0.25	3	0	0.00	0	0	0	0	0	0
	Tributary Totals (surveyed reaches)	5.16		24	5.77	0	0	8	0	0	0
	Rock Creek subbasin Totals	**24.97**		**99**		**0**	**17**	**16**	**0**	**1**	**0**
	Mainstem Contribution %			*76*		~	*100*	*50*	~	*100*	~
	Tributary Contribution %			*24*		~	*0*	*50*	~	~	~

Results of 2015 Steelhead spawning surveys in the Rock Creek Subbasin

Stream	Reach	Miles	# Passes	Reach Redds Totals	Redds /Mile	Live Observed			Morts		
						Floy Tag	No Floy	Unknown	Floy Tag	No Floy	Unknown
Mainstem	Rock Creek Boat Launch to Hwy 8 Bridge	3.6	2	9	2.50	0	0	4	0	2	0
	Hwy 8 Bridge to Squaw Cr, confluence	5.6	3	42	7.50	0	0	18	0	1	0
	Squaw Cr. confluence to Unnamed Trib.	7.02	3	32	4.56	0	0	5	0	0	0
	Unnamed Trib. to Quartz Confluence	3.59	2	28	7.80	0	0	3	0	1	0
	Mainstem Totals (surveyed reaches)	19.81		111	22.36	0	0	30	0	4	0
Tributaries	Luna Creek	0.5	2	1	2	0	0	0	0	0	0
	Squaw Cr. at confluence to end of survey	4.16	3	48	11.54	0	0	5	0	0	0
	Badger Gulch at confluence	0.25	2	0	0	0	0	0	0	0	0
	Tributary Totals (surveyed reaches)	4.91		49	13.54	0	0	5	0	0	0
	Rock Creek subbasin Totals	**24.72**		**160**		**0**	**0**	**35**	**0**	**4**	**0**
	Mainstem Contribution %			*69*		~	~	*86*	~	*100*	~
	Tributary Contribution %			*31*		~	~	*14*	~	*0*	~

Temperature and water quality monitoring

Air temperature, stream temperature and water quality were monitored at key locations on a seasonal basis in order to characterize the chemical and physical conditions of the subbasin, see Figure B-4. Water temperature was taken at ten sites throughout mainstem Rock Creek and its tributaries (Walaluuks, Luna, Badger, and Quartz creeks) in 30-minute increments using Onset Corporation Hobo temperature probes. The purpose of air temperature monitoring was to enable a quality control check of the water temperature data. During the summer months when sections of Rock Creek turn dry, the water temperature data was quality control checked against air temperatures. Basic water quality parameters were measured 3–10 times per year at eight sites (Figure B-3). Water quality measurements were taken using a YSI, Incorporated Model 85 Handheld Dissolved Oxygen, Conductivity, and Temperature meter. Parameters collected included dissolved oxygen (mg/L), conductivity (µs), turbidity and pH and temperature °C. Water temperature data collected is represented in Appendix C, Table C-i. Water quality and temperature data are compiled in the Rock Creek database.

We monitored water quality at a total of eight sites in Rock Creek (RM 1.3, RM 5, RM 13, RM 21), Quartz Creek (RM 7.4), Luna Creek (RM 5.2), Walaluuks Creek (RM 1) and Newell Spring (RM 1.25). Water quality field data collection was conducted at each site only if there was actual instream flow. During the summer months, six out of eight sites went dry, and data was not collected for those sites until the fall or winter months when instream flow resumed. All water quality data are stored in the Rock Creek water quality and temperature database.

The uppermost water quality site in the Rock Creek basin is the Box Canyon Road location (RM 21) at 2,500 feet in a forested area in the headwaters. During most years, this site turns intermittent with a few remnant pools. Water quality was collected from November through June, and on some years, there was no access to the station because of high snowpack-related road closures (December – January). The Quartz Creek headwaters site (RM 7.4) is located in a heavily forested area. Access to this site is restricted from December through February in some years because of high snowpack-related road closures.

Luna Creek (RM 5.2), Walaluuks Creek (RM 1), and Newell Spring (RM 0.25) are all tributary streams where water quality was monitored on a monthly basis when there was actual instream flow. Luna and Walaluuks streams turn intermittent during the late spring months till December each year. Newell Spring is a tributary of Walaluuks Creek and provides vital cool spring water perennially, especially during the summer when Walaluuks turns intermittent.

The Site II water quality site is in lower Rock Creek (RM 5) and is this location turns intermittent in late June. The Army Corps of Engineers Park site (RM 1.3) is the water quality monitoring site lowest in Rock Creek immediately upstream of the inundated pool. This site turned dry in the summer months from July through October each year.

Annual water availability is the limiting factor affecting water quality in all reaches of Rock Creek and its tributary streams. Six out of 8 monitoring sites turned completely dry each summer causing fish stranding or migration to larger pools. Dissolved oxygen levels seemed to be in the normal ranges when there was adequate instream flow, and were lower during the summer months when instream flows became limited and large numbers of fish aggregated in the pools. pH levels seemed to be in the normal range at all sites throughout the year. Turbidity levels were high only during the winter and spring months when there were rain-on-snow melting events in the watershed; the remainder of the year, turbidity was low.

Summaries of water temperature data for each location are presented in Appendix C (Table C-i). Water quality measurements were dependent on the presence of actual instream flow, and therefore not recorded if there was no instream flow at the time of monthly site visit. We attempted to keep all Hobo water temperature units in the stream year-round; however, some of the units were occasionally washed on shore or lost during high flow events, stolen, or recorded air temperature in pools that had dried up.

A 16°C limit for surface water has been set by the Washington Department of Ecology as an indicator of stream health for salmonid habitat and a 20°C limit for non-salmonid habitat (Washington Department of Ecology, Chapter 173-201A, *Water Quality Standards for the Surface Waters of the State of Washington*). Rock Creek subbasin water temperatures exceeded 18°C at all of the sites during 2013 – 2015 monitoring years. Water temperature at 6 of 8 sites exceeded 22°C, primarily during the summer months (June through September) illustrated in Table C-i in Appendix C. Luna Creek (RM 5.2) retained minimal instream flows through the summer and did not exceed 20°C. The Luna Creek monitoring site had the lowest summer stream temperatures of all the sites, with average maximum water temperature ranges ranging from 12°C to 16°C. Rock Creek lower temperature monitoring sites frequently exceeded 22°C during the months of July through September. In the summer of 2015, the water temperatures were exceedingly warmer than stream temperatures collected from 2013 and 2014.

During each summer month, intermittency in Rock Creek progresses, forcing juvenile salmonids and other fish species to aggregate in larger pools. Many pools go completely dry during the latter summer months, leaving fragmented summer rearing habitat and causing salmonid mortality. In response to elevated stream temperatures, steelhead reduce their foraging and agonistic activity (Sloat and Osterback, 2013). Persistent summer pools in Rock Creek are found in well shaded reaches in the watershed and where there is groundwater connectivity to the stream channel. Upper reaches of Rock, Quartz, and Squaw creeks have perennial flow, and the water temperature are well below the Washington Department of Ecology's 16°C surface water limit. Downstream of the perennial flow sections are reaches with little to no stream cover or shade that annually turn intermittent.

Springs and Seeps throughout the subbasin are very important natural features that provide over summer rearing habitat in the perennial pools. Lower subbasin springs provide cool water to the pools; however, many of those pools lack riparian shade and cover so those pools fill with algae and eventually dry out. There maybe incentive to plan riparian plantings in those areas where there is lack of stream cover. Temperatures taken from those pools exceeded 20°C, whereas, pools in well shaded locations had a 11 -18°C range (See Report A). Protection and enhancement of springs in the subbasin should be a key management strategy since juvenile salmonids rely upon spring input into the system for their survival.

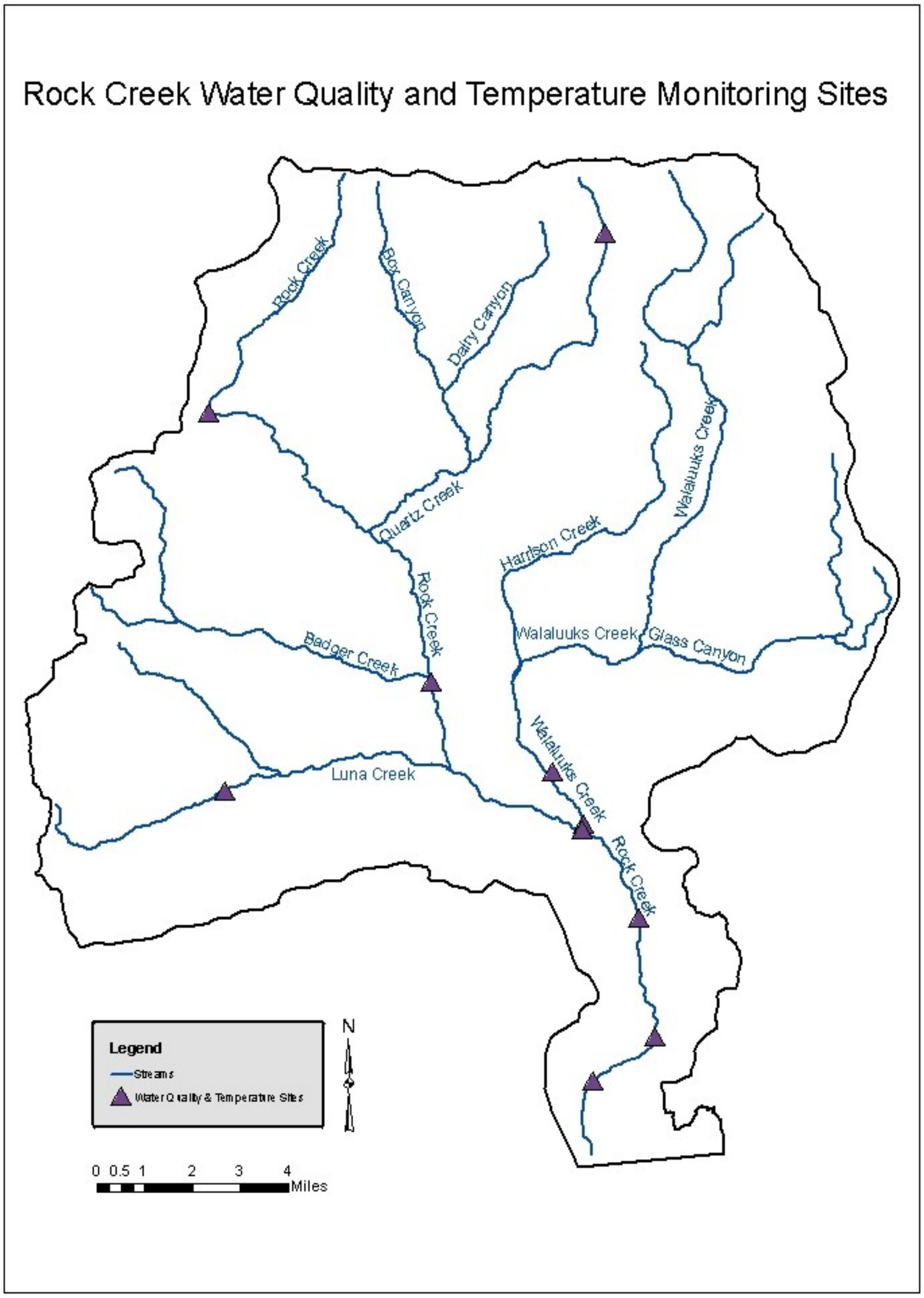

Figure B-3. Water quality and temperature monitoring sites in the Rock Creek subbasi

2. Conservation Lease, Spring Enhancement, and Revegetation

Conservation Lease

A conservation lease was initiated by Yakama Nation Fisheries to Yakama Nation Realty to lease 200 acres (Appendix B, Figure B-i) for cattle grazing exclusion, conservation, and enhancement of riparian plantings and spring enhancement projects in 2013. The application was submitted by Yakama Nation Fisheries with a follow-up in 2014. The leasing process is a lengthy process and required a property survey which took the longest to complete since all applications are based on first come first serve basis. When the lease is in place, there will be assurance that cattle will be excluded from the property so the riparian corridor could recover from previous cattle grazing and the spring enhancement project would be protected.

Spring Enhancement

Two springs were located in lower Rock Creek (Appendix B, Figure B-ii) that provide vital cool temperature to the mainstem Rock Creek for juvenile over summer rearing. The first spring is called the Highway 8 Spring (RM 3.6) and is located in lower Rock Creek near the Old Highway 8 stream crossing. The spring originates from the upper Goodnoe Hills and provides perennial spring water to a pool under the Old Highway 8 bridge. This pool is perennial and each year is loaded with juvenile fish during the summer months. The pool is also completely dependent upon the spring for input and to keep cool during the hottest of months of the summer. The second spring is also in lower Rock Creek at a site called Canapu Spring (RM 5.8) and is approximately 2 rivermiles upstream of the Old Highway 8 Spring. This spring was identified as also providing vital spring water to an outcrop of cottonwood trees and coyote willow stands in Rock Creek. This spring also supports some of our successful riparian tree plantings we conducted back in 2010 - 2013.

Spring enhancement was completed at both sites in the Spring 2015. Erosion mats and straw waddles were place along the steep canyon wall above the Old Highway 8 Spring to minimize the erosion process of soils to the spring site. Native trees and willows were planted at both spring enhancement sites which included invasive weed removal. Cattle exclusion was included at both locations. A permaculture design was implemented at the Canapu site where shallow ditches (1'depth x 2.5' width) following the contour of the terrain. On the top of each ditch wood debris was placed and native trees were planted in the ditches and mulched. At both locations there were no cattle grazing or watering troughs needed.

Tree planting and weed removal

The overall objective of the revegetation project was to plant native trees and shrubs in Rock Creek riparian corridors. Species chosen for revegetation include alder *(Alnus spp.)*, black cottonwood *(Populus trichocarpa)*, ponderosa pine *(Pinus ponderosa)*, red-osier dogwood *(Cornus stolonifera)*, chokecherry *(Prunus virginiana)*, wild rose (*Rosa sp.)*, and coyote willow *(Salix exigua).* All of the plant species selected are native to the Rock Creek watershed; these plantings will increase the vegetative diversity of the area. The riparian plantings will aid in protecting streambanks, reducing bank erosion, providing habitat complexity, and decreasing surface water temperatures through increased riparian cover.

Site visits were conducted throughout the Rock Creek subbasin to characterize the native vegetative community in various riparian areas. Large and healthy willow bunches were identified for future willow-cutting sites. Rock Creek subbasin instream flows become intermittent through the summer months, and sufficient soil moisture is essential for the survival and growth of trees and shrubs. Topographic maps and orthophotos were used to identify where springs and groundwater may be available to support plantings, and revegetation sites were chosen based on their proximity to these sites and soil moisture. Land ownership was an additional criterion. Tribally owned sites received higher priority for revegetation due to uncertainty of ownership and land management on some non-tribal properties along the creek, which could affect long-term success of the plantings. Site preparation was conducted prior to tree planting with brush and debris clearing. Trees were planted during late February and early April when the soil was saturated to allow for root establishment and growth. Weed mats were tacked onto the earth below the trees with pins, and mulch placed on top to assist trees in maintaining water storage. Star thistle (*Centaurea solstitialis)*, bull thistle (*Cirsium vulgare*), Himalayan blackberry (*Rubus armeniacus*) and other invasive weeds were hand-removed from tree planting sites and adjacent areas to prevent encroachment. Follow-up weed control occurred on an annual basis.

Revegetation efforts began in the spring of 2008 and continued through spring 2015. A total of 500 trees, shrubs and willow cuttings were planted on 14 acres along the mainstem Rock Creek riparian corridor and the uplands immediately adjacent to the creek between RM 3.8 – RM 5.3 (Appendix B, Figure B-i). There are a total of three main planting sites, all located in lower Rock Creek: Highway 8 site (RM 3.95); Canapu site (RM 5.05); and Site 2 Trees (RM 5.5). The revegetation effort was concentrated between RM 3.95 to RM 5.5, and occurred on both sides of the creek at the spring enhancement sites. (See Figure 2.)

Trees were hand-watered once or twice weekly during the warm summer months for the first two years after planting. Weed treatments were performed annually on all 14 acres of the revegetated riparian area. Weeds were removed by hand and mechanical means (weed-eaters, etc.) in revegetated and adjoining areas to discourage encroachment into planting sites. Two sites were used at model sites for blackberry removal in the riparian and wetland sites (Appendix B, Figure B-ii). The first site in lower Rock Creek, Old Highway 8 spring (RM 3.8), we manually removed blackberry brush in the spring of 2015. The second site, Shike's site (RM 10) we burned the blackberry brush in the spring of 2015, then we applied one treatment of herbicide treatment post burning in August 2015 by a licensed weed contractor. Future treatments for the Shike's site to keep the Blackberry brush from encroaching is an organic application mix of Dawn dish detergent, salt, and vinegar. Based on the two methods of blackberry removal, we found that burning and herbicide application was a more successful approach for removal. Two months post burning of blackberry brush, we found wetland plants and trees reestablish in the wetland that was covered by a 10 feet layer of blackberry brush.

During post-planting site visits, very few trees and shrubs were observed that had been affected by beaver activity. The trees affected were not removed from the ground, and there was natural re-growth occurring at the base of the trees. The survival rate ranged from 40–60% based on annual observations the first two years after planting.

Implications for habitat restoration in the subbasin

The main purpose of the Rock Creek Fisheries Project was to understand the current habitat conditions, protect and conserve existing good quality habitat and expand on these focal areas, and to identify protection and/or restoration sites and actions. Since 2008, data have been collected throughout the basin, including water temperature, water quality, habitat, spawner abundance and redd counts, juvenile fish population abundance and distribution, steelhead genetics, fish pathogens, and steelhead life history characteristics gained from PIT-tagging and detections. A study focused on fluvial reconnaissance with observations on geomorphology and suitability for anadromous salmonid habitat actions was initiated 2013 by Yakama Nation. That project combined with the efforts described here will help to identify and refine future project development opportunities for restoration sites in the Rock Creek subbasin.

Property within the subbasin consist of public, private, and Tribal identities. Properties throughout Klickitat County are becoming more parcelized each year and with the parcelization comes the demand for water. Properties in the western subbasin are being broken into many small 5 – 20 acre homesteads with many having man-made ponds for aesthetic purposes. These homestead expansion is primarily in the Badger and Luna creeks sub-watersheds. For each new homestead site, there is expected to be another exempt well. Badger and Luna creeks turn intermittent before all other tributary streams in Rock Creek. The demand for water is anticipated to increase in the Rock Creek subbasin over the years if there is no cap or regulations on exempt wells.

Yakama Nation staff created relationships with many of the private landowners within the subbasin to obtain access through their property for data collection and identification of potential restoration projects. There are extensive government, tribal, and Nature Conservancy lands in Rock Creek and its tributaries that could be considered for habitat protection and restoration. Some adjacent landowners are taking steps to protect habitat. The Nature Conservancy protects its lands from cattle grazing and conducts invasive weed removal. The Goodnoe Hills Windfarm, Inc. created a small wildlife reserve mitigation area in the lower Rock Creek riparian corridor that includes important salmonid spawning and rearing habitat with cattle exclusion fencing. There has also been movement from ranchers in the subbasin to work with the Washington State Conservation Commission to place their lands into conservation easements. It would be great if the conservation easements included fish, wildlife, and water resource conservation measures within the agreements.

Public outreach has been conducted to local schools and summer student camps within Klickitat County about the potential for preservation and restoration activities in Rock Creek. Many local residents are supportive of the project, interested in its results, and are supportive of the restoration of salmon and steelhead in the subbasin.

In the fall of 2006, the Washington State Department of Ecology (DOE) designated portions of Rock Creek, Luna Creek, Walaluuks Creek, and Quartz Creek as waters requiring supplemental protection (303[d] list), "those waters that are in the polluted water category, for which beneficial uses– such as drinking, recreation, aquatic habitat, and industrial use – are impaired by pollution", WDOE http://www.ecy.wa.gov/programs/Wq/303d/index.html), and imposed a more stringent water temperature criterion during the salmonid spawning and incubation season. This designation has alerted private landowners to the water temperature issue in Rock Creek subbasin, and many wish to work together with the local conservation district, Yakama Nation, and DOE towards reducing water temperatures and removal from the 303(d) list. Since the designation of portions of the basin for the 303(d) list, some changes have been made on private property to improve water quality and temperature. DOE needs to reinforce the 303(d) listing requirements of the county and private land owners.

Cattle grazing is the primary agricultural use in the subbasin. Cattle fence exclusion from the creek does not seem to be common best management practice in the subbasin. Cattle have regular access to the creek and remove the available riparian vegetation. If there were more funding available, additional cattle exclusion fences could be constructed that would protect the riparian vegetation, allow for natural willow and tree recruitment to promote channel stability.

For restoration purposes, access may pose a challenge in the headwaters and some mid-reaches of Rock Creek and its tributary streams. The lowest 18.6 river miles of Rock Creek and the lowest 2 miles of Walaluuks Creek are accessible by road for restoration. Upstream of RM 18.6 in Rock Creek and upstream of RM 2 in Walaluuks Creek, there are no access roads. We have been accessing upstream of these locations by walking in and out 3 miles or more to conduct surveys. If restoration were identified in those reaches, then alternative modes of transportation would have to be considered, such as a helicopter. The headwaters of Rock Creek are owned by a private timber company which, in the past few years, put the land up for sale. Yakama Nation contacted the company to inquire about accessing their property to assess the headwater conditions and look for possible meadow or wetland restoration project sites. The company is not interested in restoration, and their focus is on selling the lands.

There are funding resources available that could assist with the cost of preservation and restoration of salmonid habitat in the Rock Creek subbasin. The NMFS Middle Columbia Steelhead Recovery Plan and NPCC Rock Creek Subbasin Plan strategies along with the cumulative RM&E data collected in the subbasin over the years will be considered in the process of prioritizing locations for salmonid habitat enhancement. Spring enhancement, riparian rehabilitation, cattle exclusion fence construction, pool enhancement, floodplain reconnection, channel stabilization, and large wood placement are examples of possible restoration strategies that were identified in the salmon recovery and subbasin plans. Low or non-existent instream flow, high summer water temperatures, and lack of summer juvenile rearing habitat are a few of the main limiting factors in Rock Creek. Addressing these will be key to any habitat restoration in the basin.

During each late spring and month, intermittency in Rock Creek progresses, forcing juvenile salmonids and other fish species to aggregate in larger pools. Many pools go completely dry during the later summer months, leaving fragmented summer rearing habitat and causing salmonid mortality. In response to elevated stream temperatures, steelhead reduce their foraging and agonistic activity (Sloat and Osterback, 2013). Persistent summer pools in Rock Creek are found in well shaded reaches in the watershed and where there is spring connection to the stream channel. Upper reaches of Rock, Quartz, and Walaluuks creeks have perennial flow, and the water temperature are well below the Washington Department of Ecology's 16°C surface water limit. Downstream of the perennial flow sections are reaches with little to no stream cover or shade that annually turn intermittent.

Acknowledgments

We would like to take this opportunity to thank all those individuals and organizations that have helped contribute in some way to the Rock Creek project. A special thanks to private landowners for their cooperation and allowing access through their property for monitoring. The following Yakama Nation (YN) technicians assisted in collecting valuable fish and habitat information: Seymour Billy, Sonya Jackson, Sandy Pinkham, Rodger Begay, Roger Stahi, and Jeremy Takala. Mike Babcock, YN Data Systems Manager, provided assistance with data management. Bill Sharp, YN Fisheries Research Scientist, provided assistance and management of the project. Jill Hardiman, Matthew Sholtis, and Ian Jezorek with United States Geological Survey (USGS) were cooperators with set-up of PIT-tag interrogation system (PTIS), collection of fish population and habitat data, PIT-tagging, and monitoring.

Appendix A. Rock Creek Subbasin

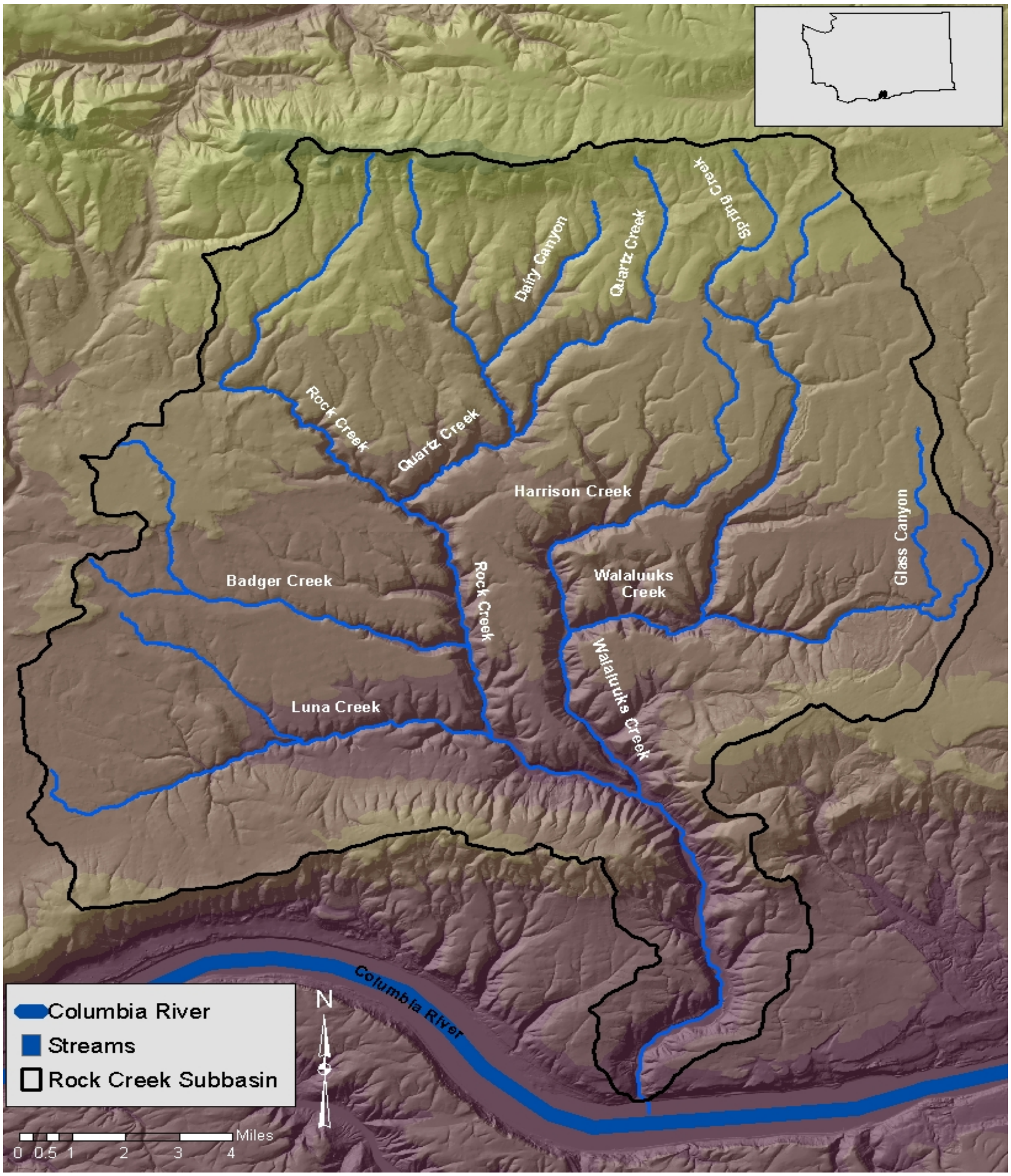

Figure A-i. Rock Creek subbasin in southeastern Washington state.

Appendix B. Conservation Lease, Spring Enhancement, and Revegetation

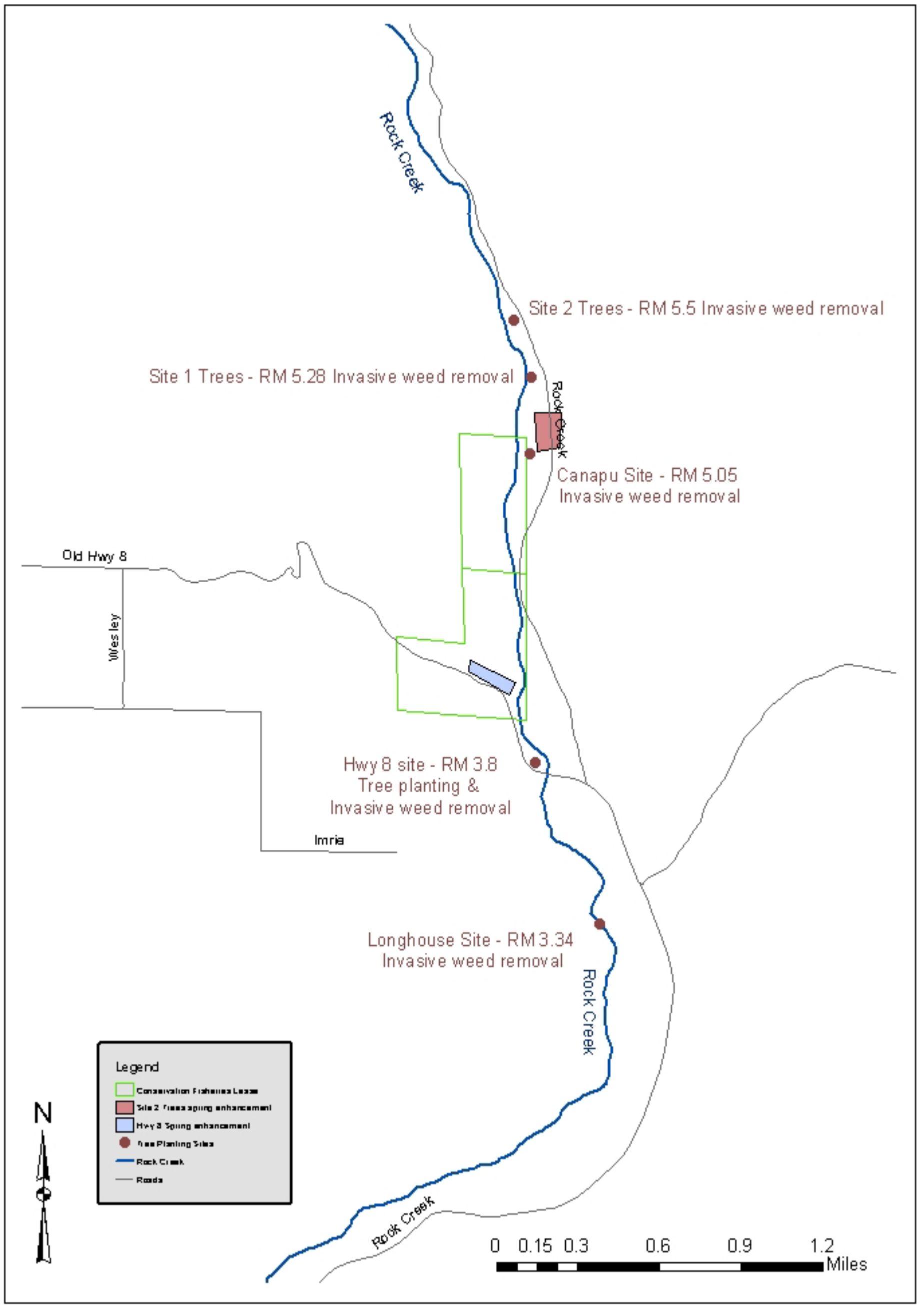

Figure B-i. Conservation fisheries lease, spring enhancement sites, and tree planting and invasive weed removal sites in Rock Creek, 2003 - 2015.

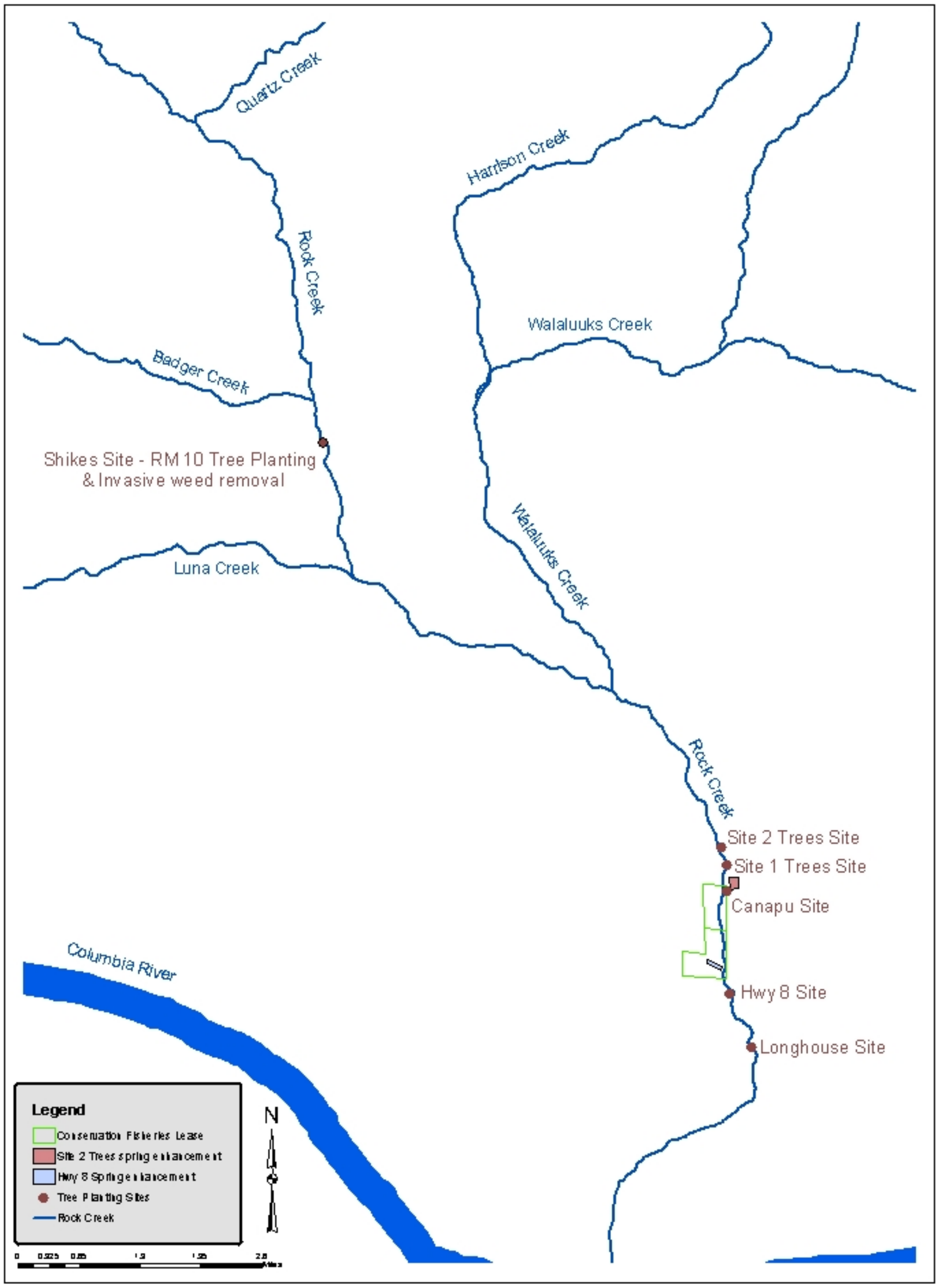

Figure B-ii. Shike's site (RM 10) tree planting and invasive weed removal in Rock Creek, 2013 – 2015.

Appendix C. Water temperature monitoring

Table C-i. Monthly stream temperature summaries from 8 stream sites in the Rock Creek subbasin for the reporting period (5/1/2013 – 12/31/2015). All temperatures and ranges in degree Celsius (°C). Months in which no data were collected are omitted from the table. See description under temperature monitoring section in Report B for an explanation of metrics used.

Monthly water temperature summary at Bickleton Bridge (Rock Creek RM 13), 2013.

2013	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
June	30	0	0	0	0	0	0	30	24	8	4	0	21.6	4.7	3
July	31	0	0	0	0	0	0	31	31	31	31	0	22.3	3.5	2.2
August	31	0	0	0	0	0	0	31	31	31	31	0	20.1	2	1.5
September	30	0	0	0	0	0	0	30	21	18	16	0	19.2	1.7	1.3
October	31	0	0	0	0	0	0	7	0	0	0	0	12.5	2.7	2
November	30	0	10	0	10	0	0	0	0	0	0	0	10.4	3.9	1.5
December	31	9	30	0	27	0	0	0	0	0	0	0	7.5	3.9	1.2

Monthly water temperature summary at Bickleton Bridge (Rock Creek RM 13), 2014.

2014	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	29	0	26	0	0	0	0	0	0	0	5.9	1.8	1
February	28	8	28	4	27	0	0	0	0	0	0	0	5.5	2.3	1.2
March	31	0	16	0	3	0	0	0	0	0	0	0	9.5	4.2	2.9
April	30	0	0	0	0	0	0	4	0	0	0	0	13	5	3.4
May	31	0	0	0	0	0	0	29	0	0	0	0	16.3	4.3	2.9
June	30	0	0	0	0	0	0	30	22	2	0	0	17.8	3.5	2.5
July	31	0	0	0	0	0	0	31	31	31	30	0	20.4	3.6	1.7
August	31	0	0	0	0	0	0	31	31	31	31	0	20.2	1.6	1.2
September	30	0	0	0	0	0	0	30	27	2	0	0	17.8	1.9	1.4
October	31	0	0	0	0	0	0	28	0	0	0	0	15.9	2.1	1.4
November	30	0	1	0	1	0	0	4	0	0	0	0	13	3.8	1.4
December	31	2	18	2	15	0	0	0	0	0	0	0	7.2	2.6	1.1

Monthly water temperature summary at Bickleton Bridge (Rock Creek RM 13), 2015.

2015	**# days recorded**	**# 1-day min**		**# 1-day avg**		**# 1Day Max**		**#7-Day Avg Daily Max**					**Monthly 1-day max**	**Monthly 1-day max**	**Monthly ave daily range**
		< 0.5	**< 4.4**	**<0.5**	**<4.4**	**>23**	**>24**	**>12**	**>16**	**>17.5**	**>18**	**>22**			
January	31	3	22	2	20	0	0	0	0	0	0	0	7.7	2.6	1
February	28	0	10	0	3	0	0	0	0	0	0	0	7.9	3	1.7
March	31	0	6	0	2	0	0	0	0	0	0	0	13.3	4.9	3
April	30	0	0	0	0	0	0	15	0	0	0	0	14.9	5.8	4
May	31	0	0	0	0	0	0	31	11	5	0	0	18.7	4.8	3.2
June	30	0	0	0	0	0	0	30	30	30	27	0	21.5	4.5	3
July	31	0	0	0	0	0	0	31	31	31	31	0	21.4	2.4	2
August	31	0	0	0	0	0	0	31	31	31	31	0	20	2.5	1.7
September	30	0	0	0	0	0	0	30	24	2	1	0	18.3	2.4	1.8
October	31	0	0	0	0	0	0	31	0	0	0	0	16.1	2.2	1.6
November	30	0	7	0	5	0	0	1	0	0	0	0	12.7	2.1	1.4
December	31	0	23	0	21	0	0	0	0	0	0	0	8.2	2.5	1.1

Monthly water temperature summary at Box Canyon Rd. (Rock Creek RM 21), 2013.

2013	**# days recorded**	**# 1-day min**		**# 1-day avg**		**# 1Day Max**		**#7-Day Avg Daily Max**					**Monthly 1-day max**	**Monthly 1-day max**	**Monthly ave daily range**
		< 0.5	**< 4.4**	**<0.5**	**<4.4**	**>23**	**>24**	**>12**	**>16**	**>17.5**	**>18**	**>22**			
June	30	0	0	0	0	0	0	30	7	3	2	0	20.3	7.3	5.3
July	15	0	0	0	0	2	1	15	15	15	15	4	24.3	12.7	8.9
August	28	0	0	0	0	28	28	28	28	28	28	28	27.2	6.3	3.2
September	30	0	0	0	0	14	8	30	30	30	30	18	27.5	3.9	2.2
October	31	0	0	0	0	2	1	31	31	31	31	0	24	6.3	3.1

November	30	0	0	0	0	0	0	30	30	24	17	0	20.8	4.2	2.1
December	16	0	0	0	0	0	0	16	16	16	16	0	20.7	4.3	2.1

Monthly water temperature summary at Box Canyon Rd. (Rock Creek RM 21), 2014.

2014	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	29	9	29	4	29	0	0	0	0	0	0	0	3.1	1.8	0.9
February	28	13	28	10	28	0	0	0	0	0	0	0	4.1	2.2	1
March	31	1	30	0	24	0	0	0	0	0	0	0	7.2	4.1	2.7
April	30	0	15	0	0	0	0	0	0	0	0	0	11.7	6.1	4
May	11	0	0	0	0	0	0	0	0	0	0	0	12.4	6.6	4.5
June	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
July	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
August	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
September	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
October	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
November	6	0	2	0	1	0	0	0	0	0	0	0	7.6	2.3	1.4
December	31	3	30	2	24	0	0	0	0	0	0	0	5.9	2.8	1.1

Monthly water temperature summary at Box Canyon Rd. (Rock Creek RM 21), 2015.

2015	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	3	29	2	27	0	0	0	0	0	0	0	6.4	1.8	1
February	28	0	20	0	14	0	0	0	0	0	0	0	6.9	2.5	1.7
March	31	0	14	0	8	0	0	0	0	0	0	0	9.7	4.1	2.7

April	2	0	2	0	1	0	0	0	0	0	0	0	7.9	3.7	2.9
May	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
June	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
July	12	0	0	0	0	7	2	12	12	12	12	12	26.5	10.8	8
August	19	0	0	0	0	19	18	19	19	19	19	19	29.3	8.5	4.6
September	30	0	0	0	0	25	16	30	30	30	30	30	26.7	7	3.8
October	31	0	0	0	0	11	3	31	31	31	31	18	25.4	6.3	3.1
November	27	0	0	0	0	12	12	27	27	27	27	17	28.1	8.9	3.3
December	19	3	18	1	18	1	1	1	1	1	1	1	28.5	6.7	1.4

Monthly water temperature summary at the Longhouse (Rock Creek RM 2.2), 2013.

2013	**# days recorded**	**# 1-day min**		**# 1-day avg**		**# 1Day Max**		**#7-Day Avg Daily Max**					**Monthly 1-day max**	**Monthly 1-day max**	**Monthly ave daily range**
		< 0.5	**< 4.4**	**<0.5**	**<4.4**	**>23**	**>24**	**>12**	**>16**	**>17.5**	**>18**	**>22**			
June	30	0	0	0	0	0	0	30	30	30	28	0	22	4.7	3.3
July	31	0	0	0	0	8	1	31	31	31	31	13	24	5.3	4
August	31	0	0	0	0	1	0	31	31	31	31	7	23.1	3.9	2.6
September	30	0	0	0	0	0	0	30	23	19	18	0	21.2	2.8	1.8
October	31	0	0	0	0	0	0	31	0	0	0	0	13.7	2.4	1.7
November	30	0	0	0	0	0	0	17	0	0	0	0	13.2	2.2	1.2
December	31	0	6	0	2	0	0	0	0	0	0	0	10	2	0.8

Monthly water temperature summary at the Longhouse (Rock Creek RM 2.2), 2014.

2014	**# days recorded**	**# 1-day min**		**# 1-day avg**		**# 1Day Max**		**#7-Day Avg Daily Max**					**Monthly 1-day max**	**Monthly 1-day max**	**Monthly ave daily range**
		< 0.5	**< 4.4**	**<0.5**	**<4.4**	**>23**	**>24**	**>12**	**>16**	**>17.5**	**>18**	**>22**			
January	31	0	0	0	0	0	0	0	0	0	0	0	7.8	1.6	0.8

February	28	0	19	0	9	0	0	0	0	0	0	0	7	3.6	1.6
March	31	0	3	0	2	0	0	0	0	0	0	0	11.5	4.7	3.1
April	30	0	0	0	0	0	0	27	0	0	0	0	15.6	5.2	3.9
May	31	0	0	0	0	0	0	31	20	15	10	0	19.1	4.8	3.8
June	30	0	0	0	0	0	0	30	30	30	28	0	19.9	4.4	3.4
July	31	0	0	0	0	7	1	31	31	31	31	16	24.1	4.9	3.6
August	31	0	0	0	0	4	0	31	31	31	31	15	23.4	3.5	2.5
September	30	0	0	0	0	0	0	30	30	18	12	0	18.9	3.3	1.9
October	31	0	0	0	0	0	0	31	8	0	0	0	17.2	2	1.4
November	30	0	0	0	0	0	0	9	0	0	0	0	14.7	2.5	1.3
December	31	0	2	0	2	0	0	0	0	0	0	0	9.9	1.8	0.7

Monthly water temperature summary at the Longhouse (Rock Creek RM 2.2), 2015.

2015	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
February	28	0	1	0	0	0	0	0	0	0	0	0	9.8	3.2	1.8
March	31	0	0	0	0	0	0	8	0	0	0	0	14.7	4.8	3.2
April	30	0	0	0	0	0	0	30	2	0	0	0	16.9	5.4	4.2
May	31	0	0	0	0	0	0	31	27	13	11	0	19.7	4.8	3.4
June	30	0	0	0	0	2	0	30	30	30	30	4	23.5	4.3	3.3
July	31	0	0	0	0	11	2	31	31	31	31	13	25.2	5.1	3.1
August	31	0	0	0	0	1	0	31	31	31	31	0	23.3	3.3	2.2
September	30	0	0	0	0	0	0	30	24	7	3	0	19.1	2.6	1.8
October	31	0	0	0	0	0	0	31	4	0	0	0	16.8	2.1	1.4
November	30	0	0	0	0	0	0	17	0	0	0	0	14.4	2.4	1.3
December	31	0	4	0	2	0	0	0	0	0	0	0	10.7	1.9	1

Monthly water temperature summary Luna Creek (RM 5.2), 2013.

2013	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
June	30	0	0	0	0	0	0	30	20	4	2	0	18.9	6.9	4.4
July	31	0	0	0	0	0	0	31	18	9	6	0	19.5	4.9	2.9
August	31	0	0	0	0	0	0	31	0	0	0	0	16.2	2.1	1.5
September	30	0	0	0	0	0	0	30	7	0	0	0	16.8	2.6	1.5
October	31	0	0	0	0	0	0	0	0	0	0	0	11.6	3.5	2.1
November	30	0	8	0	1	0	0	0	0	0	0	0	9.8	2.9	1.3
December	31	0	19	0	14	0	0	0	0	0	0	0	8.2	2.1	1.2

Monthly water temperature summary Luna Creek (RM 5.2), 2014.

2014	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
February	28	1	28	0	27	0	0	0	0	0	0	0	6.7	3.3	1.8
March	31	0	15	0	3	0	0	0	0	0	0	0	11.2	6.5	4.4
April	30	0	0	0	0	0	0	19	0	0	0	0	15.4	7.5	5.3
May	31	0	0	0	0	0	0	31	0	0	0	0	15.4	7	4.2
June	30	0	0	0	0	0	0	30	0	0	0	0	15	3.4	2.4
July	31	0	0	0	0	0	0	31	9	0	0	0	17.1	3.8	2
August	31	0	0	0	0	0	0	31	1	0	0	0	16.3	2	1.2
September	30	0	0	0	0	0	0	30	0	0	0	0	15.9	3.7	2.2
October	31	0	0	0	0	0	0	19	0	0	0	0	15.3	3.4	1.9
November	30	0	11	0	9	0	0	0	0	0	0	0	11.1	2.2	1.3
December	31	1	7	0	7	0	0	0	0	0	0	0	8.3	2.3	0.9

Monthly water temperature summary Luna Creek (RM 5.2), 2015.

2015	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	26	0	21	0	0	0	0	0	0	0	7.7	3	1.2
February	28	0	11	0	3	0	0	0	0	0	0	0	8.5	4	2.5
March	31	0	8	0	2	0	0	1	0	0	0	0	14	6.6	4.2
April	30	0	0	0	0	0	0	17	0	0	0	0	14.4	7.1	5.2
May	31	0	0	0	0	0	0	31	0	0	0	0	14.3	5.1	2.9
June	30	0	0	0	0	0	0	30	0	0	0	0	15.6	2.4	1.6
July	31	0	0	0	0	0	0	31	0	0	0	0	16.2	2.4	1.8
August	31	0	0	0	0	0	0	31	6	0	0	0	16.8	2.2	1.6
September	30	0	0	0	0	0	0	30	0	0	0	0	15.3	2.8	1.9
October	31	0	0	0	0	0	0	18	0	0	0	0	13.7	2.8	1.6
November	30	0	7	0	5	0	0	0	0	0	0	0	11.2	2	1.2
December	31	0	23	0	18	0	0	0	0	0	0	0	8.6	3.4	1.3

Monthly water temperature summary Newell Spring (Walaluuks Creek tributary RM 0.2), 2013.

2013	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
June	30	0	0	0	0	0	0	30	15	6	4	0	21.1	4.7	2.8
July	31	0	0	0	0	0	0	31	31	31	29	0	22.4	3.4	2.2
August	31	0	0	0	0	0	0	31	31	31	29	0	20.1	2.4	1.5
September	30	0	0	0	0	0	0	30	19	16	12	0	19.5	1.7	1
October	31	0	0	0	0	0	0	2	0	0	0	0	12.6	1.4	0.6
November	30	0	9	0	8	0	0	0	0	0	0	0	10.2	2.3	0.6
December	31	0	20	0	16	0	0	0	0	0	0	0	7.3	2	0.8

Monthly water temperature summary Newell Spring (Walaluuks Creek tributary RM 0.2), 2014.

2014	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	15	0	10	0	0	0	0	0	0	0	9.5	2.9	1.3
February	28	5	11	3	9	0	0	0	0	0	0	0	10.2	4.7	2.1
March	31	0	2	0	1	0	0	0	0	0	0	0	13.4	4.7	2.5
April	30	0	0	0	0	0	0	21	0	0	0	0	15.6	6	2.5
May	31	0	0	0	0	0	0	31	7	0	0	0	17.8	6.1	3.7
June	30	0	0	0	0	0	0	30	22	4	0	0	18.4	5.3	3.2
July	31	0	0	0	0	1	0	31	31	31	31	0	23.3	5.4	3.6
August	31	0	0	0	0	0	0	31	31	30	29	0	22.1	3.6	2.2
September	30	0	0	0	0	0	0	30	19	2	0	0	18	3.4	2.2
October	9	0	0	0	0	0	0	9	3	0	0	0	17.3	4	3
November	9	0	0	0	0	0	0	6	0	0	0	0	12.9	2	1.3
December	9	0	5	0	4	0	0	0	0	0	0	0	7.3	1.4	0.8

Monthly water temperature summary Newell Spring (Walaluuks Creek tributary RM 0.2), 2015.

2015	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	1	5	0	4	0	0	0	0	0	0	0	11.3	3.8	1.2
February	28	0	0	0	0	0	0	0	0	0	0	0	12.3	4.3	2.5
March	31	0	0	0	0	0	0	24	0	0	0	0	16.1	5.8	3.8
April	30	0	0	0	0	0	0	27	0	0	0	0	16.3	7.8	5
May	31	0	0	0	0	0	0	31	12	5	0	0	18.9	5.9	3.4

June	30	0	0	0	0	1	0	30	30	27	23	3	23.1	4.5	3.1
July	31	0	0	0	0	1	0	31	31	31	30	7	23.2	6.7	3.6
August	31	0	0	0	0	0	0	31	31	30	29	0	22.7	5.5	3.4
September	30	0	0	0	0	0	0	30	8	2	2	0	19.7	5.2	3.4
October	9	0	0	0	0	0	0	9	0	0	0	0	16.7	5.1	3.5
November	9	0	0	0	0	0	0	0	0	0	0	0	12.4	2.4	1.9
December	9	0	5	0	4	0	0	0	0	0	0	0	11	2.1	1.4

Monthly water temperature summary Quartz Creek (RM 9.4), 2014.

2014	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
February	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
March	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
April	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
May	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
June	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
July	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
August	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
September	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
October	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
November	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
December	27	0	11	0	7	0	0	0	0	0	0	0	6.7	2.3	1

Monthly water temperature summary Quartz Creek (RM 9.4), 2015.

2015	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave

		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			daily range
January	31	0	27	0	24	0	0	0	0	0	0	0	6.6	1.6	1
February	28	0	16	0	8	0	0	0	0	0	0	0	7.1	2.7	1.6
March	31	0	14	0	5	0	0	0	0	0	0	0	10.2	4.7	2.9
April	30	0	14	0	0	0	0	0	0	0	0	0	12.1	6.2	4.5
May	31	0	0	0	0	0	0	0	0	0	0	0	12.1	5.9	3.3
June	30	0	0	0	0	2	0	14	7	5	5	2	24	10.1	2.9
July	29	0	0	0	0	29	29	29	29	29	29	29	30.4	13.2	4.9
August	31	0	0	0	0	31	31	31	31	31	31	31	30	4.9	2.7
September	30	0	0	0	0	30	25	30	30	30	30	30	27.1	3.6	1.8
October	31	0	0	0	0	22	10	31	31	31	31	31	25.8	2.7	1.2
November	30	0	0	0	0	20	12	30	30	30	30	30	25.9	5	1.9
December	1	0	0	0	0	1	1	1	1	1	1	1	25.6	2.9	2.9

Monthly water temperature summary Walaluuks Creek (RM 1), 2013.

2013	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
June	30	0	0	0	0	0	0	30	3	1	1	0	18.4	3.8	2.6
July	31	0	0	0	0	0	0	31	31	24	18	0	19.4	3.6	2.5
August	15	0	0	0	0	0	0	15	15	15	9	0	19.2	4.2	2.2
September	9	0	0	0	0	0	0	9	3	1	0	0	17.9	2	1
October	31	0	0	0	0	0	0	1	0	0	0	0	12	1.6	1
November	30	0	9	0	9	0	0	0	0	0	0	0	8.8	2.3	0.9
December	31	6	29	2	28	0	0	0	0	0	0	0	6.6	2	1.2

Monthly water temperature summary Walaluuks Creek (RM 1), 2014.

2014	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	31	0	30	0	0	0	0	0	0	0	5.3	1.4	0.8
February	28	6	28	4	28	0	0	0	0	0	0	0	5.2	2.6	1.6
March	31	0	17	0	4	0	0	0	0	0	0	0	9	4.2	2.9
April	30	0	0	0	0	0	0	0	0	0	0	0	12.3	4.8	3.4
May	31	0	0	0	0	0	0	24	0	0	0	0	14.8	4.2	3
June	30	0	0	0	0	0	0	30	1	0	0	0	16.6	3.8	3
July	16	0	0	0	0	0	0	16	16	8	5	0	19.7	3.2	1.6
August	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
September	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
October	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--
November	25	0	12	0	9	0	0	0	0	0	0	0	10.8	3.1	0.8
December	31	0	10	0	7	0	0	0	0	0	0	0	7	1.9	0.8

Monthly water temperature summary Walaluuks Creek (RM 1), 2015.

2015	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	1	29	0	24	0	0	0	0	0	0	0	6.3	2.5	0.9
February	28	0	15	0	5	0	0	0	0	0	0	0	7.1	3	1.8
March	31	0	8	0	2	0	0	0	0	0	0	0	11.7	4.6	2.9
April	30	0	0	0	0	0	0	0	0	0	0	0	12.5	4.5	3.4
May	31	0	0	0	0	0	0	18	0	0	0	0	16	3.6	2.7
June	30	0	0	0	0	0	0	30	26	5	3	0	19.2	4	2.9
July	8	0	0	0	0	0	0	8	8	8	8	0	21.6	5.1	2.7
August	19	0	0	0	0	13	6	19	19	19	19	19	26.5	8.4	4.5
September	30	0	0	0	0	6	1	30	30	30	30	12	24.2	7	4

October	31	0	0	0	0	0	0	31	31	31	31	0	22.6	6	3.1
November	2	0	0	0	0	0	0	2	2	2	2	0	18.4	2.5	1.7
December	31	0	23	0	21	0	0	0	0	0	0	0	8.3	2.7	1

Monthly water temperature summary for Site 2 Trees (Rock Creek RM 5), 2013.

2013	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
June	30	0	0	0	0	2	1	30	30	30	30	3	24.5	5.9	3.9
July	31	0	0	0	0	26	19	31	31	31	31	31	27	6	4.1
August	10	0	0	0	0	9	9	10	10	10	10	10	28.2	7.5	5.7
September	24	0	0	0	0	11	10	24	22	18	17	13	29.9	11.4	5.8
October	31	0	0	0	0	0	0	26	0	0	0	0	15.9	4.2	2.3
November	30	0	7	0	2	0	0	0	0	0	0	0	11.9	3.4	1.2
December	31	2	21	2	20	0	0	0	0	0	0	0	8.9	3	1.4

Monthly water temperature summary for Site 2 Trees (Rock Creek RM 5), 2014.

2014	# days recorded	# 1-day min		# 1-day avg		# 1Day Max		#7-Day Avg Daily Max					Monthly 1-day max	Monthly 1-day max	Monthly ave daily range
		< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	20	0	16	0	0	0	0	0	0	0	7.4	2	1
February	28	4	26	2	15	0	0	0	0	0	0	0	7	3.7	1.6
March	31	0	5	0	2	0	0	0	0	0	0	0	10.8	4.9	3.1
April	30	0	0	0	0	0	0	26	0	0	0	0	15.5	5.7	4.2
May	31	0	0	0	0	0	0	31	20	16	13	0	19.8	5.7	4.5
June	30	0	0	0	0	0	0	30	30	30	30	0	21.6	5.1	3.5
July	31	0	0	0	0	25	19	31	31	31	31	28	29.8	8.8	4.7

Appendix D. References

71 FR 834. Federal Register. Vol. 71, No.3. January 5, 2006. Rules and Regulations

Allen, B., Munz, C., and Harvey, E. 2013. Fish Distribution and Population Dynamics in Rock Creek, Klickitat County, Washington. U.S. Geological Survey and Yakama Nation. Cook, WA.

Aspect Consulting LCC. 2008. Watershed Management Plan Rock-Glade Watershed (WRIA 31). Ecology Watershed Planning Grant No. G020010.

Bunte, Kristin and Steven R. Abt. 2001. Sampling Surface and Subsurface Particle-Size Distributions in Wadeable Gravel- and Cobble-Bed Streams for Analyses in Sediment Transport, Hydraulics, and Streambed Monitoring. Rocky Mountain Research Station RMRS-GTR-74, 428 pages.

Crawford, B., T.R. Mosey, and D.H. Johnson. 2007. Carcass counts. Pages 59-86 in D.H. Johnson, B.M. Shrier, J.S. O'Neal, J.A. Knutzen, X. Augerot, T.A. O'Neil, and T.N. Pearsons. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Faulkner, J. R., S. G. Smith, W. D. Muir, D. M. Marsch, and J. G. Williams, 2010 Survival estimates for the passage of spring migration juvenile salmonids through Snake and Columbia River Dams and reservoirs, 2010. by NOAA Fisheries, for BPA project # 19930290.

Gallagher, S.P., P.K.J. Hahn, and D.H. Johnson. 2007. Redd counts. Pages 197-234 in D.H. Johnson, B.M. Shrier, J.S. O'Neal, J.A. Knutzen, X. Augerot, T.A. O'Neil, and T.N. Pearsons. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Harrelson, C.C., Rawlings, C.L., Potyondy, J.P., (1994). Stream channel reference sites: An illustrated guide to field techniques. US Department of Agriculture Forest Service General Technical Report RM-245. Fort Collins, CO. USDA U.S. Forest Service.

Heil, N. (Ed) 2009. National Wild Fish Health Survey - Laboratory Procedures Manual. 5.0 Edition. U.S. Fish and Wildlife Service, Warm Springs, GA

Hauer Richard F. and Gary A. Lamberti. 1996. Methods in Stream Ecology. Academic Press. San Diego, CA.

Lautz, K. 2000. Salmon and Steelhead Habitat Limiting Factors Water Resource Inventory Area 31. Washington State Conservation Commission. Olympia, WA.

Matala, A. 2012. Evaluation of steelhead trout (*Oncorhynchus mykiss*) in Rock Creek watershed of the middle Columbia River Basin. Columbia River Inter-Tribal Fish Commission. Hagerman, ID.

Matala. A. 2013. Genetic evaluation of steelhead trout (*Oncorhynchus mykiss*) in the Rock Creek watershed of the middle Columbia River Basin. Columbia River Inter-Tribal Fish Commission. Hagerman, ID.

Montgomery, D.R., & Buffington, J.M. (1998). Channel processes, classification, and response, in Naiman, R. and Bilby, R., eds., River Ecology and Management: Lessons from the Pacific Coastal Ecoregion. New York. Springer-Verlag.

Murphy, Brian R. and David W. Willis. 1996. Fisheries Techniques, Second Edition. American Fisheries Society.

Mobrand Biometrics, Inc. 2004. Ecosystem Diagnosis and Treatment Online User Manual.

Mobrand Biometrics, Inc. 2004. Ecosystem Diagnosis and Treatment Scenario Builder User Manual.

Northwest Power and Conservation Council. 2004. Data taken from the Lower Mid-Columbia Mainstem Subbasin Plan. NPCC, Portland, OR.

NOAA Fisheries. 2009. Rock Creek Recovery Plan for the Middle Columbia River Steelhead DPS.

Sloat, M.R and Osterback, A.K. 2013. Maximum stream temperature and the occurance, abundance, and behavior of steelhead trout (*Oncorhynchus mykiss*) in a southern California stream. Canada Journal Fish. Aquat.Sci 70:64-73 (2013)

WRIA 31 Planning Unit. 2008. Watershed Management Plan Rock-Glade Watershed (WRIA 31). Project No. 030009-004-01. January 2008.

Washington State Department of Ecology. 2010. Washington State Department of Ecology Stream Flow Monitoring. https://fortress.wa.gov/ecy/wrx/wrx/flows/station

Washington State Department of Ecology. 2012. Water Quality Standards for Surface Waters of the State of Washington. Chapter 173-201A WAC. Publication No. 06-1-091. January 2012.

Wolman, M.G., 1954. A Method of Sampling Coarse River-Bed Material. Transactions of the American Geophyisical Union. 35(6):951-956.