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

2010 Annual Report

Performance Period

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The Confederated Tribes and Bands of

the Yakama Nation

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

The overall project goal is to characterize the fish habitat conditions of the Rock Creek subbasin to prioritize sites for future restoration projects. This report describes the preliminary results of the data collection for salmonid fish populations and habitat in the Rock Creek subbasin in south-eastern Washington. The Rock Creek subbasin is of great significance to the Yakama Nation, and to the Rock Creek Band in particular. Oral history regarding historic runs of anadromous and resident fish and perennial flows in the subbasin indicate that fish populations and habitat conditions have been significantly altered between historic and present conditions. The subbasin has been identified as a unique watershed with high potential productivity for steelhead (as evidenced by spawner surveys) but with significant habitat limitations (low flow, high stream temperatures, and riparian, channel and floodplain degradation). NOAA-Fisheries identified Rock Creek as critical habitat for the threatened Middle Columbia River Steelhead DPS (NOAA 2005). Though a potentially productive system, there are substantial gaps in knowledge about habitat conditions limiting fish populations in Rock Creek. For example, while steelhead (*Oncorhynchus mykiss*) spawner abundance was high in some reaches, prior to this project there was no information about where perennial fish habitat occurred in sufficient quantity and quality to produce the high spawner abundance. The project includes monitoring and evaluation activities that develop, analyze, and report information pertaining to fish distribution, natural production, genetics, and disease profiling in order to prioritize restoration and protection actions.

The project also addresses many of the information gaps identified in the NOAA-Fisheries Rock Creek Steelhead Recovery Plan and the Northwest Power & Conservation council's (NPCC) Rock Creek Subbasin Plan, which state that there is a significant need for ongoing monitoring and evaluation within the Rock Creek watershed, and that it is considered a high priority.

Environmental and biological attributes were collected for this project throughout the subbasin, ranging from the headwaters originating in the Simcoe Mountains to the confluence with the Columbia River. The collection, evaluation and input of data into the Ecosystem Diagnosis and Treatment (EDT) model are a continuous process. The EDT model was used in the watershed analysis to assist in determining the appropriate sites for future restoration activities, while understanding that data collected through this project were needed to help further refine the EDT model for the basin.

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 juvenile fish abundance, distribution, movement, habitat use, life history, growth, survival to adulthood and adult distribution, relative abundance, and spawning behavior, e.g. kelting

2. EDT modeling- to evaluate habitat quality and identify areas with high potential for habitat restoration

3. Genetics- to determine the genetic composition of resident trout and steelhead (*O. mykiss*) population, and to compare genetic samples for heterogeneity within the subbasin

4. Revegetation- Riparian re-vegetation along stream corridor to increase stream shading and lower stream temperatures

Description of Project Area – Rock Creek subbasin

The Rock Creek subbasin encompasses an area of approximately 223 square miles of southeastern Washington. Rock Creek joins the Columbia River at river mile (RM) 230 (river kilometer or (RKM) 370), approximately 12 miles (19.2 kilometers) upstream of John Day Dam (Figure 1). From its headwaters in the Simcoe Mountains, Rock Creek flows in a southerly to southeasterly direction to the Columbia River. Elevations range from 200 feet at the confluence of Rock Creek and the Columbia River to over 3200 feet in the Simcoe Mountains. Major tributaries to Rock Creek include Quartz Creek, Badger Creek, Luna Creek, Harrison Creek, and Squaw Creek.

Rock Creek and its tributaries originate on a plateau which transitions from coniferous forest to shrub-steppe; land use in the uplands is managed forest, grazing, and some rural residential. The uplands are also seeing increased wind power development. From the plateau, the stream enters steep-walled canyons where the channel becomes confined. Land cover in the canyon ranges from coniferous forest to mixed conifer-deciduous forest. Downstream of the canyons, streams enter alluvial valleys where channels transition from moderately confined to unconfined channels. The predominant land use activity within the alluvial valley and on the adjacent terrace slopes is cattle grazing.

Rock Creek currently supports fall Chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon, summer steelhead (*O. mykiss*), resident rainbow trout (*O. mykiss*), and other native and introduced fish species. Non-native species are primarily found in the lower reaches of the subbasin. Rock Creek steelhead are part of the Middle Columbia River Steelhead Distinct Population Segment (DPS), 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. The lowest 2.5 river miles of Rock Creek contain essential spawning habitat for coho and fall Chinook populations during the fall and winter months. Juvenile steelhead, coho, fall Chinook, and resident rainbow trout rear in Rock Creek and its tributaries throughout the year.

Acknowledgements

We would like to take this opportunity to thank all those individuals and organizations that have helped contribute in some way to this project. A special thanks to private landowners for their cooperation and allowing access through their property for monitoring. The following Yakama Nation technicians assisted in collecting valuable fish and habitat information: Bronsco Jim Jr., Sandy Pinkham, Rodger Begay, Roger Stahi, Jeremy Takala and Andrew Nomee. Mike Babcock, YN Data Systems Manager, provided assistance with data management. Bill Sharp, YN Fisheries Research Scientist, provided assistance and management of the project. Brady Allen, Carrie Munz, 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.

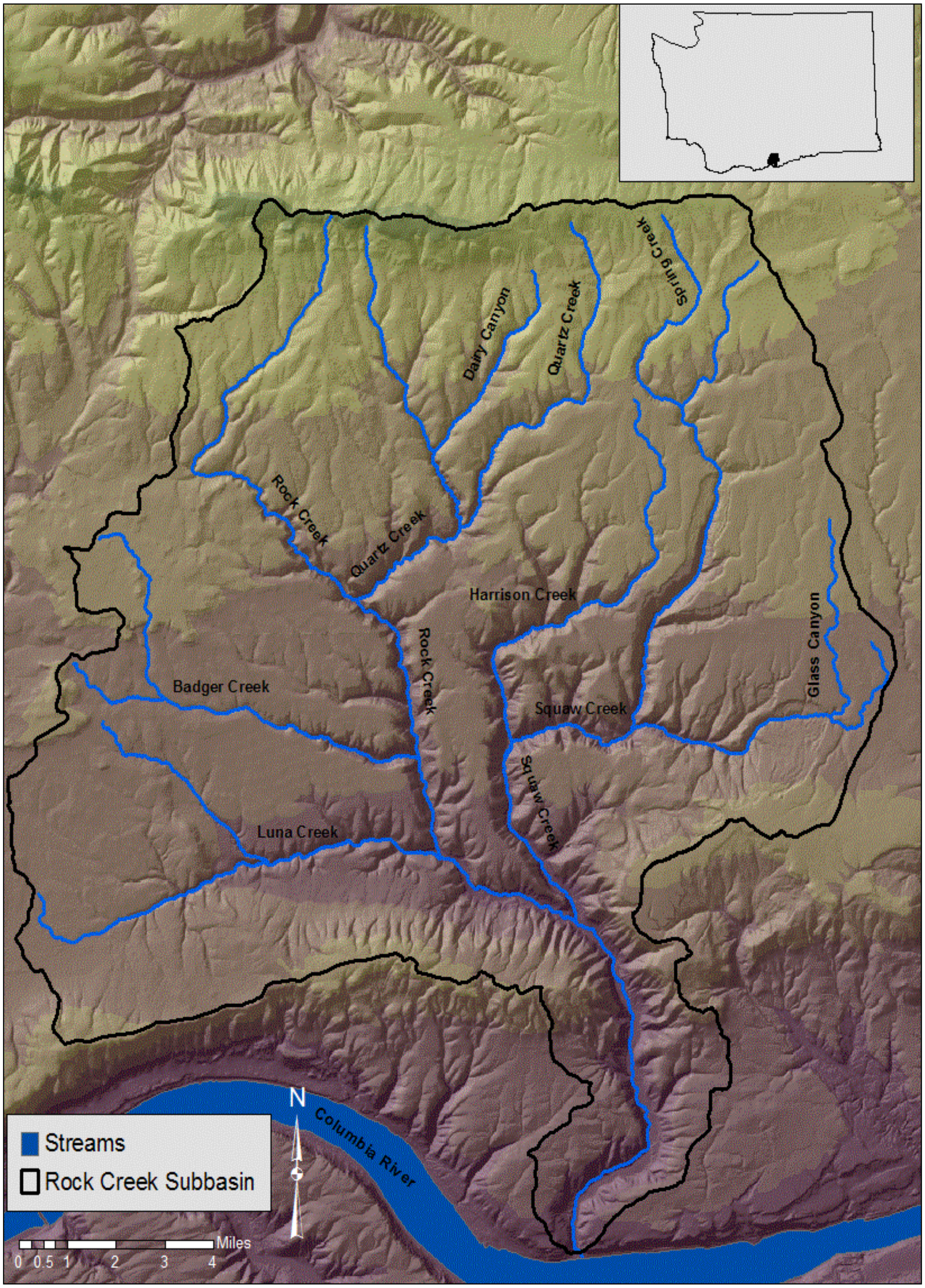


Figure 1. Rock Creek subbasin in southeastern Washington.

1. Monitoring & Evaluation

Overall Objective: Gather baseline environmental and biological data throughout the subbasin to understand the current conditions of native salmonids and associated habitat conditions. This fish and habitat assessment is the first to be conducted throughout the entire Rock Creek subbasin. Monitoring and evaluation allows for continuous assessment of fish and habitat conditions and for identification of possible restoration project opportunities.

Task 1.a Spawning ground surveys (redd counts) and scale collection

Objective: Redd counts and spawner surveys were employed to monitor spatial and temporal redd distribution of fall Chinook, coho, and steelhead, and to collect biological data from carcasses. Spawning ground surveys provide a means of monitoring annual adult escapement as well as spawner distribution.

Methods: Regular foot and one-man pontoon surveys were conducted within the known geographic range for each target species. Individual 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. Attempts were made to cover the entire known spawning range of each species, although for steelhead some gaps in survey coverage exist. 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).

Fall Chinook surveys were conducted from mid-October through mid-December; coho surveys were conducted from late October through late February; steelhead surveys began in January and continued through late May. The lower reaches of Rock Creek have intermittent flow and 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 during the spawning season.

Results: Spawner survey results are discussed below. Figure 2 exhibits the observed 2010 redd distribution for fall Chinook and Figure 3 exhibits the 2011 steelhead redd distributions. A tabular summary of spawning ground survey results by species is presented in Appendix A.

Fall Chinook

Fall Chinook surveys were conducted from early November through late December, covering approximately 2.5 river miles during the 2009 and 2010 spawning seasons. Fall Chinook spawning activity was observed between RM 1 and RM 2.5. The majority of observed spawning occurs adjacent to the Rock Creek Lake (Army Corps Park) near the mouth of Rock Creek. For the 2009 fall and winter months there were no redds, live adults, or carcasses found in the 2.5 mile reach. There was insufficient instream flow and connectivity to allow fish passage upstream of the mouth of Rock Creek. For the 2010 spawning season, 2 live adults, 2 carcasses and six redds were observed and recorded.

Coho

Coho surveys were conducted between November and January, covering nearly 2.5 river miles. The majority of observed spawning occurs from RM 1 to RM 2.5. For the 2009 - 2010 spawning season, no coho redds, no carcasses and one live adult were located and recorded within the spawning reach. During the 2010- 2011 spawning season there was a total of 3 live adults, 2 redds, and 1 carcass.

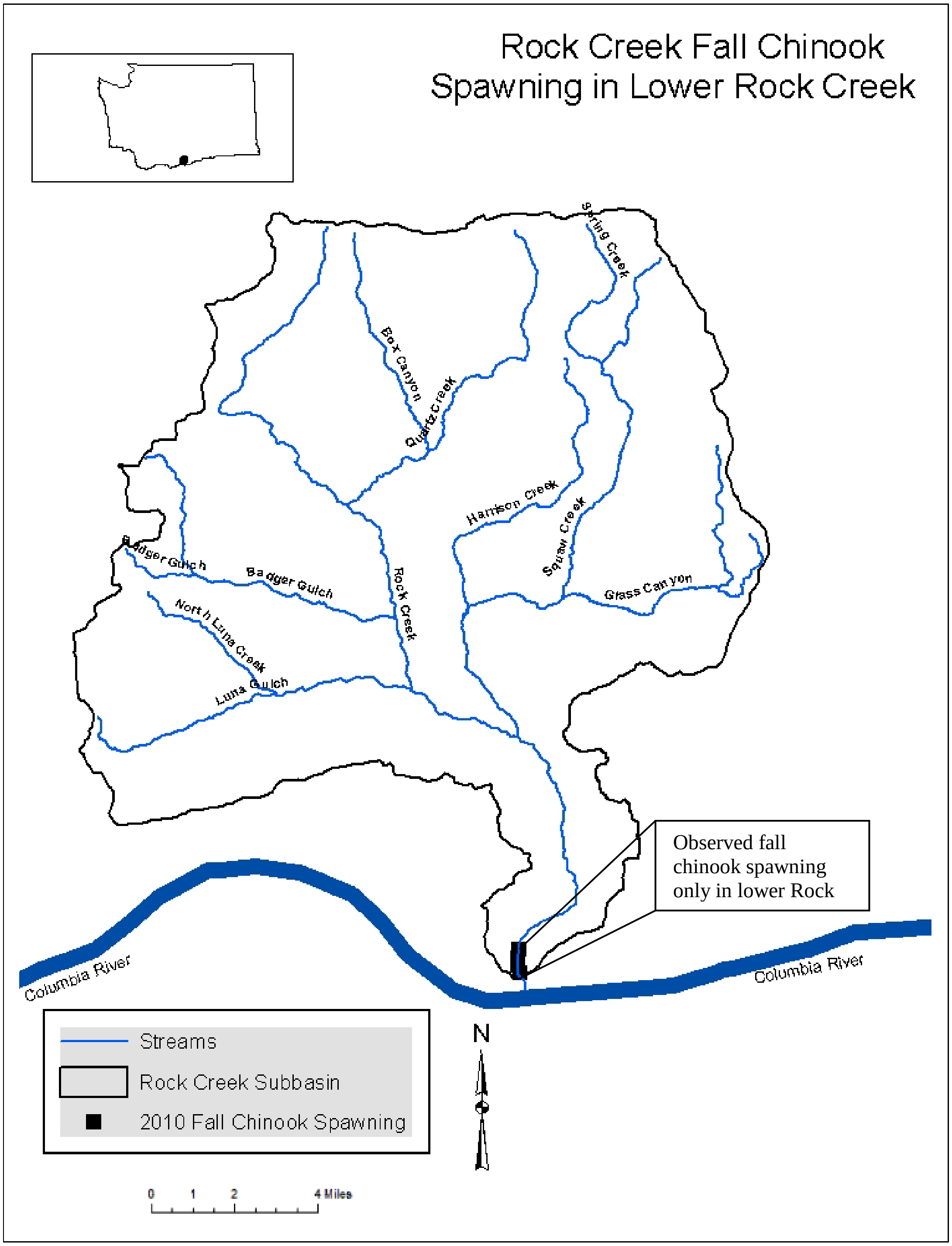


Figure 2. Rock Creek fall Chinook spawning vicinity map 2010.

Steelhead

Steelhead surveys were conducted between January and May, covering approximately 26.77 miles with between 2–3 passes at 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), Squaw Creek (RM 0- RM 5), Luna Gulch (RM 0 –RM .5), and Badger Gulch (RM 0 – RM .5). High spring flows and turbidity often limited the timing and safe access to survey reaches. Steelhead spawning is widespread through the lower to mid reaches of Rock Creek and Squaw Creek. A total of 127 redds, 104 live adults, and 3 carcasses were enumerated during the 2010 spawning season. A total of 287 redds, 154 live adults, and 2 carcasses were enumerated during the 2011 spawning season. The majority of steelhead redds were observed and documented in mainstem Rock Creek from RM 1- RM 13.5 and in Squaw Creek from RM 0 – RM 5.5. We attempted to cover the entire steelhead spawning range (80% coverage) in the subbasin in the 2011 spawning season.

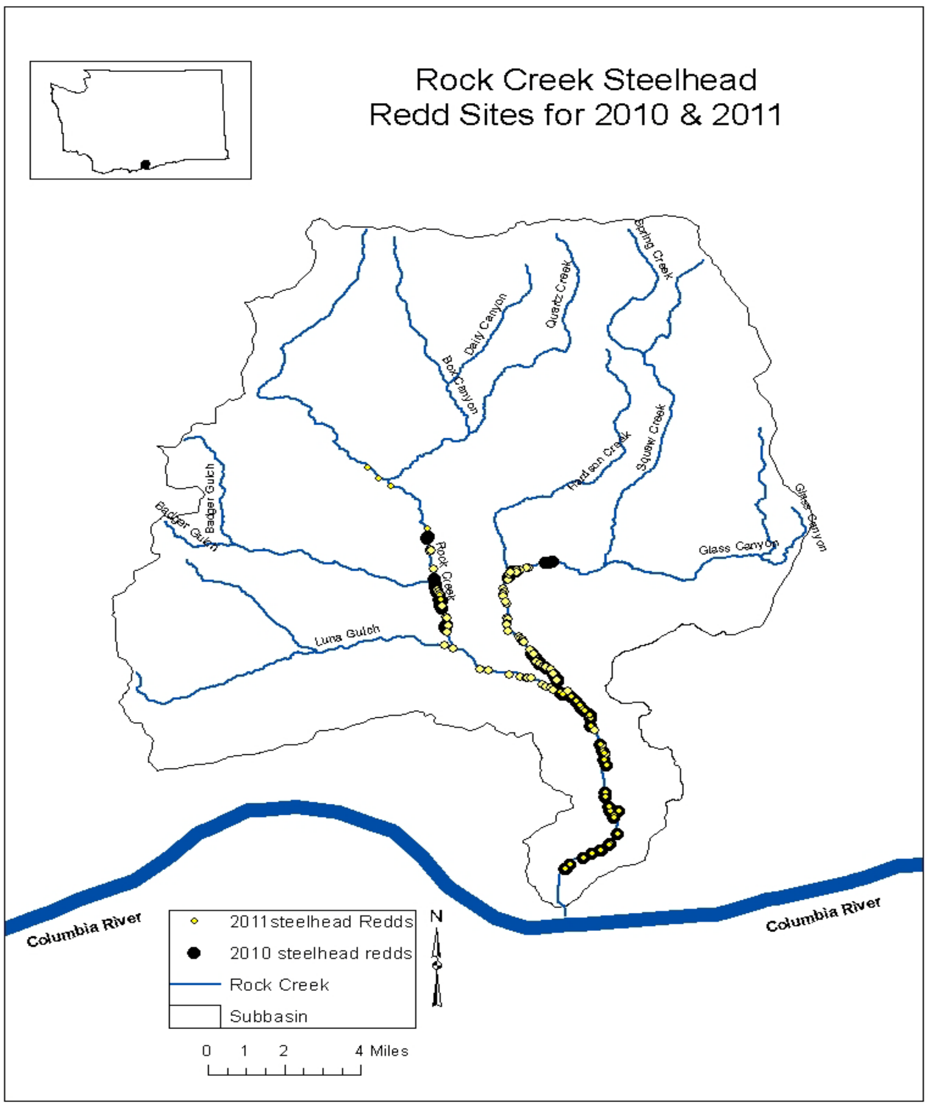


Figure 3. Rock Creek steelhead redd distribution map for 2010 and 2011.

Task 1.b Juvenile anadromous and resident salmonid population survey and scale collection

Objective: Gather baseline information to determine juvenile anadromous and resident salmonid spatial distribution and relative abundance throughout the basin.

Methods: Fish distribution, relative abundance, length frequency, weights, and population density were determined from backpack electrofishing data. We used a stratified, randomized systematic sampling design. Habitat surveys were conducted prior to electrofishing to measure the length, width, and depth of pools and non-pools in all anadromous fish-bearing reaches for which we had landowner permission and access. Electrofishing was stratified to pools only (most riffles were too shallow to sample in the fall when temperatures were appropriate for electrofishing). We randomly selected the starting pool and systematically electrofished every third subsequent pool greater than 70 cm in maximum depth. Fish sampling consisted of single-pass electrofishing up and back within each pool. In future sampling in the fall, we will conduct mark-recapture population estimates in a randomly selected subset of these pools. Captured fish were transferred into a 5-gallon bucket holding stream water until processed. Fish were anesthetized with Tricane Methane Sulphonate (MS-222) prior to data collection. Fish identification, weight and length were recorded from sampled fish. All trout greater than 70 mm fork length were PIT-tagged as described in Task 1.c. All fish species' presence and relative abundance were noted during the electrofishing surveys to get an understanding of fish biodiversity and distribution in the subbasin. Staff from USGS Columbia River Research Laboratory assisted with this work.

Results: In the fall of 2009, a total of 36 pools were sampled over about 29 kilometers of stream to understand fish distribution, distribute PIT-tags in juvenile trout within the watershed, and assess habitat and access conditions for the following years population estimates. In the spring of 2010, we electrofished randomly selected pools, and we began conducting mark-recapture population estimates in a subset of those pools. Unfortunately, an unusually strong thunderstorm occurred overnight when we had blocknets installed for two-day mark recapture estimates, resulting in an expected increase in stream flows, and *O. mykiss* fry were impinged on the nets. This event caused us to exceed our NOAA Section 10 Take Permit for allowable take and all fish sampling ceased until the following year. For juvenile salmonid sampling seasons in 2011 and out-year's, we were covered under a new NOAA take permit which allowed for additional handling of *O. mykiss* fry since they were so abundant during our 2010 spring sampling efforts. In 2011, population estimates were not conducted in the spring to avoid any unintended fish mortalities, but electrofishing for fish distribution and PIT tag distribution occurred during June 2011 in pools scheduled for population estimates in the fall. This was intended to evaluate over summer survival and growth in these selected pools. Petersen mark-recapture population estimates were conducted in eight pools in Rock Creek and four pools in Squaw Creek during the fall 2011.

We found a total of nine species of fish during our sampling in 2009 through 2011: steelhead/rainbow trout (*O. mykiss*), coho salmon (*O. kisutch*), shorthead sculpin (*Cottus confusus*), speckled dace (*Rhinichthys osculus*), redside shiner (*Richardsonius balteatus*), bridgelip suckers (*Catostomus columbianus*), northern pikeminnow (*Ptychocheilus oregonensis*), smallmouth bass (*Micropterus dolomieu*), and brown bullhead (*Ameiurus nebulosus*).

In 2009, rainbow trout were rare in Rock Creek downstream of the Squaw Creek confluence (RKM 13), with only 4 individuals captured. However, sampling during 2009 occurred only in the fall after much of Rock Creek had become intermittent. Rainbow trout were common and even abundant upstream of rkm 13 and in Squaw Creek during 2009. We found rainbow trout to be abundant throughout all areas sampled in Rock and Squaw creeks in the spring of 2010 and both spring and fall of 2011. This indicates that additional years of study are needed to understand the extent of salmonid mortality in Rock Creek below RKM 8.

Age-0 and age 1+ rainbow trout/ steelhead were found in all pools sampled in Rock Creek (RKM 2 – RKM 21) and Squaw Creek (RKM 2 – RKM 8) in spring 2010. We conducted no electrofishing surveys upstream of RKM 21, although we observed abundant rainbow trout in that area during visual surveys. Age-0 rainbow trout densities were more concentrated in mid to higher reaches of Rock Creek (Figure 4). There did not seem to be a particular pattern in Squaw Creek with a higher density only in RKM 4.

In 2009, juvenile coho were present in only 2 (RKM 6.9 and RKM 15.3) of 36 pools sampled. During the spring of 2010, coho were found in 7 of the 31 pools sampled, but were not abundant. We found only 12 juvenile coho individuals compared to over 950 rainbow trout. In 2011, we found coho in all but two of the 39 pools sampled throughout Rock and Squaw creeks. They were also far more abundant than in previous years. We found 2,002 coho individuals compared to 3,325 rainbow trout. In contrast to the previous years, coho were found in nearly every pool in 2011. The results for population estimates are displayed in the figures below (Figure 5).

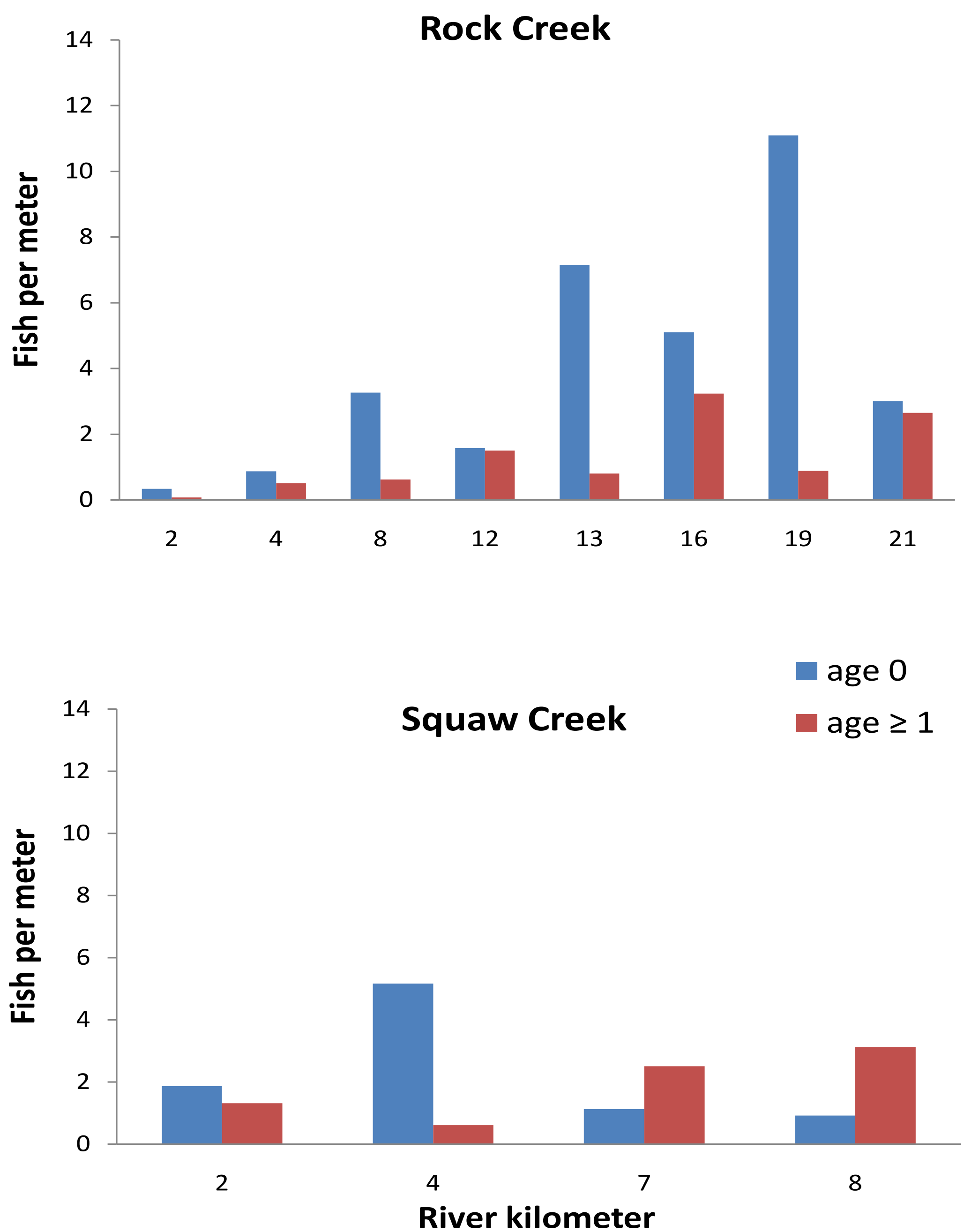


Figure 4. Population estimates of Rainbow trout/steelhead during fall of 2011 in Rock and Squaw creeks, Washington

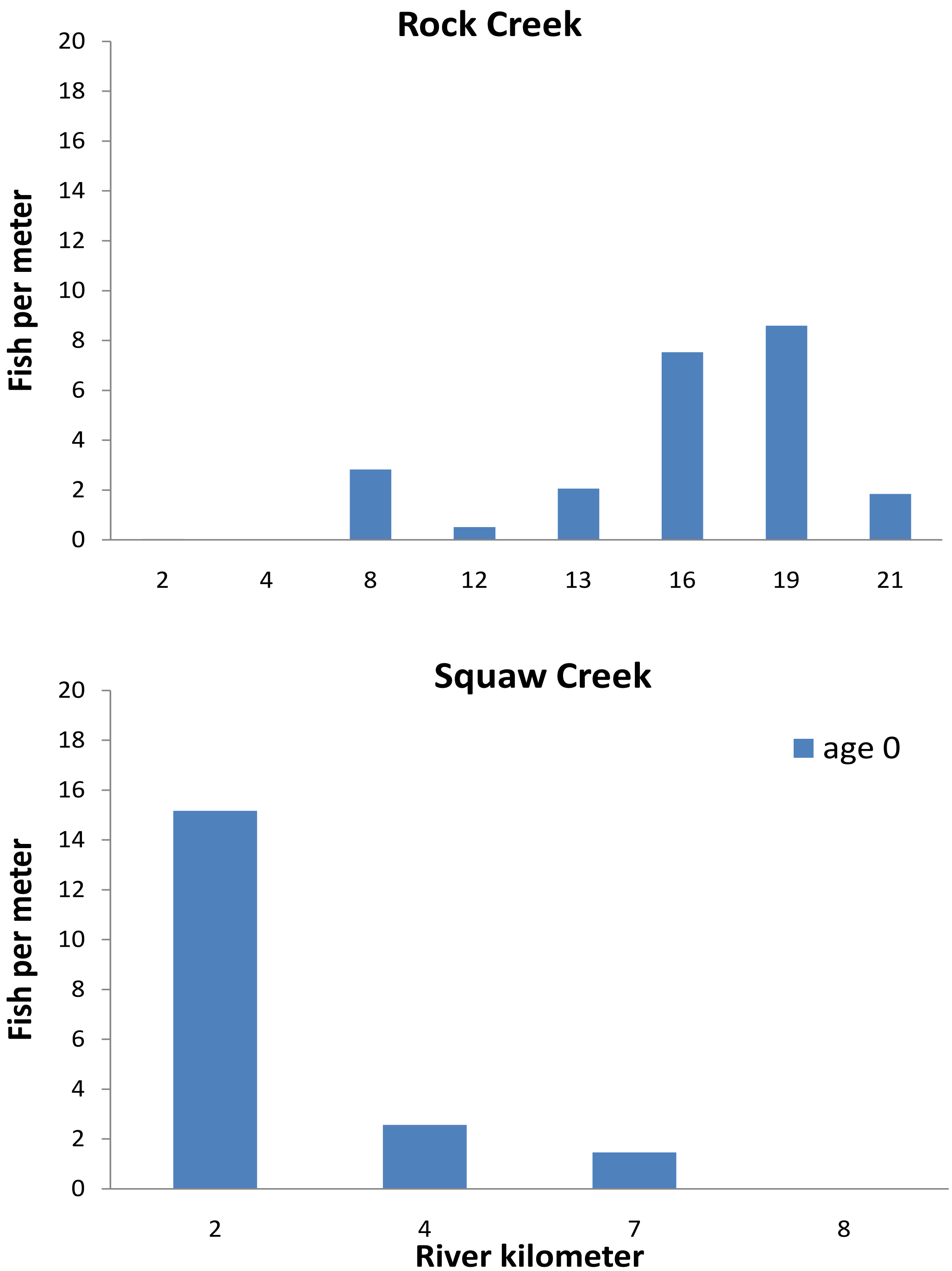


Figure 5. Population estimates of coho salmon during the fall 2011 in Rock and Squaw creeks, Washington.

Task 1.c Juvenile steelhead PIT-tagging and United States Geological Survey (USGS) collaborative research

Objective: Monitor juvenile steelhead movement within Rock Creek and its tributary streams. Additional benefits include monitoring movements through Columbia River dams and estimation of outmigrant survival and smolt-to-adult returns. Maintain two instream multiplexing PIT-tag units at two sites located in Rock Creek and Squaw Creek (Figure 6).

Methods: In order to track movements, growth, and other life history attributes of juvenile steelhead, we PIT-tagged *O. mykiss* over 70-mm fork length captured during our stream surveys as described in Task 1.b, up to 1200 fish per year. This project is the first to conduct in-depth fish population surveys in the Rock Creek subbasin. The ISO FDX-B, 134.2 kHz (12 mm) PIT tags were used to detect fish movement at the remote instream PIT-tag readers in Rock Creek. Fish tagged in 2009 through 2011 during our electrofishing surveys and recaptured provide growth and movement information. Tagged fish that migrate downstream and exhibit a potadromous or anadromous life history can be detected at Columbia River mainstem dams as well as in the estuary. All PIT-tag data were entered in the PTAGIS database, which is maintained by Pacific States Marine Fisheries Commission. PIT-tagged fish returning as adults can be detected at mainstem dams. The two remote instream PIT-tag readers installed in Rock Creek in fall of 2009 were able to detect the movement of adult steelhead into and out of Rock Creek including adult steelhead as strays, as pre-spawn adults, and as post-spawn kelts. The PIT-tag interrogation systems (PTIS) installed by USGS and maintained by the Yakama Nation are able to detect the timing and movement of juvenile and adult PIT tagged steelhead into the Columbia River and Rock Creek watershed.

Results: We PIT tagged a total of 208 juvenile *O. mykiss* in the spring of 2011. Most fish with fork lengths greater than 70-mm were collected from stratified reaches in Rock Creek between RKM 2 through RKM 17, and Squaw Creek RKM 0 through RKM 8. We did not meet our 1200 PIT tagged fish goal because of the juvenile mortality incident in 2010. It took approximately ten months to reapply for a new NOAA Section 4(d) Endangered Species Act Take Permit to continue the fish population surveys and PIT-tagging. Further PIT-tagging and analysis of PTIS detections will allow us to determine the primary areas of smolt productivity, which will aid in prioritizing areas for restoration and/or preservation.

Adult steelhead detections August 2009 to June 2011

From August 2009 to June 2011, a total of 23 adult steelhead PIT-tagged by other agencies were detected spending a portion of their life history or spawning in Rock Creek. Eleven fish were tagged as juveniles at Lower Granite Dam and transported by barge, indicating that the highest proportion of stray steelhead using Rock Creek were barged. Five fish were tagged and released from hatcheries in Idaho, one at the Hagerman Hatchery, one at the Irrigon Hatchery, one at Clearwater Hatchery, and two at the Magic Valley Hatchery. One fish was tagged in Trout Creek, a tributary of the Deschutes River. Six of the 23 steelhead were tagged as adults at the Bonneville Dam adult fish facility and had unknown juvenile rearing locations. Eight of the 23 fish were of hatchery origin; the other 15 fish were of wild origin. Nineteen of the 23 steelhead (83%) were detected about 100 km upriver of Rock Creek at the McNary Dam adult fish ladder prior to traveling into Rock Creek. The adult steelhead entered Rock Creek beginning in January, with most entering in March and the last one entering on April 12, 2011. Twelve of the 23 fish traveled and likely spawned, upstream of the Squaw Creek interrogation system. Much more of this information will be available as the fish we tagged as juveniles begin to return as adults.

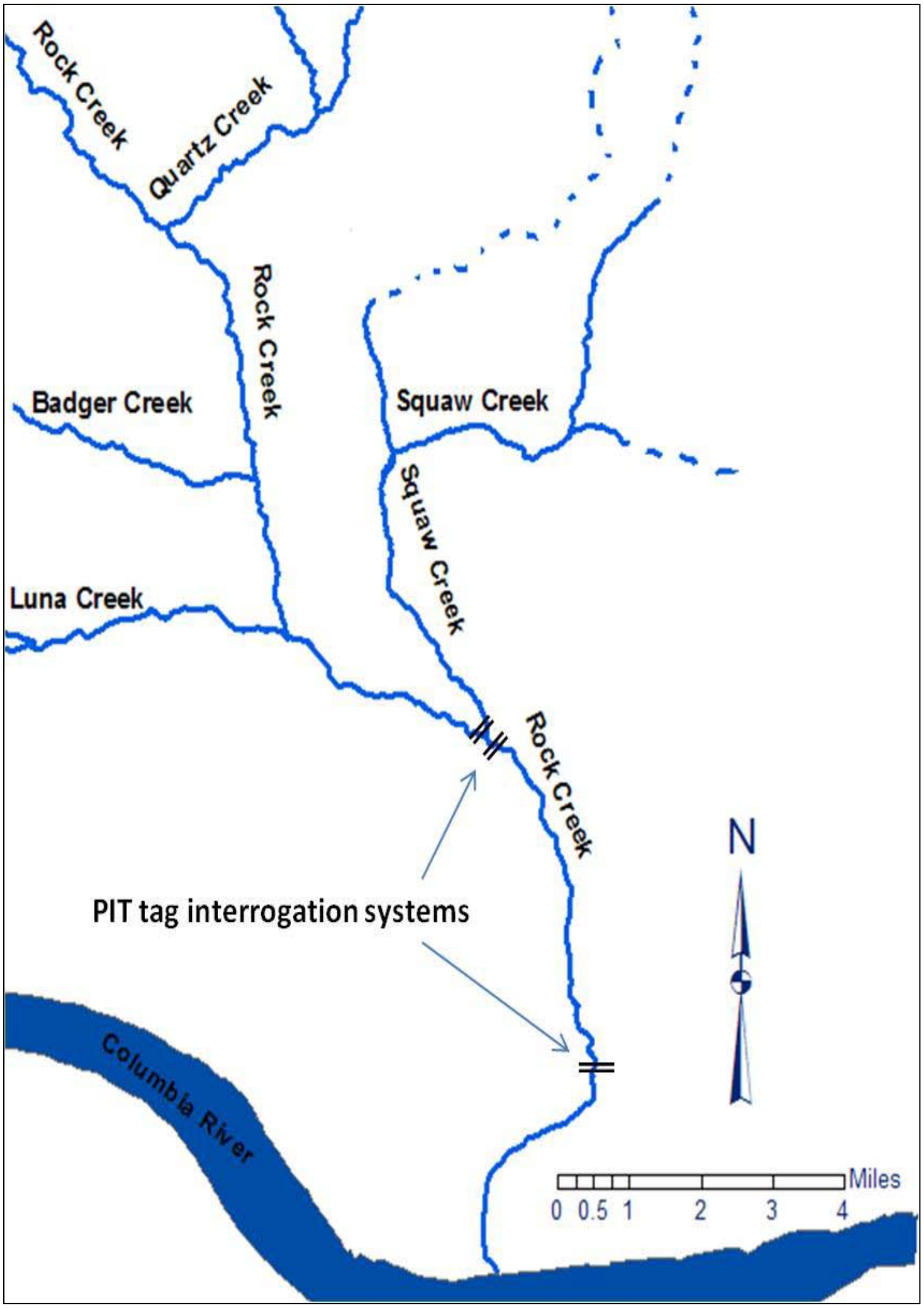


Figure 6. Locations of PIT-tag interrogation systems (PTIS) in Rock Creek subbasin.

Task 1.d Sediment Monitoring

Objective: To monitor sediment and substrate conditions at selected sites in the Rock Creek subbasin.

Methods: Surface substrate was sampled at two spawning sites in mainstem Rock Creek and one in Squaw Creek in 2009 and 2010. The first site is of particular interest for continuous monitoring due to the Klickitat County 2009 bridge replacement project at the Bickleton Bridge crossing. The second site is near the Rock Creek confluence where there has been observed fall Chinook, coho, and steelhead spawning in recent years. The third site is located in Squaw Creek within primary steelhead spawning habitat. Data collected is represented in Appendix B.

Wolman pebble count methodologies were used to conduct the sampling. Each pebble count used a systematic method of sampling material on the surface of the streambed and was used to develop a particle size distribution. Each measured particle represented a portion of the streambed covered by particles of a certain size, and not the percent by volume or weight. The procedure required an observer with a metric ruler or gravelometer to wade the stream and a second person to take notes. Particles were tallied using size classes that are either grouped or further refined using Wentworth size classes. Basically, size doubles with each class or smaller class; intervals are based on ½ phi values. The latter classes were generally used when detailed particle size data were needed.

To conduct the Wolman count, personnel selected a transect perpendicular to the stream in a scour pool tail-out or in a low-gradient riffle. At a minimum, one transect per habitat unit and/ or ten transects per stream segment are required. Starting at the bankfull stage mark, steps were made along the transect and the first particle encountered when placed in front of the sampler's toe was sampled. Each particle was measured at the intermediate axis with a metric ruler. For each transect, the particle counts for each size class are recorded on the Substrate Field Data Form.

The numbers generated from the Wolman pebble counts created a characterization of the composition of the streambed at one particular point in time at three observed spawning reaches. The composition of the streambed represented characteristics of the stream such as effects of flooding, sedimentation, or other physical impacts to the stream. The Wolman pebble count method is a tried and tested method for measuring sediment size on the bed surface.

Results: This year (2010) was the third year of monitoring, and future pebble counts will be conducted in additional reaches of Rock Creek to collect substrate attribute data to for the EDT model in 2011-2013. Summaries for each pebble count site are presented in Appendix B (Table B1 – Table B3). The results of the pebble count data collected during the two-year comparison monitoring effort at three spawning locations in the subbasin indicate the average substrate type for the Army Corps Park site was the coarse gravel type. The average substrate type found at both the Bickleton Bridge and the Squaw Creek sites, both located higher in the subbasin, was small cobble for both study years 2008 - 2010. The Army Corps Park site had a higher evidence of sand and sediments in 2009 than in the 2010 sampling season. The three-year comparisons for the Army Corps Park and Squaw Creek site indicate that there was a lower percentage of sands and fine sediments in 2009 than in 2010. Contingency table p-values for all three particle size criteria are less than 0.05 indicating there is a significant difference in fine sediment between the 2009 reference site and the 2010 study at the Squaw Creek and Bickleton Bridge site. The Army Corps of Engineers Park site indicated that only the 4mm particle size criterion was at 0.05, thus indicating that there is no significant difference between 2009 and 2010.

Task 1.e Temperature and water quality monitoring

Objective: Monitor stream temperature and water quality at selected sites on a seasonal basis to characterize the chemical and physical conditions of the subbasin at key locations.

Methods: Water temperature was monitored at ten sites throughout mainstem Rock Creek and its tributaries (Squaw, Harrison, Luna, Badger, and Quartz creeks). Water temperature measurements were taken at 30-minute increments using Onset Corporation Hobo temperature probes. Air temperature was monitored at three locations in the subbasin with the Hobo temperature probes. Basic water quality parameter measurements were recorded seasonally at eight sites (3 – 10 times per year). Water quality measurements were taken using aYSI-85 water quality meter. Parameters collected included dissolved oxygen, conductivity, turbidity and pH. During the summer of 2010 (July – September), an additional 18 Hobo temperature probes were placed into the electrofished pools where fish population surveys were conducted (Table 1).

Results: Summaries of water and air temperature data for each location are presented in Appendix C (Table C1). These summaries include (for each month during the reporting period): the number of days during which temperature was recorded; the number of times the daily minimum temperature was less than 0.5°C and 4.4°C; the number of times the daily average temperature was less than 0.5°C and 4.4°C; the number of times the daily maximum temperature was greater than 23°C and 24°C; the number of times the 7-day average daily maximum temperature was greater than 12°C, 16°C, 17.5°C, 18°C, and 22°C (the 7-day average daily maximum was calculated by averaging the daily maximum temperatures across the time period that started 3 days prior to and ended 3 days after a given day); the monthly 1-day maximum temperature (the highest instantaneous temperature recorded in a given month); the monthly 1-day maximum range (the largest daily range in temperature recorded during a given month); and the monthly average daily range (the average daily range in temperature recorded during a given month).

Water quality and temperature data were incorporated into the EDT Stream Reach Editor. Water quality measurements were conditional on the presence of actual instream flow. Sections of Rock Creek and its tributaries turn intermittent during the warmer summer months; groundwater-fed pools are distributed throughout the subbasin. Water quality was not recorded if there was no instream flow at the time of monthly site visit.

Water temperature was collected at 18 additional locations in Rock and Squaw Creek during July-September of 2010. These are the same locations where population estimates of salmonids occurred. This additional temperature monitoring aided in understanding how temperature affects fish distribution and population abundance in individual pools. A 16°C limit for surface water has been set by the Washington Department of Ecology as in 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). We recorded water temperatures that exceeded 16°C at all of the sites in 2010. Water temperature at 9 of 18 sites exceeded 20°C (Table 1).

Table 1. Number of days per year when maximum water temperature exceeded 16° and 20°C, and maximum water temperature recorded at locations in Rock Creek, July-September 2010. Data are from Onset Corporation's Stow Away and Tidbit temperature loggers. Sites are listed from downstream to upstream.

RKM	Number of days > 16 2010	Number of days >20 2010	Maximum 2010
Rock Creek			
11	81	45	23.8
13	85	0	18.9
14.2	86	18	21.2
16.9	92	0	18.2
18.7	59	2	21.0
18.8	46	1	21.5
25.7	29	0	19.8
27.1	36	0	18.2
27.5	38	0	18.1
Squaw Creek			
0.7	31	21	21.7
1.3	62	0	18.9
1.8	27	5	23.5
2.2	59	0	17.9
7.3	52	0	18.9
7.7	36	0	16.9
Quartz Creek			
0	45	1	20.2
0.5	50	6	20.8
0.6	53	11	20.9

Task 1.f Habitat assessment

Objective: The purpose of assessing habitat is to characterize the present state and processes that create and maintain it so that appropriate restoration options and obstacles can be identified and prioritized.

Methods: Rock Creek and its tributaries were stratified into reaches using a USGS topographical map (1:24,000) and stream geomorphologic features (e.g. gradient, channel confinement, and tributary confluences). Habitat surveys were conducted on 15 stream reaches throughout the subbasin using EDT methodologies. Each habitat survey reach assesses similar geomorphic characteristics throughout, such as pattern, slope, confinement, or sediment size. The information collected for each survey section included width measurements at wetted channel and ordinary high watermark; habitat type frequency and length; large woody debris and log jam counts; confinement; riparian function; and embeddedness observations (Murphy & Willis, 1996); (Harrelson et al., 1994).

Habitat types were divided into seven categories: primary pool, large cobble riffle, small cobble riffle, pool tailout, glide, off-channel habitat, or side channel. Large woody debris information was also included in the habitat surveys such as enumeration of wood pieces in the stream channel and tally of logs in log jams. Riparian function attributes and condition were also documented for each surveyed stream reach.

Results: Habitat data were input into the Rock Creek EDT model. Original habitat survey data (2008-2010) are stored in the EDT Access database. Habitat surveys will continue to be conducted for two more years (2011-2012) and the data incorporated into the EDT model. Model results are discussed in Appendix D.

Task 1.g Pathogen Sampling

Objective: Document pathogen presence and severity within the watershed. A sub-sample of fish captured during population studies and all fish incidentally killed during sampling for distribution and abundance will be put on ice and delivered to the U.S. Fish and Wildlife Service's Lower Columbia River Fish Health Center (LCRFHC) which will provide a thorough disease profile as part of the U.S Fish and Wildlife Service's National Wild Fish Health Survey. An approximate total of 60 samples of steelhead and 20-60 samples of other resident species were collected from the mainstem Rock Creek and Squaw Creek site locations including three survey sites in lower, middle, and upper reaches of mainstem Rock Creek. A baseline data set describing existing levels of pathogens in the watershed's salmonids will be uploaded to National Wild Fish Health Survey database http://www.fws.gov/wildfishsurvey to contribute to the development of a disease profile. The USFWS LCRFHC conduct pathogen analysis following the National Wild Fish Health Survey - Laboratory Procedures (Heil, 2009).

Methods: No samples were collected for pathogen analysis of Rock Creek juvenile steelhead/rainbow trout and other resident species.

Results: A USFWS pathogen analysis was not performed this year because during our spring juvenile population survey season we unexpectedly exceeded our NOAA Section 10 Take Permit for ESA-listed "threatened" Middle Columbia River Steelhead. During the 2011 contract year we plan to continue sending a sub-sample of fish captured during our juvenile population surveys to the USFWS Fish Health Center.

During fish surveys in 2009, 2010, and 2011, USGS and YN personnel detected blackspot (*Uvulifer ambloplitis)* and copepods (*Salmincola californiensis*) on juvenile steelhead and juvenile coho in the field.

2. EDT Modeling

Overall Objective: The Ecosystem Diagnosis and Treatment (EDT) model was utilized in this fish and habitat assessment to compare the historical and current habitat conditions of Rock Creek and its tributaries. The EDT model was applied to understand the effects of environmental attributes on each life history stage of each species to guide protection strategies and restoration measures consistent with the Rock Creek Steelhead DPS Recovery Plan.

Task 2.a EDT Database and modeling

Objective: The project's goals include establishing baseline data for watershed and habitat conditions in Rock Creek to prioritize sites for restoration. Data were collected, compiled, analyzed, and put into the EDT model. Historic watershed conditions were also researched and incorporated into the EDT model.

EDT modeling assessed the Rock Creek watershed and field investigations were conducted to assess the impact and magnitude of past land use activities, as well as identifying restoration opportunities and their potential benefits.

Methods: Stream reaches were delineated based on the geomorphic channel classification system according to characteristics such as stream gradient, confinement, channel morphology, bed material, and bedform pattern (Montgomery & Buffington, 1998). Environmental and biological attribute data was collected in fifteen geomorphic reaches throughout the subbasin. Data was compiled, analyzed, and put into the EDT model. Historic watershed conditions were researched (e.g. GLO maps, air photos, flow data) and incorporated into the EDT model. All data were evaluated and incorporated into the EDT Stream Reach Editor Access database. Model iterations and baseline reports were received from the Jones and Stokes EDT website http://www.edt.icfi.com/edt/.

Results: Baseline reports were created from the online EDT website. A baseline report for steelhead was generated and broken into four sections. The first report gave a graphical view of the reach with percent potential change in abundance, productivity, and diversity index for both degradation and restoration of each reach. The second report illustrated effects to compare each EDT stream reach with environmental attributes modeling various protection and restoration strategies (e.g. protection and restoration benefits). The third report illustrated effects on each life history stage by species under the current state of environmental attributes (e.g. channel stability, flow, food, harassment). The fourth report represented a reach-by-reach analysis of overall restoration or preservation benefit for each life history trajectory and productivity change. EDT model results for steelhead are included in Appendix D. All baseline reports will be used in the evaluation process of future restoration projects in Rock Creek and its tributaries. A list of potential key restoration and protection projects from the resultant EDT baseline reports was created for the Rock Creek subbasin.

The NMFS Middle Columbia Steelhead Recovery Plan and NPCC Rock Creek Subbasin Plan goals and objectives were also considered in the process of creating the priority list. Overall, EDT modeling assisted in subbasin and field investigations to further identify cumulative impacts and the magnitude of past land use activities. The EDT model will continue to be updated as additional information is incorporated.

A list of restoration and protection projects to benefit anadromous and resident fish species in the Rock Creek subbasin is shown in Table 2. Locations identified by the EDT model for restoration efforts are listed. In 2007 – 2008, the US Fish and Wildlife Service funded a riparian planting and cattle exclusion fence construction project in cooperation with Yakama Nation. In 2008- 2010, additional riparian planting of native tree species and invasive weed removal was continued to expand the riparian re-vegetation in Rock Creek between RM 4 – RM 6.

Restoration of degraded upland processes and floodplain function and channel migration processes have not begun. Additional assessment needs to be conducted and funding research pursued to locate specific sites for restoration projects. During the 2012 – 2013 field season, a companion study is being led by Yakama Nation in cooperation with the Eastern Klickitat Conservation District to assess geomorphic conditions and refine future project development for identified restoration sites in the subbasin.

Table 2. Implementation status of prioritized list of restoration and protection projects in Rock Creek.

Priority list for restoration and protection projects to benefit fall Chinook, coho, steelhead, and other native fish species in Rock Creek					
Identified Actions	EDT model Identified Locations	Actual Restoration Efforts	Implementing Source	Restoration Location Status	Implement Year
1. Restore riparian condition and function					
Actions:	Rock Creek mouth to Luna Creek confluence	1. Native riparian revegetation	Yakama Nation / USFWS	Rock Creek mainstem RM 4-6	2007-2008
a. restore and enhance natural vegetative communiti es	Luna Creek	2. Native riparian revegetation	Yakama Nation / BPA	Rock Creek mainstem RM 4-6	2008-2010
b. develop grazing strategies to promote riparian recovery	Badger Creek	3. Local rancher outreach	Yakama Nation / BPA	Sub-basin wide	2008-2010
c. eraticate invasive plant species from riparian areas	Squaw Creek	4. Invasive weed removal	Yakama Nation / BPA	Rock Creek mainstem RM 4-6	2008-2010
2. Improve degraded water quality and reduce water temperatures					
Actions:	Rock Creek mouth to Badger Creek confluence	1.Native riparian revegetation	YN / USFW'S / BPA	Rock Creek mainstem RM 4-6	2007-2010
a. restore natural functions and processes through actions above	Luna Creek	2. Invasive weed removal	Yakama Nation / BPA	Rock Creek mainstem RM 4-6	2008-2010
b. construct water and sediment control basins	Badger Creek				
	Squaw Creek				
	Harrison Creek				
3. Restore degraded upland processes					
Actions:	Rock Creek	1. Local landowner outreach	Yakama Nation / BPA	Sub-basin wide	2008-2010
a. restore natve upland plant communities	Luna Creek	2. Need additional assessment	Multiple agencies	Sub-basin wide	2011 2017
b. implement BMP's on forest, agriculture, and grazing lands	Badger Creek				
c. implement road management actions to reduce erosion and sediment imputs					
4. Restore floodplain function and channel migration processes					
Actions:	Rock Creek	1. Need additional assessment	Yakama Nation / BPA	Identified restoration sites	2015-2017
a. reconnect side channels	Squaw Creek				
b. remove dikes	Luna Gulch				
c. reconnect floodplain channel					
d. relocate or improve floodplain infrastructure and roads					

3. Genetics

Overall objective: Utilize genetic techniques to determine the genetic population structure of Rock Creek steelhead trout. These analyses will be coupled with genetic sampling in adjacent subbasins and will aid in understanding genetic similarities and differences with other populations in the Columbia River Basin. Genetic sampling and analysis will also determine the extent to which unmarked hatchery steelhead stray into the subbasin.

Task 3.a Genetic sample collection, data synthesis and analysis

Objective: Compare genetic samples collected from fish population sampling sites for heterogeneity and population differences within the subbasin.

Methods: In 2009, samples were collected from a total of seven sampling sites in the Rock Creek mainstem and in Squaw Creek. A total of 59 genetic samples were collected: 30 samples were collected in Squaw Creek and 29 samples were collected from mainstem Rock Creek. In 2010 - 2011, a stratified approach was used during sampling and an additional 100 samples were submitted to the geneticists for analysis. Samples were collected from a total of 20 sites in Rock Creek (RKM 1- RKM 35), Squaw Creek (RKM 0 – RKM 8), and one site in Luna Creek (RKM 0.1). Tissue samples (fin clips) from a sub-sample of juvenile steelhead captured during electrofishing were removed and preserved (95% ethanol) for genetic analysis.

Results: In this evaluation the geneticists characterized the juvenile steelhead trout by using two, 96-SNP panels developed by Columbia River Inter-Tribal Fish Commission (CRITFC). A total of 155 samples were submitted to the CRITFC Hagerman (Idaho) Genetics Lab. Genomic DNA was extracted from digested tissue samples using a standard Qiagen® DNeasy™ protocol and descriptive statistics including allele frequencies using the analysis program GenAlEx version 6.2. A genetic stock identification (GSI) analysis was conducted in order to ascertain the probable orgin/s of the sampled Rock Creek and Squaw Creek population.

The results of the genetic analysis indicated genetic similarity between collections of juvenile *O. mykiss* within the Rock Creek watershed (including Squaw Creek tributary) and Snake River stocks. Other studies suggest a relatively high stray rate within middle Columbia River tributaries including the Klickitat River and Deschutes River (Matala 2012). A detailed genetics report is included in Appendix E.

4. Revegetation

Overall objective: Plant native trees in Rock Creek riparian zones. Native trees and shrubs include alder *(Alnus spp.),* black cottonwood *(Populus trichocarpa),* ponderosa pine *(Pinus ponderosa),* red-osier dogwood *(Cornus stolonifera),* chokecherry *(Prunus virginiana)* and coyote willow *(Salix exigua).* All of the chosen plant species are native to the Rock Creek watershed, and 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.

Task 4.a Tree planting and weed removal

Objective: Identify key sites for revegetation from an evaluation of orthophotos, topographic maps and site visits. Locate willow stands for future cutting collection. Prepare planting sites prior to planting, and plant trees. Manually remove invasive weeds within the tree-planting locations and dispose of weeds.

Methods: Site visits were conducted throughout the Rock Creek subbasin to identify native vegetation in various riparian zones. Large and healthy willow bunches were identified for future willow-cutting sites. The Rock Creek subbasin turns intermittent through the summer months and sufficient soil moisture is essential for the survival and growth of the trees. Topographic maps were used to identify where springs and groundwater may be available to support tree plantings, and revegetation sites were chosen based on their proximity to these sites and soil moisture. Site preparation was conducted prior to tree planting with brush and debris clearing. Trees were planted during the early spring months (late February and early March) when the soil was saturated to allow for root establishment and growth. Weed mats were tacked onto the earth below the trees with pins. Star thistle, bull thistle, and other invasive weeds were hand removed from tree planting sites and areas nearby to prevent encroachment.

Results: 200 live-stake willow cuttings and 150 rooted trees were planted along 2.0 riparian acres of Rock Creek (between RM 3.5 and RM 4). Hand watering each plant once a week during the summer sustained them until the fall rains. Weeds were controlled over a total of 2 riparian acres including some hand removal in upland areas to discourage encroachment into planting sites. There was approximately 50% survival of total trees and shrubs planted in the riparian area.

Task 4.b Willow nursery

Objective: Create nursery of native willow cuttings (coyote willow, *Salix exigua*) collected from Rock Creek to plant in containers for future planting opportunities in Rock Creek. The objective is to plant native willows, from Rock Creek, adapted to local conditions, from Rock Creek at sites throughout the subbasin. From previous year's experience, the coyote willow had higher survival in the nursery (from live cutting to root and stem development) than through live stake plantings.

Methods: Two hundred willow cuttings were collected from three sites for growing in containers. Coyote willow was collected from large, healthy bunches. Willows were taken back to the nursery and soaked in water for two weeks. A nursery was constructed to house the containerized willows. Rooted willow cuttings were planted in the containers and watered 2-3 times per week.

Results: Two hundred willows were planted in the nursery with a 65% survival rate. The willows that survived will be planted in the spring of 2011. Willows are watered 2-3 times per week during the warm summer months. During the spring of 2011, additional willow cutting will be collected and planted in the nursery for future revegetation purposes.

5. Appendices

Appenidix A. Spawning ground survey results for fall Chinook, coho and steelhead

Table A1. Fall Chinook spawning survey tabular data.

Results of 2010 Fall Chinook spawning surveys in the Rock Creek Subbasin

			#	Reach Redds	Redds	Live Observed			Morts		
Stream	Reach	Miles	Passes	Totals	/Mile	Floy Tag	No Floy	Unknown	Floy Tag	No Floy	Unknown
Mainstem	Rock Creek conflu. to Hwy 8 Bridge	2.5	3	6	0.8	0	0	2	0	2	0
	Mainstem Totals (surveyed reach)	2.5		6	0.8	0	0	2	0	2	0

Results of 2009 Fall Chinook spawning surveys in the Rock Creek Subbasin

			#	Reach Redds	Redds	Live Observed			Morts		
Stream	Reach	Miles	Passes	Totals	/Mile	Floy Tag	No Floy	Unknown	Floy Tag	No Floy	Unknown
Mainstem	Rock Creek conflu. to Hwy 8 Bridge	2.5	2	0	0	0	0	0	0	0	0
	Mainstem Totals (surveyed reach)	2.5		0	0	0	0	0	0	0	0

Table A2. Coho spawning survey tabular data.

Results of 2010 - 2011 Coho spawning surveys in the Rock Creek Subbasin

			#	Reach Redds	Redds	Live Observed			Morts		
Stream	Reach	Miles	Passes	Totals	/Mile	Floy Tag	No Floy	Unknown	Floy Tag	No Floy	Unknown
Mainstem	Rock Creek conflu. to Hwy 8 Bridge	2.5	3	2	0.8	0	0	3	0	1	0
	Mainstem Totals (surveyed reach)	2.5		2	0.8	0	0	3	0	1	0

Results of 2009 - 2010 Coho spawning surveys in the Rock Creek Subbasin

			#	Reach Redds	Redds	Live Observed			Morts		
Stream	Reach	Miles	Passes	Totals	/Mile	Floy Tag	No Floy	Unknown	Floy Tag	No Floy	Unknown
Mainstem	Rock Creek conflu. to Hwy 8 Bridge	2.5	2	0	0	0	0	1	0	0	0
	Mainstem Totals (surveyed reach)	2.5		0	0	0	0	1	0	0	0

Table A3. Steelhead spawning survey tabular data.

Results of 2011 Steelhead spawning surveys in the Rock Creek Subbasin											
				Reach							
			#	Redds	Redds	Live Observed			Morts		
Stream	Reach	Miles	Passes	Totals	/Mile	Floy Tag	No Floy	Unknown	Floy Tag	No Floy	Unknown
Mainstem	Rock Creek Boat Launch to Hwy 8 Bridge	3.6	3	21	5.83	2	18	0	0	1	0
	Hwy 8 Bridge to Squaw Cr, confluence	5.6	3	60	10.71	0	20	14	0	1	0
	Squaw Cr. confluence to Unnamed Trib.	7.02	2	95	13.53	0	15	0	0	0	0
	Unnamed Trib. to first Rock Creek falls	4.58	2	11	2.4	0	2	2	0	0	0
	Mainstem Totals (surveyed reaches)	20.8		187	30.08	2	55	16	0	2	0
Tributaries	Luna Creek	0.5	3	5	10	0	0	5	0	0	0
	Squaw Cr. at confluence tg end of survey	4.97	3	95	19.11	0	0	73	0	0	0
	Badger Gulch at confluence	0.5	3	0	0	0	0	3	0	0	0
	Tributary Totals (surveyed reaches)	5.97		100	29.11	0	0	81	0	0	0
	Rock Creek subbasin Totals	**26.77**		**287**		**2**	**55**	**97**	**0**	**2**	**0**
	Mainstem Contribution %			*65*		*100*	*100*	*16*	~	*100*	~
	Tributary Contribution %			*35*		*0*	*0*	*84*	~	*0*	~

Results of 2010 Steelhead spawning surveys in the Rock Creek Subbasin											
				Reach							
			#	Redds	Redds	Live Observed			Morts		
Stream	Reach	Miles	Passes	Totals	/Mile	Floy Tag	No Floy	Unknown	Floy Tag	No Floy	Unknown
Mainstem	Rock Creek Boat Launch to Squaw Cr.	6.7	3	63	9.40	0	45	0	1	2	2
	Rock Creek Luna confl. to Bick Br.	2.5	3	26	10.40	0	18	0	0	0	0
	Mainstem Totals (surveyed reaches)	9.2		89	19.80	0	63	21	1	2	0
Tributaries	Luna Creek	1.5	3	0	0.00	0	0	0	0	0	0
	Squaw Creek at confluence	1.25	3	27	21.60	0	0	10	0	0	0
	Squaw Creek at Harrison conflu.	1.25	2	11	8.80	0	0	10	0	0	0
	Harrison Creek confluence	1	2	0	0.00	0	0	0	0	0	0
	Badger Gulch at confluence	0.5	3	0	0.00	0	0	0	0	0	0
	Tributary Totals (surveyed reaches)	5.5		38	30.40	0	0	20	0	0	0
	Rock Creek subbasin Totals	**14.7**		**127**		**0**	**63**	**41**	**1**	**2**	**0**
	Mainstem Contribution %			*70*		~	*100*	*51*	~	*100*	~
	Tributary Contribution %			*30*		~	*0*	*49*	~	*0*	~

Appendix B. Sediment sampling data from 2009 -2010

Table B1. Army Corps of Engineers Park of lower Rock Creek (RM 2) tabular data.

Reference (2009) and study (2010) particle size comparisons (2mm, 4mm, 8mm)

2mm

	<	> or =	Total
Reference	6	101	107
Study	22	95	117
Total	28	196	224

Reference <	Study <	Average <	Average >=
5.6%	18.8%	12.5%	87.5%
		p-value	0.0027

4 mm

	<	> or =	Total
Reference	29	71	100
Study	28	72	100
Total	57	143	200

Reference <	Study <	Average <	Average >=
29.0%	28.0%	28.5%	71.5%
		p-value	0.5000

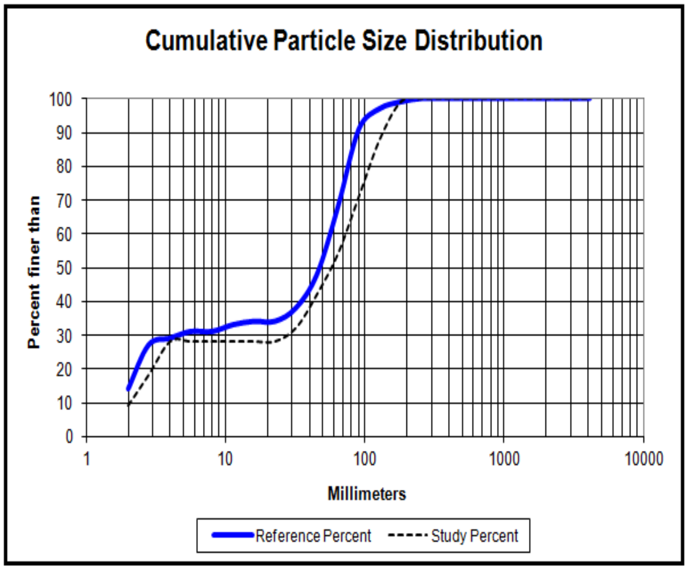
8 mm

	<	> or =	Total
Reference	31	69	100
Study	28	72	100
Total	59	141	200

Reference <	Study <	Average <	Average >=
31.0%	28.0%	29.5%	70.5%
		p-value	0.3782

Cumulative Distribution

Size finer than (mm)	Reference Percent	Study Percent
2	14	9
2.8	27	18
4	29	28
5.6	31	28
8	31	28
11.3	33	28
16	34	28
22.6	34	28
32	38	32
45.3	48	42
64	68	54
90.5	91	71
128	97	88
181	99	99
256	100	100
362	100	100
512	100	100
1024	100	100
2048	100	100
4096	100	100



Histogram

Size finer than (mm)	Reference Percent	Study Percent
2	14	9
2.8	13	9
4	2	10
5.6	2	0
8	0	0
11.3	2	0
16	1	0
22.6	0	0
32	4	4
45.3	10	10
64	20	12
90.5	23	17
128	6	17
181	2	11
256	1	1
362	0	0
512	0	0
1024	0	0
2048	0	0
4096	0	0

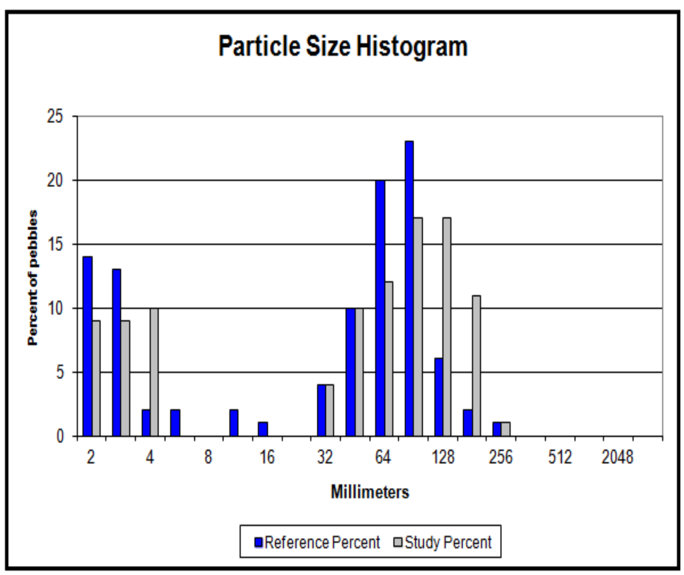


Table B2. Bickleton Bridge (Bridge Replacement Site) of Rock Creek (RM 13) tabular data.

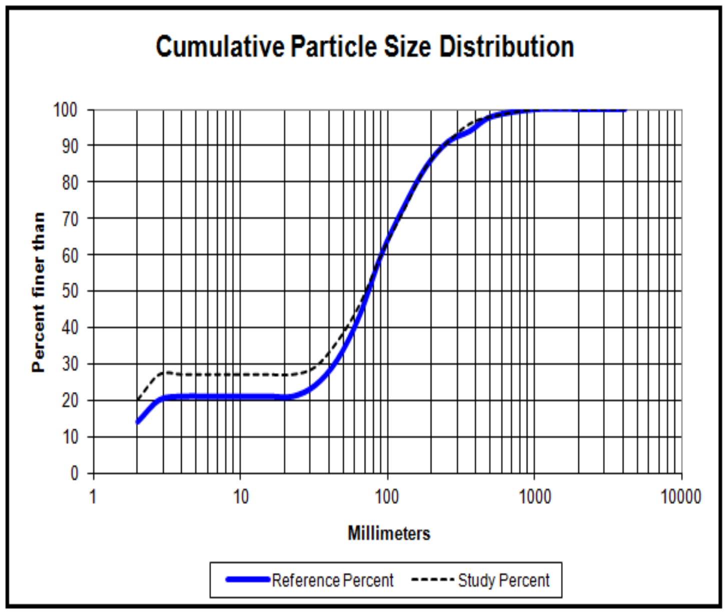
Reference (2009) and study (2010) particle size comparisons (2mm, 4mm, 8mm)

2mm			
	<	> or =	Total
Reference	6	101	107
Study	22	95	117
Total	28	196	224
Reference <	Study <	Average <	Average >=
5.6%	18.8%	12.5%	87.5%
		p-value	0.0027

4 mm			
	<	> or =	Total
Reference	21	79	100
Study	27	73	100
Total	48	152	200
Reference <	Study <	Average <	Average >=
21.0%	27.0%	24.0%	76.0%
		p-value	0.2039

8 mm			
	<	> or =	Total
Reference	21	79	100
Study	27	73	100
Total	48	152	200
Reference <	Study <	Average <	Average >=
21.0%	27.0%	24.0%	76.0%
		p-value	0.2039

Cumulative Distribution		
Size finer than (mm)	Reference Percent	Study Percent
2	14	20
2.8	20	27
4	21	27
5.6	21	27
8	21	27
11.3	21	27
16	21	27
22.6	21	27
32	24	29
45.3	31	36
64	43	46
90.5	60	60
128	73	72
181	84	84
256	91	91
362	94	96
512	98	98
1024	100	100
2048	100	100
4096	100	100



Histogram		
Size finer than (mm)	Reference Percent	Study Percent
2	14	20
2.8	6	7
4	1	0
5.6	0	0
8	0	0
11.3	0	0
16	0	0
22.6	0	0
32	3	2
45.3	7	7
64	12	10
90.5	17	14
128	13	12
181	11	12
256	7	7
362	3	5
512	4	2
1024	2	2
2048	0	0
4096	0	0

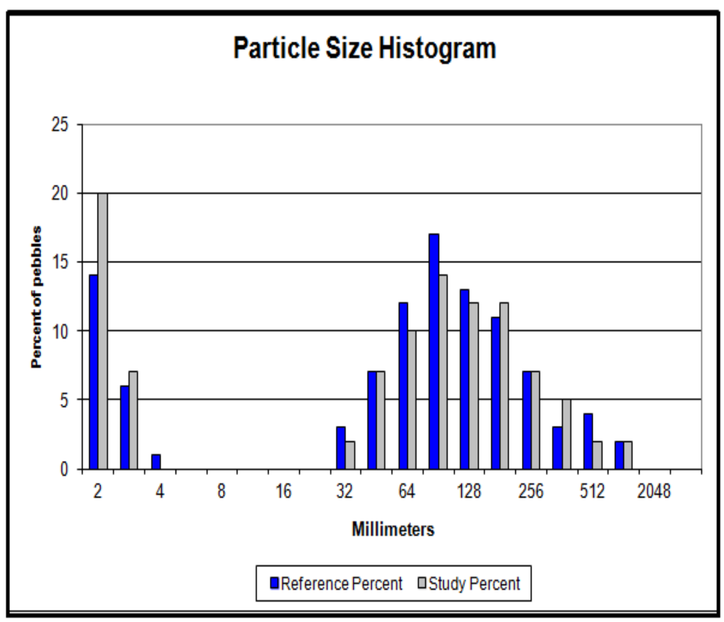


Table B3. Squaw Creek (RM 1) tabular data.

Reference (2009) and study (2010) particle size comparisons (2mm, 4mm, 8mm)

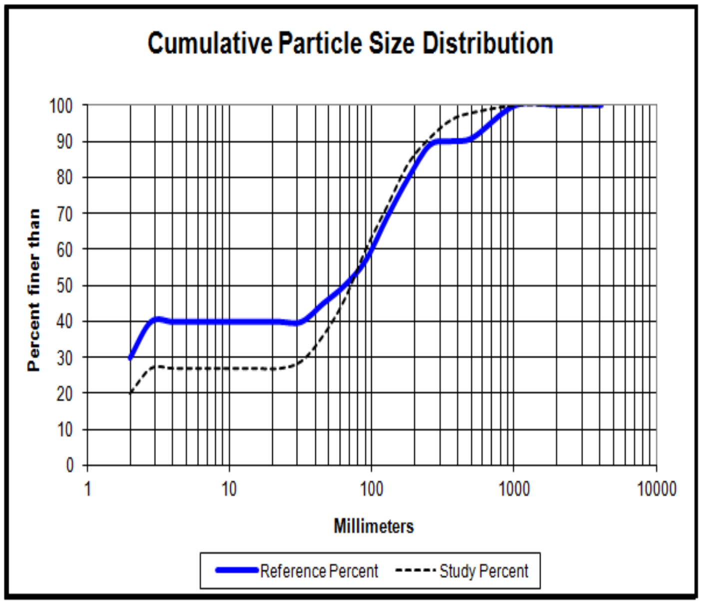
2mm	<	> or =	Total
Reference	6	101	107
Study	22	95	117
Total	28	196	224
Reference <	Study <	Average <	Average >=
5.6%	18.8%	12.5%	87.5%
		p-value	0.0027

4 mm	<	> or =	Total
Reference	40	60	100
Study	27	73	100
Total	67	133	200
Reference <	Study <	Average <	Average >=
40.0%	27.0%	33.5%	66.5%
		p-value	0.0361

8 mm	<	> or =	Total
Reference	40	60	100
Study	27	73	100
Total	67	133	200
Reference <	Study <	Average <	Average >=
40.0%	27.0%	33.5%	66.5%
		p-value	0.0361

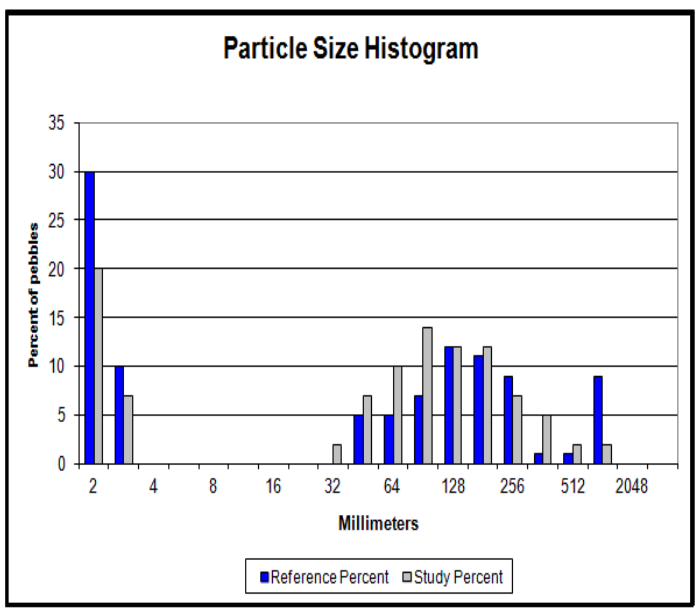
Cumulative Distribution

Size finer than (mm)	Reference Percent	Study Percent
2	30	20
2.8	40	27
4	40	27
5.6	40	27
8	40	27
11.3	40	27
16	40	27
22.6	40	27
32	40	29
45.3	45	36
64	50	46
90.5	57	60
128	69	72
181	80	84
256	89	91
362	90	96
512	91	98
1024	100	100
2048	100	100
4096	100	100



Histogram

Size finer than (mm)	Reference Percent	Study Percent
2	30	20
2.8	10	7
4	0	0
5.6	0	0
8	0	0
11.3	0	0
16	0	0
22.6	0	0
32	0	2
45.3	5	7
64	5	10
90.5	7	14
128	12	12
181	11	12
256	9	7
362	1	5
512	1	2
1024	9	2
2048	0	0
4096	0	0



Appendix C. Temperature monitoring

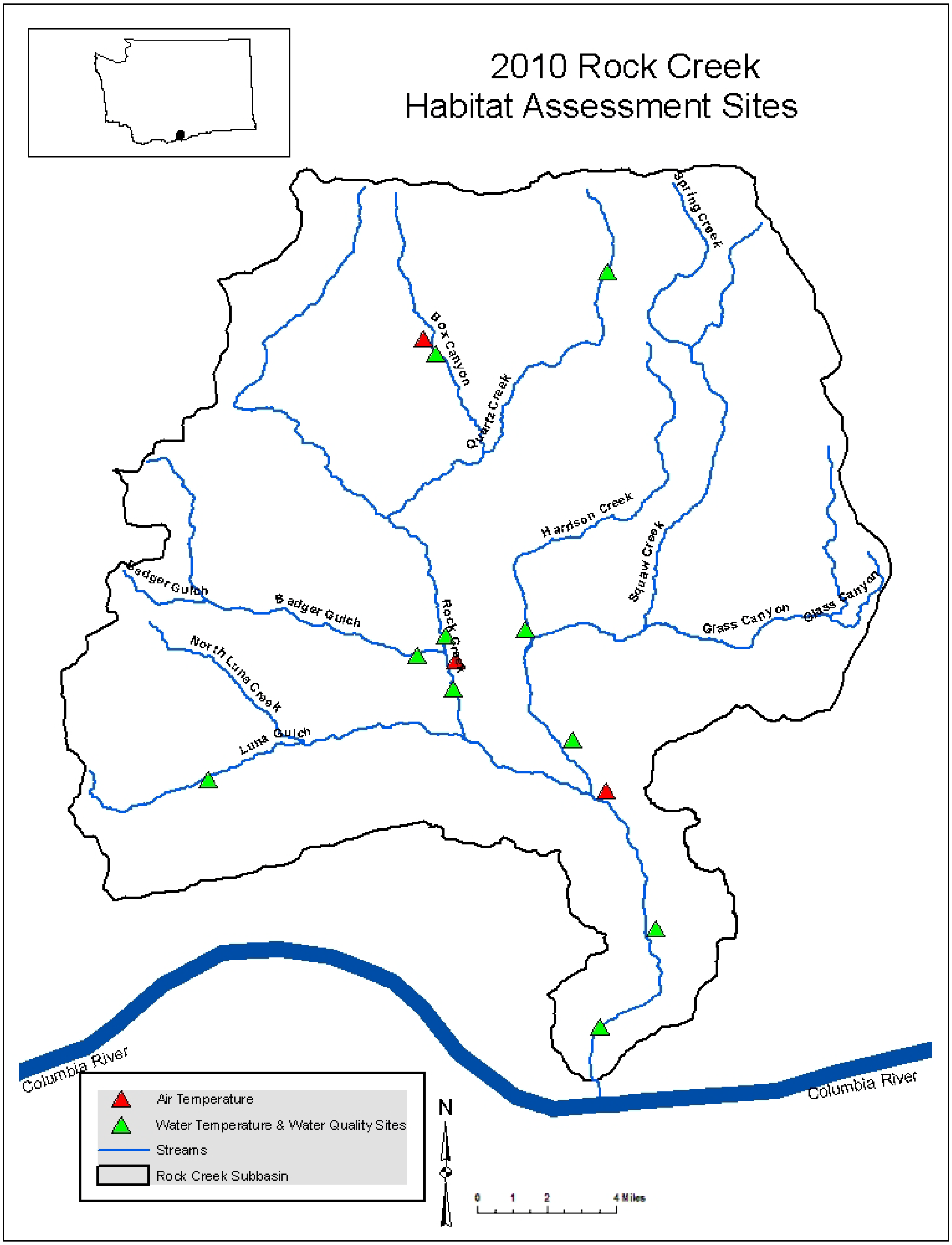


Figure C1. Air/water temperature and water quality monitoring sites in Rock Creek subbasin 2010.

Table C1. Monthly stream and air temperature summaries from 13 sites (10 stream sites, 3 air sites) in the Rock Creek subbasin for the reporting period (6/1/2010 – 5/31/2011). All temperatures and ranges in degree Celsius. "—" indicates no data. See description under Temperature monitoring section in the narrative for an explanation of metrics used.

Monthly Temperature Summaries (degrees C)

Army Corps Park Water Temperature

2010	# Days Recorded	# 1Day Min < 0.5	# 1Day Min < 4.4	# 1Day Avg <0.5	# 1Day Avg <4.4	# 1Day Max >23	# 1Day Max >24	#7Day Avg Daily Max >12	#7Day Avg Daily Max >16	#7Day Avg Daily Max >17.5	#7Day Avg Daily Max >18	#7Day Avg Daily Max >22	Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
June	30	0	0	0	0	2	0	30	30	30	29	4	23.8	6.8	5.0
July	31	0	0	0	0	23	16	31	31	31	31	28	25.6	7.2	5.6
August	31	0	0	0	0	10	5	31	31	31	31	18	24.6	5.5	3.8
September	30	0	0	0	0	0	0	30	30	30	30	0	21.4	5.1	3.5
October	31	0	0	0	0	0	0	31	9	3	2	0	19.8	4.6	2.2
November	30	0	2	0	1	0	0	9	0	0	0	0	16.4	2.4	1.5
December	31	0	10	0	7	0	0	0	0	0	0	0	7.4	2.7	1.0

Army Corps Park Water Temperature

2011	# Days Recorded	# 1Day Min < 0.5	# 1Day Min < 4.4	# 1Day Avg <0.5	# 1Day Avg <4.4	# 1Day Max >23	# 1Day Max >24	#7Day Avg Daily Max >12	#7Day Avg Daily Max >16	#7Day Avg Daily Max >17.5	#7Day Avg Daily Max >18	#7Day Avg Daily Max >22	Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
January	5	2	5	0	5	1	1	0	0	0	0	0	24.5	26.7	7.8
February		0	0	0	0	0	0	0	0	0	0	0	--	--	--
March	31	0	4	0	0	1	1	0	0	0	0	0	25.4	20.0	3.3
April	30	0	0	0	0	0	0	8	0	0	0	0	14.1	6.5	4.3

Bickleton Bridge Water Temperature

2010	# Days	# 1Day Min		# 1Day Avg		# 1Day Max		#7Day Avg Daily Max					Monthly 1-	Monthly - 1 Day	Monthly Avg
	Recorded	< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22	Day Max	Max Range	Daily Range
June	30	0	0	0	0	0	0	30	10	4	1	0	18.9	4.2	2.9
July	31	0	0	0	0	0	0	31	31	26	25	0	21.3	4.4	3.5
August	31	0	0	0	0	0	0	31	31	29	28	0	21.1	3.6	2.9
September	30	0	0	0	0	0	0	30	29	3	0	0	18.6	3.1	2.3
October	31	0	0	0	0	0	0	14	3	0	0	0	17.2	2.7	1.8
November	30	0	9	0	8	0	0	0	0	0	0	0	12.3	2.4	1.5
December	31	1	30	0	26	0	0	0	0	0	0	0	5.9	1.8	0.9

Bickleton Bridge Water Temperature

2011	# Days	# 1Day Min		# 1Day Avg		# 1Day Max		#7Day Avg Daily Max					Monthly 1-	Monthly 1- Day	Monthly Avg
	Recorded	< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22	Day Max	Max Range	Daily Range
January	31	6	25	2	17	0	0	0	0	0	0	0	7.0	2.6	1.4
February	28	4	23	2	19	0	0	0	0	0	0	0	6.4	3.5	1.8
March	31	0	25	0	9	0	0	0	0	0	0	0	9.6	3.6	2.4
April	30	0	9	0	0	0	0	0	0	0	0	0	10.5	5.9	3.7

Bickleton Bridge Air Temperature

2010	# Days	# 1Day Min		# 1Day Avg		# 1Day Max		#7Day Avg Daily Max					Monthly	1- Monthly 1 - Day	Monthly Avg
	Recorded	< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22	Day Max	Max Range	Daily Range
June	30	0	1	0	0	13	10	30	30	30	30	16	30.2	18.8	13.7
July	31	0	0	0	0	27	25	31	31	31	31	31	36.8	23.9	17.8
August	31	0	0	0	0	27	25	31	31	31	31	31	36.2	23.6	16.7
September	30	0	0	0	0	17	16	30	30	30	30	21	31.2	21.5	13.5
October	31	3	16	0	0	2	2	30	22	21	20	4	26.6	21.4	13.4
November	30	19	24	9	18	0	0	11	5	0	0	0	22.1	17.6	9.6
December	31	28	31	16	28	0	0	0	0	0	0	0	11.7	10.8	5.0

Bickleton Bridge Air Temperature

2011	# Days	# 1Day Min		# 1Day Avg		# 1Day Max		#7Day Avg Daily Max					Monthly 1- Day Max	Monthly 1- Day Max Range	Monthly Avg Daily Range
	Recorded	< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	23	28	11	20	0	0	5	0	0	0	0	15.5	16.5	9.2
February	28	23	27	6	18	0	0	8	0	0	0	0	17.9	19.3	11.8
March	31	21	27	0	14	0	0	27	1	0	0	0	18.7	17.5	12.7
April	30	15	25	0	1	2	2	30	13	6	2	0	24.6	25.2	14.7

Box Canyon Road Water Temperature

2010	# Days	# 1Day Min		# 1Day Avg		# 1Day Max		#7Day Avg Daily Max					Monthly 1- Day Max	Monthly 1- Day Max Range	Monthly Avg Daily Range
	Recorded	< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
June	30	0	0	0	0	0	0	27	4	0	0	0	17.3	6.4	4.7
July	2	0	0	0	0	0	0	2	0	0	0	0	14.5	4.1	3.0
August		0	0	0	0	0	0	0	0	0	0	0	--	--	--
September		0	0	0	0	0	0	0	0	0	0	0	--	--	--
October		0	0	0	0	0	0	0	0	0	0	0	--	--	--
November	22	3	11	0	9	1	1	1	0	0	0	0	29.7	25.3	3.1
December	31	2	31	1	31	0	0	0	0	0	0	0	4.7	2.3	1.1

Box Canyon Road Water Temperature

2011	# Days	# 1Day Min		# 1Day Avg		# 1Day Max		#7Day Avg Daily Max					Monthly 1- Day Max	Monthly 1- Day Max Range	Monthly Avg Daily Range
	Recorded	< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	6	31	5	27	0	0	0	0	0	0	0	5.5	2.0	1.2
February	28	9	28	4	28	0	0	0	0	0	0	0	4.8	2.7	1.5
March	31	1	29	0	29	0	0	0	0	0	0	0	6.4	3.0	1.9
April	30	0	30	0	8	0	0	0	0	0	0	0	8.8	6.1	3.8

Box Canyon Road Air Temperature

2010	# Days Recorded	# 1Day Min < 0.5	# 1Day Min < 4.4	# 1Day Avg <0.5	# 1Day Avg <4.4	# 1Day Max >23	# 1Day Max >24	#7Day Avg Daily Max >12	#7Day Avg Daily Max >16	#7Day Avg Daily Max >17.5	#7Day Avg Daily Max >18	#7Day Avg Daily Max >22	Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
June	30	2	14	0	0	7	7	30	26	20	16	7	26.3	19.8	14.1
July	31	1	7	0	0	24	22	31	31	31	31	27	31.9	22.9	18.5
August	31	0	9	0	0	23	20	31	31	31	30	26	33.2	23.8	18.0
September	30	4	11	0	0	11	6	30	29	26	23	6	28.6	21.6	14.8
October	31	17	25	0	7	2	2	22	7	5	5	1	26.4	21.5	13.2
November	30	23	28	18	20	0	0	1	0	0	0	0	14.4	14.9	8.5
December	31	30	31	27	31	0	0	0	0	0	0	0	7.4	12.1	5.1

Box Canyon Road Air Temperature

2011	# Days Recorded	# 1Day Min < 0.5	# 1Day Min < 4.4	# 1Day Avg <0.5	# 1Day Avg <4.4	# 1Day Max >23	# 1Day Max >24	#7Day Avg Daily Max >12	#7Day Avg Daily Max >16	#7Day Avg Daily Max >17.5	#7Day Avg Daily Max >18	#7Day Avg Daily Max >22	Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
January	31	26	30	15	27	0	0	0	0	0	0	0	13.4	15.3	8.3
February	28	25	28	20	27	0	0	0	0	0	0	0	12.6	17.9	9.7
March	31	28	29	11	29	0	0	0	0	0	0	0	13.3	13.0	8.7
April	30	23	29	1	24	0	0	0	0	0	0	0	17.3	17.4	11.2

Longhouse Site Water Temperature

2010	# Days Recorded	# 1Day Min < 0.5	# 1Day Min < 4.4	# 1Day Avg <0.5	# 1Day Avg <4.4	# 1Day Max >23	# 1Day Max >24	#7Day Avg Daily Max >12	#7Day Avg Daily Max >16	#7Day Avg Daily Max >17.5	#7Day Avg Daily Max >18	#7Day Avg Daily Max >22	Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
June	30	0	0	0	0	0	0	30	30	27	25	0	21.4	5.7	4.2
July	31	0	0	0	0	4	0	31	31	31	31	9	23.4	5.2	4.2
August	31	0	0	0	0	14	5	31	31	31	31	23	24.7	6.9	5.0
September	30	0	0	0	0	0	0	30	30	30	30	0	21.8	6.3	4.2
October	31	0	0	0	0	0	0	31	8	3	2	0	19.5	3.9	2.1
November	30	0	0	0	0	0	0	18	0	0	0	0	14.8	1.6	0.9
December	31	0	6	0	3	0	0	0	0	0	0	0	8.6	3.5	0.8

Longhouse Site Water Temperature

2011	# Days Recorded	# 1Day Min < 0.5	# 1Day Min < 4.4	# 1Day Avg <0.5	# 1Day Avg <4.4	# 1Day Max >23	# 1Day Max >24	#7Day Avg Daily Max >12	#7Day Avg Daily Max >16	#7Day Avg Daily Max >17.5	#7Day Avg Daily Max >18	#7Day Avg Daily Max >22	Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
January	31	0	16	0	11	1	1	7	0	0	0	0	48.1	43.5	2.7
February	28	1	17	0	7	0	0	0	0	0	0	0	7.9	3.5	2.3
March	31	0	7	0	0	0	0	0	0	0	0	0	11.3	3.9	2.6
April	30	0	0	0	0	0	0	7	0	0	0	0	13.7	6.2	4.1

Luna Creek Water Temperature

2010	# Days Recorded	# 1Day Min < 0.5	# 1Day Min < 4.4	# 1Day Avg <0.5	# 1Day Avg <4.4	# 1Day Max >23	# 1Day Max >24	#7Day Avg Daily Max >12	#7Day Avg Daily Max >16	#7Day Avg Daily Max >17.5	#7Day Avg Daily Max >18	#7Day Avg Daily Max >22	Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
June	30	0	0	0	0	0	0	30	0	0	0	0	15.7	5.0	2.6
July	31	0	0	0	0	0	0	31	0	0	0	0	16.1	2.8	1.9
August	31	0	0	0	0	0	0	31	0	0	0	0	15.6	2.0	1.3
September	30	0	0	0	0	0	0	30	0	0	0	0	14.7	2.1	1.3
October	31	0	0	0	0	0	0	9	0	0	0	0	14.1	2.7	1.6
November	30	0	0	0	0	0	0	0	0	0	0	0	10.6	1.6	1.0
December	31	1	26	0	21	0	0	0	0	0	0	0	6.2	2.6	1.3

Luna Creek Water Temperature

2011	# Days Recorded	# 1Day Min < 0.5	# 1Day Min < 4.4	# 1Day Avg <0.5	# 1Day Avg <4.4	# 1Day Max >23	# 1Day Max >24	#7Day Avg Daily Max >12	#7Day Avg Daily Max >16	#7Day Avg Daily Max >17.5	#7Day Avg Daily Max >18	#7Day Avg Daily Max >22	Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
January	31	3	28	0	22	0	0	0	0	0	0	0	7.5	3.0	1.8
February	28	3	26	0	21	0	0	0	0	0	0	0	7.0	3.6	2.5
March	31	0	24	0	7	0	0	0	0	0	0	0	12.9	6.8	4.1
April	30	0	6	0	0	0	0	12	0	0	0	0	14.4	9.5	6.2

Newell Spring Water Temperature

2010	# Days	# 1Day Min		# 1Day Avg		# 1Day Max		#7Day Avg Daily Max					Monthly 1- Day Max	Monthly 1- Day Max Range	Monthly Avg Daily Range
	Recorded	< 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	9	2	0	0	18.2	4.6	2.5
July	31	0	0	0	0	0	0	31	29	26	26	0	21.3	6.2	4.3
August	31	0	0	0	0	0	0	31	28	23	20	0	21.4	6.3	3.8
September	30	0	0	0	0	0	0	30	21	3	0	0	19.2	5.3	3.3
October	31	0	0	0	0	0	0	13	2	0	0	0	17.6	4.6	3.0
November	30	3	9	1	8	0	0	1	0	0	0	0	13.7	3.5	2.1
December	31	0	5	0	1	0	0	0	0	0	0	0	10.9	3.5	1.4

Newell Spring Water Temperature

2011	# Days	# 1Day Min		# 1Day Avg		# 1Day Max		#7Day Avg Daily Max					Monthly 1- Day Max	Monthly 1- Day Max Range	Monthly Avg Daily Range
	Recorded	< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	0	6	0	2	0	0	0	0	0	0	0	11.3	3.4	2.0
February	28	1	7	0	2	0	0	0	0	0	0	0	10.8	4.4	2.9
March	31	0	0	0	0	0	0	3	0	0	0	0	14.0	5.5	3.6
April	30	0	0	0	0	0	0	24	0	0	0	0	15.4	6.7	4.5

Newell Road Air Temperature

2010	# Days	# 1Day Min		# 1Day Avg		# 1Day Max		#7Day Avg Daily Max					Monthly 1- Day Max	Monthly 1- Day Max Range	Monthly Avg Daily Range
	Recorded	< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
June	30	0	0	0	0	21	16	30	30	30	30	30	33.0	21.3	15.1
July	31	0	0	0	0	31	31	31	31	31	31	31	40.0	24.6	19.0
August	31	0	0	0	0	30	29	31	31	31	31	31	41.1	30.0	19.2
September	30	0	0	0	0	28	28	30	30	30	30	30	39.1	28.4	18.3
October	31	3	13	0	0	18	16	31	30	26	26	22	36.4	29.4	18.2
November	30	18	22	9	15	1	1	18	13	6	6	0	26.5	20.5	11.7
December	31	25	31	12	26	0	0	0	0	0	0	0	15.1	13.5	7.0

Newell Road Air Temperature

2011	# Days Recorded	# 1Day Min < 0.5	# 1Day Min < 4.4	# 1Day Avg <0.5	# 1Day Avg <4.4	# 1Day Max >23	# 1Day Max >24	#7Day Avg Daily Max >12	#7Day Avg Daily Max >16	#7Day Avg Daily Max >17.5	#7Day Avg Daily Max >18	#7Day Avg Daily Max >22	Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
January	31	22	28	9	17	0	0	13	3	0	0	0	20.5	20.8	11.5
February	28	19	26	6	16	0	0	16	6	3	0	0	22.7	23.6	15.1
March	31	20	26	0	3	3	0	30	27	22	16	0	23.8	23.4	17.0
April	30	13	23	0	0	4	4	30	30	30	30	0	30.7	25.9	18.0

Quartz Creek Water Temperature

2010	# Days Recorded	# 1Day Min < 0.5	# 1Day Min < 4.4	# 1Day Avg <0.5	# 1Day Avg <4.4	# 1Day Max >23	# 1Day Max >24	#7Day Avg Daily Max >12	#7Day Avg Daily Max >16	#7Day Avg Daily Max >17.5	#7Day Avg Daily Max >18	#7Day Avg Daily Max >22	Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
June	30	0	0	0	0	0	0	25	0	0	0	0	14.8	6.4	4.7
July	1	0	0	0	0	0	0	1	0	0	0	0	12.4	3.7	3.7
August		0	0	0	0	0	0	0	0	0	0	0	--	--	--
September		0	0	0	0	0	0	0	0	0	0	0	--	--	--
October		0	0	0	0	0	0	0	0	0	0	0	--	--	--

Quartz Creek Water Temperature

2011	# Days Recorded	# 1Day Min < 0.5	# 1Day Min < 4.4	# 1Day Avg <0.5	# 1Day Avg <4.4	# 1Day Max >23	# 1Day Max >24	#7Day Avg Daily Max >12	#7Day Avg Daily Max >16	#7Day Avg Daily Max >17.5	#7Day Avg Daily Max >18	#7Day Avg Daily Max >22	Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
January		0	0	0	0	0	0	0	0	0	0	0	--	--	--
February		0	0	0	0	0	0	0	0	0	0	0	--	--	--
March		0	0	0	0	0	0	0	0	0	0	0	--	--	--
April		0	0	0	0	0	0	0	0	0	0	0	--	--	--

Site 2 Trees Water Temperature

2010	# Days	# 1Day Min		# 1Day Avg		# 1Day Max		#7Day Avg Daily Max					Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
	Recorded	< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
June	30	0	0	0	0	2	0	30	30	26	23	3	23.5	6.8	5.1
July	31	0	0	0	0	17	11	31	31	31	31	26	24.9	6.9	4.7
August	31	0	0	0	0	20	14	31	31	31	31	26	25.8	6.9	4.8
September	30	0	0	0	0	0	0	30	30	30	30	0	21.5	5.8	3.4
October	31	0	0	0	0	0	0	31	8	3	2	0	19.5	3.0	1.6
November	30	0	6	0	3	0	0	6	0	0	0	0	13.9	2.3	1.5
December	31	0	11	0	9	0	0	0	0	0	0	0	7.2	2.8	0.9

Site 2 Trees Water Temperature

2011	# Days	# 1Day Min		# 1Day Avg		# 1Day Max		#7Day Avg Daily Max					Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
	Recorded	< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	1	16	0	14	0	0	0	0	0	0	0	7.5	1.9	1.2
February	28	1	20	0	8	0	0	0	0	0	0	0	7.6	3.5	2.2
March	31	0	12	0	0	0	0	0	0	0	0	0	10.8	3.7	2.5
April	30	0	0	0	0	0	0	0	0	0	0	0	12.3	5.7	3.5

Squaw Creek 1 Water Temperature

2010	# Days	# 1Day Min		# 1Day Avg		# 1Day Max		#7Day Avg Daily Max					Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
	Recorded	< 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	4	0	0	0	17.3	3.7	2.7
July	2	0	0	0	0	0	0	2	0	0	0	0	15.3	2.7	2.3
August		0	0	0	0	0	0	0	0	0	0	0	--	--	--
September		0	0	0	0	0	0	0	0	0	0	0	--	--	--
October		0	0	0	0	0	0	0	0	0	0	0	--	--	--
November	22	0	8	0	8	1	1	2	0	0	0	0	29.4	22.1	2.2
December	31	1	30	1	23	0	0	0	0	0	0	0	5.7	3.9	1.1

Squaw Creek 1 Water Temperature

2011	# Days	# 1Day Min		# 1Day Avg		# 1Day Max		#7Day Avg Daily Max					Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
	Recorded	< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	7	31	4	27	1	1	0	0	0	0	0	48.5	47.6	3.0
February	28	3	28	1	23	0	0	0	0	0	0	0	5.9	3.0	2.0
March	31	0	28	0	19	0	0	0	0	0	0	0	9.7	4.6	2.7
April	30	0	7	0	0	0	0	0	0	0	0	0	11.0	6.3	4.2

Squaw Confluence Water Temperature

2010	# Days	# 1Day Min		# 1Day Avg		# 1Day Max		#7Day Avg Daily Max					Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
	Recorded	< 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	21	18	5	25.3	10.1	5.7
July	31	0	0	0	0	0	0	31	31	31	31	0	22.3	7.3	4.5
August	31	0	0	0	0	3	0	31	31	31	31	17	23.6	6.1	4.2
September	30	0	0	0	0	0	0	30	30	25	22	0	21.3	5.8	3.4
October	31	0	0	0	0	2	2	31	14	8	4	0	26.4	20.5	5.3
November	30	9	19	7	10	1	0	18	6	5	5	0	23.8	17.5	8.6
December	31	4	19	0	11	0	0	0	0	0	0	0	10.2	9.1	1.8

Squaw Confluence Water Temperature

2011	# Days	# 1Day Min		# 1Day Avg		# 1Day Max		#7Day Avg Daily Max					Monthly 1-Day Max	Monthly 1-Day Max Range	Monthly Avg Daily Range
	Recorded	< 0.5	< 4.4	<0.5	<4.4	>23	>24	>12	>16	>17.5	>18	>22			
January	31	9	20	5	15	0	0	0	0	0	0	0	10.0	5.6	2.1
February	28	1	20	0	9	0	0	0	0	0	0	0	7.6	3.4	2.3
March	31	0	12	0	0	0	0	0	0	0	0	0	11.3	4.2	2.6
April	30	0	0	0	0	0	0	1	0	0	0	0	12.7		

NOTE: All Temperatures and Ranges in degrees C, -- Indicates No Available Data.

Appendix D. EDT modeling results

Table D1. Summary of relative importance of areas for protection and restoration of Rock Creek steelhead.

Rock Creek (YN) Summer Steelhead

Relative Importance Of Geographic Areas For Protection and Restoration Measures

Geographic Area	Protection benefit Category/rank		Restoration benefit Category/rank	
Badger Gulch	E	11	D	11
Luna	A	3	A	3
Quartz	A	9	A	3
Rock Above Quartz	A	4	A	7
Rock Below Squaw	A	1	A	1
Rock Between Badger and Unnamed	A	6	A	9
Rock Between Luna and Badger	A	8	A	6
Rock Between Squaw and Luna	A	5	A	5
Rock Between Unnamed and Quartz	A	6	A	8
Squaw Cr	A	2	A	2
Unnamed Trib	A	9	A	10

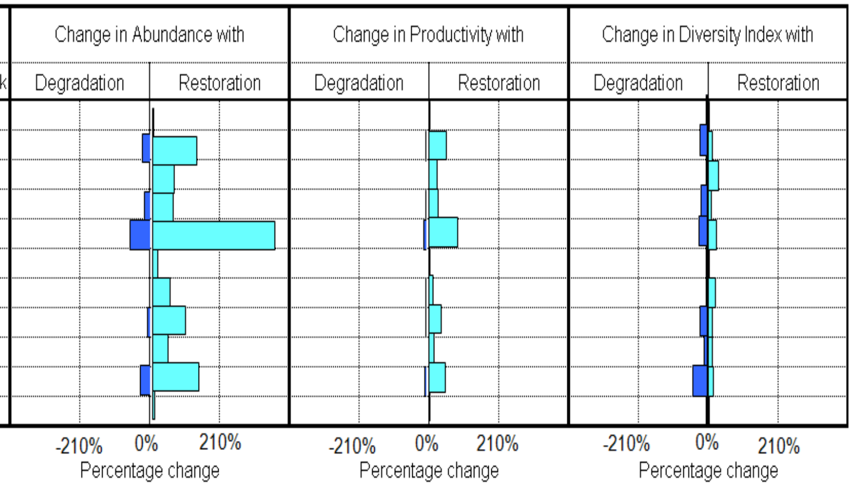


Table D2. Rock Creek steelhead life stage summary across all geographic areas.

Rock Creek (YN) Summer Steelhead
Life Stage Summary Across All Geographic Areas

Life stage	Relevant months	Productivity change (%)	Life Stage Rank	Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
				Change in attribute impact on survival															
Spawning	Feb-May	-4.9%	6							Moderate loss	Small loss					Small loss	Small loss		Moderate loss
Egg incubation	Mar-Jun	-31.2%	2	Moderate loss												High loss	High loss		Moderate loss
Fry colonization	Apr-Jul	-15.2%	4	Small loss				Moderate loss	High loss	Moderate loss		Moderate loss			Small loss		Moderate loss		Moderate loss
0-age active rearing	May-Oct	-40.7%	1	Small loss		Small loss		Moderate loss	High loss	Moderate loss				Moderate loss	Small loss	Small loss	Moderate loss		High loss
0,1-age inactive	Oct-Mar	-17.5%	3	Small loss				Small loss	High loss	Moderate loss									Moderate loss
1-age migrant	Mar-Jun	-0.4%	9							Small loss					Small loss				Small gain
1-age active rearing	Mar-Oct	-14.0%	5					Small loss	High loss	Moderate loss							Small loss		Moderate loss
2+-age active rearing	Mar-Oct	-12.9%	8					Small loss		Moderate loss									Moderate loss
2+-age migrant	Mar-Jun	-0.1%	14							Small loss					Small loss				Moderate gain
2+-age transient rearing	Jan-Dec	0.0%	15																
Prespawning migrant	Jun-Feb	-0.1%	12																Small gain
Prespawning holding	Sep-Apr	-0.2%	11																Moderate gain

1/ Ranking based on effect over entire geographic area. 2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.

Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY

NA = Not applicable

	Loss	Gain
None		
Small	• (small filled dot)	◦ (small open circle)
Moderate	●	○
High	● (large)	○ (large)
Extreme	● (largest)	○ (largest)

Rock Creek Steelhead Version 3
Baseline Stock-Recruitment
(recruitment measured at return in absence of all harvest)

Parameter	Historic	Current
Capacity	1,006	285
Productivity	4.0	1.4

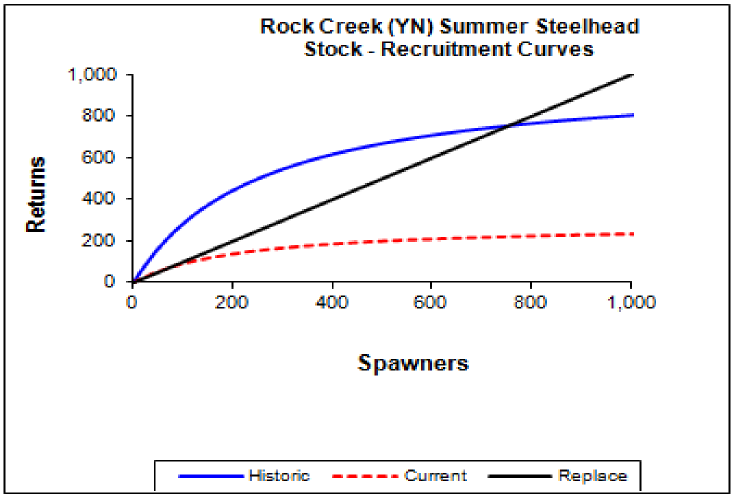


Figure D1. Rock Creek steelhead baseline stock - recruitment.

Appendix E. Genetics

Evaluation of steelhead trout (*Oncorhynchus mykiss*) in the Rock Creek watershed of the middle Columbia River Basin

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Date submitted: February 02, 2012

Objective/Background

This report summarizes a genetic evaluation of steelhead trout in Rock Creek and Squaw Creek (a tributary of Rock Creek) in the Middle Columbia River Basin (Figure 1). The watershed supports both anadromous steelhead and resident *O. mykiss*, and is part of the Mid-Columbia Evolutionarily Significant Unit (ESU) for steelhead, currently listed as "threatened" under the Endangered Species Act (Busby et al. 1996). However, status of Rock Creek steelhead is unknown (WDF and WDW, 1993). Rock Creek summer steelhead are wild origin and presumably distinct from other mid-Columbia stocks based on geographic isolation of the spawning population (WDF and WDW, 1993). Adult fish begin migrating up the Columbia River from May to November, and spawning occurs in the Rock Creek watershed from February through April. Juvenile life history information specific to this watershed remains largely undocumented (Lautz 2000). Anadromous *s*teelhead trout are known to occur in Rock Creek up to 1/4 mile above the confluence with Quartz Creek, and in Squaw Creek up to the confluence with Harrison Creek (Figure 1).

Methods

In this evaluation, juvenile fish were characterized using two 96-SNP panels developed by CRITFC. The panels complement those used in development of a basin-wide genotypic baseline for steelhead and will aid in identifying distinctions (or similarities) between the Rock Creek/Squaw Creek (RSC) population and populations throughout the Columbia River Basin (see Ackerman et al. 2011; Hess et al. 2011 for SNP panel details). Genotypes compiled for juvenile *O. mykiss* sampled in 2008 include: n=34 from a location in Rock Creek identified as Highway 8 Bridge, n=51 from a location in Rock Creek identified as "downstream of the Bickleton Rd. Crossing", and n=72 from Squaw Creek. The 2009-2010 juvenile *O. mykiss* collections include: n=43 from unknown locations in Rock Creek, and n=69 from unknown locations in Squaw Creek. Due to small sample sizes, the temporal samples from 2009 and 2010 were combined; collections for analysis are identified as "Rock09" and "Squaw09". Populations used to define the baseline for these analyses are described in appendix 1.

Genomic DNA was extracted from digested tissue samples using a standard Qiagen® DNeasy™ protocol. Samples were genotyped at 192 SNP markers with Taqman chemistry and Fluidigm 96.96 dynamic array chips to generate high throughput genotyping. For additional details on locus/primer specifications, locus optimizations, and detailed laboratory methods, see: Hess et al. 2011, and Matala et al. 2011.

Descriptive statistics including allele frequencies were generated using the analysis program GenAlEx version 6.2 (Peakall and Smouse 2006). The program GENEPOP v. 3.3 (Raymond and Rousset 1995) was used to test for deviations from Hardy-Weinberg equilibrium (HWE) expectations, evaluated across SNP loci and populations. Deviations may be indicative of non-random mating (e.g., population mixtures) or possible marker amplification problems (e.g., null alleles). The significance level ($\alpha = 0.05$) was corrected for multiple tests using a modified BY-FDR method (Benjamini and Yekutieli 2001) as implemented by Narum (2006). A matrix of pairwise F_{ST} (among-group variation) for all pairs of collections was generated in GENEPOP. A pairwise matrix of Nei's standard genetic distance (Nei 1972) and an un-rooted neighbor-joining (NJ) tree were generated using PHYLIP version 3.68 (Felsenstein 2008). The NJ tree displays the relationship among all populations as their respective proximities in the tree topology, where the sum of branch lengths represents the genetic distance between any two populations. The SEQBOOT option was implemented to generate 1000 simulated data sets, and a consensus topology with bootstrap support was generated using the CONSENSE option in PHYLIP. The analysis program GenAlEx version 6.2 (Peakall and Smouse 2006) was used to conduct multivariate principal coordinate analysis (PCA) to graphically display patterns or clusters of genetic similarity among 11 analysis populations. The method reduces redundant variables into a smaller subset of the most informative, where each successive PCA axis explains proportionately less of the total variation. Generally the first 2-3 axes will reveal most of the separation among distinct groups. We used both the option to convert the F_{ST} distance matrix to a covariance matrix, and the option to standardize (dividing the covariance input by $\sqrt{n-1}$). Eigen values by axis and sample Eigen vectors from PCA analysis (GenAlEx version 6.2) were displayed graphically using a free Microsoft Excel add-in available from W. A. *Kamakura, and found* at http://faculty.fuqua.duke.edu/~kamakura/bio/WagnerKamakuraDownloads.htm

A maximum likelihood method described by Wang and Santure (2009) and implemented in the program COLONY version 2.0 (Jones and Wang 2009) was used to estimate relatedness among all sampled individuals from Rock Creek and Squaw Creek. Parameter settings for the likelihood computation were: model – 1 (inbreeding), mating system - monogamy, species - diploid, number of runs – 1, length of run – medium, analysis method – full likelihood, marker type – codominant, allelic dropout rate – 0.0001, and mutation rate – 0.0001. Only full sibling groups identified with at least 80% probability were considered and no half-sib groups were considered.

Genetic stock identification (GSI) analyses were conducted in order to ascertain the probable origin/s of the sampled Rock Creek and Squaw Creek population. Although the RSC group may comprise a distinct population within the region (e.g., the Columbia River Basin), these tests help differentiate which populations or regions represented in the SNP baseline for steelhead are most similar to the RSC group. Note that the baseline for GSI analysis did not include any lower Columbia River populations (coastal lineage). The program ONCOR version 1.0 (available at: http://www.montana.edu/kalinowski) was first used to conduct tests of 100% Simulations on the baseline to determine its resolving power (or accuracy) for differentiating all representative stocks in the baseline. This is achieved by simulating a "fishery mixture sample" for each baseline population, where 100% of the individuals in the sample are from the same population. ONCOR uses the method of Anderson et al. (2007) to simulate mixture genotypes (based the observed population allele frequencies), and estimate their probability of occurrence in the baseline population being evaluated. For the 100% simulations, the mixture sample size parameter was set at 200 and the number of iterations was set at 1000. In addition to 100% simulations, a 'leave-one-out' (LOO) individual assignment procedure was performed on the baseline using ONCOR. In this jackknife method each individual is sequentially removed from the baseline, the allele frequencies in the population are recalculated in the absence of that individual, and the removed individual is assigned back to the most likely population of origin among all baseline populations. Both the 100% simulation and LOO methods provide the assignment accuracy to population of origin, and to reporting group; population groups established on the basis of genetic similarity and geographic proximity. Following the power analysis, the RSC groups were treated as an unknown fishery mixture and assigned origin (using the LOO method) among three reporting groups: the middle Columbia River, upper Columbia River, and Snake River.

Results

A total of ten significant HWE deviations were observed across 940 tests; 5 collections and 188 SNPs (excluded sex marker and hybrid markers). Both the “Rock08-Hwy 8 Bridge” and “Rock09” collections had zero deviations. There were 2 deviations in the “Squaw09” collection, 3 deviations in the “Rock08-Bickleton” collection, and 5 deviations in the “Squaw08” collection. Results indicated no inherent population or marker related problems, although kinship may have contributed to some issues of genotypic disequilibrium (Table 1). Kinship analyses revealed 61 total groups of full siblings, of which 20 were comprised of three or more individuals. Some observed sibships spanned multiple years (i.e., individuals from the same family sampled at different ages), and a substantial number spanned multiple sampling locations, including those between Rock Creek and Squaw Creek (Table 1). This latter result provides anecdotal evidence of movement throughout the watershed and a likely verification of gene flow among resident fish.

Pairwise Fst, indicating the amount of variation attributable to differences between populations, did not show significant differentiation among RSC collections exclusively (mean Fst=0.006). The mean pairwise Fst across all collections evaluated in these analyses, including 36 baseline and 5 RSC, was 0.073 (Figure 2). Results of pairwise testing revealed a high degree of similarity between RSC and many collections from the middle Columbia River, upper Columbia River, and Snake River regions. Those populations within the lower Columbia River, representing the coastal lineage of *O. mykiss*, were genetically discrete and highly differentiated from all remaining populations. Therefore the RSC population can be confidently characterized as an inland lineage group, with no discernible influence from lower Columbia stocks (Figures 2, 3 and 4).

Neighbor joining tree topology and clusters of collections in PCA plots provide corroborating evidence of genetic similarity between RSC and Snake River stocks. Those showing greatest similarity include Asotin Creek, the Clearwater River, and the Grande Ronde River. Collections that are more highly differentiated from RSC include the south and middle forks of both The Salmon River and Clearwater River subbasins with the Snake River Basin. With the exception of the Klickitat River and Yakima River, middle Columbia River collections also appear to share a relatively high degree of genetic similarity with RSC population (Figures 3 and 4).

The GSI results show a high level of accuracy for baseline assignment to reporting group using the 100% simulation method. Results are less definitive based on the LOO method, where Snake River collections are relatively discrete, but middle Columbia River collections exhibit a large degree of ambiguity. Using LOO, the percent correct assignment to reporting group of origin is marginal, with the exception of the Yakima and Klickitat rivers (Table 2). Evaluation of RSC using the "unknown" mixed stock fishery approach revealed a significant Snake River influence Nearly 80% of assignments across the 5 RSC collections were to the Snake River reporting group, and the mean assignment probability was ~87% (Figure 5). Ten percent of total assignments were to the middle Columbia River reporting group.

Discussion

These results indicate genetic similarity between collections of juvenile *O. mykiss* within the Rock Creek watershed (including the Squaw Creek Tributary) and Snake River stocks. The different analyses employed in this evaluation were generally complementary. Other studies suggest a relatively high stray rate within middle Columbia River tributaries including the Klickitat River and Deschutes River, where as many as 1/3 of a hatchery sample in the latter was recently identified (using a parentage based tagging approach; PBT) as progeny of Snake River broodstocks (pers. comm. Maureen Hess, CRITFC; pers. comm. Matt Smith, USFWS). Given that there may be a significant Snake River stray influence throughout the middle Columbia region, it stands to reason that there is likely to be difficulty in differentiating populations between the two regions. In fact, high rates of mis-assignment between the two regions in GSI tests specifically points to such a conclusion. If and when resources allow, characterization of the Rock Creek/Squaw Creek population is likely to benefit greatly from continued genetic monitoring and evaluations that include archival samples (if available) and adult sampling. Archival samples will allow a glimpse through time that may indicate significant temporal variation, where historically the population may have been well differentiated from, and/or less impacted by exogenous stocks. If it is feasible to collect adult steelhead samples, our current genetic tools will allow highly confident identification of any individuals that are the progeny of Snake River hatcheries. It is important to note that the samples analyzed to date are from juvenile fish. This indicates that if the observed genetic similarity in Rock Creek to stocks from the Snake River accurately reflects out of basin straying, those individuals represent effective migrants and a high level of gene flow (e.g., reproductive success in Rock Creek).

Acknowledgments

Contributing CRITFC staff: Lori Maxwell, Laboratory Technician; Shawn Narum, Lead Geneticist

References

Ackerman, M., and M. Campbell. 2011. Chinook and steelhead genotyping for genetic stock identification at lower granite dam. ANNUAL PROGRESS REPORT July 1, 2010 — June 30, 2011 Submitted to Bonneville Power Administration. Contract #48347; Project # 2010-026-00

Anderson EC, RS Waples, ST KALINOWSKI (2007). An improved method for estimating the accuracy of genetic stock identification. Canadian Journal of Fisheries and Aquatic Sciences (Accepted pending revision July 24, 2007). Benjamini Y., and D. Yekutieli. 2001. The control of false discovery rate under dependency. Annals of Statistics 29:1165-1188.

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarsino. 1996. Status review of west coast steelhead from Washington, Idaho, Oregon, and California. Technical memorandum NMFW-NWFSC-27. National Oceanic and Atmospheric Administration, Seattle, Washington. (Also available from http://www.nwr.noaa.gov/1salmon/salmesa/pubs.htm# Status Reports).

Felsenstein, J. 1992. PHYLIP (Phylogeny Inference Package) Version 3.5C. Department of Genetics. SK-50, University of Washington, Seattle, 98195, USA.

Hess, J. E., N. Campbell, A. P. Matala and S. R. Narum. 2011. Genetic assessment of Columbia River Stocks: 2010 annual report. Submitted to Bonneville Power Administration. Contract #41224; Project # 2008-907-00 https://pisces.bpa.gov/release/documents/documentviewer.aspx?doc=P120015

Jones, O. and J. Wang. 2009. COLONY: a program for parentage and sibship inference from multilocus genotype data. Molecular Ecology Resources 10: 551–555.

Lautz, K. 2000. Salmon and Steelhead Habitat Limiting Factors. Washington State Conservation Commission Report.

Matala, A. P., J. Hess and S. R. Narum. 2011. Resolving adaptive and demographic divergence among Chinook salmon populations in the Columbia River Basin. Transactions of the American Fisheries Society 140:783–807.

Narum, S. R. 2006. Beyond Bonferroni: Less conservative analyses for conservation genetics. Conservation Genetics 7:783-787.

Nei, M. 1972. Genetic distance between populations. The American Naturalist 106:283-292.

Peakall, R., P.E. Smouse. 2006. GENALEX 6: genetic analysis in Excel. Population genetic software for teaching and research. Molecular Ecology Notes 6, 288-295.

Raymond, M. and F. Rousset. 1995. Genepop: population genetics software for exact tests and ecumenicism. Journal of Heredity 83: 248-249.

Wang, J., and A. W. Santure. 2009. Parentage and sibship inference from multi-locus genotype data under polygamy. Genetics 181: 1579-1594.

Washington Dept. of Fisheries and Washington Department of Wildlife [WDF and WDW]. 1993. Washington State Salmon and Steelhead Stock Inventory. Appendix Three: Columbia River Stocks. Washington Department of Fisheries, Washington Department of Wildlife. 580 pp.
Washington Department of Fish and Wildlife [WDFW]. 1998

Table 1. A summary of estimated relatedness. Groups are numbers of individual juvenile O. mykiss identified as full siblings using the program COLONY. Results are: a.) 20 groups of three or more full-siblings, b.) 41 sibling pairs. There were 93 individuals with no full siblings identified.

a.)

Sib-Group	Rock 08 (Bickleton)	Rock 08 (Hwy. 8 Bridge)	Rock 09	Squaw 08	Squaw 09	**Total**
1	---	---	---	9	2	11
2	6	3	---	---	---	9
3	2	5	---	---	---	7
4	2	2	1	1	---	6
5	2	2	---	---	---	4
6	2	1	---	1	---	4
7	2	1	---	---	---	3
8	---	---	1	2	---	3
9	---	---	---	3	---	3
10	---	---	---	3	---	3
11	---	---	---	2	1	3
12	---	---	---	---	3	3
13	---	---	---	---	3	3
14	---	3	---	---	---	3
15	4	---	---	---	---	4
16	3	---	---	---	---	3
17	4	1	---	---	---	5
18	---	---	---	2	3	5
19	---	---	---	3	2	5
20	---	---	---	4	---	4
Total	27	18	2	30	14	91

b.)

sibling pairs (n=2)	Rock 08 (Bickleton)	Rock 08 (Hwy. 8 Bridge)	Rock 09	Squaw 08	Squaw 09
Rock 08 (Bickleton)	**6**				
Rock 08 (Hwy. 8)	2	**---**			
Rock 09	1	**---**	**6**		
Squaw 08	---	4	3	**8**	
Squaw 09	---	---	---	2	**9**

Table 2. Assignment tests and genetic stock ID. Values less than 0.75 appear in bold italics. Populations of the inland lineage were not included in GSI analyses. Results were generated using two methods for assignment to reporting group implemented in ONCOR. In the jackknife or leave-one-out (LOO) method results depict number of total individuals per collection that assigned to their reporting group (region) of origin. The simulation results are the average rate of correct assignment to reporting group across tests.

		LOO		100% simulation test		
Collection	Reporting Group	(N)	% correct	Average	SD	(95% C.I.)
Deschutes	Middle Columbia	76	***0.553***	0.982	0.014	(0.949 , 1.000)
Fifteenmile	Middle Columbia	35	***0.657***	0.993	0.007	(0.974 , 1.000)
John-Day	Middle Columbia	123	***0.585***	0.968	0.022	(0.911 , 0.999)
Klickitat	Middle Columbia	156	0.929	1.000	0.001	(0.995 , 1.000)
Umatilla	Middle Columbia	12	***0.583***	0.930	0.025	(0.883 , 0.971)
Yakima	Middle Columbia	108	0.852	0.996	0.006	(0.980 , 1.000)
Entiat	Upper Columbia	123	***0.626***	0.971	0.016	(0.935 , 0.996)
Methow	Upper Columbia	44	0.795	0.937	0.029	(0.871 , 0.982)
Wenatchee	Upper Columbia	58	***0.655***	0.970	0.017	(0.938 , 0.996)
Asotin	Snake	28	0.750	0.802	0.050	(0.700 , 0.893)
Clearwater	Snake	75	0.907	0.978	0.016	(0.945 , 1.000)
Grande Ronde	Snake	177	0.814	0.978	0.017	(0.940 , 1.000)
Imnaha	Snake	69	0.899	0.986	0.013	(0.955 , 1.000)
Salmon	Snake	293	0.874	0.989	0.009	(0.966 , 1.000)
Tucannon	Snake	43	***0.651***	0.781	0.045	(0.694 , 0.886)

Figure 1. Map of the Columbia River Basin. The Rock Creek watershed is highlighted by the yellow oval (inset). Adjacent Columbia River tributaries are as follows: 3 – White Salmon River, 19 – Klickitat River, 13 & 14 – Hood River summer-run and winter-run, 10 – Fifteenmile Creek, 8 – Deschutes River, and 16 – John Day River.

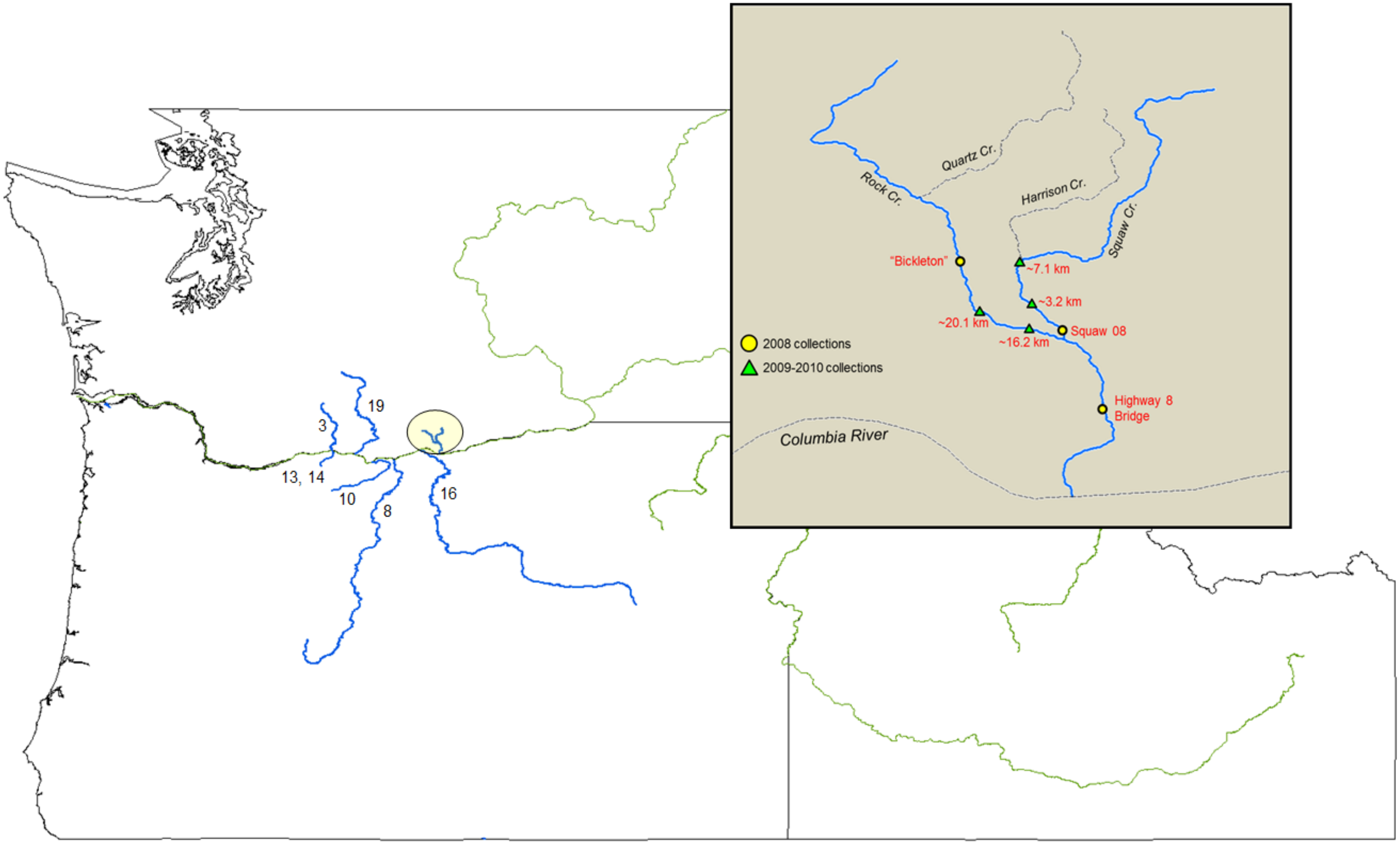


Figure 2. Comparison of among-group genetic variation (pairwise F_{st}). Results are the mean of all pairwise comparisons for each of the 41 putative populations: 5 RSC collections and 36 collections from the Columbia River SNP baseline for *O. mykiss* (red text). Note that white circles represent the mean of pairwise comparisons between each collection and only the five RSC collections.

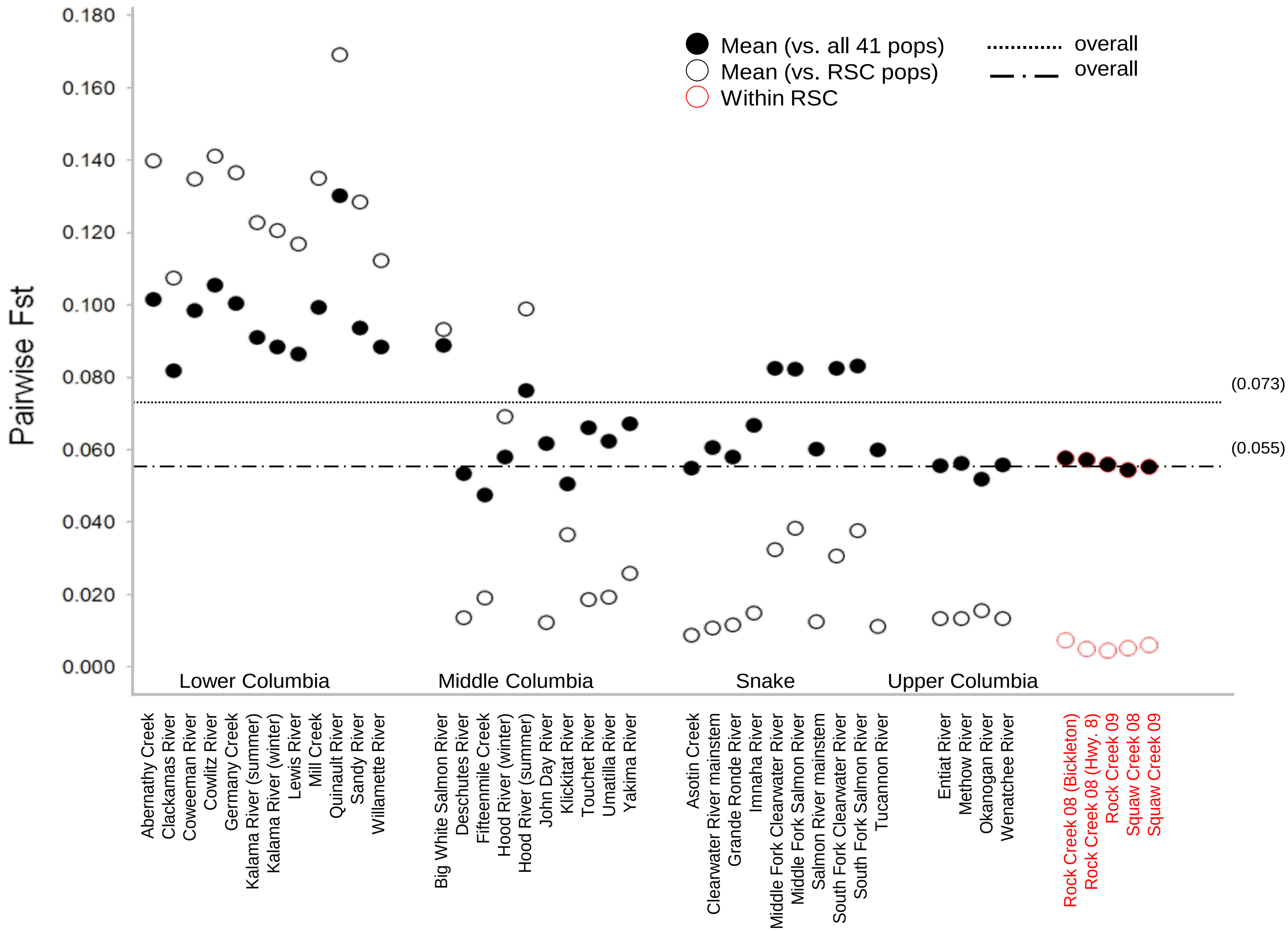


Figure 3. Neighbor-Joining (radial) tree topology identifying the genetic distance relationship (Nei 1987) between Rock and Squaw Creek collections and populations from the SNP baseline. Significant consensus topology across 1000 replicate data sets is shown with bootstrap support at branch nodes (red text).

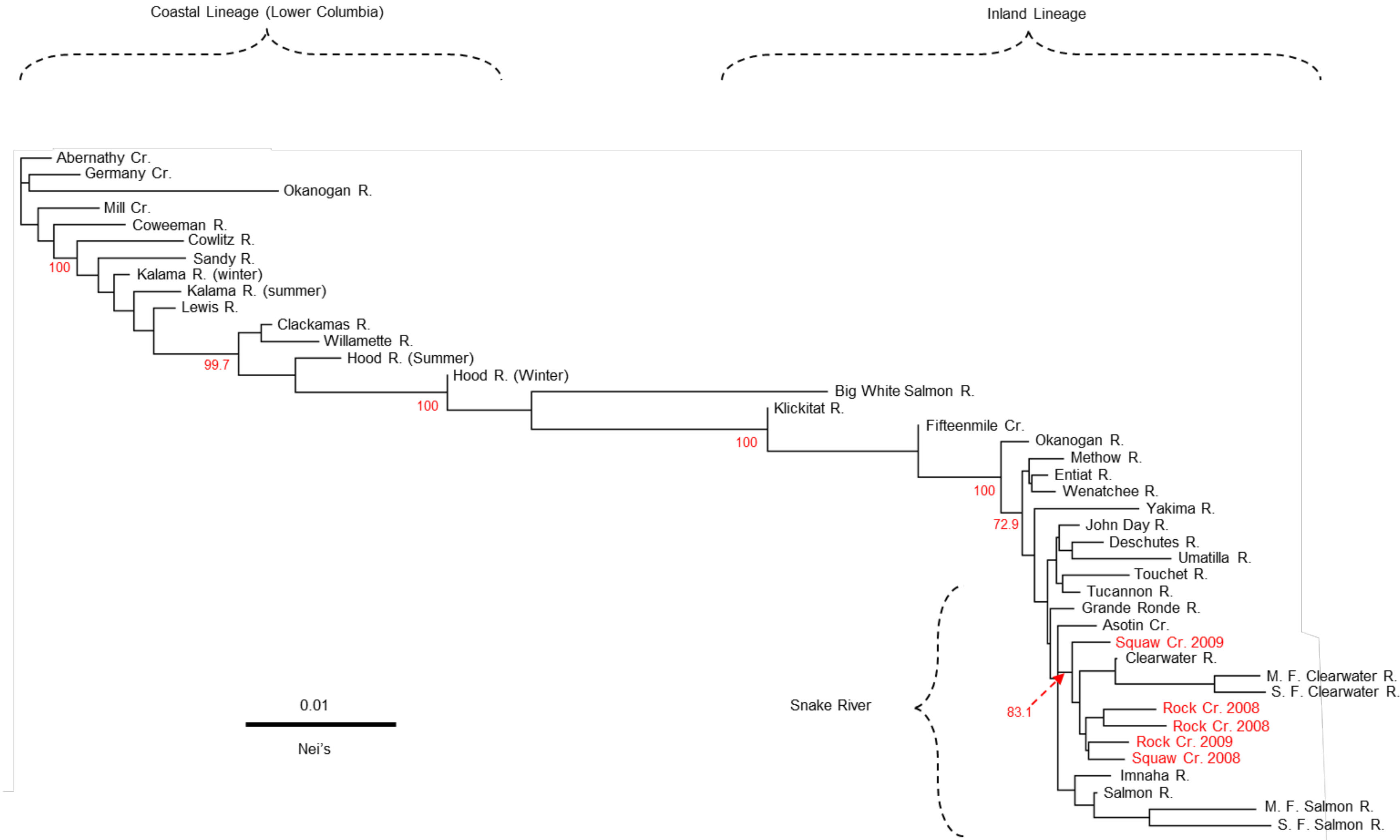


Figure 4. Principle Coordinates Analysis (PCA) plot. Results are presented in two perspectives (a. b.), with rotation on the x- and y-axes to show multi-dimensional clustering; see appendix 1 for collection designation by number.

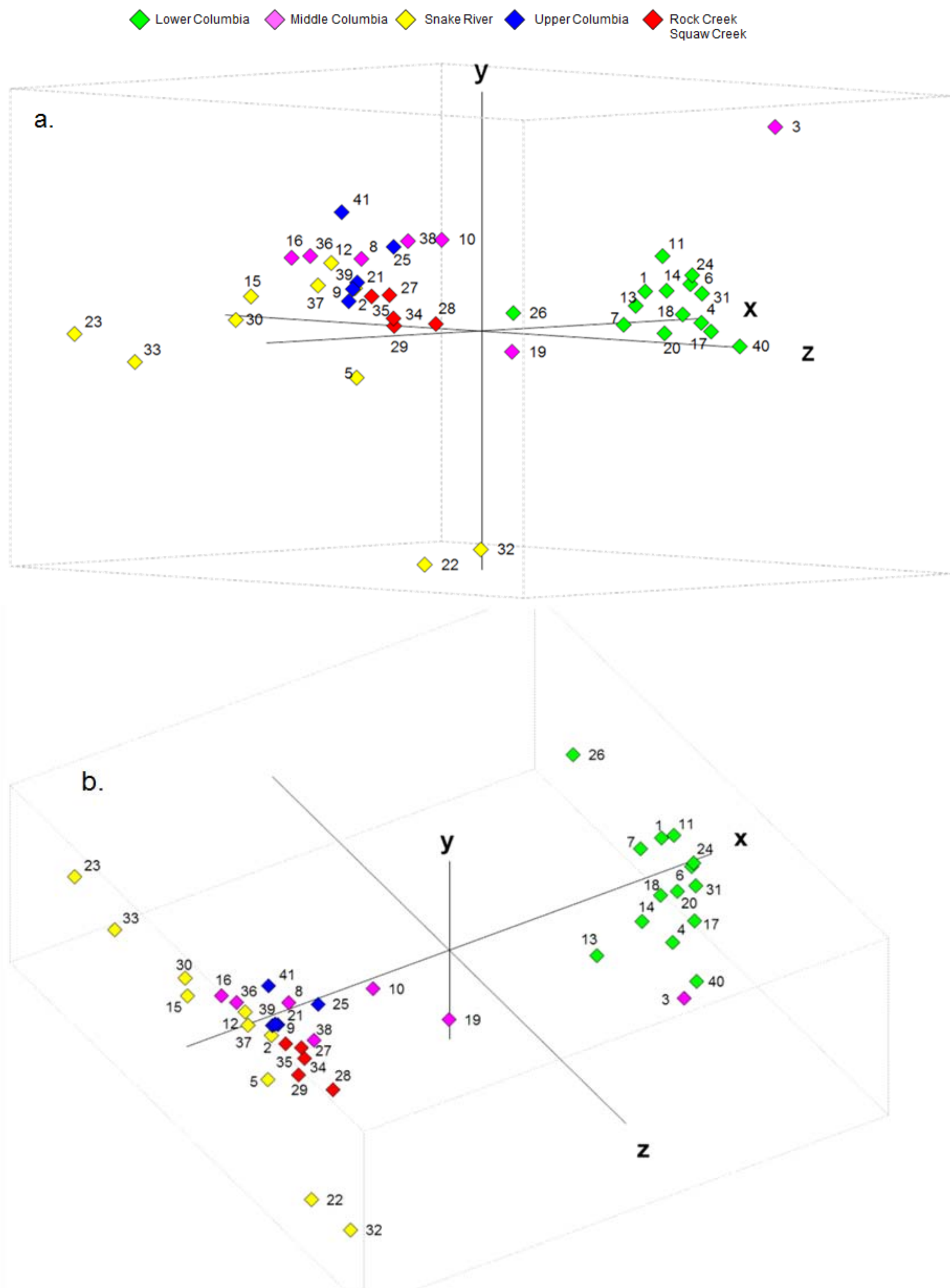
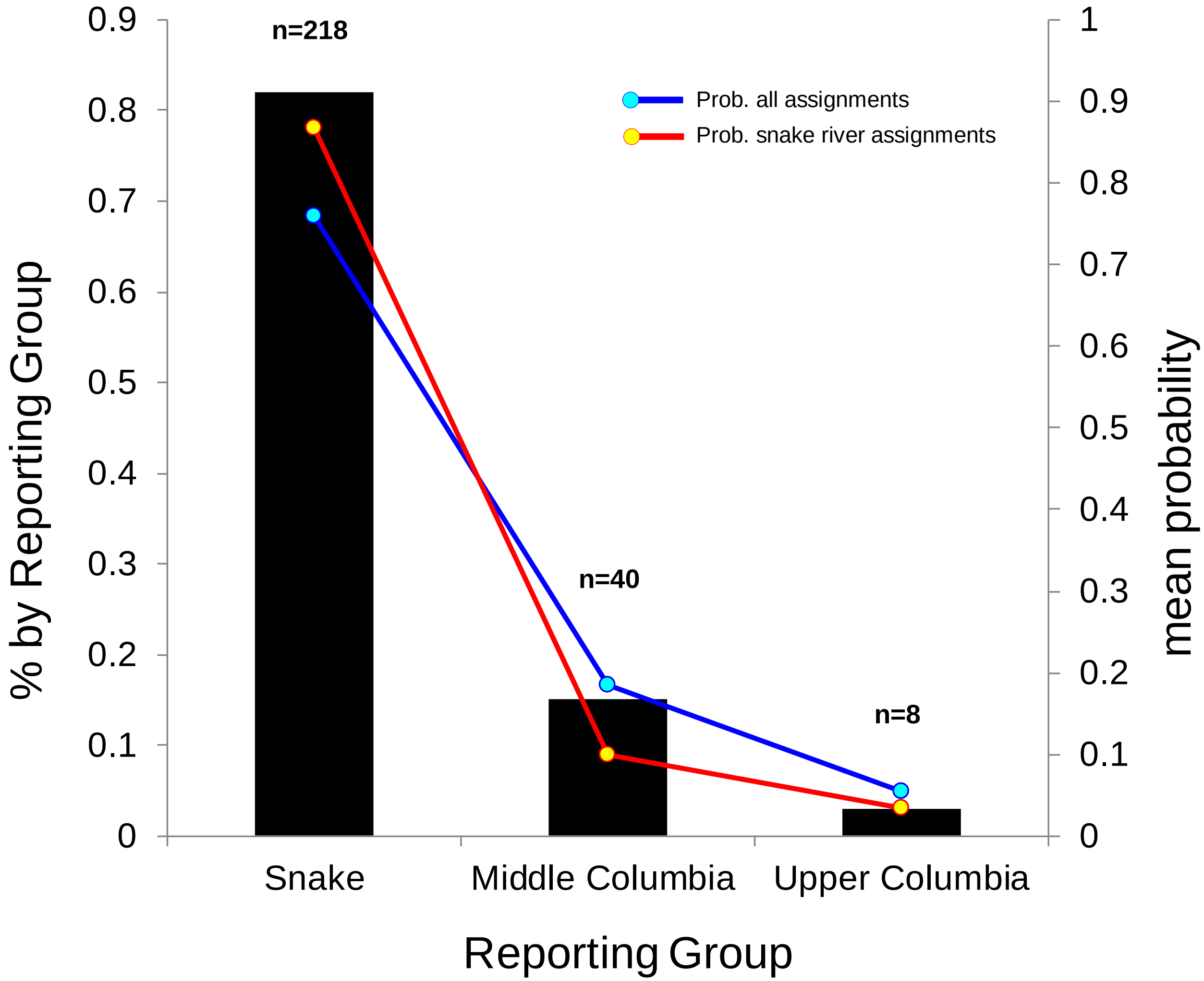


Figure 5. Mixed stock assignment results. The Rock Creek and Squaw Creek collections (n=266) were treated as a mixture of unknown origin, where each individual in the mixture was assigned to the most likely baseline population of origin using ONCOR (see Table 2). No lower Columbia (coastal lineage) populations were represented in the baseline. Results of assignment to population were grouped by GSI reporting group (region), consisting of three options: Snake River, middle Columbia and upper Columbia.



Appendix 1. Steelhead (*O. mykiss*) baseline groups used in these analyses. Collections in the Snake River that clustered closest with RSC in PCA and genetic distance analyses are identified with (*).

ID#	Location / Collection	Region	Lineage	(n)
1	Abernathy Creek	lower Columbia	coastal	165
*2	Asotin Creek	Snake	Inland	49
3	Big White Salmon River	middle Columbia	Inland	81
4	Clackamas River	lower Columbia	coastal	245
*5	Clearwater River mainstem	Snake	Inland	200
6	Coweeman River	lower Columbia	coastal	47
7	Cowlitz River	lower Columbia	coastal	94
8	Deschutes River	middle Columbia	Inland	260
9	Entiat River	upper Columbia	Inland	238
10	Fifteenmile Creek	middle Columbia	Inland	91
11	Germany Creek	lower Columbia	coastal	48
*12	Grande Ronde River	Snake	Inland	426
13	Hood River (winter)	middle Columbia	Inland	54
14	Hood River (summer)	middle Columbia	Inland	35
15	Imnaha River	Snake	Inland	186
16	John Day River	middle Columbia	Inland	367
17	Kalama River (summer)	lower Columbia	coastal	94
18	Kalama River (winter)	lower Columbia	coastal	94
19	Klickitat River	middle Columbia	Inland	438
20	Lewis River	lower Columbia	coastal	173
21	Methow River	upper Columbia	Inland	92
22	Middle Fork Clearwater River	Snake	Inland	358
23	Middle Fork Salmon River	Snake	Inland	322
24	Mill Creek	lower Columbia	coastal	44
25	Okanogan River	upper Columbia	Inland	294
26	Quinault River	Washington Coast	coastal	92
27	**Rock Creek 08 (Bickleton)**	**middle Columbia**	**Inland**	**51**
28	**Rock Creek 08 (Hwy. 8)**	**middle Columbia**	**Inland**	**33**
29	**Rock Creek 09**	**middle Columbia**	**Inland**	**43**
30	Salmon River mainstem	Snake	Inland	548
31	Sandy River	lower Columbia	coastal	28
32	South Fork Clearwater River	Snake	Inland	167
33	South Fork Salmon River	Snake	Inland	137
34	**Squaw Creek 08**	**middle Columbia**	**Inland**	**70**
35	**Squaw Creek 09**	**middle Columbia**	**Inland**	**69**
36	Touchet River	middle Columbia	Inland	89
*37	Tucannon River	Snake	Inland	95
38	Umatilla River	middle Columbia	Inland	34
39	Wenatchee River	upper Columbia	Inland	147
40	Willamette River	lower Columbia	coastal	267
41	Yakima River	upper Columbia	Inland	262

Appendix F. References

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

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.

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.