Implementation of Fisheries Enhancement Opportunities on the Coeur d'Alene Reservation

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EXECUTIVE SUMMARY

The BPA project entitled "Implementation of Fisheries Enhancement Opportunities on the Coeur d'Alene Reservation" mitigates for lost fishery resources that are of cultural significance to the Coeur d'Alene Tribe. This project funds management actions, and research, monitoring, and evaluation (RME) activities associated with these actions, which are carried out by the Coeur d'Alene Tribe's Fisheries Program to recover depressed populations of westslope cutthroat trout in the Coeur d'Alene basin. This report summarizes RME data collected during 2013 and 2014 that describe the status and trends of cutthroat trout in target watersheds, the status of physical factors in stream environments that may be limiting recovery objectives, and the response of stream habitats and trout populations to implemented habitat restoration and non-native fish suppression measures. The report also describes the in-stream and riparian restoration actions that were implemented in 2013 and 2014.

Research, monitoring, and evaluation summary

Data collected in 2013 and 2014 improved the understanding of populations of westslope cutthroat trout (WCT) in two watersheds on the Coeur d'Alene Tribe reservation that support the adfluvial life-history variant. Trapping operations were modified to increase the accuracy and precision of abundance estimates for migratory WCT. Adfluvial spawner estimates over the last three years have been variable but have averaged around 300 adults in the upper Lake Creek watershed. In the Benewah creek watershed, only around 20 migratory adults have been estimated to annually ascend into the upper reaches over the last two years, which has been a 67% decline from earlier estimates. Juveniles were captured over a much greater extent of the outmigration period with implementation of the rotary screw trap. Outmigration estimates obtained with screw traps, which were substantially greater than earlier estimates, have approximated 8000 and 1350 fish in Lake and Benewah creek watersheds, respectively.

During summer surveys, more extensive spatial sampling of rearing tributaries revealed WCT to be found in reaches further upstream than previously documented. High densities of WCT were discovered in previously unsurveyed upstream reaches of the East Fork of Bozard and the West Fork of Lake Creek (WFL) in the Lake Creek watershed. In tributaries of the upper Benewah Creek watershed, WCT were also found in previously unsurveyed upstream sections, and were generally well-distributed across sampled reaches, albeit at lower densities than those recorded in the Lake Creek watershed. However, in some cases, a more patchy or restricted distribution was detected in the Benewah watershed, with sub-optimal water quality conditions (e.g., Whitetail Creek) or displacement by non-native brook trout (e.g., lower reach of Schoolhouse Creek) likely explaining the patterns observed.

The prevalence of the adfluvial life-history variant was found to differ among tributaries in both watersheds. In the Lake Creek watershed, a greater percentage of migratory adults were found to ascend the Bozard sub-drainage than other tributaries. Similarly, more juveniles were found to outmigrate from reaches of the Bozard sub-drainage than the WFL sub-drainage. In the upper Benewah watershed, outmigrant data indicated that Windfall Creek was likely a primary supporter of adfluvial production with the West Fork of Benewah secondarily contributing; the South Fork of Benewah seemingly supported a predominantly resident WCT population. Seasonal movements were also detected in both watersheds during the reporting period, with fish utilizing mainstem reaches during summer and fall rearing periods (e.g., upper mainstem of Lake Creek) and moving downstream into larger mainstem habitats during the winter (e.g., restored sections of the upper Benewah mainstem). The movements detected illustrate the importance of protecting or restoring seasonal (e.g., overwintering) habitats in these watersheds.

In the reach of the Benewah mainstem treated with phase one restoration actions (i.e., rkm 14.0-16.5), an active beaver dam complex has developed over the last four years, increasing pool habitat and inundating channel length. Moreover, the influence of the dam complex has extended into riparian zones, elevating groundwater tables and saturating floodplain habitats that should promote rapid growth of the scrub-shrub wetland community. Though canopy cover has been reduced along this reach, apparently from beaver activity, stream temperature metrics have not been found to increase over the last four years due to the increased solar exposure. In contrast to the phase one reach, the influence of beaver across the phase two restoration reach (i.e., rkm 16.6-19.9) was virtually absent during the reporting period. Beaver dams, which use to populate this reach, have been essentially eliminated over the last four years. Consequently, local groundwater tables recede more quickly in this reach than in the phase one reach and in control reaches upstream. More importantly, stream temperature metrics during the reporting period have been found to rapidly increase across this reach due to the lack of streamside shading. Until beaver re-colonize the phase two reach and exert their influence on water tables in the riparian zone, additional measures may be required (e.g., supplemental watering) to increase the probability that planted vegetation will survive and grow to provide the shade necessary to reduce thermal loading in this reach.

The brook trout suppression program in the upper Benewah watershed, which was initiated in 2004, has apparently managed to keep densities of brook trout at a reasonable level. Though tactics have changed since 2009, in which the present objective is to inhibit reproductive success rather than attempt to remove as many fish as possible, densities of brook trout over the last four years have generally been the lowest observed over the program. Furthermore, WCT have comprised approximately 80% of the salmonid community in upper Benewah tributaries over the last four years in comparison to 58% during the earlier years of the suppression efforts. However, the upsurge in reproduction recorded in 2013 alludes to the compensatory resilience of brook trout and cautions against overly relaxing suppression measures.

The two year research study conducted to examine the impact of non-native northern pike on WCT during lake residence indicated that this predator may be substantially limiting the number of migratory adult WCT that could potentially spawn in monitored adfluvial watersheds. Specifically, WCT were found to comprise 10 to 30% of the dietary biomass annually consumed by pike ages two to four. In addition, pike were found to exert a greater influence on WCT in Windy Bay, the bay into which Lake Creek enters, than in other sampled bays at the northern and southern end of Lake Coeur d'Alene. Bioenergetic models estimated that more than 50% of the annual spawning run of WCT in Lake Creek could be consumed by northern pike in Windy Bay. Accordingly, a three year pilot suppression program is being developed for Windy Bay, commencing in 2015, in which northern pike will be annually removed during spring periods, when they are concentrated for spawning and when the potential for spatial and temporal overlap with migratory WCT is high, to evaluate the response of WCT to these measures.

Restoration treatments implemented in 2013 and 2014

The planning exercise completed in 2011 resulted in prioritization of restoration actions within the tributaries that encompass the upper watersheds and identification of 105 projects in the Benewah Creek and Lake Creek watersheds. This list was subsequently revised as additional project scoping could take place, resulting in a refined list of 65 and 31 projects in the Benewah and Lake watersheds, respectively. Collectively these projects affect approximately 21 km of road, 28 km of riparian and stream habitats (many of these projects overlap) and 18 fish passage projects. Significant progress has been made to implement these projects since we went through this planning exercise. Agreements have been negotiated to implement projects with all the industrial landowners and with Benewah County, as well as with several smaller private landowners. These agreements help to build relationships that will facilitate implementation well into the future. In the Benewah Creek watershed, 11 projects have been completed since 2012, representing approximately 20 percent of the projected scope of work for the watershed; while three projects have been completed in the Lake Creek watershed, representing nearly 10 percent of the projected scope of work. Work completed during this reporting period included additions of large wood to improve habitat complexity within 1350 m of upper WF Benewah Creek and 600 m in EF Bozard Creek, respectively. A total of 21.4 ha (53.1 acres) of previously farmed uplands with highly erodible soils was reforested adjacent to 1447 m of streams in the upper Lake Creek watershed. More than 1070 m of forest roads were treated in Benewah Creek to reduce sediment transport to streams supporting spawning and rearing of cutthroat trout. Three fish passage projects were completed to improve access to 6270 m of high quality habitats. If similar resources are available to implement this scope of work into the foreseeable future, one can anticipate that 12 to 15 years may be required to achieve the restoration goals associated with these projects.

1.0 PROJECT BACKGROUND

Historically, the Coeur d'Alene Indian Tribe depended on runs of anadromous salmon and steelhead along the Spokane River and Hangman Creek as well as resident and adfluvial forms of trout and char in Coeur d'Alene Lake for subsistence. Dams constructed in the early 1900s on the Spokane River in the City of Spokane and at Little Falls (further downstream) were the first dams that initially cut-off the anadromous fish runs from the Coeur d'Alene Tribe. These fisheries were further eliminated following the construction of Chief Joseph and Grand Coulee Dams on the Columbia River. Together, these actions forced the Tribe to rely solely on the resident fish resources of Coeur d'Alene Lake for their subsistence needs.

The Coeur d'Alene Tribe is estimated to have historically harvested around 42,000 westslope cutthroat trout (*Oncorhynchus clarki lewisi*) per year (Scholz et al. 1985). In 1967, Mallet (1969) reported that 3,329 cutthroat trout were harvested from the St. Joe River, and a catch of 887 was reported from Coeur d'Alene Lake. This catch is far less than the 42,000 fish per year the tribe harvested historically. Today, only limited opportunities exist to harvest cutthroat trout in the Coeur d'Alene Basin. It appears that a suite of factors have contributed to the decline of cutthroat trout stocks within Coeur d'Alene Lake and its tributaries that include the construction of Post Falls Dam in 1906, changes in land cover types, impacts from agricultural activities, and introduction of exotic fish species (Mallet 1969; Scholz et al. 1985; Lillengreen et al. 1993).

The decline in native cutthroat trout populations in the Coeur d'Alene basin has been a primary focus of study by the Coeur d'Alene Tribe's Fisheries and Water Resources programs since 1990. The overarching goals for recovery have been to restore the cutthroat trout populations to levels that allow for subsistence harvest, maintain genetic diversity, and increase the probability of persistence in the face of anthropogenic influences and prospective climate change. This included recovering the lacustrine-adfluvial life history form that was historically prevalent and had served to provide resiliency to the structure of cutthroat trout populations in the Coeur d'Alene basin. To this end, the Coeur d'Alene Tribe closed Lake Creek and Benewah Creek to fishing in 1993 to initiate recovery of westslope cutthroat trout.

However, achieving sustainable cutthroat trout populations also required addressing biotic factors and habitat features in the basin that were limiting recovery. Early in the 1990s, BPA-funded surveys and inventories identified limiting factors in Tribal watersheds that would need to be remedied to restore westslope cutthroat trout populations. The limiting factors included: low-quality, low-complexity mainstem stream habitat and riparian zones; high stream temperatures in mainstem habitats; negative interactions with nonnative brook trout in stream habitats; and potential survival bottlenecks in Coeur d'Alene Lake. In 1994, the Northwest Power Planning Council adopted recommendations set forth by the Coeur d'Alene Tribe that would address these limiting factors to support the recovery of cutthroat trout populations and the re-establishment of a fishery (NWPPC Program Measures 10.8B.20). Recommended actions included, but were not limited to, the implementation of habitat restoration and enhancement measures in Alder, Benewah, Evans, and Lake Creeks (Figure 1), and the development of a monitoring program to evaluate the effectiveness of the habitat improvement projects.

Since that time, the BPA project entitled "Implementation of Fisheries Enhancement Opportunities on the Coeur d'Alene Reservation" (#1990-044-00), which is sponsored and implemented by the Coeur d'Alene Tribe Fisheries Program, has supported the various recovery measures, which have included habitat enhancement and restoration actions, non-native biological control, and monitoring and evaluation that would inform future management decisions. This annual report summarizes previously unreported data collected during the 2013 and 2014 calendar years to fulfill the contractual obligations for the BPA project. Even though the contract performance period for this project crosses fiscal and calendar years, the timing of data collection and analysis as well as implementation of restoration projects lends itself to this reporting schedule. The report is formatted into two primary sections: (1) A research, monitoring, and evaluation (RME) report which comprises status and trend and action effectiveness monitoring; and (2) A habitat restoration report which comprises summaries of in-stream and riparian projects implemented in Lake and Benewah creek sub-watersheds.

2.0 STUDY AREA

The study area addressed by this report consists of the southern portion of Coeur d'Alene Lake and four watersheds – Alder, Benewah, Evans, and Lake - which feed the lake (Figure 1). These areas are part of the larger Coeur d'Alene sub-basin, which lies in three northern Idaho counties Shoshone, Kootenai and Benewah. The basin is approximately 9,946 square kilometers and extends from the Coeur d'Alene Lake upstream to the Bitterroot Divide along the Idaho-Montana border. Elevations range from 646 meters at the lake to over 2,130 meters along the divide. This area formed the heart of the Coeur d'Alene Tribe's aboriginal territory, and a portion of the sub-basin lies within the current boundaries of the Coeur d'Alene Indian Reservation.

Coeur d'Alene Lake is the principle water body in the sub-basin. The lake is the second largest in Idaho and is located in the northern panhandle section of the state. The lake lies in a naturally dammed river valley with the outflow currently controlled by Post Falls Dam. The lake covers 129 square kilometers at full pool with a mean depth of 22 meters and a maximum depth of 63.7 meters.

The four watersheds currently targeted by the Tribe for restoration are located mostly on the Reservation (Figure 1), but cross boundaries of ownership and jurisdiction, and have a combined basin area of 34,853 hectares that include 529 kilometers of intermittent and perennial stream channels. The climate and hydrology of the target watersheds are similar in that they are influenced by the maritime air masses from the pacific coast, which are modified by continental air masses from Canada. Summers are mild and relatively dry, while fall, winter, and spring bring abundant moisture in the form of both rain and snow. A seasonal snowpack generally covers the landscape at elevations above 1,372 meters from late November to May. Snowpack between elevations of 915 and 1,372 meters falls within the "rain-on-snow zone" and may accumulate and deplete several times during a given winter due to mild storms (US Forest Service 1998). The precipitation that often accompanies these mild storms is added directly to the runoff, since the soils are either saturated or frozen, causing significant flooding.

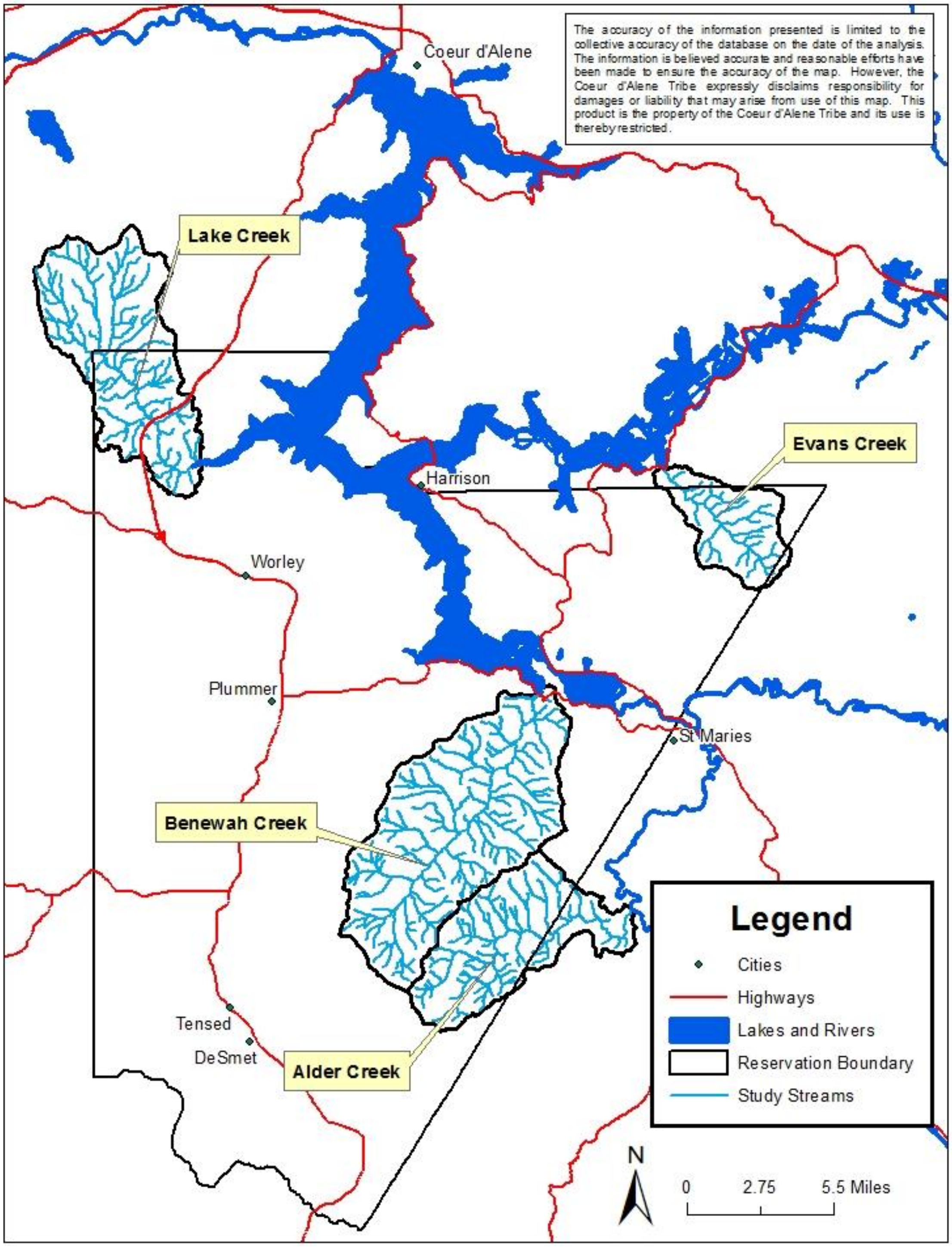


Figure 1. Locations of the four focal watersheds in the Coeur d'Alene Basin targeted by BPA project 1990-044-00.

3.0 RESEARCH, MONITORING, AND EVALUATION REPORT

3.1 Abstract

Data collected in 2013 and 2014 improved the understanding of populations of westslope cutthroat trout (WCT) in two watersheds on the Coeur d'Alene Tribe reservation that support the adfluvial life-history variant. Trapping operations were modified to increase the accuracy and precision of abundance estimates for migratory WCT. Adfluvial spawner estimates over the last three years have been variable but have averaged around 300 adults in the upper Lake Creek watershed. In the Benewah creek watershed, only around 20 migratory adults have been estimated to annually ascend into the upper reaches over the last two years, which has been a 67% decline from earlier estimates. Juveniles were captured over a much greater extent of the outmigration period with implementation of the rotary screw trap. Outmigration estimates obtained with screw traps, which were substantially greater than earlier estimates, have approximated 8000 and 1350 fish in Lake and Benewah creek watersheds, respectively.

During summer surveys, more extensive spatial sampling of rearing tributaries revealed WCT to be found in reaches further upstream than previously documented. High densities of WCT were discovered in previously unsurveyed upstream reaches of the East Fork of Bozard and the West Fork of Lake Creek (WFL) in the Lake Creek watershed. In tributaries of the upper Benewah Creek watershed, WCT were also found in previously unsurveyed upstream sections, and were generally well-distributed across sampled reaches, albeit at lower densities than those recorded in the Lake Creek watershed. However, in some cases, a more patchy or restricted distribution was detected in the Benewah watershed, with sub-optimal water quality conditions (e.g., Whitetail Creek) or displacement by non-native brook trout (e.g., lower reach of Schoolhouse Creek) likely explaining the patterns observed.

The prevalence of the adfluvial life-history variant was found to differ among tributaries in both watersheds. In the Lake Creek watershed, a greater percentage of migratory adults were found to ascend the Bozard sub-drainage than other tributaries. Similarly, more juveniles were found to outmigrate from reaches of the Bozard sub-drainage than the WFL sub-drainage. In the upper Benewah watershed, outmigrant data indicated that Windfall Creek was likely a primary supporter of adfluvial production with the West Fork of Benewah secondarily contributing; the South Fork of Benewah seemingly supported a predominantly resident WCT population. Seasonal movements were also detected in both watersheds during the reporting period, with fish utilizing mainstem reaches during summer and fall rearing periods (e.g., upper mainstem of Lake Creek) and moving downstream into larger mainstem habitats during the winter (e.g., restored sections of the upper Benewah mainstem). The movements detected illustrate the importance of protecting or restoring seasonal (e.g., overwintering) habitats in these watersheds.

In the reach of the Benewah mainstem treated with phase one restoration actions (i.e., rkm 14.0-16.5), an active beaver dam complex has developed over the last four years, increasing pool habitat and inundating channel length. Moreover, the influence of the dam complex has extended into riparian zones, elevating groundwater tables and saturating floodplain habitats that should promote rapid growth of the scrub-shrub wetland community. Though canopy cover has been reduced along this reach, apparently from beaver activity, stream temperature metrics have not been found to increase over the last four years due to the increased solar exposure. In

contrast to the phase one reach, the influence of beaver across the phase two restoration reach (i.e., rkm 16.6-19.9) was virtually absent during the reporting period. Beaver dams, which use to populate this reach, have been essentially eliminated over the last four years. Consequently, local groundwater tables recede more quickly in this reach than in the phase one reach and in control reaches upstream. More importantly, stream temperature metrics during the reporting period have been found to rapidly increase across this reach due to the lack of streamside shading. Until beaver re-colonize the phase two reach and exert their influence on water tables in the riparian zone, additional measures may be required (e.g., supplemental watering) to increase the probability that planted vegetation will survive and grow to provide the shade necessary to reduce thermal loading in this reach.

The brook trout suppression program in the upper Benewah watershed, which was initiated in 2004, has apparently managed to keep densities of brook trout at a reasonable level. Though tactics have changed since 2009, in which the present objective is to inhibit reproductive success rather than attempt to remove as many fish as possible, densities of brook trout over the last four years have generally been the lowest observed over the program. Furthermore, WCT have comprised approximately 80% of the salmonid community in upper Benewah tributaries over the last four years in comparison to 58% during the earlier years of the suppression efforts. However, the upsurge in reproduction recorded in 2013 alludes to the compensatory resilience of brook trout and cautions against overly relaxing suppression measures.

The two year research study conducted to examine the impact of non-native northern pike on WCT during lake residence indicated that this predator may be substantially limiting the number of migratory adult WCT that could potentially spawn in monitored adfluvial watersheds. Specifically, WCT were found to comprise 10 to 30% of the dietary biomass annually consumed by pike ages two to four. In addition, pike were found to exert a greater influence on WCT in Windy Bay, the bay into which Lake Creek enters, than in other sampled bays at the northern and southern end of Lake Coeur d'Alene. Bioenergetic models estimated that more than 50% of the annual spawning run of WCT in Lake Creek could be consumed by northern pike in Windy Bay. Accordingly, a three year pilot suppression program is being developed for Windy Bay, commencing in 2015, in which northern pike will be annually removed during spring periods, when they are concentrated for spawning and when the potential for spatial and temporal overlap with migratory WCT is high, to evaluate the response of WCT to these measures.

3.2 Introduction

3.2.1 Status and trend monitoring

Abundance and productivity of cutthroat trout

The status and trend of adfluvial westslope cutthroat trout (WCT) populations in Lake and Benewah creeks are monitored by tracking the number of returning adult spawners and outmigrating juveniles at the watershed scale. It is imperative that trajectories in spawners are reliably tracked given that one of the primary objectives of recovery efforts is to augment the number of adult WCT that return to adfluvial watersheds to support a persistent meta-population structure in the Coeur d'Alene basin and to ultimately provide a sustainable fishery. Monitoring annual numbers of outmigrating juveniles permits the tracking of watershed-wide trajectories in juvenile production, and aids in the assessment of the collective in-stream population response to restoration actions (Bradford et al. 2005). Survival rates of WCT during lake residence, a key vital rate in influencing population trajectories of adfluvial cutthroat trout (Stapp and Hayward 2002), are also tracked to understand whether processes in Lake Coeur d'Alene are limiting adult production.

Spatial distribution of trout populations

The status and trend of salmonid populations are also monitored annually at sites distributed across tributary and mainstem reaches in target watersheds. Monitoring populations at a spatial scale finer than the watershed will permit an examination of whether abundance trajectories differ across sub-drainages or across reaches within sub-drainages. The detection of declining trends or persistently low numbers of fish at the reach scale may signal localized degradation or deficiencies in habitat conditions that need to be addressed and prioritized for prospective habitat improvements. The tracking of temporal changes in the spatial distribution of trout populations will also permit an examination of expansion rates to evaluate whether newly created suitable habitat (e.g., barrier removal) is undergoing colonization. Overall, monitoring the spatial distribution of WCT populations should reveal whether connectivity is improving to transform a patchy distribution to a more robust structure.

Diversity of cutthroat trout populations

Examining the diversity of seasonal and life-history behaviors of WCT in monitored watersheds will improve the understanding of in-stream habitat use and adfluvial production. Monitoring in-stream movement patterns will provide data on seasonal habitats used (e.g., overwintering), and could aid in evaluating the response to restorative actions implemented to improve the quality of seasonal habitats. Monitoring the propensity of WCT to move out of stream habitats and into the lake will identify tributaries within adfluvial watersheds that support the migratory life-history strategy. Understanding the current spatial distribution of the adfluvial life-history variant may aid in prioritizing future restoration efforts.

Stream and riparian habitat

Physical habitat attributes are monitored in mainstem and tributary reaches of watersheds to examine factors that may be limiting recovery of WCT populations. Watershed-wide assessments have identified a deficiency of habitat complexity in tributaries that support WCT, primarily resulting from a paucity of recruited, channel-forming large pieces of wood and a concomitant lack of pool and spawning habitat (Duck Creek Associates 2008). This report covers monitoring surveys that describe physical habitat features in two tributaries of the upper Lake Creek watershed to provide baseline data that will aid in guiding the implementation of prospective habitat restoration measures.

3.2.2 Action effectiveness monitoring

Stream temperature response to restoration

Summer rearing temperatures have been considered to be a primary factor in explaining distributional patterns of cutthroat trout (Dunham et al. 1999; Paul and Post 2001; Sloat et al. 2001; de la Hoz Franco and Budy 2005). Similarly, in the Lake and Benewah Creek watersheds, WCT have consistently been found at higher densities in cooler tributary reaches than in warmer mainstem reaches throughout the summer. Many of the in-stream restorative actions, such as pool formation and riparian re-vegetation, have been implemented to address sub-optimal summer water temperatures. Given that high water temperatures have been considered to be a major factor limiting WCT production, stream temperatures are monitored annually to track changes over time and to examine responses to restoration measures.

Riparian and in-channel habitat response to restoration

In the upper Benewah watershed, large-scale restorative efforts were implemented from 2005 to 2012 across approximately 5 km of contiguous mainstem habitat to address dysfunctional stream processes (Firehammer et al. 2010, 2011, 2012, 2013). This reach was targeted because it had the potential to increase carrying capacity and production of juvenile WCT given its proximity and connectivity to important spawning tributaries. The first phase of restoration consisted of intensive channel re-construction over 2.5 stream km, which entailed meander reactivation, streambed elevation to promote overbank flooding, pool creation and deepening, and large wood additions for cover and bank stabilization. The second phase of restoration proceeded upstream of phase one but used a more passive approach. As part of the approach, engineered wood structures were installed in the stream to emulate the flow obstruction effects of natural beaver dams and to attenuate stream power to promote the establishment of more stable, persistent beaver dam complexes that would gradually aggrade the streambed over time and, via backwater effects, promote connectivity between the channel and adjacent floodplain habitats.

Effectiveness monitoring across stream reaches treated during the first phase consists of measuring physical attributes linked to the quality of salmonid habitat and tracking changes in these attributes to assess whether restored conditions are being maintained. Effectiveness monitoring across phase two reaches consists of tracking indices associated with the stability of beaver dam complexes (e.g., dam turnover) and evaluating changes in habitat either created or influenced by the dam complexes. Groundwater levels in riparian areas, as an indicator of connectivity between main channel and floodplain habitats, are also monitored along phase two stream reaches to evaluate the response to the restoration measures.

Cutthroat trout response to restoration

Effectiveness monitoring is conducted in tributaries of the upper Benewah watershed to evaluate the response of WCT to the implementation of habitat enhancement measures. Restoration prescriptions have been developed for specific tributaries that were prioritized during a prior planning exercise (Firehammer et al. 2011). These prescriptions entailed the incremental implementation of localized projects (e.g., large wood additions, culvert removal) over time to progressively increase the spatial extent of treated tributary habitat. Data collected annually across both treated and untreated (i.e., control) tributaries will serve in analyses to examine response metrics of WCT (e.g., abundance, survival rates) at the tributary scale to the collective restoration efforts.

Trout response to non-native brook trout removal

A removal program was initiated in 2004 to suppress the numbers of non-native brook trout *(Salvelinus fontinalis)* in mainstem and tributary habitats in the upper Benewah watershed. This control was deemed necessary because brook trout have been shown to negatively impact cutthroat trout when populations of the two species overlap (Griffith 1988; Adams et al. 2001; Peterson and Fausch 2003; Peterson et al. 2004; Shepard 2004). However, unlike other brook trout removal projects that have focused on chemical eradication and subsequent measures to prevent re-colonization (Shepard et al. 2003), our approach was tempered by the desire to maintain connectivity with the lake to promote the migratory life-history variant of WCT. We felt that the benefits of unimpeded access and the expression of the WCT adfluvial life-history greatly outweighed the benefits of brook trout eradication in isolated tributaries (Peterson et al. 2008). Our suppression strategy entails annually removing fish before fall spawning periods and installing temporary barriers to impede access to spawning habitat. Monitoring the success of the removal program is conducted by examining changes in metrics of brook trout and WCT abundance in index reaches in the upper Benewah watershed.

3.2.3 Research into non-native impacts

Results from past monitoring efforts indicate that juvenile to adult return rates for WCT in adfluvial watersheds are eight to ten times lower than those that have been reported in other lake systems (Gresswell et al. 1994; Huston et al. 1984). It was imperative to better understand whether predation was a predominant mechanism regulating survival rates in Lake Coeur d'Alene. A couple small-scale research studies conducted in Lake Coeur d'Alene over the last twenty years suggested that northern pike, an introduced non-native piscivorous species, could be a significant predator on native WCT (Rich 1992; Anders et al. 2003). However, the studies were somewhat limited in that they lacked the required temporal and spatial resolution to rigorously quantify predatory impacts. Consequently, a research study from 2011 to 2013 was sub-contracted through the University of Idaho to examine the demographics and seasonal dietary preferences of northern pike in select bays of Lake Coeur d'Alene to better describe the potential for this piscivore to impact survival rates of WCT. The study methodology and results are detailed in an article published in a journal of the American Fisheries Society (Appendix D), with significant findings and management recommendations highlighted in the discussion section of this report.

3.3 Methods

Abundance and productivity of cutthroat trout

Migration traps, located downriver of spawning tributaries and of treated stream reaches, were installed at river kilometer (rkm) 7.2 in Lake Creek (Figure 2) and at rkm 14.1 in Benewah Creek (i.e., 9-mile; Figure 3) during the spring to capture adfluvial WCT. A floating weir trap was used in both watersheds to intercept ascending adults. The trap was based on the resistant-board weir design (Tobin 1994; Stewart 2002), but modified to allow the panels to be manually raised or lowered as flow levels changed (Photo 9). In Lake Creek, descending adults and juveniles were captured in 2013 using a modified fence-weir trap with pop-out panels that could be temporarily removed during high flows (Photo 10). In 2014, the fence-weir design was discontinued in favor of a rotary-screw trap to capture juvenile outmigrants and descending adults. Descending adults were also captured at the floating weir trap by cutting a circular opening in one of the panels into which a 6 inch diameter tube was inserted to transport fish downriver to a livebox. In Benewah Creek, similar modifications were made to the floating weir trap to capture descending adults and a rotary screw trap was used in 2013 and 2014 to capture juvenile outmigrants.

Total length (TL, mm) and weight (Wt, g) were recorded from adults captured at traps, and all ascending adults received an opercle punch. In addition, adults that had not been previously tagged received an HDX PIT-tag that was inserted into the muscle tissue near the pelvic fin. Opercle punches served to evaluate tag retention and to generate abundance estimates (Chapman 1951; Appendix A). Total length was collected from all juveniles captured in traps, with weights collected from fish that received PIT-tags. Adipose fins were clipped on tagged fish for identification in recapture events and to assess tag retention. Juveniles were typically tagged every 2-4 days and used in trap efficiency trials to generate outmigrant estimates (Carlson et al. 1998; Appendix A). Juveniles from efficiency trials that were interrogated at distant, upstream fixed PIT-tag stations were not considered available for recapture and omitted from analysis.

An array of full-duplex (FDX) pass-through antennas spanning the stream was located immediately downstream of the floating weir trap in Lake Creek to interrogate fish that had been tagged with FDX tags in prior years (Figure 2; Photo 11). Collectively, interrogations from this reporting period and from prior years served to generate estimates of return rates for juveniles and adults tagged since 2005. In addition, fish that were tagged in prior years and interrogated at this site during their spawning ascension were used to generate annual estimates of the number of adults that approached the trap site (Appendix A).

Spatial distribution of trout populations

Electrofishing surveys were conducted during summer periods to describe the distribution and abundance of WCT and brook trout at sites distributed across tributaries in the Lake Creek (Figure 2) and Benewah Creek (Figure 3) watersheds. Across tributaries in the Lake Creek watershed and in Bull and Coon creeks in the lower Benewah Creek watershed, the same sites were surveyed in both years. Sites were selected according to a stratified-randomized approach in West Fork Benewah (WFB), South Fork Benewah (SFB), and Windfall creeks in the upper Benewah Creek watershed, given that these sub-drainages also served in action effectiveness monitoring designs to evaluate the tributary-scale response of WCT to stream restoration. In Whitetail and Schoolhouse creeks in the upper Benewah Creek watershed, traditional index sites were surveyed in 2013, but new locations distributed over a greater spatial scale in each tributary were surveyed in 2014. Sites typically ranged from 75 to 100 m in length.

Electrofishing procedures used straight DC current and 300-400 volts of output and followed established protocol to standardize capture efficiency (Reynolds 1983). Block nets were placed at site boundaries to prevent immigration and emigration during sampling. Captured trout were enumerated, measured for total length, and weighed, and most of the WCT longer than 75 mm received PIT tags. Length distributions of captured salmonids were used to classify fish as either young-of-the-year (age-0) or older fish (age 1+). Site abundances for age-0 and age 1+ fish were indexed using single pass catch, and converted to fish/100 m of stream length to permit comparisons across sites and years.

Diversity of cutthroat trout populations

Fixed half-duplex (HDX) directional PIT-tag arrays were installed to detect movements of tagged fish. In the Benewah watershed, arrays were installed at the mouths of SFB, WFB, and Windfall creeks, and were located at 12-mile bridge and 9-mile bridge to bound the reach that underwent stream restoration from 2005 to 2012 (Figure 3). In the upper Lake Creek watershed, arrays were installed at the mouths of the upper fork of Lake Creek (UFL), the West Fork of Lake creek (WFL), and Bozard Creek, the three primary spawning and rearing tributaries (Figure 2). Data collected at these sites in combination with active detections (e.g., migrant traps) were summarized to describe seasonal movements and the spatial distribution of the adfluvial life-history variant in each watershed. Detection efficiencies at passive interrogation sites in both watersheds were generally high over both high and low flow periods throughout the study period, yielding confidence in the conclusions drawn (Table B-1).

Stream temperature

In the upper Benewah creek watershed, air temperatures in representative forested and open meadow habitats, and stream temperatures at fixed locations along mainstem reaches and in primary tributaries, were continuously monitored every 30 minutes using dataloggers (Onset Computer Corp.). Overall mean daily temperatures, the mean of daily maximum temperatures, and the percent time temperatures exceeded 17°C, an upper limit for optimal cutthroat trout growth (Bear et al. 2007), were computed over July and August for each stream logger to permit comparisons over years and across stream reaches.

Stream and riparian habitat

In the upper Lake Creek watershed, physical attributes were measured at seven 100 m sites and at eight 150 m sites respectively distributed across the Bozard and WFL sub-watersheds to assess the quality of trout habitat (Figure 2). In the upper Benewah Creek watershed, four 150 m sites were surveyed along the mainstem reach that received treatments during phase one restoration (i.e., rkm 14.0 at 9-mile bridge to rkm 16.5); two additional 150 m sites were surveyed along a control reach approximately 2.5 km further upstream (Figure 3). Surveys in upper Benewah were conducted to evaluate changes in physical attributes since completion of the restoration measures. Attributes measured at sites included percent pool, pool volume, and residual pool depth; counts and volume of large woody debris; percent canopy cover; and percent fines in riffle and pool tailouts (Appendix A).

Beaver dams were surveyed in both 2013 and 2014 along a 3.3 km reach of the upper Benewah mainstem that received treatments during the second phase of restoration (i.e., rkm 16.6 to rkm 19.9 at 12-mile bridge; Figure 3). At each dam, attributes that described morphology were recorded, including dam type, which indexed the apparent stability and complexity of the dam, and the recent building activity associated with the dam; the materials used to build the dam; and the dam width and height (Appendix A). Data collected during surveys were used to evaluate changes in the spatial distribution of beaver dams and in dam building activity across years and to evaluate the overall state of the beaver dam complex in the upper Benewah watershed.

Groundwater was measured in 2014 at wells distributed across three distinct floodplain locations in the upper Benewah watershed. A cluster of near-stream wells was located at 9-mile bridge (n=4), at 12-mile bridge (n=5), and at the downstream end of the reach addressed by phase two restoration (n=5). In addition, three, six, and eight wells were randomly distributed across the downstream end of the phase two restoration reach at sites located near (< 20 m), at intermediate distances (20-50 m), and far (65-150 m) from the stream, respectively. Average declines in water depth over summer periods were calculated for each well group and compared across groups. Additionally, deviations of 2014 base flow groundwater levels from those calculated in 2008-2009 were averaged across wells for each group to assess changes over time.

Cutthroat trout response to restoration

Coarse-scale channel features (e.g., land use, valley width, elevation, and channel gradient) were used to partition reaches in each of SFB, WFB, and Windfall creeks into 3-4 contiguous strata (Figure 3). In each year, two to four 100 m sites were randomly selected within each stratum, with more sites generally assigned to longer strata. In at least 50% of sites within each stratum, abundance of age 1+ WCT was estimated using mark-recapture methodology in which block nets remained deployed and the recapture event occurred the day after the marking event. Abundance at sites that did not receive a recapture event was estimated using the mean first pass capture probability generated from the mark-recapture sites (Figure B-1). The overall abundance of age 1+ WCT across delineated reaches in each sub-drainage was estimated using models that incorporated both measurement and sampling error (Hankin 1984; Appendix A).

Trout response to non-native brook trout removal

Single-pass electrofishing was used in late summer to remove brook trout from a 2 km main-stem reach in the upper Benewah watershed from the 12-mile bridge upstream to the confluence of WFB and SFB creeks (Figure 3). High densities of adult brook trout have historically been found in this reach, and suitable spawning habitat is seemingly much more prevalent in this reach than in mainstem reaches downriver. Brook trout were also removed from the lowermost 0.5 km of Windfall creek, given the production recently observed in this sub-drainage. Temporary barriers were installed immediately upriver of 12-mile bridge and at the mouth of Windfall Creek to prevent access to upriver habitat. Trends in brook trout removed from the 2 km index reach, a reach that has been consistently addressed since 2005, were examined to evaluate the response of brook trout to the suppression program. In addition, mean density indices of age 1+ brook trout and WCT were computed across tributary index reaches in the upper Benewah watershed that have been regularly sampled since 2004 to evaluate temporal trout responses to the suppression efforts.

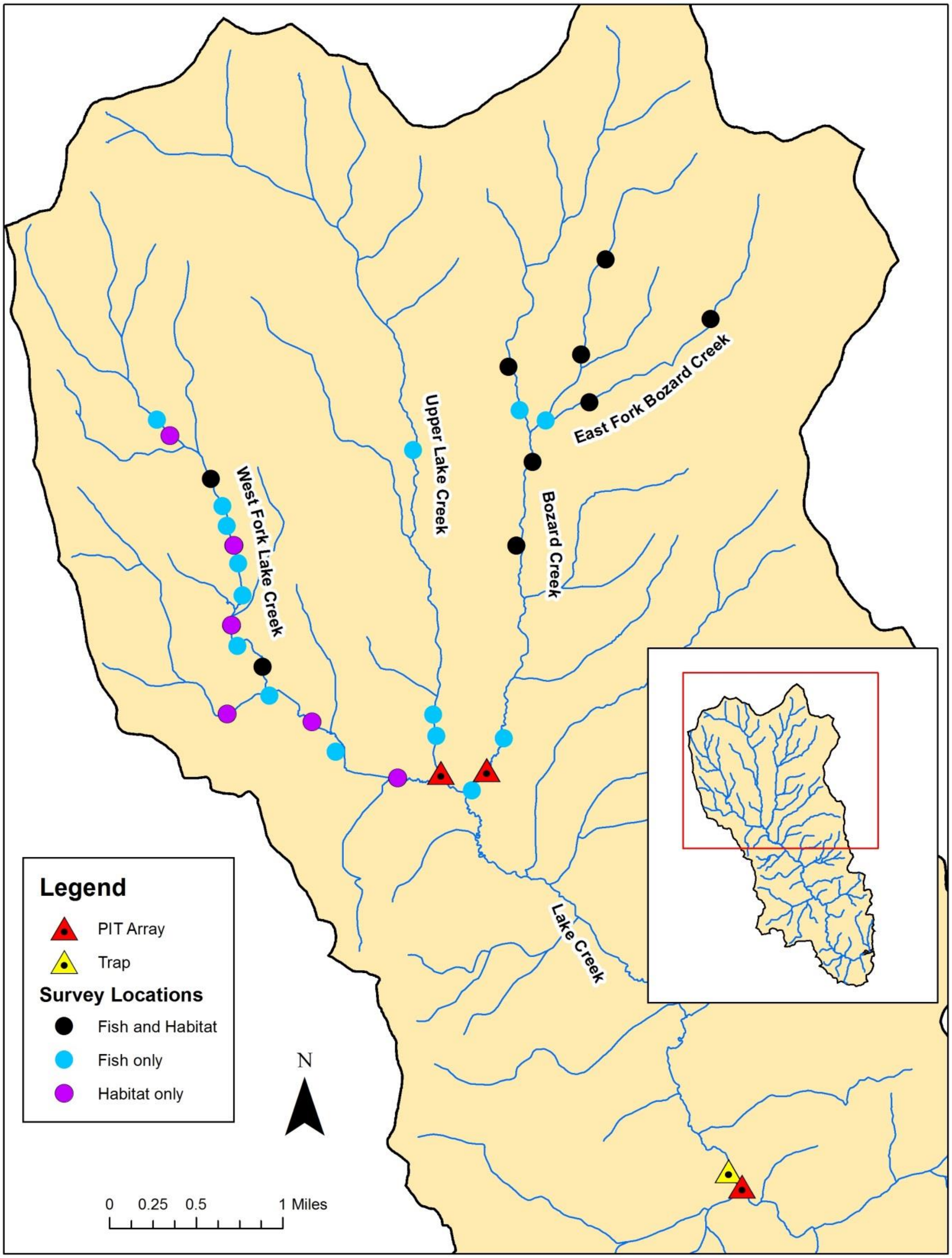


Figure 2. Sites surveyed for habitat and fish distribution in the Lake Creek watershed. Locations of fixed PIT interrogation stations and migrant traps are also displayed.

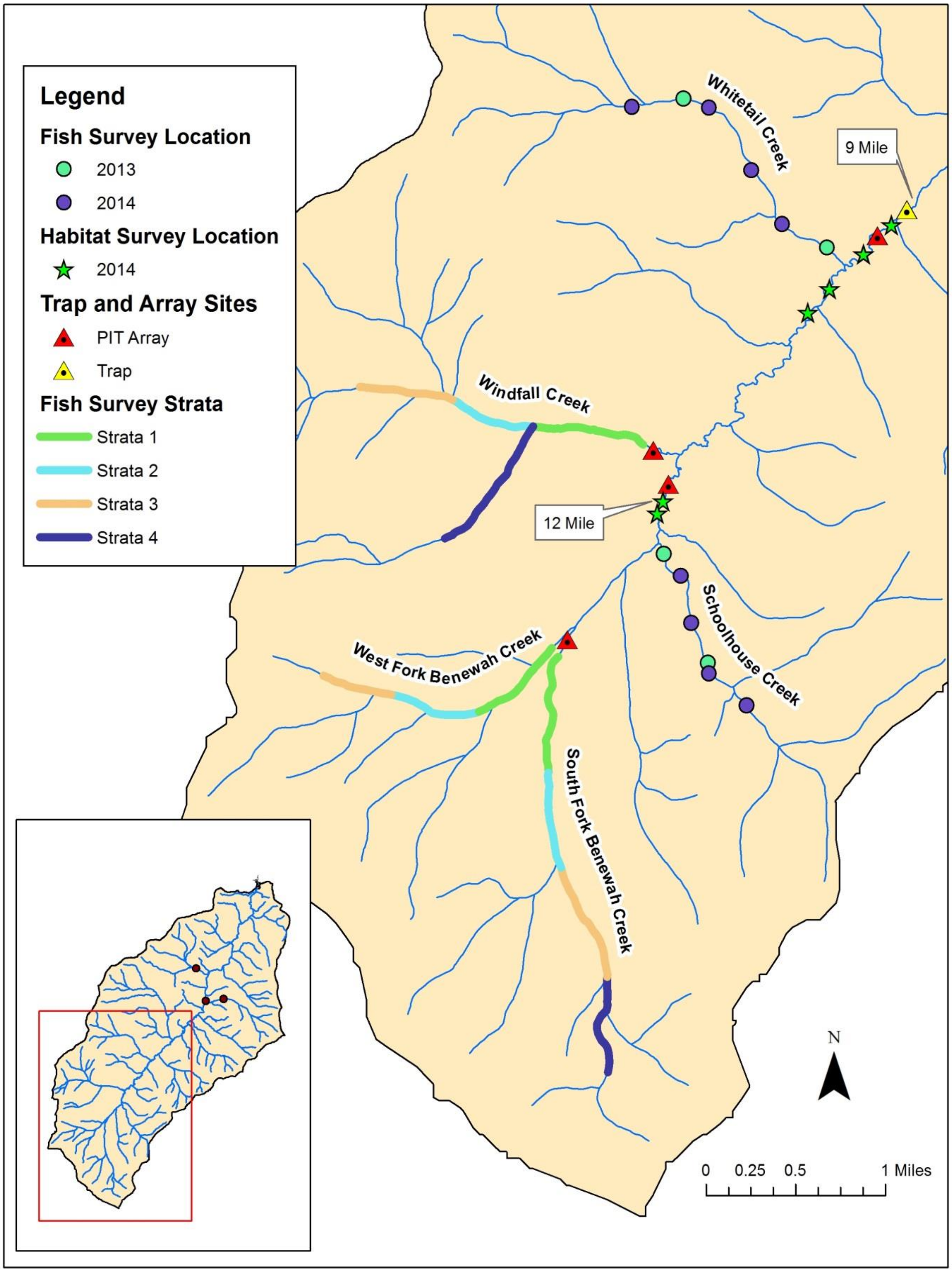


Figure 3. Sites and reach strata surveyed for habitat and fish distribution in the Benewah Creek watershed. Locations of fixed PIT interrogation stations and migrant traps are also displayed. The northernmost filled circle and the two more southerly filled circles displayed on the overview map are fish distribution sites surveyed in Coon and Bull creeks, respectively.

3.4 Results

3.4.1 Status and trend monitoring

3.4.1.1 Abundance and productivity of cutthroat trout

Lake Creek

In 2013, thirty-five ascending adult WCT were captured at the trap site, with seven (20%) of these identified as males (mean TL, 371 mm; mean Wt, 469 g) and 27 (77%) identified as females (mean TL, 371 mm; mean Wt, 479 g). Twenty-seven of the captured adults received PIT-tags. Approximately 70% of the fish were captured during the first week in April (Figure 4). On several occasions during March and April, the trap panels were lowered because of high flows or to permit lingering adults to ascend. Thirty-five putative adults that had been PIT tagged in prior years were interrogated by the FDX array; 17 of the 35 (49%) were found to linger more than 7 d downstream of the trap, and only four (11%) were captured.

A total of 94 descending adults of which 9 had an opercle punch was captured in 2013, yielding a spawner abundance estimate of 313 ± 146 fish. In comparison, 363 ± 225 fish were estimated to have approached the trap, when adults that were interrogated at the fixed FDX array at the trap site were used in the mark-recapture analysis. Of the 94 adults captured, 37 (39%) were identified as males (mean TL, 379 mm; mean Wt, 466 g) and 57 (61%) identified as females (mean TL, 346 mm; mean Wt, 333 g). More than 50% of the adults were captured during the first two weeks in May under declining levels of discharge and increasing stream temperatures (Figure 4). Two of the six (33%) adults, both females, that had been tagged in 2013 and recaptured shed their tags; all of the males were found to retain their tags.

In 2014, one hundred and thirty-nine ascending adult WCT were captured at the trap site, with thirty-eight (27%) of these identified as males (mean TL, 388 mm; mean Wt, 546 g) and 100 (72%) identified as females (mean TL, 360 mm; mean Wt, 432 g). One hundred and twelve of captured adults received PIT-tags. Approximately 50% of the fish were captured during the second week in April (Figure 4). In each of the last three weeks in April, panels were lowered for a day because of high levels of discharge or to permit lingering fish to ascend. Twenty-five putative adults that had been PIT tagged in prior years were interrogated by the FDX array; lingering behavior of more than 7 d was detected in 13 of the 25 (52%) fish. Eighteen of the 25 (72%) adults were captured, a much greater capture rate than that observed in 2013.

A total of 101 descending adults of which 64 had an opercle punch was captured in 2014, yielding a spawner abundance estimate of 219 ± 23 fish. In comparison, 191 ± 41 fish were estimated to have approached the trap, when adults that were interrogated at the fixed FDX array at the trap site were used in the mark-recapture analysis. Of the 101 adults captured, 32 (32%) were identified as males (mean TL, 381 mm; mean Wt, 472 g) and 69 (68%) identified as females (mean TL, 351 mm; mean Wt, 351 g). Approximately 40% of the adults were captured during the first two weeks in May under declining levels of discharge and increasing stream temperatures (Figure 4). All 49 adults that had been tagged in 2014 and recaptured were found to retain their tags; tag loss was also not detected for fish tagged as adults in prior years.

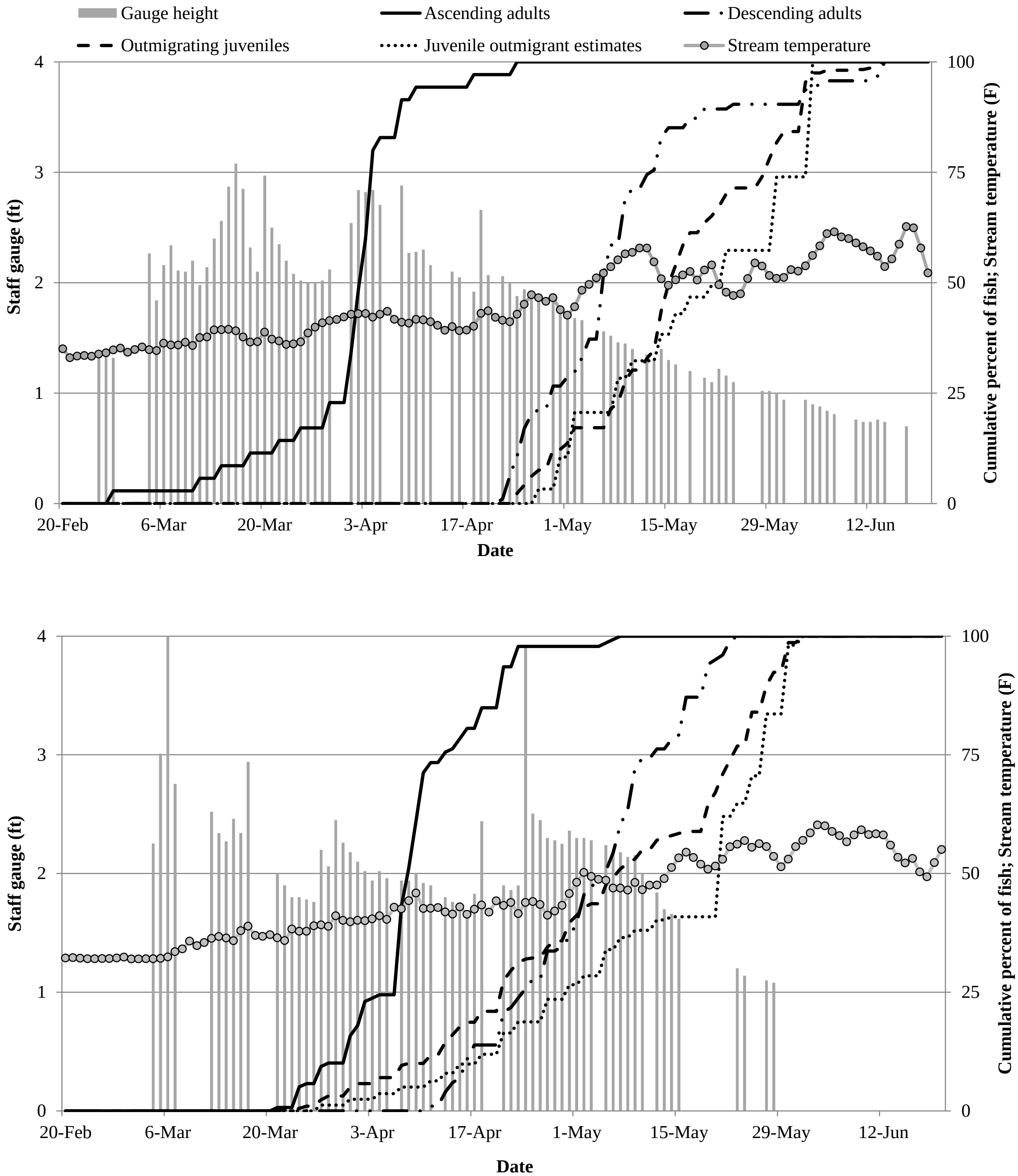


Figure 4. Cumulative distribution of captured adults, captured juveniles, and estimated juvenile outmigrants in 2013 (top panel) and 2014 (lower panel) in Lake Creek. Staff gauge heights and mean daily water temperatures are also displayed.

In 2013, a total of 1003 outmigrating juvenile WCT was captured of which 680 received PIT tags. Daily capture rates were relatively consistent from the time of trap installation on April 22, after periods of high discharge had passed, until early June (Figure 4). Thirteen trap efficiency trials were conducted (mean, 50 fish/trial) to generate an outmigrant abundance estimate of 3795 ± 990 fish. Trap efficiencies were generally less than 20% during trial periods from late April to early May, averaged 55% during the middle of May, and then declined to values less than 20% in late May and early June (Table B-2). The low trap efficiencies in combination with the large numbers of juveniles captured daily during the latter portion of the outmigration is reflected in the slightly later shift in the temporal distribution of the estimated outmigrant cohort when compared with the timing of captured juveniles (Figure 4). During May and June, 13-24% of release trial fish were recaptured after their respective trial period in approximately half of the trials, and more notably, 12 to 30% (mean, 22%) of release trial fish were detected at distant upstream fixed PIT array stations in most of the trials (Table B-2).

In 2014, a total of 2480 outmigrating juvenile WCT was captured of which 799 received PIT tags. Only 25% of these juveniles were captured during the first month (March 21 – April 21), but daily capture rates increased thereafter and were relatively consistent over the remaining 40 d (Figure 4). Twenty-four trap efficiency trials were conducted (mean, 31 fish/trial) to generate an outmigrant abundance estimate of 7980 ± 1505 fish. Trap efficiencies from late March to the middle of May were relatively consistent averaging 48%, but toward the end of May under declining levels of discharge efficiencies decreased, typically ranging from 13 to 39% (mean, 22%; Table B-3). The low trap efficiencies in combination with the large number of juveniles captured daily after the middle of May is reflected in the later shift in the temporal distribution of the estimated outmigrant cohort when compared with the timing of captured juveniles. For example, whereas 50% of the juveniles were captured by May 6, approximately 50% of the juvenile outmigrants was estimated to have descended after May 20 (Figure 4). Throughout most release trials, fish were typically recaptured during their respective trial period; percentages of fish that were recaptured later exceeded 10% only during late March (Table B-3). Only six release trial fish were detected at distant upstream fixed PIT array stations in 2014 (Table B-3), a percentage substantially less than that observed in 2013.

Benewah Creek

In 2013 and 2014, eleven and ten ascending adult WCT were respectively captured from late March to early May at the 9-mile trap site (Figure 5). Eight and seven of the ascending adults received PIT-tags in 2013 and 2014, respectively. On several occasions in April of each year, trap panels were lowered to permit adults that were potentially lingering to ascend. Seven descending adults of which three had an opercle punch were captured in 2013, yielding a spawner abundance estimate of 23 ± 12 fish. Five descending adults of which two had an opercle punch were captured in 2014, yielding a spawner abundance estimate of 21 ± 13 fish. In both years, descending adults were typically captured from the middle of April to the middle of May (Figure 5). Collectively over the trapping season, total length averaged 315 mm (n=6) and 384 mm (n=2) for males, and 348 mm (n=9) and 414 mm (n=11) for females in 2013 and 2014, respectively. In both years, all recaptured adults that were tagged at the trap retained their tags.

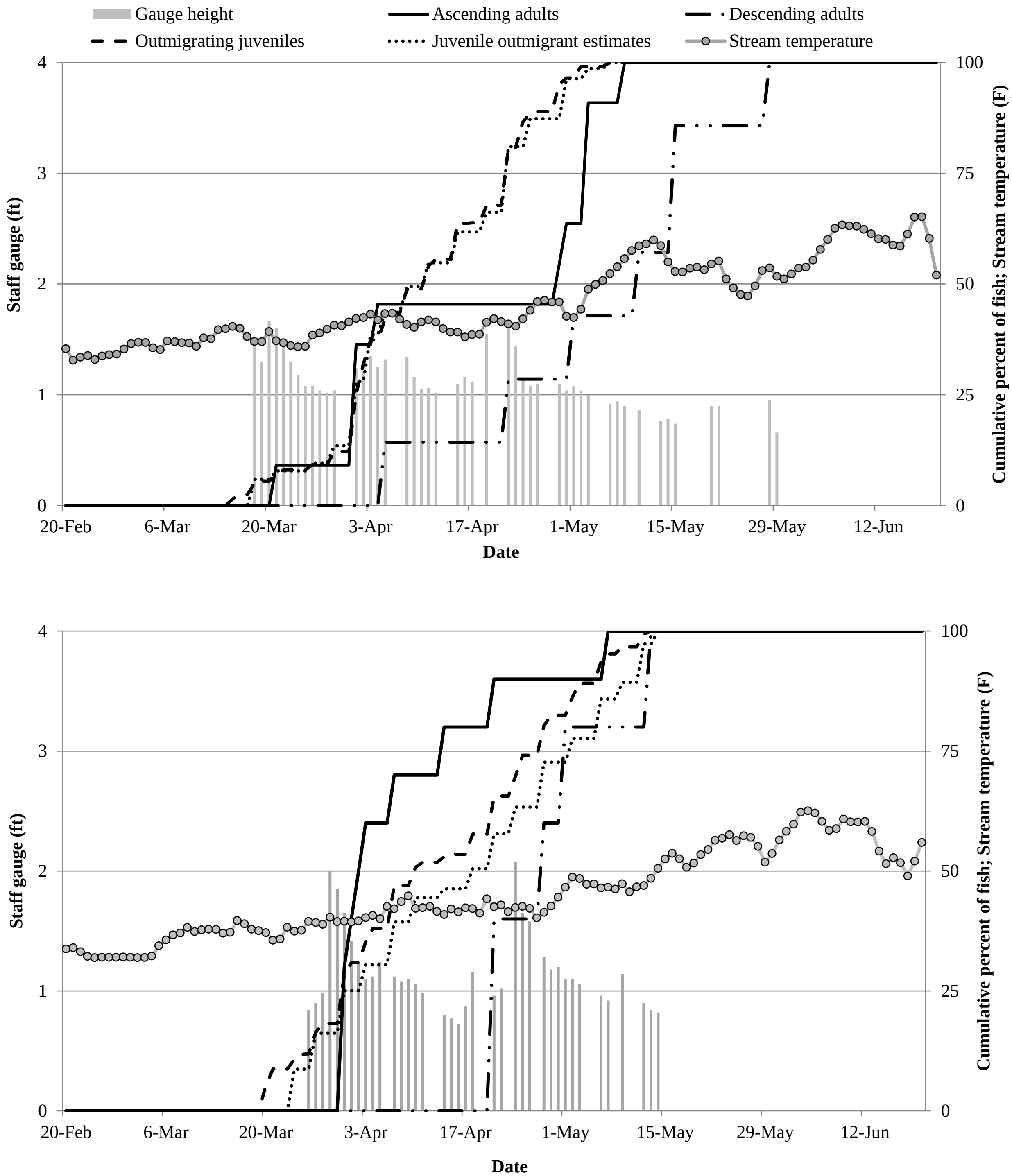


Figure 5. Cumulative distribution of captured adults, captured juveniles, and estimated juvenile outmigrants in 2013 (top panel) and 2014 (lower panel) in Benewah Creek. Staff gauge heights and mean daily water temperatures are also displayed.

In 2013, a total of 658 outmigrating juvenile WCT was captured of which 371 received PIT tags. Though daily capture rates were modest during March following trap deployment, capture rates considerably increased thereafter so that 50% of the 658 fish were captured by the first week in

April (Figure 5). From then on daily capture rates were relatively consistent, though few fish were captured after April. Sixteen trap efficiency trials were conducted (mean, 23 fish/trial) to generate an outmigrant abundance estimate of 1118 ± 131 fish. Trap efficiencies averaged 59% across trial periods (range, 38-80%; Table B-4). The relative consistency in efficiency was reflected in similar timing distributions between captured juveniles and estimated outmigrants; fifty percent of fish were estimated to have descended by April 10 (Figure 5). Release trial fish were typically recaptured during their respective trial period; percentages of fish that were recaptured later exceeded 10% only during release trials conducted in late March (Table B-4).

In 2014, a total of 884 outmigrating juvenile WCT was captured of which 420 received PIT tags. Daily capture rates were relatively consistent from the time of deployment on March 19 to May 14, when declining flows rendered the screw trap inoperable; fifty percent of the juveniles were captured by April 10 (Figure 5). Sixteen trap efficiency trials were conducted (mean, 26 fish/trial) to generate an outmigrant abundance estimate of 1576 ± 199 fish. Trap efficiencies averaged 59% (range, 42-76%) across all trial periods except the last two conducted from May 9 to May 14, in which efficiencies declined to 13-18% (Table B-5). The relative consistency in trap efficiency over most of the season was reflected in similar timing distributions between captured juveniles and estimated outmigrants; fifty percent of fish were estimated to have descended by April 18 (Figure 5). Release trial fish were typically recaptured during their respective trial period, with only seven fish recaptured during later periods (Table B-5).

Temporal trends in both watersheds

Annual estimates of WCT spawners in Lake Creek averaged 314 adults over the last three years, and have generally been greater but more variable than prior estimates (Figure 6). In addition, whereas more adults were estimated to have approached than ascended the trap site during the early years, abundance estimates have been more similar (i.e., overlapping confidence intervals) since 2012. Though precision has varied widely in Lake Creek since 2011, the estimate of ascending spawners in 2014 was rather precise (± 10%). In Benewah Creek, the inability to consistently capture ascending adults prior to this reporting period has resulted in a paucity of adult estimates. Despite this shortcoming, adult abundances have consistently been lower in Benewah Creek than in Lake Creek, and abundance estimates generated during the last two years indicate a 67% decline from those generated in earlier years (Figure 6).

In Lake Creek, notwithstanding the high flow years of 2008, 2011, and 2012, annual estimates of juvenile outmigrants averaged 3450 fish and were relatively consistent prior to 2014 (Figure 7); high flow years either precluded the attainment of an estimate or delayed trap installation so that estimates were negatively biased. In 2014, the first year in which the screw trap was used, the generated outmigrant estimate was more than twice those generated in earlier years. In Benewah Creek, juvenile outmigrant estimates were also either unattainable or negatively biased in the aforementioned high flow years. Since 2013, the first year in which the screw trap was used, annual estimates of outmigrants averaged 1347 fish, which was three times greater than the outmigrant estimates generated during the amenable flows years of 2009 and 2010 (Figure 7). Notably, trap deployments have occurred earlier in both watersheds in years in which the rotary screw trap has been used.

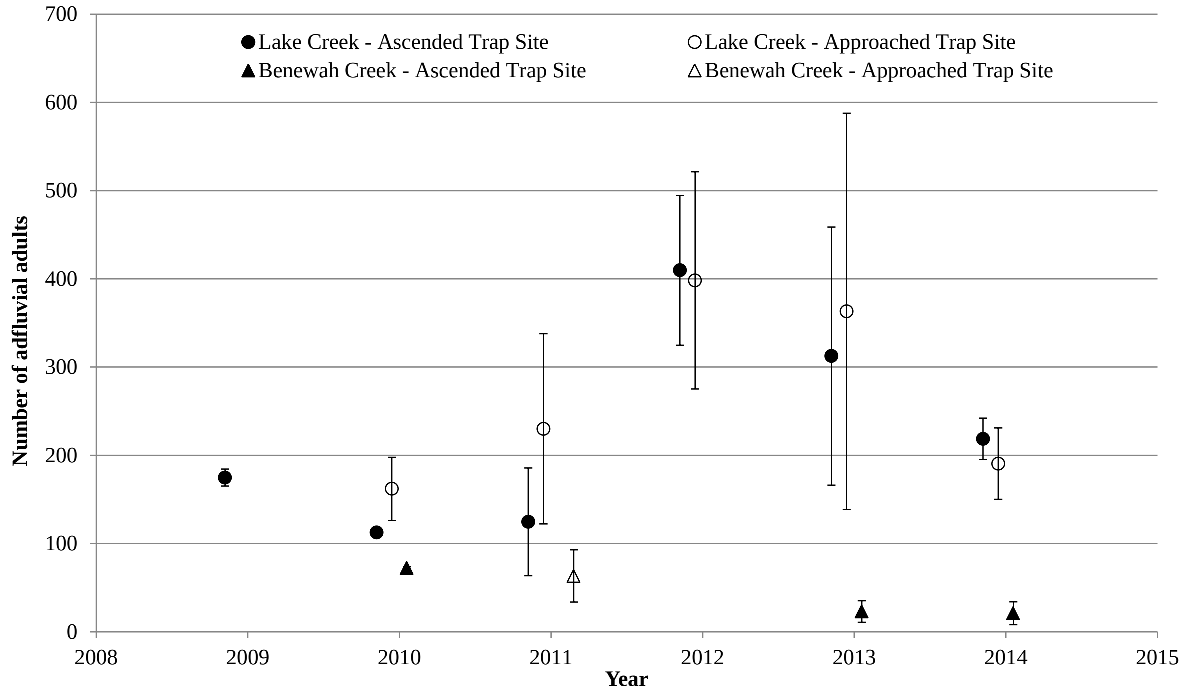
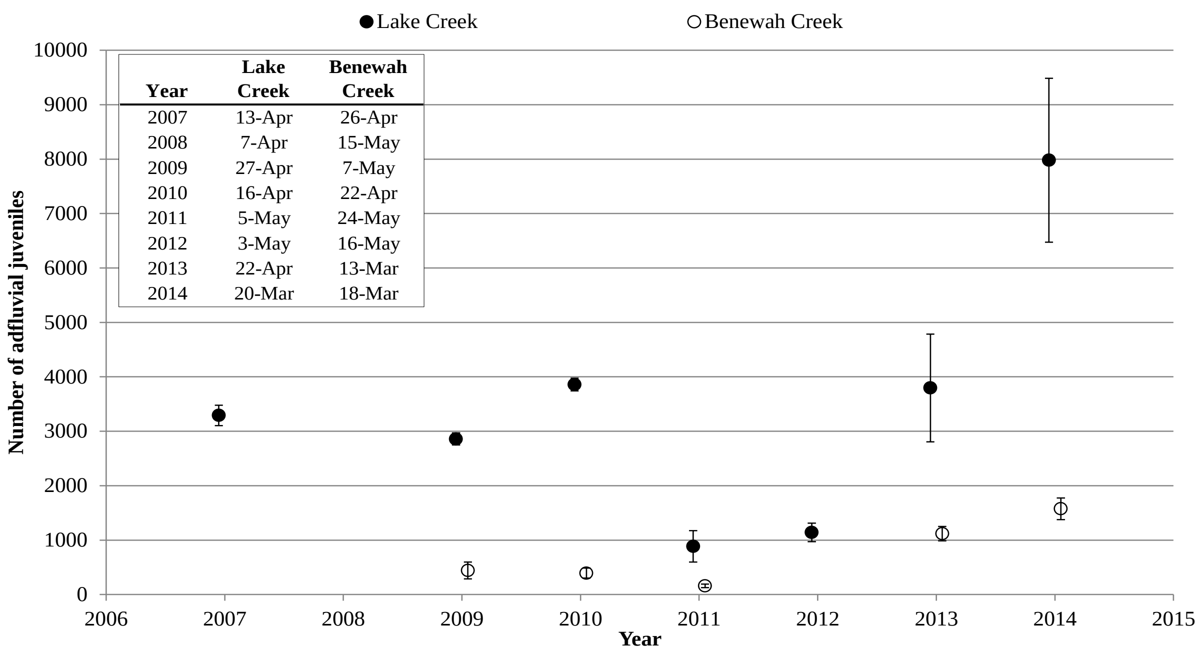


Figure 6. Abundance estimates with 95% confidence intervals for adfluvial adults that ascended and approached the trap sites in Lake and Benewah creeks from 2009 to 2014.



Year	Lake Creek	Benewah Creek
2007	13-Apr	26-Apr
2008	7-Apr	15-May
2009	27-Apr	7-May
2010	16-Apr	22-Apr
2011	5-May	24-May
2012	3-May	16-May
2013	22-Apr	13-Mar
2014	20-Mar	18-Mar

Figure 7. Abundance estimates with 95% confidence intervals for adfluvial juvenile outmigrants in Lake and Benewah creeks from 2007 to 2014. Inset table displays the dates of trap deployment in each year.

Return rates of juvenile WCT have consistently been low in both watersheds since commencement of the tagging program (Table 1). Return rates of cohorts tagged from 2005 to 2011 ranged between 1.3 - 2.9% in Lake Creek and 0 - 3.0% in Benewah Creek (not enough years have elapsed to account for variable lake residence times to confidently evaluate the return rates for the juvenile cohorts tagged in 2012). Return rates for fish that were tagged as adults from 2009 to 2011 have ranged from 31 to 43% across both watersheds; only 25% of adults tagged in 2012 in Lake Creek have been estimated to return over the last two years (Table 1).

Table 1. Return rates of juvenile and adult adfluvial cutthroat trout tagged from 2005 to 2012 in Lake and Benewah creek watersheds. The number of tagged adults was discounted by estimates of tag retention to compute return rates.

	Lake Creek Watershed					**Benewah Creek Watershed**				
	Juveniles		**Adults**			**Juveniles**		**Adults**		
Tag Year	**Number tagged**	**Number returned (%)**	**Number tagged**	**Percent tag retention**	**Number returned (%)**	**Number tagged**	**Number returned (%)**	**Number tagged**	**Percent tag retention**	**Number returned (%)**
2005	681	13 (1.9)	.	.	.	.	.	.	.	.
2006	789	10 (1.3)	.	.	.	.	.	.	.	.
2007	786	14 (1.8)	.	.	.	.	.	.	.	.
2008	614	8 (1.3)	.	.	.	202	6 (3.0)	.	.	.
2009	696	9 (1.3)	105	88	40 (43)	96	2 (2.1)	.	.	.
2010	966	28 (2.9)	83	70	18 (31)	185	2 (1.1)	66	84	19 (34)
2011	219	4 (1.8)	8	100	3 (38)	42	0 (0.0)	.	.	.
2012	484	1 (0.2)	96	59	14 (25)	16	1 (6.3) [a]	2	.	1 (50)

[a] The one fish that has returned was tagged at 233 mm and deemed a hybrid

3.4.1.2 Spatial distribution of trout populations

Lake Creek watershed

Density indices of age 1+ WCT (fish/100 m) generally increased from downstream to upstream in each of the three major sub-drainages in the upper Lake Creek watershed (Table 2). In the Bozard sub-drainage, densities in 2013 and 2014 in the mainstem of Bozard Creek respectively averaged only 6.6 and 9.1 across sites in the lowermost kilometer, but were found to respectively average 23.2 and 46.6 across sites further upstream. In the primary branch of the East Fork of Bozard Creek (EFB), densities averaged 56.3 in 2013 and 83.1 in 2014, with individual site values the highest recorded over both years in the Bozard sub-drainage. Similar patterns were observed in the WFL sub-drainage in 2013 and 2014, with densities respectively averaging 3.6 and 2.0 across the lowermost two sites, increasing over the next kilometer upstream, and then attaining high values that respectively averaged 68.8 and 51.6 from rkm 3.5 to rkm 4.7; densities recorded at the uppermost site, which was located in higher gradient step-pool habitat, were substantially lower than those at nearby downstream sites. Though few sites were sampled in the UFL sub-drainage, densities within each year were lowest at the most downstream site (range, 1.6-6.6) and highest at the most upstream site (range, 21.3-36.1); densities at the intermediate site varied considerably between years (range, 9.8-34.1). Age-0 WCT displayed similar patterns of distribution, with the highest densities within each sub-drainage occurring along those reaches where age1+ fish were found to be most prevalent (Table 2).

Table 2. Single pass density indices (fish/100 m) for age 1+ and age 0 cutthroat trout sampled by electrofishing tributary sites in the upper Lake Creek watershed, 2013 and 2014. Numbers in parentheses following stream names indicate the river kilometer at which the stream confluences with the main channel.

		2013 density indices (fish/100 m)		2014 density indices (fish/100 m)	
Stream	**River km**	**Age 1 +**	**Age 0**	**Age 1 +**	**Age 0**
Bozard Creek (13.4)					
	0.1	8.2	6.6	3.9	6.6
	0.8	4.9	1.6	14.3	1.2
	2.7	13.1	5.6	43.3	13.1
	3.6	24.8	0	47.2	10.5
	4.1	32.8	9.8	44.6	21.0
	4.6	21.9	9.4	51.2	87.9
East Fork of Bozard Creek (4.0)					
	0.1	59.1	16.4	93.2	15.7
	0.6	52.9	13.2	70.9	28.9
	2.1	57.0	45.0	85.3	23.6 [a]
Tributary to East Fork Bozard Creek (0.2)					
	0.7	21.0	10.0	13.1	7.9 [a]
	1.7	32.0	9.0	48.6	7.9 [a]
Upper Fork of Lake Creek (13.8)					
	0.3	1.6	0	6.6	1.3
	0.5	9.8	0	34.1	0.0
	3.3	21.3	8.2	36.1	13.1
West Fork Lake Creek (13.8)					
	1.2	3.3	0	3.9	0.0
	2.2	3.9	0	0.0	0.0
	2.6	21.0	9.2	18.4	2.6
	3.1	45.9	13.1	22.3	27.6
	3.5	64.0	16.4	69.6	22.3
	3.9	70.9	27.6	19.7	15.7
	4.2	67.3	1.6	49.9	21.0
	4.4	82.7	13.1	72.2	11.8
	4.7	59.1	17.1	46.9	2.7
	5.4	28.9	2.6	10.9	0.0

[a] Many other age-0 fish observed but not captured

In both the Bozard and UFL sub-drainages, densities of age 1+ and age-0 WCT were greater in 2014 than in 2013 at most of the survey sites (Table 2). In 2014, age-0 fish were especially found in large numbers at the uppermost site in the mainstem of Bozard Creek, and, though not captured, field notes indicated that they were also abundant in the upper reaches of the main branch of EFB and also across sites in a surveyed secondary tributary of EFB. Conversely, densities of age 1+ fish were greater in 2013 than in 2014 across most of the sites surveyed in the WFL sub-drainage; consistent differences in age-0 densities between years were not as evident (Table 2).

Benewah Creek watershed

The longitudinal pattern in density indices (fish/100 m) of age 1+ WCT that was observed in the upper Lake Creek watershed was not as evident across all sub-drainages in the Benewah Creek watershed (Table 3). Densities were generally comparable across survey sites within each of Windfall, SFB, and WFB creeks, respectively averaging 17.6, 22.0, and 12.8 in 2013, and 24.6, 21.0, and 22.2 in 2014. In some years, however, densities varied markedly across sites within a sub-drainage (e.g., Windfall Creek in 2013) or were consistently lower throughout a specific sub-drainage reach (e.g., uppermost reach in WFB in 2013 and lowermost reach in SFB in 2014). In comparison, densities of age 1+ WCT over both years in the Whitetail sub-drainage were substantially less in lower reaches, averaging 7.2, than in the uppermost reach, where densities averaged 51.2. Schoolhouse creek also displayed increasing densities from downstream to upstream in both years, with densities ranging from 32.8 to 38.1 across uppermost sites in 2014.

Noticeable differences in the distribution of age-0 WCT were observed among sub-drainages in the Benewah watershed (Table 3). In Coon and Bull creeks, high densities of fish were often observed across survey sites. In Windfall creek, though densities varied considerably among sites, moderate to high densities of age-0 fish (range, 18.0-44.0) were consistently observed in the lowermost surveyed reach and in an intermediate reach (i.e., rkm 2.8). Moderate to high densities of age-0 fish (range, 18.0-82.0) were also observed in WFB, with the highest density observed in the uppermost site surveyed in 2014. In comparison, age-0 fish were found at low densities across surveyed reaches in Whitetail, Schoolhouse, and SFB creeks.

In the Benewah watershed, differences in the spatial distribution of brook trout were observed among and within surveyed sub-drainages (Table 3). In both years, brook trout were virtually absent from upper reaches of most of the sub-drainages, and found at low densities across sites in WFB. In 2013, age 1+brook trout were typically found only in lower reaches of Windfall, Schoolhouse, and SFB creeks, and often at moderately low densities that did not exceed 5.0. In comparison, age-0 brook trout were observed at relatively greater numbers than age 1+ fish in lowermost reaches of many of the sub-drainages in 2013, with densities in excess of 20 recorded in each of Bull, Whitetail, Windfall, and SFB creeks. Age-0 production in 2013 was reflected in the numbers of age 1+ fish observed in 2014 (Table 3). Densities of age 1+ brook trout in lowermost surveyed reaches ranged from 10.5-14.4 in Bull and Whitetail creeks, 7.0-8.7 in Windfall creek, 13.0-17.1 in SFB, and 9.5-39.4 in Schoolhouse creek. Age-0 fish were rarely captured across surveyed sites in 2014.

Table 3. Single pass density indices (fish/100 m) for age 1+ and age 0 cutthroat trout and brook trout sampled by electrofishing tributary sites in the Benewah Creek watershed, 2013 and 2014. Numbers in parentheses following stream names indicate the river kilometer at which the stream confluences with the main channel.

	2013 density indices (fish/100 m)					2014 density indices (fish/100 m)				
		Cutthroat trout		Brook trout			Cutthroat trout		Brook trout	
Stream	**River km**	**Age 1 +**	**Age 0**	**Age 1 +**	**Age 0**	**River km**	**Age 1 +**	**Age 0**	**Age 1 +**	**Age 0**
Coon Creek (7.3)										
	0.8	1.6	59.1	0	0	.	.	.	.	.
Bull Creek (8.9)										
	0.1	26.2	16.4	0	27.9	0.1	22.3	21.0	14.4	3.9
	1.1	8.2	31.2	0	0	1.1	35.4	124.7 [a]	0	0
Whitetail Creek (15.2)										
	0.2	9.8	0.0	1.6	24.6	0.7	6.6	0	10.5	0
	2.2	52.5	9.8	0	0	1.3	5.2	0	1.3	0
	.	.	.	.	.	2.0 [b]	.	.	.	.
	.	.	.	.	.	2.6	49.9	0	0	0
Windfall Creek (18.6)										
	0.8	16.0	44.0	1.0	58.0	0.9	28.4	28.4	8.4	4.2
	1.4	11.6	16.5	13.6	5.8	1.2	19.4	1.9	8.7	0
	2.3	18.0	6.0	4.0	1.0	1.4	23.0	13.0	7.0	0
	2.8	22.0	39.0	0	0	2.3	21.0	11.0	4.0	0
	3.1	0	5.2	1.0	0	2.8	33.0	18.0	3.0	0
	3.5	12.0	14.0	0	0	3.6	20.0	0	0	0
	3.8	11.5	6.7	0	0	3.9	18.5	0	0	0
Tributary to Windfall Creek (2.2)										
	0.2	55.0	22.0	0	0	0.6	25.0	7.0	0	0
	0.5	19.0	3.0	0	0	0.7	23.0	0	0	0
	0.7	7.8	0	0	0	1.3	35.0	0	0	0
	1.4	21.0	4.0	0	0	.	.	.	.	.
Schoolhouse Creek (19.6)										
	0.1	6.6	0.0	6.6	11.5	0.4	15.7	0	39.4	5.2
	1.2	11.5	9.8	1.6	13.1	0.8	16.7	1.2	9.5	0
	.	.	.	.	.	1.3	38.1	6.6	15.7	0
	.	.	.	.	.	1.8	32.8	2.6	10.5	1.3
South Fork Benewah Creek (21.5)										
	0.4	15.0	3.0	5.0	33.0	0.2	9.0	0	13.0	0
	0.8	14.0	0	3.0	3.0	0.6	12.4	2.9	17.1	1.0
	1.3	17.0	1.0	5.0	11.0	1.8	26.0	1.0	4.0	0
	2.0	20.0	2.0	1.0	2.0	2.2	31.0	0	1.0	0
	2.4	41.0	3.0	2.0	0	3.0	37.0	3.0	1.0	0
	2.6	34.0	7.0	0	0	3.4	23.0	1.0	0	0
	3.8	11.0	0	0	0	3.7	18.0	2.0	0	0
	4.1	24.0	1.0	0	0	4.2	11.2	1.9	0	0
West Fork Benewah Creek (21.5)										
	0.1	14.0	22.0	0	17.0	0.3	32.0	5.0	6.0	0
	0.7	21.0	21.0	0	2.0	0.8	21.0	2.0	1.0	0
	1.3	22.0	13.0	0	0	1.4	26.0	26.0	0	0
	1.6	15.0	18.0	0	0	1.7	13.0	25.0	1.0	0
	2.2	1.1	15.3	0	0	2.1	30.0	1.0	0	0
	2.4	4.0	0	0	0	2.3	11.0	82.0	0	0

[a] Many other age-0 fish observed but not captured

[b] Reach was dewatered at time of sampling

3.4.1.3 Diversity of cutthroat trout populations

Lake Creek watershed

In the upper Lake Creek watershed, the extent of stream length supporting juvenile WCT that were detected moving downriver in the spring was greatest in the Bozard sub-drainage (Table 4). The spatial distribution of fish tagged in the summer of 2012 was restricted to traditional index reaches, and consequently detections the following spring did not adequately illustrate differences among the sub-drainages. Nevertheless, passive downriver detections and active recaptures at the migrant trap were greater for fish tagged in lower reaches of EFB than those tagged across other reaches in the upper watershed. Fish were tagged over a greater spatial extent across the upper watershed in the summer of 2013 to better describe the distribution of the adfluvial variant. During the spring of 2014, 20 and 40% of the fish that were tagged across approximately 5.2 km of stream length in the Bozard sub-drainage (including Bozard Creek and the lower reach of EFB) were actively and passively detected, respectively. Similar percentages of active and passive downriver detections were observed for WFL fish, but only for those fish tagged across the lowermost 3.1 km. For fish tagged in reaches further upstream in WFL, rates of detection declined with only 2-6% detection rates observed for fish tagged in the uppermost reach. Comparably low detection rates were also observed for fish tagged in uppermost reaches of EFB and in its secondary tributary. The size of tagged fish did not appreciably differ between Bozard and WFL, though fish in each sub-drainage were generally larger in the most downriver reach. Overall, the largest fish were tagged in the UFL, the sub-drainage with the lowest spring detection rates.

Sub-drainages that were ascended by adfluvial adult WCT in the upper Lake Creek watershed in 2013 and 2014 reflected that observed in the juvenile outmigrant detection data (Table 5). In both years, approximately two-thirds of the adults that were PIT-tagged at the migrant trap ascended Bozard Creek. In comparison, only 11% and 6% of the tagged adults on average ascended the WFL and UFL sub-drainages, respectively. Though few fish were detected in consecutive spring migrations, spawning stream fidelity was observed. All three of the adults that ascended Bozard Creek in 2013 and returned in 2014 selected Bozard once again. More notably, one fish that had ascended UFL in 2013, a sub-drainage that evidently was not selected by many adults, and was found to return the following year, again ascended UFL.

In the Lake Creek watershed, differences in the timing of outmigration were observed among groups of tagged juveniles in 2014 (Figure 8). Fifty percent of juveniles tagged during summer surveys in the Bozard and WFL sub-drainages that were recaptured in the migrant trap in 2014 were caught after May 19. In comparison, juveniles that were tagged at the migrant trap in 2013 (evidently not outmigrating that year) descended much earlier in 2014, with fifty percent of these fish captured before April 21. Only four of these fish (21%) had been passively detected at upstream tributary PIT arrays after their date of release at the trap site in 2013, indicating that most had meanwhile likely reared in the six km of mainstem habitat upstream of the trap site before their recapture in 2014. Daily growth rates from date of release to date of recapture were greater for fish that had been tagged at the trap in 2013 than for fish that were tagged in Bozard and WFL sub-drainages (Figure 9).

Table 4. Active and passive detections during spring migratory periods for cutthroat trout PIT-tagged across reaches in three sub-drainages of upper Lake Creek. The number of passively detected fish that were found to temporarily move upstream into a sub-drainage during the spring are also displayed along with their mean residence times.

						Detected moving temporarily into tributaries before apparent movement downstream					
						West Fork Lake		Upper Lake		Bozard	
Stream	River kilometer reach	Number tagged	Mean length (mm)	Captured in trap (%)	Detected at PIT sites (%)	Number (%)	Mean elapsed days	Number (%)	Mean elapsed days	Number (%)	Mean elapsed days
Fish tagged during the summer and fall of 2012 and detected during the spring of 2013											
Bozard Creek (13.4)											
	0.0 - 3.0	15	151	0 (0)	3 (20)	0 (0)	.	1 (33)	32	0 (0)	.
	3.0 - 4.6	41	117	3 (7)	7 (17)	0 (0)	.	3 (43)	40	1 (14)	29
East Fork of Bozard Creek (4.0)											
	0.0 - 0.6	55	109	8 (15)	19 (35)	0 (0)	.	4 (21)	18	0 (0)	.
	2.1	.	.	.	.	.	.	.	.	.	.
Tributary to East Fork Bozard Creek (0.2)											
	0.0 - 1.7	.	.	.	.	.	.	.	.	.	.
Upper Fork of Lake Creek (13.8)											
	0.0 - 0.7	8	202	0 (0)	1 (13)	0 (0)	.	1 (100)	85	0 (0)	.
	3.3	31	131	1 (3)	4 (13)	0 (0)	.	0 (0)	.	0 (0)	.
West Fork Lake Creek (13.8)											
	0.0 - 3.1	0	.	.	.	.	.	.	.	.	.
	3.1 - 4.2	48	123	4 (8)	9 (19)	0 (0)	.	0 (0)	.	0 (0)	.
	4.2 - 5.4	.	.	.	.	.	.	.	.	.	.
Fish tagged during the summer and fall of 2013 and detected during the spring of 2014											
Bozard Creek (13.4)											
	0.0 - 3.0	22	138	5 (23)	9 (41)	0 (0)	.	6 (67)	41	2 (22)	10
	3.0 - 4.6	59	113	12 (20)	22 (37)	1 (5)	41	12 (55)	48	0 (0)	.
East Fork of Bozard Creek (4.0)											
	0.0 - 0.6	55	103	10 (18)	24 (44)	1 (4)	52	19 (79)	52	0 (0)	.
	2.1	30	118	2 (7)	7 (23)	0 (0)	.	5 (71)	64	0 (0)	.
Tributary to East Fork Bozard Creek (0.2)											
	0.0 - 1.7	34	101	0 (0)	3 (9)	1 (33)	21	1 (33)	66	0 (0)	.
Upper Fork of Lake Creek (13.8)											
	0.0 - 0.7	7	184	0 (0)	1 (14)	1 (100)	5	1 (100)	19	1 (100)	1
	3.3	13	131	0 (0)	0 (0)	.	.	.	.	.	.
West Fork Lake Creek (13.8)											
	0.0 - 3.1	56	128	12 (21)	20 (36)	0 (0)	.	0 (0)	.	0 (0)	.
	3.1 - 4.2	106	112	13 (12)	26 (25)	1 (4)	4	1 (4)	7	0 (0)	.
	4.2 - 5.4	108	113	2 (2)	7 (6)	0 (0)	.	0 (0)	.	0 (0)	.

Though the timing of capture in the migrant trap was similar between fish tagged in the Bozard sub-drainage and those tagged in the WFL sub-drainage, there were marked differences in their behavior as they moved downstream in the spring out of their respective tagging tributaries. For example, 29 and 65 fish that had been tagged in the Bozard sub-drainage were passively detected during spring migratory periods in 2013 and 2014, respectively. However, 28% of the 29 and 66% of the 65 were found upon exiting Bozard Creek to temporarily move into the UFL sub-drainage, and spend on average more than 40 d before moving back downstream (Table 4). Ascension up the WFL was rarely observed in fish from the Bozard sub-drainage, and notably movement up either the UFL or Bozard Creek was hardly detected for fish that had been tagged in the WFL sub-drainage. For juveniles tagged in sub-drainages during summer surveys, daily growth rates were noticeably greater for fish captured at the migrant trap later than those captured earlier in the spring (Figure 9).

Table 5. Summary of fates of adult adfluvial cutthroat trout tagged at migrant traps in Lake Creek (rkm 7.2) and Benewah Creek (rkm 14.1) as they were ascending upstream in 2013 and 2014.

Lake Creek Watershed			**Benewah Creek Watershed**		
Metric	**2013**	**2014**	**Metric**	**2013**	**2014**
Adults tagged in current year	27	112	Adults tagged in current year	8	7
Adults returning from prior year	.	4	Adults returning from prior year	.	1
Ascended Bozard Creek (13.4)			Ascended Windfall Creek (18.6)		
Number	18	76 [a]	Number	3 [b]	2 [c,d]
Percent	67	66	Percent	38	25
Ascended West Fork Lake Creek (13.8)			Ascended South Fork Benewah Creek (21.5)		
Number	2	16	Number	2 [e]	0
Percent	7	14	Percent	25	0
Ascended Upper Fork Lake Creek (13.8)			Ascended West Fork Benewah Creek (21.5)		
Number	2	5 [f]	Number	1 [g]	2 [g]
Percent	7	4	Percent	13	25

[a] Three fish also ascended Bozard in 2013

[b] One was briefly detected at the site but was not found to ascend

[c] One was briefly detected and the other visited the site multiple times, but neither was found to ascend

[d] One fish was found to ascend Windfall in 2013

[e] One spent a day upstream; the other visited the site multiple times but was not found to ascend

[f] One fish also ascended the upper Lake Fork in 2013

[g] One fish identified as a hybrid

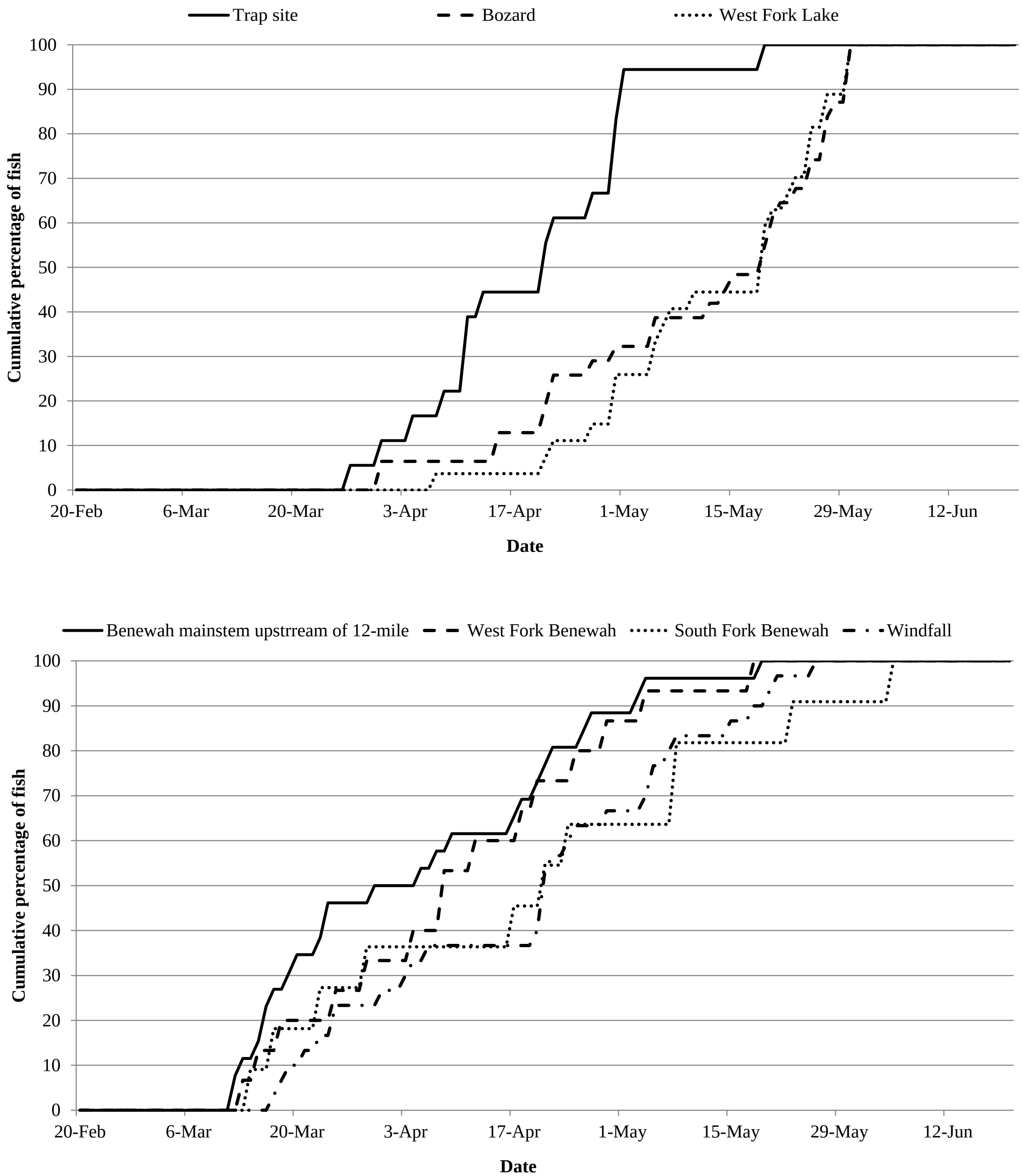


Figure 8. Cumulative distribution curves for tagged juveniles captured in the migrant trap in Lake Creek (upper panel) or passively detected at the 9-mile array in Benewah Creek (lower panel) in the spring of 2014. Lake Creek juveniles were tagged at the migrant trap in spring of 2013 and during summer surveys in the Bozard and WFL sub-drainages. Benewah Creek juveniles were tagged in WFB, SFB, and Windfall sub-drainages, and along a 2 km reach of the Benewah mainstem upriver of 12-mile bridge during summer surveys.

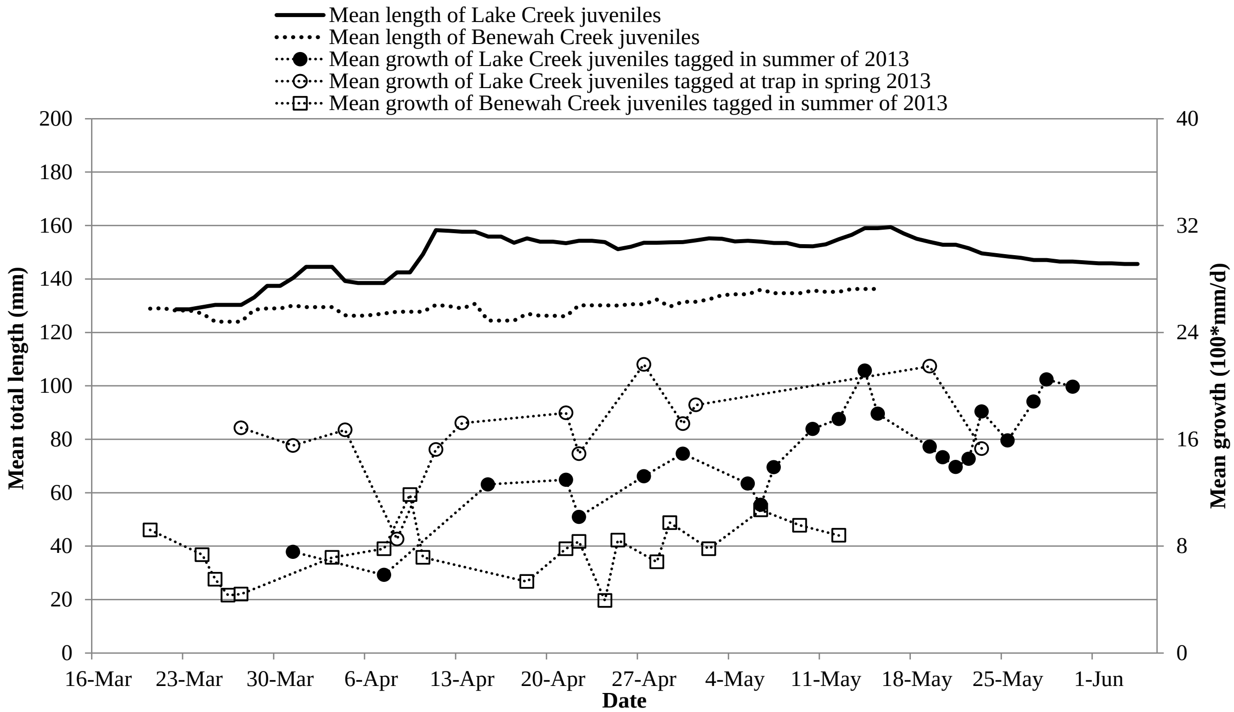


Figure 9. Mean total length of juvenile cutthroat trout and mean growth rates of PIT-tagged juveniles since time of tagging that were captured in migrant traps in Lake and Benewah creek watersheds in 2014

Benewah Creek watershed

In the upper Benewah watershed, higher rates of downstream movement in the spring was observed over both years from juvenile WCT tagged in the Windfall sub-drainage than in other sub-drainages (Table 6). For juveniles tagged in the lower 2.3 km of Windfall creek and along reaches of a secondary tributary, 11 and 16% were respectively recaptured at the migrant trap in 2013 and 2014, and 23% were passively detected at the nearby 9-mile PIT array in each year. In comparison, fish tagged in the lower 1.5 km of WFB were recaptured at rates of 2 and 10% and passively detected at 9-mile at rates of 9 and 20% in 2013 and 2014, respectively; detection percentages were even less for fish tagged in the lower 2.1 km of SFB, with only 2-5% recaptured and 9-15% passively interrogated over both years. Furthermore, when considering the same reaches of all three sub-drainages, passive interrogation data collected at stream mouths indicated that 33 and 48% of fish tagged in Windfall exited the stream during the spring in 2013 and 2014, respectively. In comparison, 21 and 41% of fish tagged in WFB and only 11 and 24% of fish tagged in SFB were found to exit their stream of tagging in 2013 and 2014, respectively. In general, detection rates were low for fish tagged in upper reaches of all three sub-drainages. Tagged fish were generally larger in the most downstream reach in each sub-drainage, with fish in the SFB and the Benewah mainstem typically greater in length than those tagged elsewhere.

Few ascending adfluvial adult WCT were tagged at the Benewah Creek trap in either year, so a robust assessment of preferred sub-drainages could not be conducted. Nevertheless, some observations were noteworthy (Table 5). In each year, a couple fish were found to either ascend or temporarily enter Windfall Creek, with one fish entering in both years. On the other hand, only one short-lived ascension (i.e., 1 day) was detected up the SFB over both years. In the WFB, two of the three fish that ascended were classified as hybrids at time of tagging.

Table 6. Active and passive detections during spring migratory periods for cutthroat trout PIT-tagged across reaches in the upper Benewah watershed.

Stream	River kilometer reach	Number tagged	Mean length (mm)	Captured in trap (%)	Last detected at 9-mile PIT site (%)	Detected at PIT sites (%)
Fish tagged during summer and fall of 2012 and detected during the spring of 2013						
Benewah						
	20.0 - 21.5	.	.	.	.	.
Windfall (18.6)						
	0.0 - 2.3	41	134	6 (15)	10 (24)	14 (34)
	2.3 - 3.8	21	109	0 (0)	2 (10)	5 (24)
Tributary to Windfall (2.2)						
	0.0 - 1.4	42	96	3 (7)	9 (21)	13 (31)
West Fork Benewah (21.5)						
	0.0 - 1.5	43	127	1 (2)	4 (9)	9 (21)
	1.5 - 2.5	25	110	0 (0)	2 (8)	2 (8)
Tributary to West Fork Benewah (1.0)						
	0.0 - 1.0	21	120	0 (0)	0 (0)	0 (0)
South Fork Benewah (21.5)						
	0.0 - 2.1	53	130	1 (2)	5 (9)	6 (11)
	2.1 - 4.1	32	122	0 (0)	1 (3)	1 (3)
Tributary to South Fork Benewah (2.1)						
	0.0 - 1.0	8	118	0 (0)	0 (0)	0 (0)
Fish tagged during summer and fall of 2013 and detected during the spring of 2014						
Benewah						
	20.0 - 21.5	111	140	6 (5)	25 (23)	55 (50)
Windfall (18.6)						
	0.0 - 2.3	45	122	7 (16)	12 (27)	21 (47)
	2.3 - 3.8	44	117	0 (0)	0 (0)	1 (2)
Tributary to Windfall (2.2)						
	0.0 - 1.4	80	100	13 (16)	17 (21)	39 (49)
West Fork Benewah (21.5)						
	0.0 - 1.5	70	115	7 (10)	14 (20)	29 (41)
	1.5 - 2.5	25	114	1 (4)	1 (4)	4 (16)
Tributary to West Fork Benewah (1.0)						
	0.0 - 1.0	.	.	.	.	.
South Fork Benewah (21.5)						
	0.0 - 2.1	66	137	3 (5)	10 (15)	16 (24)
	2.1 - 4.1	62	121	0 (0)	1 (2)	1 (2)
Tributary to South Fork Benewah (2.1)						
	0.0 - 1.0	.	.	.	.	.

In the Benewah watershed, differences in the timing of outmigration in 2014, as evidenced by passive detections at the 9-mile array, were observed among groups of tagged juveniles (Figure 8). Fish tagged in the 2 km Benewah mainstem reach upstream of 12-mile bridge outmigrated the earliest, with 50% of array detections occurring before March 30. In addition, thirty percent of these fish were passively detected before deployment of the screw trap on March 19. In comparison, fifty percent of the detected fish from the WFB sub-drainage were found to descend past 9-mile after April 8. Fish from the SFB and Windfall sub-drainages outmigrated the latest, with 50% of detections occurring after April 21. Generally, growth rates of outmigrating juveniles in the upper Benewah watershed from time of tagging to time of recapture in the trap were lower than those observed in the Lake Creek watershed (Figure 9). Furthermore, other than early time periods in the trapping season, the mean size of juveniles captured in migrant traps was typically 20-25 mm smaller in Benewah Creek than in Lake Creek in 2014 (Figure 9).

Fall and winter movements of cutthroat trout

WCT tagged during summer surveys in adfluvial watersheds were detected moving downstream during fall and winter periods of 2013 and 2014, though differences were observed among tagging locations and between years (Table 7). In the upper Benewah watershed, 17-18% of the fish tagged over both years in WFB were detected moving out of WFB, with 4-7% of tagged fish last detected in the mainstem reach between 12-mile and 9-mile, and 5-7% of tagged fish last detected moving downstream of the 9-mile HDX station. Similar downstream movements were observed for fish tagged in the 2 km mainstem reach upstream of 12-mile, with 13-19% last detected between 12-mile and 9-mile and 8-9% last detected downstream of 9-mile. In comparison, fish tagged in SFB were rarely detected and fish tagged in Whitetail Creek were not detected during fall and winter periods. In Windfall Creek, only 3% of tagged fish were detected moving downstream in 2013, but during the fall and winter of 2014, 14% were detected moving downstream with more than half of these fish last detected downstream of 9-mile. Though only a small number of fish were tagged in Schoolhouse Creek in the summer of 2014, 10% of these fish were detected at downstream fixed HDX arrays during the fall and winter. Approximately 40% of the fish detected moving downstream of the 9-mile HDX station during fall and winter periods of 2013 and 2014 temporarily resided in the mainstem reach between 12-mile and 9-mile for an average of 83 and 25 d, respectively. Of fish last detected between 12-mile and 9-mile in the fall and winter of 2013, 50% were detected moving downstream of the 9-mile station the following spring. In the upper Lake Creek watershed, 4.5 and 14.5% of fish tagged in the Bozard sub-drainage were detected moving downstream out of Bozard in fall and winter periods of 2013 and 2014, respectively. In comparison, less than 1% of fish tagged in the WFL sub-drainage were detected moving downstream out of WFL in both years.

3.4.1.4 Status of tributary habitat

Many of the physical attributes associated with the quality of trout habitat were more favorable in upper than in lower reaches in the Bozard and WFL sub-drainages (Table 8). Percent canopy cover estimates in the lowermost three km of each sub-drainage were less than 67%, which was below the performance standard of 75% that has been established for 2nd and 3rd order tributaries by the fisheries program. Canopy cover estimates at all remaining sites upstream exceeded the performance standard, averaging 90% in each sub-drainage.

Fine sediment in riffle and tailpool habitats was more prevalent in downstream than in upstream reaches across both sub-drainages (Table 8). Percent fine estimates in wetted areas ranged between 21 and 27 for lowermost sites, which exceeded the performance standard of 15%; the standard was also exceeded at sites in secondary tributaries of EFB (39%) and WFL (23%). At all other sites, percent fine estimates in wetted areas met the standard, averaging 11 and 8% in Bozard and WFL sub-drainages, respectively. Bankfull percent fine estimates were consistently greater than those computed across wetted areas, and reflected the geology of the watershed and the fine-grained soils that constitute the banks and streambed outside the active channel.

Large woody debris (LWD) metrics were greater in upstream than in downstream reaches of both sub-drainages (Table 8). Counts of LWD in the main channel of Bozard Creek and in the lower three km of WFL did not exceed 10 pieces/100 m, whereas counts in most sites in upper reaches of both sub-drainages exceeded this value. Volumes of LWD were also greater in upstream than in downstream reaches, though most of the sites were far from meeting the performance standard of 6.0 m^3/100 m; only one site in each sub-drainage either approached or exceeded this standard.

Pool metrics were greater in downstream, lower gradient reaches than in upstream higher gradient reaches in both sub-drainages (Table 8). Percent pool and mean residual pool depth respectively averaged 59% and 0.37 m across the two most downstream sites in Bozard creek (rkm 2.7-3.6), and 76% and 0.49 m across the three most downstream sites in WFL (rkm 0.5-2.6). In comparison, percent pool and mean residual pool depth respectively averaged 29% and 0.19 m in the Bozard sub-drainage, and 29% and 0.26 m in the WFL sub-drainage for sites further upstream and in secondary tributaries. Generally, pool metrics and wetted stream width were greater in WFL than in Bozard in each of downstream and upstream reaches (Table 8).

Table 7. Cutthroat trout tagged in mainstem habitat and in tributaries of the upper Benewah watershed detected moving downstream during the fall and winter of 2013 (September 18, 2013 – February 23, 2014) and the fall and winter of 2014 (September 2, 2014 – February 7, 2015).

		2013 fall and winter detections (%)				2014 fall and winter detections (%)		
			Location of last detection				Location of last detection	
Tagging location	**Tagged in 2013**	**Moving out of tagging tributary**	**Mainstem reach between 12-mile and 9-mile**	**Downstream of 9-mile**	**Tagged in 2014**	**Moving out of tagging tributary**	**Mainstem reach between 12-mile and 9-mile**	**Downstream of 9-mile**
Benewah mainstem [a]	111	.	21 (0.19)	10 (0.09)	106	.	14 (0.13)	9 (0.08)
South Fork Benewah	128	1 (0.01)	0 (0)	0 (0)	140	3 (0.02)	1 (0.01)	0 (0)
West Fork Benewah	94	16 (0.17)	4 (0.04)	7 (0.07)	113	20 (0.18)	8 (0.07)	6 (0.05)
Schoolhouse	.	.	.	.	63	6 (0.1)	3 (0.05)	2 (0.03)
Windfall	169	5 (0.03)	5 (0.03)	0 (0)	201	28 (0.14)	12 (0.06)	16 (0.08)
Whitetail	.	.	.	.	33	0 (0)	0 (0)	0 (0)

[a] Tagged in mainstem reach between 12-mile bridge and the confluence of South and West Forks of Benewah Creek

Table 8. Physical habitat attributes measured at 100 m sites in Bozard and West Fork Lake sub-drainages in the upper Lake Creek watershed. Numbers in parentheses following stream names indicate the river kilometer at which the stream confluences with the main channel.

				Mean fines (%)		Large woody debris		Pool habitat	
Stream	**River km**	**Mean wetted width (m)**	**Mean canopy cover (%)**	**Bankfull**	**Wetted**	**Count (#/100 m)**	**Volume (m^3/100 m)**	**Percent pool**	**Mean residual pool depth (m)**
Bozard Creek (13.4)									
	2.7	1.9	0	40	24	3	0.29	65	0.37
	3.6	2.2	86	26	7	3	0.16	53	0.37
	4.6	1.6	87	27	8	5	0.22	40	0.17
East Fork of Bozard Creek (4.0)									
	0.6	2.1	83	40	14	10	5.80	47	0.21
	2.1	1.7	85	41	15	13	2.57	10	0.20
Tributary to East Fork Bozard Creek (0.2)									
	0.7	1.6	99	70	39	13	1.05	27	0.18
	1.7	1.6	99	52	9	12	2.62	22	0.19
West Fork Lake Creek (13.8)									
	0.5	2.0	59	66	21	3	0.12	72	0.56
	1.9	2.5	67	54	27	2	0.08	82	0.51
	2.6	2.1	48	43	9	7	0.26	74	0.41
	3.3	2.1	78	30	5	14	1.29	44	0.31
	4.0	2.6	98	28	12	5	0.50	28	0.27
	4.7	2.5	90	35	13	18	3.15	29	0.27
	5.3	2.3	100	20	3	23	15.63	12	0.25
Tributary to West Fork Lake Creek (2.3)									
	0.5	1.1	87	55	23	7	2.62	30	0.20

3.4.2 Action effectiveness monitoring

3.4.2.1 Response of stream temperature to restoration

During the reporting period, summer stream temperatures in the upper Benewah watershed increased downstream over the 6.4 km mainstem section from the mouth of Schoolhouse Creek to 9-mile bridge, though rates of increase differed among reaches (Figure 10). Across the uppermost 2.5 km, the percent time in which temperatures exceeded 17ºC during July and August remained relatively unchanged in each year, averaging 6.8 and 14.5% in 2013 and 2014, respectively. Comparable with previous years, however, percent exceedances were found to substantially increase further downriver, with pronounced changes observed over specific reaches. In 2013 and 2014, percent exceedances respectively increased at high rates (i.e., %/km) of 37 and 28 along the reach located 2.6-3.9 rkm upstream of 9-mile. Rates of increase and resulting percent exceedance values over this reach were greater in 2013 and 2014 than in prior years, though summer air temperatures recorded over the reporting period were the highest observed since 2008. Consistent with prior years, rates of increase in 2013 and 2014 were also high (19-26 %/km) along the reach located 0.4-1.1 rkm upstream of 9-mile. Percent exceedances at 9-mile bridge during summer periods over the last two years (85-90%) were the highest recorded since 2008 (Figure 10). Incidentally, water temperatures rarely exceeded 17ºC in six tributaries in the upper Benewah watershed during July and August, averaging only 1.4 percent exceedance over the reporting period.

Despite the warmer summers of 2013 and 2014, the downstream increase in stream temperature metrics across the reach addressed by the first phase of mainstem restoration (i.e., 2.6 km reach upstream of 9-mile) was not appreciably greater, and often was lower, than that recorded in previous years (Table 9). Over July and August, average daily stream temperatures increased 1.9-2.0 ºC and average daily maximum temperatures increased 1.0-1.1 ºC across the restored reach in 2013 and 2014. These increases were the lowest recorded since 2007. In addition, the downstream increase in the percent time temperatures exceeded 17 ºC was comparable and often lower during the reporting period than that observed in years with cooler summers.

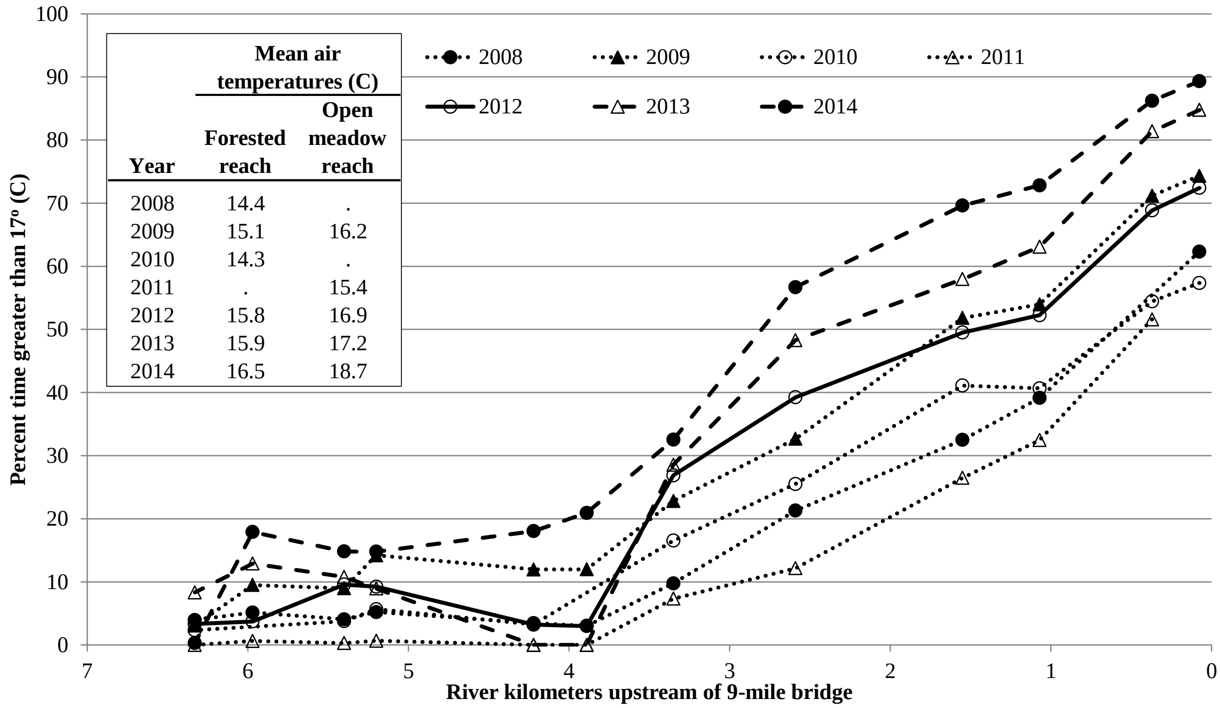


Figure 10. Longitudinal change in the percent time stream temperatures exceeded 17ºC over July and August across mainstem reaches upstream of 9-mile bridge in the Benewah watershed, 2008-2014. Mean air temperatures during July and August in an open meadow and forested reach in the upper Benewah watershed are displayed in the inset table.

Table 9. The downstream increase in three stream temperature metrics across the first 2.6 stream kilometers upstream of 9-mile bridge, 2007-2014. Temperature metrics were computed over the months of July and August.

Temperature metric	2007	2008	2009	2010	2011	2012	2013	2014
Mean of daily mean temperature	2.7	2.7	2.7	2.1	2.4	2.0	1.9	2.0
Mean of daily maximum temperature	3.1	3.1	2.4	2.1	2.5	1.9	1.1	1.0
Percent time temperature exceeded 17º C	29.2	41.0	41.7	31.9	39.4	33.2	36.5	32.6

3.4.2.2 Response of stream and riparian habitat to restoration

Physical habitat

Physical habitat attributes measured at sites along the 2.5 km reach that was treated during the first phase of restoration changed since the 2010 survey, though some attributes and sites changed more noticeably than others. Pool habitat metrics computed across the lowermost treated site (i.e., rkm 14.1) were substantially greater in 2014 than in 2010, with percent pool increasing by a value of 30 and pool volume increasing over three-fold (Table 10). In comparison, these two pool metrics in each of the other treated and control sites were comparable between survey years. Mean residual pool depth and mean wetted width at rkm 14.1 also exhibited the largest increases between years for all sites surveyed.

The greatest changes in large woody debris (LWD) metrics observed between years were at rkm 14.1 and rkm 16.1 (Table 10). At the downstream site, whereas counts were similar between years, a substantial decrease in volume was detected. However, upon inspection of the collected data more of the long pieces (i.e., > 25 ft) were assigned large diameters (i.e., > 18 inches) in 2010 than in 2014 which likely contributed to the discrepancy observed. At rkm 16.1, substantial declines in both counts and volume were observed; many pieces of LWD were often placed loosely in pools and not anchored into banks or the floodplain when this reach received treatment. For each of the remaining sites, LWD metrics were comparable between years.

Table 10. Physical habitat attributes measured at four 150 m sites located in the 2.5 km reach of the Benewah mainstem that was treated during the first phase of restoration. Two additional 150 m sites further upstream served as comparative controls.

				Mean fines (%)		Large woody debris		Pool habitat		
Year	Mean bankfull width (m)	Mean wetted width (m)	Mean canopy cover (%)	Bankfull	Wetted	Count (#/100 m)	Volume (m^3/100 m)	Pool volume (m^3/100 m)	Percent pool	Mean residual pool depth (m)
River kilometer 14.10 - Restored in 2005										
2010	7.0	5.03	34.3	33.6	16.2	26.4	17.2	81.4	53.5	1.30
2014	7.0	6.69	6.9	42.0	20.0	22.1	10.9	278.5	84.5	1.65
River kilometer 14.80 - Restored in 2006										
2010	9.3	5.87	23.4	28.4	4.0	5.9	3.5	122.7	58.0	1.10
2014	8.1	5.50	16.8	35.6	11.5	5.7	5.8	131.1	54.8	1.32
River kilometer 15.70 - Restored in 2007										
2010	9.7	5.99	14.7	18.3	3.0	9.2	6.1	71.0	35.4	1.30
2014	8.1	5.57	12.9	28.0	9.8	13.9	3.6	69.6	35.7	1.38
River kilometer 16.10 - Restored in 2008										
2010	9.0	5.64	30.4	29.3	5.7	28.9	12.4	132.5	61.2	1.27
2014	7.5	6.00	34.1	31.4	20.2	16.4	4.8	125.4	65.2	1.36
River kilometer 19.72 - Control reach										
2010	6.1	2.55	56.8	59.7	11.0	9.8	2.5	13.2	46.8	0.63
2014	4.6	3.12	73.5	26.0	4.4	14.4	2.6	15.4	44.5	0.56
River kilometer 20.00 - Control reach										
2010	8.0	3.40	42.1	54.2	12.3	18.4	6.2	5.4	21.4	0.53
2014	6.4	4.40	60.1	18.6	4.7	21.0	8.1	7.3	33.2	0.57

Percent fines in wetted areas of riffle and tailpool habitats increased by a value of 3.8-14.5 between years across the four sites in the restored reach, with the highest increase observed in the most upstream site (Table 10). Fine percentages were relatively high in 2014 at rkm 14.1 and 16.1, averaging 20 percent at each site, though only two locations were available to be sampled at rkm 14.1 because of the extent of channel length inundated by a beaver dam. In comparison, percent fine averages declined between survey years at the two control sites upstream (Table 10).

Along the lowermost restored site, percent canopy cover was observed to markedly decline since 2010 (Table 10). In comparison, canopy cover estimates were relatively comparable between survey years in each of the other restored sites. For the two control sites upstream, percent canopy cover was observed to increase by a value of 16.7-18.0 since 2010. Percent canopy cover estimates in 2014 were greater in control (mean, 67%) than in downstream restored reaches, with estimates at the lower three restored sites averaging only 12% (Table 10).

Beaver influenced habitat

Beaver activity, though not documented in 2013 and 2014 surveys conducted across the Benewah mainstem reach addressed by phase two restoration, was found to be prevalent in reaches addressed by the first restoration phase. Six active beaver dams across the first mainstem stream km upstream of 9-mile bridge have been found to substantially influence both in-channel and riparian habitats. For example, whereas stream restoration conducted over 2005-2006, which entailed elevating the streambed to promote overbank flooding, increased the amount of inundated habitat by almost 100% during base flow periods, the beaver dam complex that has developed over the last four years has increased the spatial extent of wetted surface area, largely because of floodplain inundation, during base flow periods by a total of 360% percent over original, pre-restored conditions (Figure 11). Conversely, across phase two restoration reaches, not only was dam-building activity absent in recent surveys, but abandoned, intact dams, which used to inundate channel length, have been virtually eliminated during repeated winter and spring high flow events over the last four years.

Groundwater in floodplain habitat

Groundwater levels measured during 2014 summer surveys were found to decline more rapidly in floodplain habitats of the phase two restoration reach than in representative habitats of the downstream phase one reach and the upstream control reach, though the degree of decline in the phase two reach varied across well groups (Figure 12). During June, groundwater levels on average did not decrease at the well cluster in the phase two reach, which was comparable to that found in the other two clusters. However, a moderate decrease was detected in the random distribution of near-stream wells in the phase two reach and greater decreases were found for the scattered wells located further from the stream. Though all well groups displayed a decline in groundwater levels in July, the largest declines were observed for the two groups of scattered wells in the phase two reach located furthest from the stream. In August, though groundwater levels at well clusters in the phase one and control reaches were not found to decline, decreases were detected at all well groups in the phase two reach, with the largest decline observed in the group of scattered wells distant from the stream. Groundwater levels in the distant group of scattered wells in the phase two reach continued to decline throughout September. The variability in groundwater change among wells within a group was greatest for those groups in the phase two reach located further from the stream (Figure 12). Mean groundwater levels (i.e., feet below the floodplain surface) in near-stream well groups at the end of September were lowest for the cluster in the phase one reach (1.89 ft), intermediate for the cluster in the control reach (2.97 ft), higher for the cluster in the phase two reach (3.55 ft), and highest for the randomly distributed group in the phase two reach (5.53 ft).

When comparing groundwater levels measured during base-flow periods in 2014 with those measured during 2008 and 2009, a period representative of conditions prior to the completion of phase two treatments, differences were observed among the surveyed reaches (Table 11). Base-flow groundwater levels measured at well clusters located near the stream in the phase one restoration reach and the control reach were on average lower in 2014 than those measured in 2008-2009 (i.e., positive deviations). On the other hand, the two well groups located in close proximity to the stream in the phase two reach reflected a groundwater table near the channel that was relatively higher in 2014 than during the pre-restoration period. Though groundwater levels measured at phase two wells in the group located furthest from the stream were relatively lower in 2014 than the pre-restoration period, data collected during base-flow periods in 2012, a year with a milder, wetter summer than 2014, indicated groundwater levels in both near-stream and distant floodplain habitats were higher overall in the lower end of the phase two reach after treatment (Table 11).

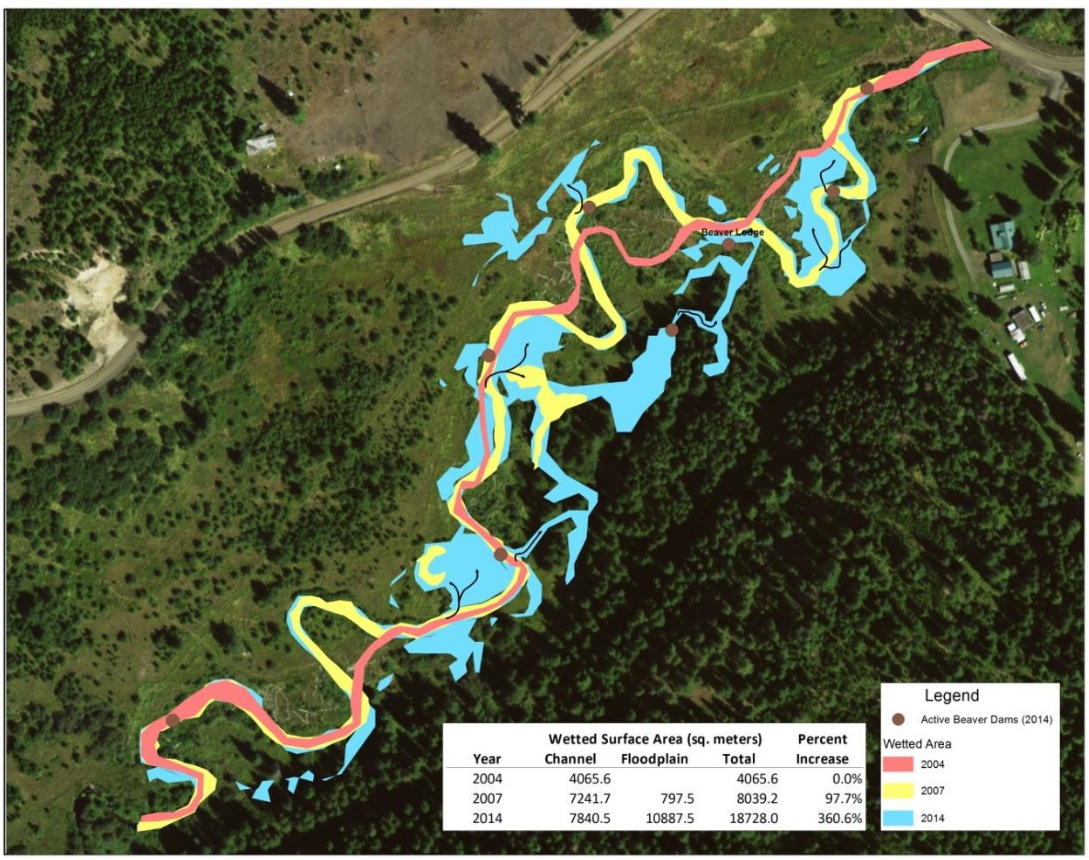


Figure 11. Change in baseflow wetted surface area over three different time periods for the first kilometer of stream reach upstream of 9-mile bridge. Time periods represented include a pre-restoration year (2004), a post-restoration year (2007), and a year that depicts the influence of an active beaver dam complex (2014). The locations of active beaver dams and floodplain flow paths are also indicated.

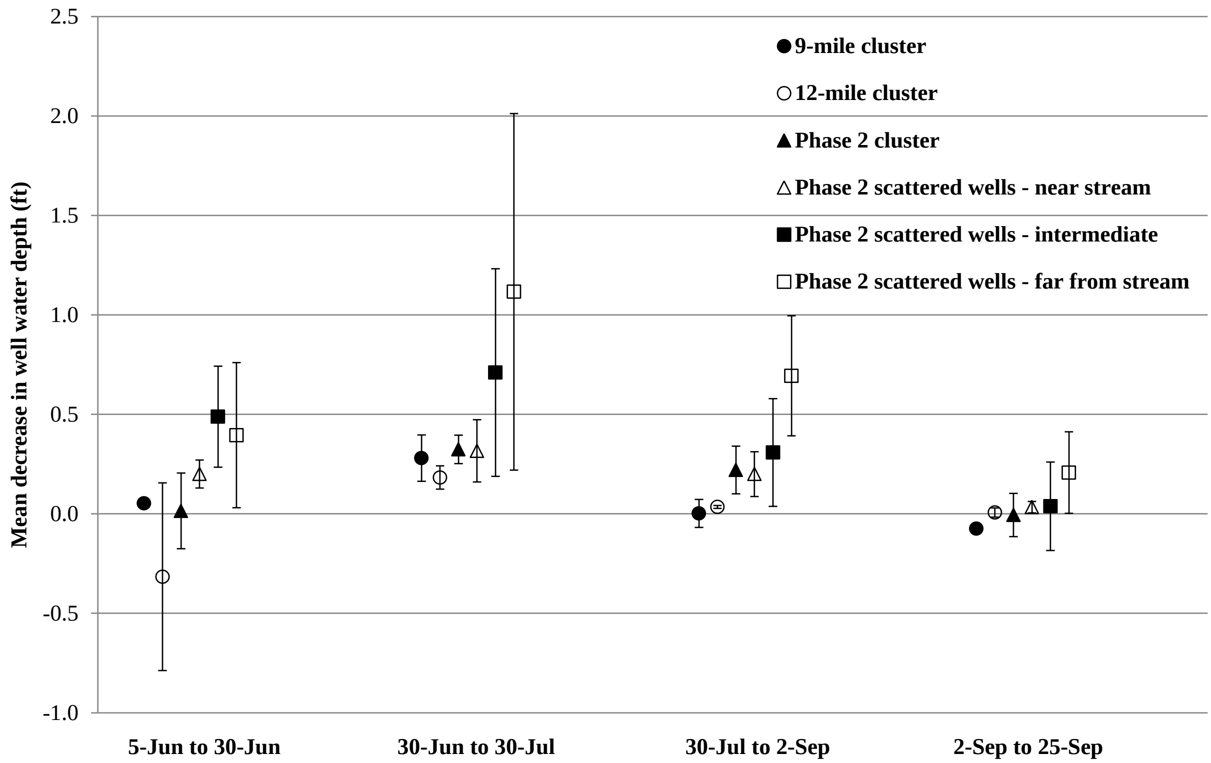


Figure 12. Mean decrease (± one standard deviation) in groundwater depths measured at groups of wells located in floodplain habitats in the upper Benewah watershed over four summer time periods in 2014. Groups consisted of near-stream, closely spaced well clusters at 9-mile bridge (phase one restoration), 12-mile bridge (control reach),and the lower end of phase two restoration, and of scattered wells in the lower end of phase two restoration that were near the stream, at intermediate distances from the stream, and distant from the stream.

Table 11. Deviations of base-flow groundwater levels measured at wells in the upper Benewah watershed in 2012 and 2014 from those averaged over 2008-2009, a representative period prior to phase two restoration. Positive and negative deviations represent lower and higher groundwater levels relative to the early period, respectively. Means and standard deviations (std. dev.) of the groundwater deviations are displayed for the six groups of wells; data were not collected during base-flow periods in 2012 for the clusters at 9-mile and 12-mile.

	2012		**2014**	
Location of groundwater wells	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Well clusters located in close proximity to stream				
Lower reach phase 1 restoration (9-mile)	.	.	0.25	0.31
Lower reach phase 2 restoration	-0.77	0.32	-0.63	0.42
Control mainstem reach (12-mile)	.	.	0.19	0.11
Scattered wells in lower reach of Phase 2 restoration				
Close proximity to stream	-0.66	0.22	-0.11	0.17
Intermediate distance from stream	-0.45	0.55	-0.03	0.80
Distant from stream	-0.15	0.68	0.53	0.55

3.4.2.3 Response of cutthroat trout to restoration

In WFB, a sub-drainage that has recently received treatment, the overall abundance of age 1+ WCT was greater in 2014 than in 2013 by 67% (Figure 13). Most of the change observed occurred in the lower reach, which was not addressed by restoration measures, and in the uppermost reach, which received LWD additions in 2013. However, abundance estimates considerably varied across sites within both reaches in 2014 yielding a rather imprecise tributary-scale estimate (±53%). Consequently, it was difficult to confidently ascertain whether overall abundance was significantly greater in 2014 than in 2013. In the Windfall sub-drainage, WCT abundance was also found to be greater in 2014 than in 2013, with rather precise tributary-scale estimates permitting confidence in the 44% increase that was observed (Figure 13). Abundance estimates were higher in 2014 than in 2013 in each of the four surveyed reaches, with high densities consistently observed in the secondary tributary (i.e., reach four). Compared with Windfall and the WFB, abundance of WCT was not found to change over the reporting period in the SFB sub-drainage (Figure 13). In each year, higher densities of fish were observed in reach three than in other reaches.

3.4.2.4 Response of cutthroat trout to brook trout suppression

In 2013, 907 brook trout were removed from the upper Benewah watershed during suppression efforts in September. Of the 907, 708 were captured over a four day effort across the 2.0 km Benewah mainstream reach from 12-mile bridge to the confluence of WFB and SFB. The other 199 fish were captured during a single day effort across the lowermost 550 m of Windfall Creek. In 2014, a total of 319 brook trout were removed during September suppression efforts. Of the 319, 204 were captured over a three day effort across the 2.0 km Benewah mainstream reach upstream of 12-mile bridge, and the other 115 fish were captured during a single day effort along the lowermost 550 m of Windfall Creek.

The number of age 1+ brook trout annually removed in each of 2013 and 2014 from the 2.0 km mainstem reach, though more than that removed in each of the previous two years, was still generally less than that observed from 2007 to 2010 and was markedly lower than that removed during the early years (Figure 14). The recent upsurge in numbers of age 1+ fish reflected the substantial increase in age-0 fish documented along this reach from 2011 to 2013. In 2014, age-0 fish were rarely captured during suppression efforts. In tributary reaches of the upper Benewah watershed, mean density indices of age 1+ brook trout in three of the last four years were the lowest recorded since commencement of the suppression program (Figure 15).

Mean density indices of age 1+ WCT in tributary reaches of the upper Benewah watershed have remained high since 2007, averaging 19.1 fish/100 m, which is almost a two-fold increase over that observed from 2004 to 2006 (Figure 15). Furthermore, the percentage of WCT as overall salmonid catch has increased over time in these tributary reaches since inception of suppression efforts. Over the last four years, WCT comprised approximately 80% of captured salmonids, whereas from 2004 to 2006, the initial years of suppression efforts, they only constituted 58% of the catch (Figure 15).

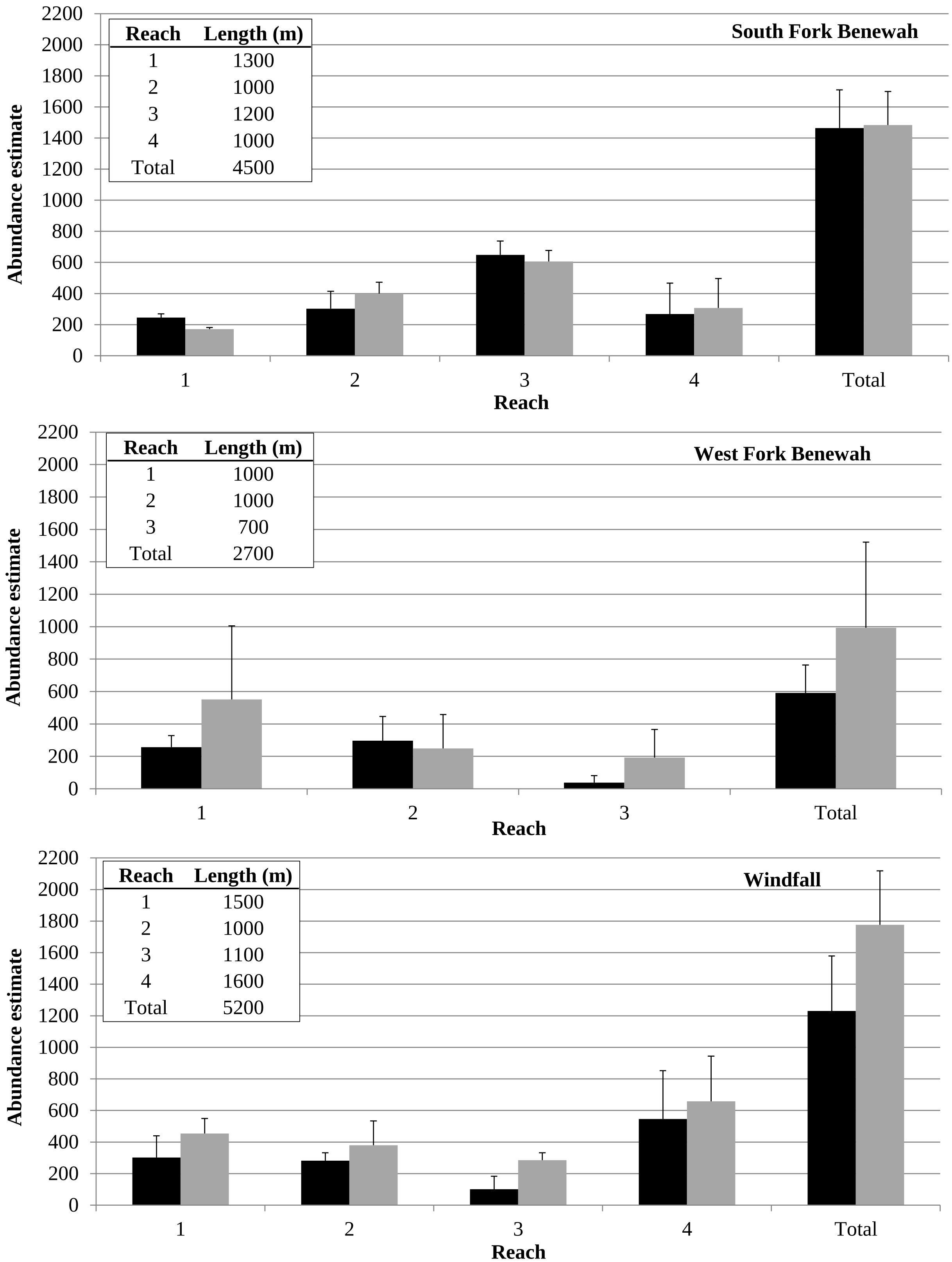


Figure 13. Reach and overall abundance (95% confidence intervals) of age 1+cutthroat trout in 2013 (black) and 2014 (grey) in South Fork Benewah, West Fork Benewah, and Windfall sub-drainages.

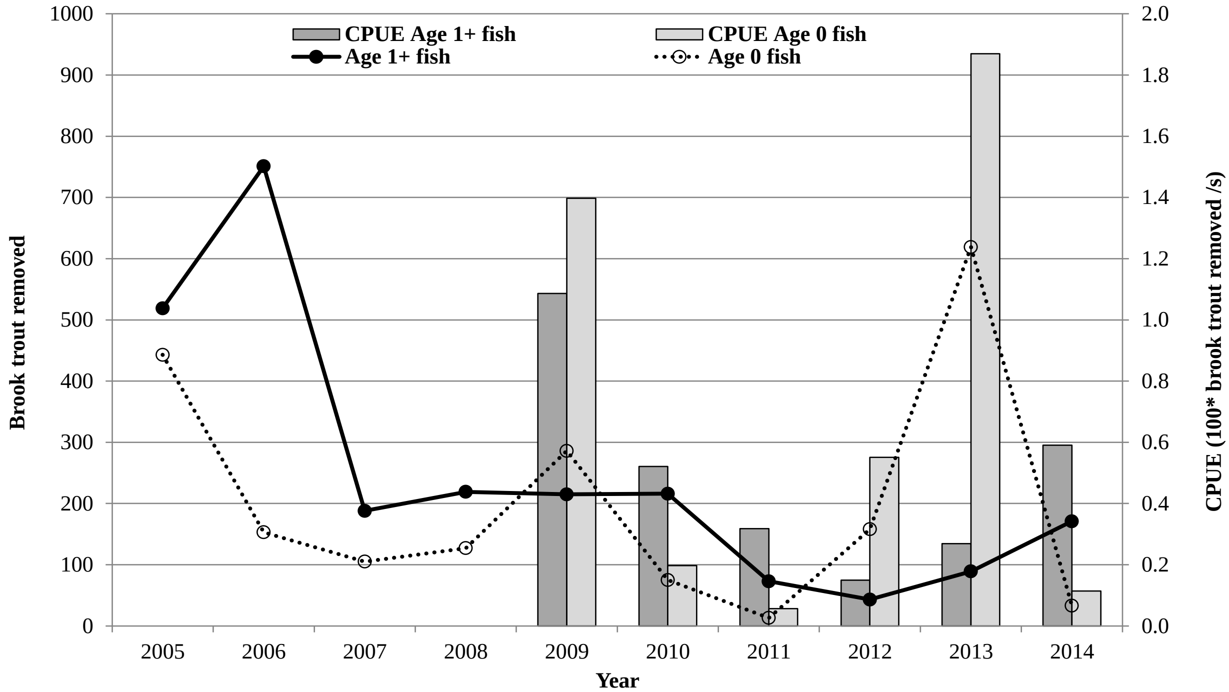


Figure 14. Numbers and CPUE of age-0 and age 1+ brook trout removed from the 2.0 km Benewah mainstem index reach upstream of the 12-mile bridge from 2005 to 2014.

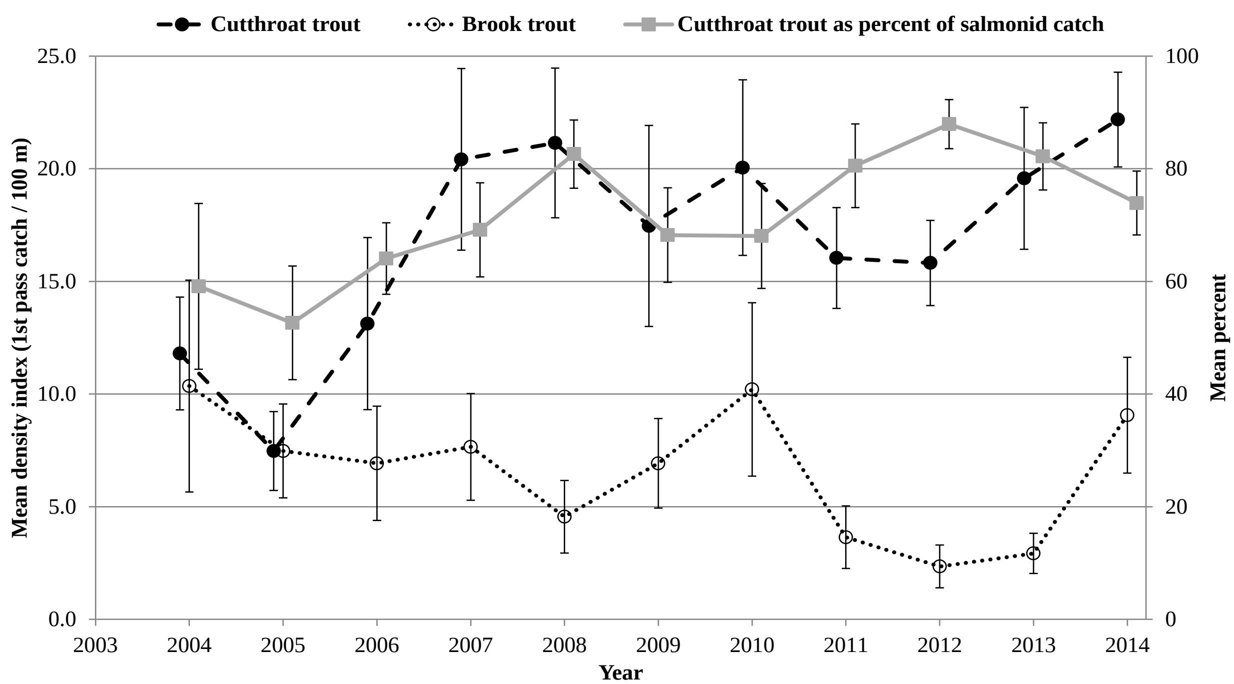


Figure 15. Mean density indices of cutthroat trout and brook trout age 1+ and older (1st pass catch/100 m) and percent of cutthroat trout as overall salmonid catch (± one standard error) across tributary sites in the upper Benewah watershed that have been regularly sampled over the years 2004-2014.

3.5 Discussion

3.5.1 Status and trend monitoring

Abundance and productivity of cutthroat trout

It is imperative to reliably track changes in the spawning population of WCT in Benewah and Lake creeks given that one of the primary objectives of recovery is to increase the number of adfluvial adults to these watersheds. Over the reporting period, adult traps in both watersheds were modified to facilitate easier access to the livebox so that a higher percentage of ascending fish could be marked to provide more certainty in abundance estimates. For example, the tube that had been used as a conduit to the livebox in Lake Creek was replaced with a more natural, picketed passageway in 2014, resulting in more ascending adults captured in 2014 than in 2013 and the attainment of a rather precise spawner abundance estimate compared with previous years. Similarly, in Benewah Creek approximately 50% of the estimated ascending spawners were captured in each year, whereas in the previous six years only once were more than one ascending fish captured (Firehammer et al. 2013, 2012, 2011, 2010, 2009). Furthermore, it is also crucial that trapping operations do not unduly disrupt migratory behavior or prevent adults from accessing upstream spawning grounds. Whereas in the past lingering adults that apparently could not negotiate the trap likely migrated back downstream (Firehammer et al. 2013, 2012), recent modifications that have permitted trap panels to be manually lowered to the streambed allow lingering adults to ascend. The comparable estimates of adults that approached the trap and those that ascended beyond the trap in Lake Creek over the last three years attest to the effectiveness of the modifications.

The accuracy of juvenile outmigrant estimates was also substantially increased over the reporting period compared with previous years as a result of the implementation of rotary screw traps in both watersheds. Screw traps were able to be installed earlier under higher levels of discharge than the fixed-panel traps resulting in a greater portion of the outmigrant run that was sampled. Indeed, in the Benewah watershed 50% of the outmigrants were estimated to have descended by the middle of April over the reporting period, which was typically much earlier than the installation date of the fixed-panel trap in previous years. The much greater juvenile outmigrant estimates in 2013 and 2014 than in previous years in the upper Benewah watershed also attest to the fact that estimates obtained with the fixed-panel trap omitted a significant portion of the outmigrant run. The outmigrant estimate obtained in Lake Creek in 2014 was also much greater than those obtained in prior years when fixed-panel traps were used. Though the large 2014 estimate could in part be attributed to the inclusion of the early portion of the run that was typically missed in prior years, it also likely reflected production from the sizable number of spawners estimated to have ascended Lake Creek in 2012.

Implementation of rotary screw traps also apparently alleviated much of the disruption of juvenile outmigrant behavior that had been observed with the fixed-panel trap (Firehammer et al. 2013). In 2014, when the screw trap was first used in Lake Creek, only a handful of release trial fish were detected at upstream PIT stations. Conversely, in 2013 when the fixed-panel design was used to capture fish, a considerable percentage of trial fish released during the latter portion of the outmigrant run were not recaptured but detected at distant upstream PIT stations. Moreover, this alluded to the possibility of additional non-recaptured release trial fish that were likely present in the reach intermediate of the trap and the upstream PIT stations, and could have explained the low trap efficiencies estimated during latter trial periods in 2013. The apparent lack of motivation to continue to outmigrate was consistent with that observed in earlier reporting periods (Firehammer et al. 2013). Previously, it had been unclear as to whether juveniles captured late in the season were not actively outmigrating but inadvertently intercepted by the trap during localized early-summer foraging movements, or if the trap interfered with behavior during latter spring periods as discharge declined. At low flows, the fixed-panel trap created a slack water environment upstream, and consequently, may not have provided the appropriate velocities that juveniles required to cue continued downriver movement. Similar delayed movements have been noted for juvenile salmonids outmigrating through impounded reaches of larger river systems (Venditti et al. 2000). However, when comparing the results from Lake Creek in 2014 with those from 2013, it seems likely that the fixed-panel trap had been interfering with juvenile behavior. Disruption of the motivation to outmigrate may even have caused some juveniles to residualize. Indeed, of the 90 release trial fish that were detected at upstream PIT stations in the spring of 2013, only four were captured in the rotary screw trap the following year.

Both the adult and juvenile outmigrant estimates obtained over the reporting period indicate that adfluvial production is much greater in the upper Lake Creek watershed than in the upper Benewah Creek watershed. Densities of WCT recorded during summer surveys in upper watershed tributaries were also considerably greater in Lake Creek than in Benewah Creek likely signifying greater production from large, highly fecund adfluvial females in the former. The differences observed between watersheds may partly be explained by the fact that migrant traps and summer surveys sample WCT further up in the watershed in Benewah Creek than in Lake Creek. Juveniles rearing in tributaries in the upper Benewah watershed far from the mouth of Benewah Creek may be less inclined to outmigrate than those rearing in tributaries further down the watershed. Several tributaries downstream of 9-mile bridge are known to support moderately high densities of juveniles during summer rearing periods, and these may likely account for a substantial percentage of the adfluvial production in the Benewah watershed. Nevertheless, the recent decline in adfluvial spawners observed over the past two years in the upper Benewah watershed is disconcerting and alludes to limiting factors downstream, especially in the lower end of the lake, which may be exacerbating an already depressed population.

Spatial distribution of cutthroat trout

Summer surveys in adfluvial watersheds covered a much greater spatial extent of tributary habitat over the reporting period than in previous years, and revealed that WCT were distributed in reaches further upstream than previously documented. For example, in the Lake Creek watershed, high densities of WCT were observed across previously un-surveyed reaches of the East Fork of Bozard sub-drainage and in upper reaches of the WFL sub-drainage. This suggests that much of the juvenile WCT production in rearing tributaries of the upper Lake Creek watershed may not have been adequately described in earlier surveys. Furthermore, the discovery of extensive stream reaches with high densities of WCT, notably the East Fork of Bozard, aids in prioritizing areas of the upper Lake Creek watershed for preservation. However, consistent with prior reporting periods, the most downstream reaches of these rearing tributaries, which are dominated by agricultural land use, still support rather low densities of juvenile WCT, and suggest that sub-optimal rearing conditions are likely contributing to the low numbers.

In the upper Benewah watershed, consistent with the spatially-expanded surveys initiated in 2012, WCT were also found to be distributed further up tributaries than previously documented in earlier reporting years. For example, in the Windfall sub-drainage moderately high numbers of fish were observed in each year across reaches of a secondary tributary that had not been sampled prior to 2012, and alludes to this section of the sub-drainage as potentially important in contributing to its production of WCT. Surveys also found WCT in uppermost reaches of the WFB, though this may have been partly due to the removal of a barrier in 2012, and in upstream, previously un-surveyed reaches of Schoolhouse and SFB creeks. In Whitetail Creek, more spatially extensive sampling in 2014 revealed that WCT were predominantly found in upstream reaches (i.e., upstream of rkm 2.0) with low numbers recorded elsewhere. The few WCT documented in much of Whitetail Creek was likely attributable in part to adverse conditions induced by an overall paucity of wetted available rearing habitat.

Notwithstanding Whitetail Creek, WCT were generally more evenly distributed across surveyed tributary reaches in the Benewah Creek watershed than in the Lake Creek watershed. However, in 2014, WCT in SFB and Schoolhouse creeks were found in lower numbers in downstream reaches, where brook trout were found to be prevalent, than in upstream reaches. Competitive interactions that displaced WCT from these lower reaches may have been giving rise to the distributional patterns observed.

Diversity of cutthroat trout populations

Interrogated movement of PIT-tagged WCT during the reporting period indicated that the prevalence of the migratory life-history variant differed among tributaries in adfluvial watersheds. In the upper Lake Creek watershed, the combination of high densities of juvenile fish across much of the Bozard sub-drainage and the fact that a relatively high percentage of these fish were detected moving downstream in the spring suggests that this sub-drainage supports greater adfluvial production than the WFL or UFL sub-drainages. Though tagged fish in downstream reaches of the WFL sub-drainage were observed to outmigrate at similar rates as those in the Bozard sub-drainage, juvenile densities in these reaches of the WFL sub-drainage were relatively low; the highest densities of juveniles in the WFL sub-drainage were recorded in upstream reaches where outmigration rates were much less. Furthermore, migratory adults during the reporting period were nearly four times more likely to select Bozard Creek than the other two tributaries, supporting this sub-drainage as the primary contributor to adfluvial production in the upper Lake Creek watershed.

In tributaries of the upper Benewah watershed, the Windfall sub-drainage appears to be a primary contributor to adfluvial production. Rates of downstream movement during the spring were detected from juveniles tagged across a much greater spatial extent of tributary habitat in the Windfall than the SFB and WFB sub-drainages during the reporting period. For example, whereas fish tagged across approximately 3.5 km of stream reach in the Windfall sub-drainage were found to outmigrate, comparable outmigration rates were detected from fish in only the lowermost 1.5 km of the WFB sub-drainage. Given that stream densities in these reaches were generally similar or greater in Windfall than in WFB, Windfall evidently provided more of the adfluvial production between the two tributaries. The SFB sub-drainage consistently supplied the lowest percentage of spring outmigrants during the reporting period, and may support more of a resident than a migratory WCT population.

The reason for the evident differences in adfluvial production among tributaries within watersheds is unclear. Under the assumption that progeny from adfluvial parents have a greater proclivity for migratory behavior, then the lack of outmigrant production may signify an absence of adfluvial spawners. Following this reasoning, obstructions may be present in reaches of some tributaries, which impede the ascension of migratory spawners in the spring and limit the amount of upstream adfluvial production. Alternatively, appropriately-sized gravels may not be available in sufficient quantities in some tributaries to support large numbers of adfluvial spawners. For example, habitat surveys have found a lack of gravel throughout reaches of the SFB sub-drainage compared with reaches sampled throughout the WFB and Windfall sub-drainages (unreported data). In the SFB sub-drainage, spawning-sized gravels may prevail in small, low order high-elevation secondary tributaries that may not be accessed by large migratory adults but frequented primarily by small resident adults. The lack of age-0 WCT encountered in surveys conducted in the SFB during the reporting period supports the scarcity of spawning in larger, higher-order stream reaches. More spatially-extensive cursory surveys may elucidate the factors that are seemingly limiting adfluvial production in certain tributaries of these two watersheds.

Tagged juvenile WCT that reared in larger mainstem reaches in adfluvial watersheds were generally found to outmigrate earlier in the spring than those that reared in primary tributaries. In the upper Lake Creek watershed, trapping procedures in 2013 may have unnaturally induced this rearing behavior (i.e., the fixed-panel trap hindered downstream movement and elicited occupation of upstream reaches prior to subsequent outmigration the following year). In the upper Benewah Creek watershed, reproduction may be occurring in mainstem reaches (i.e., upstream of 12-mile bridge) or fish spawned in tributaries (e.g., WFB sub-drainage) may be moving downstream into mainstem reaches and rearing for at least another year before outmigrating. A step-wise pattern of stream residence, in which fish gradually move downstream to larger-sized rearing habitats, has been shown in other migratory cutthroat trout populations (Zydlewski et al. 2009). Whatever the reason for mainstem rearing and the consequent link with early outmigration, it is important to preserve this behavior given that fish that have moved downstream earlier in the spring have returned as adults at higher rates than those that have left later (Firehammer et al. 2012). Thus, it is imperative to ensure that the quality of rearing habitat in mainstem reaches is protected or improved.

Unusual spring outmigrant behavior was detected in juvenile WCT that had been tagged in the Bozard sub-drainage in the upper Lake Creek watershed. A high percentage of juveniles were found to exit Bozard Creek in early spring and spend a substantial amount of time (e.g., 1-2 months) in reaches of the UFL sub-drainage prior to eventually moving downstream. It is unknown as to why fish in this sub-drainage, and not those in the other two sub-drainages, exhibited this behavior. High rearing densities of juvenile fish in combination with relatively low available rearing habitat in Bozard (e.g., habitat surveys indicated less estimated pool habitat in the Bozard than the WFL sub-drainage) may result in fish being displaced under periods of high spring discharge. Incidentally, fish were also found to emigrate out of Bozard during frequent, high flow periods in the winter of 2014. Nevertheless, Bozard Creek fish that found temporary rearing habitat during the spring and eventually outmigrated later exhibited higher growth rates than those that moved downstream earlier. Thus, given that larger juvenile outmigrants return to spawn at much higher rates than smaller fish (Firehammer et al. 2012, 2013), any improvements to lower reaches of tributaries that would create temporary spring rearing habitats for outmigrating juvenile WCT could increase their probabilities of survival to adulthood.

In the upper Benewah watershed, WCT were detected moving downstream into larger mainstem habitats during late fall and winter periods over the reporting period. Fish tagged in WFB and in the uppermost mainstem reach consistently displayed the greatest tendency to move downstream during these seasonal periods, though fish tagged in Windfall exhibited higher rates of downstream wintertime movement in 2014 than in 2013. Fish tagged in the SFB were rarely detected engaging in seasonal downstream movements during the winter, a behavior consistent with that observed during spring migratory periods and again likely indicative of a primarily resident population. Wintertime movement out of WFB, especially in years with frequent high discharge events, may be induced by a lack of available pool habitat. Habitat surveys have shown that wetted stream width is less and pool metrics are lower in the WFB when compared with other tributaries in the upper Benewah watershed (Firehammer et al. 2013). Downriver displacement by high discharge events may also have explained the differences observed in Windfall fish between the two winter periods; wintertime discharge was much more volatile with more prolonged and greater peak flows in 2014 than in 2013. Climate change scenarios in these regions are projecting warmer winters, with more rain than snow events (Barnett et al. 2008), which will likely lead to greater volatility in the winter flow regime. Thus, the protection or creation of available low-velocity, deep pools, which are preferred overwintering habitats of cutthroat trout (Jakober et al. 1998; Brown and Mackay 1995; Harper and Farag 2004; Lindstrom and Hubert 2004), is important in providing temporary refuge and ensuring high survival rates throughout the winter. Indeed, a high percentage of fish found to move downstream and overwinter in restored, deepened mainstem reaches in the upper Benewah watershed were found to survive to outmigrate the following spring.

Juvenile WCT captured during outmigration periods were generally larger in size in the upper Lake Creek watershed than in the upper Benewah Creek watershed. Although the size discrepancy could be partly explained by the possibility that a higher percentage of Lake Creek outmigrants were older fish, growth rates of juveniles from time of summertime tagging to recapture in the spring were greater in outmigrants from Lake Creek than those from Benewah Creek. The difference in growth rates could be explained by more favorable growing conditions, especially in early spring periods prior to outmigration, in upper Lake Creek than in upper Benewah Creek. In addition, research has shown that progeny of large, migratory females in populations of rainbow trout (*Oncorhynchus mykiss*) tend to grow at faster rates than those produced from small, resident females (Liberoff et al. 2014). Given that Lake Creek evidently supports a much greater number of migratory spawners than Benewah Creek, this phenomenon may also be transpiring in WCT populations in these two watersheds that currently retain different degrees of admixture of adfluvial and resident life-histories.

3.5.2 Action effectiveness monitoring

Responses to mainstem restoration in the upper Benewah watershed

Phase one restoration in mainstem channel habitats of the upper Benewah watershed, which elevated the streambed and promoted overbank flooding during bankfull flow events, apparently lessened the power of in-stream flows and permitted constructed beaver dams to persist under seasonal periods of high discharge. Consequently, the development of an active, sustained beaver dam complex in the first kilometer of stream habitat upstream of 9-mile bridge has induced changes in a number of physical habitat attributes since completion of phase one treatments. Pool habitat and inundated in-stream surface area has increased substantially over the last four years, and represent the influence established beaver dams can have on water level elevation and backwatered channel length. Furthermore, backwater effects from dams not only influenced in-channel habitat but also expanded into adjacent floodplain habitats creating spatially extensive side-channels, off-channel wetland ponds, and saturated riparian zones that persisted throughout summer and fall. Though habitat surveys indicated canopy cover markedly decreased in this reach of the restored section, evidently from the removal of stream-side vegetation by beavers for dam-building and foraging, the inundated floodplain soils and elevated groundwater table induced by the dam complex should promote rapid growth and regeneration of the scrub-shrub riparian community. Indeed, recent plantings of willows and dogwood in these floodplain habitats have exhibited high survival and growth rates.

Although stream surface area has increased and canopy cover has decreased in the beaver-dominated section of the phase one restoration area, metrics of ambient summer stream temperatures have evidently not responded to the increased exposure to sunlight. The downstream rate of increase in temperature metrics across the phase one restoration section was actually found to decrease over the last several years since the development of the dam complex. Given that riparian canopy cover was not found to increase at surveyed habitat sites across phase one restoration reaches upstream of the beaver dam complex, the results observed was not likely due to increased stream shading upstream. Alternatively, the larger volumes of water retained by the beaver dam pools (i.e., increased capacity for heat adsorption) and the sustained connectivity with groundwater in the adjacent floodplain could have buffered against the increased solar exposure. Moreover, because cooler temperatures have been documented near the bottom of restored pools in the Benewah mainstem (Firehammer et al. 2012), beaver dams that increase the depth and length of pool habitat provide a greater spatial extent of thermal refuge for WCT.

In contrast to that observed in the phase one reach, beaver activity and their influence on channel habitat in the phase two Benewah mainstem reach, which was once prevalent, has eroded over the last four years. Since 2010, virtually all of the natural dams have been severely compromised or lost during annual periods of high discharge and not rebuilt during low flow periods (Firehammer et al. 2013). Apparently, unlike the phase one reach, the entrenched nature of this reach was not capable of sufficiently attenuating stream power during these repeated flood events. Consequently, the benefits realized from an intact beaver dam complex, which includes extended periods of channel and floodplain inundation and persistent elevated local water tables, is not present during base flow periods in the phase two reach. Groundwater levels in the adjacent floodplain in this reach are higher than they were prior to restoration, likely because the treatments that increased channel length and sinuosity and that introduced obstructions (e.g., engineered flow-choke structures) also increased water retention time. However, groundwater levels are still decreasing at greater rates throughout the summer, especially with distance from the stream channel, than those in the phase one reach.

The recession of the groundwater table throughout the summer, owing to the lack of a sustained connectivity between an impounded channel and adjacent floodplain, renders it difficult to provide sufficient water to an incipient riparian vegetative community. Currently, much of the downstream end of the phase two restoration reach lacks adequate canopy cover, and consequently, stream temperatures across this reach were found to rapidly increase during the summer over the reporting period. Until beaver re-colonize this mainstem section in the upper Benewah watershed and consequently exert their influence on instream and riparian habitats, it may be necessary to supplementally water riparian plantings to increase their survival and growth to provide the shade necessary that would reduce summer stream temperatures.

Responses to tributary restoration in the upper Benewah watershed

Abundance estimates of age 1+ WCT were generated during the reporting period for three tributaries in the upper Benewah watershed that are expected to serve in prospective analyses to evaluate responses to cumulative restoration measures. Annual variability was detected in both Windfall and WFB sub-drainages, with 2014 estimates generally greater than those computed in 2013. Though the increase in abundance in the WFB sub-drainage could in part be explained by a localized response in upper reaches to treatments implemented in 2013 (i.e., large wood additions), other reaches downstream that had not received treatment also exhibited an increase in abundance. Moreover, there was a large degree of variability in abundance estimates among sites within a given reach, which generated uncertainty in reach-scale estimates. Consequently, in some years it may be necessary to increase the number of sample sites within reaches in the WFB sub-drainage to provide the precision necessary that would permit detection of a significant response to restoration measures.

Alternatively, the differences observed between years could have reflected annual differences in the number of adfluvial fish that had successfully spawned in these tributaries. Adfluvial adults during the reporting period were found to ascend each of the WFB and Windfall sub-drainages, supporting these tributaries as preferred spawning streams. Moreover, the SFB sub-drainage, which apparently contributes marginally to adfluvial production, did not exhibit noticeable differences in tributary-scale abundance estimates between years. In addition, the fact that a significant increase in juvenile abundance was detected in the Windfall sub-drainage, which had not received any recent restoration treatments, not only supports the notion that annual differences in numbers of spawners could have given rise to the observed results, but also reinforces its inclusion as a control tributary in effectiveness monitoring analyses. A couple more years of generated abundance estimates for these three tributaries should yield a better understanding of expected levels of annual variability and whether a genuine, positive trend in production is occurring in treated reaches of the WFB sub-drainage.

Responses to brook trout suppression in the upper Benewah watershed

A brook trout suppression program was initiated in the upper Benewah watershed in 2004, and initially focused on contiguous reaches of the mainstem channel from 9-mile bridge to 12-mile bridge and in tributaries where brook trout had been found in relatively high numbers. However, an inordinate amount of time was annually being expended ineffectively shocking the restored deep, pool habitat that existed downstream of 12-mile bridge. Furthermore, low gradient, depositional beaver dam pools were prevalent in this reach, which, though likely serving as suitable rearing habitats (Chisholm et al. 1987; Cunjak 1996; Lindstrom and Hubert 2004; Benjamin et al 2007), may not provide suitable spawning habitat for brook trout. Since 2009, efforts have been curtailed and tactics re-focused toward inhibiting reproduction rather than attempting to remove as many fish as possible. Currently, shocking efforts are concentrated in mainstream reaches upstream of 12-mile bridge that seemingly provide more suitable spawning habitat for brook trout than reaches downriver. Temporary barriers are also erected upstream of the 12-mile bridge and at the mouth of Windfall Creek to inhibit ascending mature brook trout from accessing upstream spawning reaches.

Even though the suppression program has reduced its annual removal efforts from approximately 3-4 weeks during the initial years of the program to a current investment of 3-4 days, it has been effective at regulating numbers of brook trout at an apparently manageable level. Generally, indices of brook trout abundance over the last four years in the index mainstem reach and across tributary sites in the upper watershed have been the lowest recorded since the inception of the program. In addition, WCT comprised a much greater percentage of the salmonid catch in upper watershed tributaries over the last four years than during the earlier years of the suppression program.

However, brook trout are still occasionally found at moderate levels in some reaches of the upper watershed. Modest numbers of age 1+ brook trout were captured in 2014 during mainstem removal efforts and at survey sites in lower reaches of Windfall, Schoolhouse, and SFB creeks. Notably, the mouths of these creeks are proximate to that section of the mainstem reach which has consistently supported the highest adult brook trout densities over the course of the suppression program (Firehammer et al. 2011), and which may be serving as a source of mobile, reproductive individuals for the colonization and establishment of local sub-populations in these lower tributary reaches (Benjamin et al. 2007). During the reporting period, an additional day was spent each year removing brook trout from the lower reach of Windfall to address the high densities observed. A similar occasional, expansion of effort may be required in these other tributaries to check brook trout production. Furthermore, though curbed removal efforts evidently have not led to substantial reproductive output in the upper watershed, the densities of age 1+ fish observed in 2014, which reflected the sizable number of age-0 brook trout recorded the year before, allude to the compensatory resilience that has been documented in brook trout populations (Meyer et al. 2006), and caution against overly relaxing suppression measures.

3.5.3 Research into non-native impacts

Results from the two year study that examined the demographics and feeding preferences of northern pike in Lake Coeur d'Alene indicated that pike could substantially impact WCT survival during lake residence (Walrath et al. 2015). Bioenergetic models that incorporated seasonal growth rates and diet found WCT to comprise a high percentage of the biomass annually consumed by pike. Though WCT were not found in the stomachs of the youngest age classes, they constituted 10 to 30% of the biomass consumed by two to four year old pike. The study also revealed that WCT consumed by pike were generally larger than the average size of a juvenile outmigrant. The mean length of WCT found in pike stomachs was 250 mm, with larger fish recovered from larger pike. Thus, sub-adults and spawning-sized WCT were found to be just as vulnerable to predation as smaller fish and apparently were the more preferred size.

The study also found temporal and spatial differences in consumption of WCT by northern pike. The highest frequency of incidence of WCT in pike stomachs occurred during spring sampling periods, whereas they were less prevalent in the diet during the summer and fall. For example, 80% of the predation on WCT in 2012 occurred during the spring. Diet of pike during winter periods could not be assessed because of difficulty of sampling. Given that considerable growth of pike was detected over the winter and that WCT were the primary food item found upon commencement of spring sampling, consumption of WCT during winter periods could also be substantial. In addition, the impact of pike on WCT was evidently more prevalent in Windy Bay than Benewah Lake and the two northern bays. Throughout the study, 75% of the WCT recovered from pike stomachs were from fish captured in Windy Bay.

Study results estimated that 335 adult WCT were consumed by the Windy Bay pike population in 2012 (Walrath et al. 2015). Given that estimates of Lake Creek spawners have averaged around 300 fish over the last three years, a considerable portion of the adult population may be annually removed by pike. Moreover, this does not account for the considerable number of sub-adults that were estimated to be culled annually by pike and consequently not permitted to attain spawner status. Obviously, pike predation has to be substantially reduced in order to permit recovery of the WCT population in Lake Creek. Fortunately, study results suggest that a pike suppression program in Windy Bay may have opportunity for success. First, the estimated size of the pike population in Windy Bay was rather modest, approximating only 300 individuals (unreported data). Second, 38% of pike tagged in Windy Bay were recaptured by sampling efforts during the study, suggesting high potential for exploitation. Third, tag reports from angled fish indicated that movement of pike among bays was rare (i.e., high site fidelity), and suggests that re-colonization of Windy Bay by pike from nearby bays may proceed slowly.

Accordingly, the Fisheries Program is planning to conduct a three-year pilot suppression effort that will commence in 2015, whereby pike will be removed from Windy Bay during spring periods when they are concentrated in shallow water environments for spawning and when there is high potential for overlap with migratory WCT. It is expected that removal efforts will be conducted with gill nets and will only be required for a period of four to six weeks. Monitoring infrastructure (e.g., migrant traps and PIT tag arrays) and protocols are already in place to evaluate the response of WCT to the pike suppression program. Several years of baseline data regarding estimates of spawner abundance and return rates of WCT have already been collected in Lake Creek with which comparisons can be drawn. It is expected that return rates of both juveniles and adults, which have respectively averaged 1.8 and 37%, should each considerably increase with a concomitant, substantial increase in the number of spawners annually ascending Lake Creek.

4.0 TRIBUTARY HABITAT RESTORATION AND PROTECTION

4.1 Abstract

The planning exercise completed in 2011 resulted in prioritization of restoration actions within the tributaries that encompass the upper watersheds and identification of 105 projects in the Benewah Creek and Lake Creek watersheds. This list was subsequently revised as additional project scoping could take place, resulting in a refined list of 65 and 31 projects in the Benewah and Lake watersheds, respectively. Collectively these projects affect approximately 21 km of road, 28 km of riparian and stream habitats (many of these projects overlap) and 18 fish passage projects. Significant progress has been made to implement these projects since we went through this planning exercise. Agreements have been negotiated to implement projects with all the industrial landowners and with Benewah County, as well as with several smaller private landowners. These agreements help to build relationships that will facilitate implementation well into the future. In the Benewah Creek watershed, 11 projects have been completed since 2012, representing approximately 20 percent of the projected scope of work for the watershed; while three projects have been completed in the Lake Creek watershed, representing nearly 10 percent of the projected scope of work. Work completed during this reporting period included additions of large wood to improve habitat complexity within 1350 m of upper WF Benewah Creek and 600 m in EF Bozard Creek, respectively. A total of 21.4 ha (53.1 acres) of previously farmed uplands with highly erodible soils was reforested adjacent to 1447 m of streams in the upper Lake Creek watershed. More than 1070 m of forest roads were treated in Benewah Creek to reduce sediment transport to streams supporting spawning and rearing of cutthroat trout. Three fish passage projects were completed to improve access to 6270 m of high quality habitats. If similar resources are available to implement this scope of work into the foreseeable future, one can anticipate that 12 to 15 years may be required to achieve the restoration goals associated with these projects.

4.2 Introduction

This is an ongoing project designed to address the highest priority objective in the Coeur d’Alene Subbasin: to protect and restore remaining stocks of native resident westslope cutthroat trout (Oncorhynchus clarki lewisi) to ensure their continued existence in the basin and provide harvestable surpluses of naturally reproducing adfluvial adult fish in Lake Coeur d'Alene and in Lake and Benewah creeks, with stable or increasing population trends for resident life history types in Evans and Alder creeks. The project objectives are tiered to the Intermountain Province Objectives 2A1-2A4 and to the Columbia River Basin Goal 2A that addresses resident fish substitution for anadromous fish losses (Intermountain Province Subbasin Plan 2004). The management approach to habitat restoration is based on identifying and protecting core refugia and expanding restoration outward from areas of relatively intact habitats and populations, coupled with an analytical approach to prioritizing actions based on the degree of impairment to processes operating at the scale of species and ecosystems and the rarity of specific habitat types. Habitat restoration and enhancement activities employ the seven highest ranked strategies for addressing this objective within the Subbasin.

Past work products have included watershed assessments and long-term monitoring data that were used as the basis for developing and ranking future habitat projects to address watershed process impairment for sediment, flood hydrology, riparian and channel function and water quality (Firehammer et al. 2011). Prioritizing restoration actions in this way is an important part of the overall exercise to ensure that limited resources (i.e., staffing and funding) can be focused on actions that will have the greatest impact in locations that will translate into the greatest benefit. The resulting list of projects developed for the Benewah and Lake creek watersheds serves this purpose and has helped guide on-the-ground work that has been implemented since the last Resident Fish Categorical Review in 2012 (appendix E – Project descriptions). The project proposal specifically identified treatments for: 1) 15 km of channel wood additions to improve habitat diversity, sediment storage, grade control, habitat cover, and connectivity with floodplains; 2) 12.7 km of riparian projects to restore and/or conserve stream adjacent forests to provide natural recruitment of coarse woody debris over time; 3) 19 km of forest road BMPs to reduce sediment delivery to important spawning and rearing habitats; and 4) 28 fish passage projects to improve access to 28.3 km of stream habitats. These collective projects support recovery of resident and migratory westslope cutthroat trout through restoration and enhancement of landscape processes that form and sustain riverine habitat diversity and provide access for fish to these restored habitats. The locations of identified and completed projects are shown in Figure 16 and Figure 17.

This report summarizes previously unreported habitat restoration actions completed during the 2013 and 2014 calendar years to fulfill the contractual obligations for the BPA project. Even though the contract performance period for this project crosses fiscal and calendar years, the timing of project implementation lends itself to this reporting schedule. This report is formatted to include summaries of projects implemented in the Benewah and Lake creek watersheds as well as a discussion of lessons learned and adaptive management.

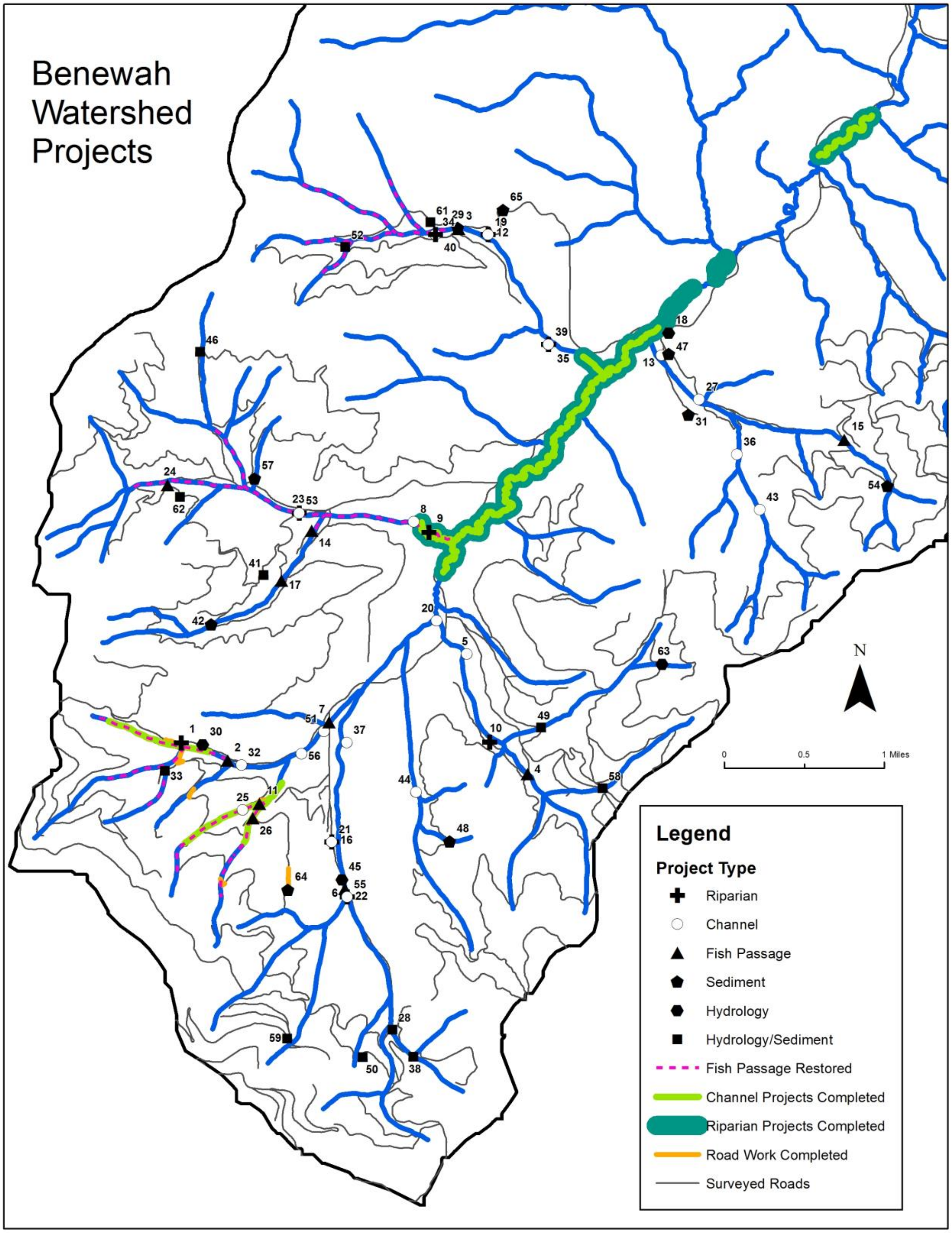


Figure 16. Locations of identified and completed projects in the Benewah Creek watershed. Project numbers are cross-referenced to the descriptive list of projects found in Appendix E.

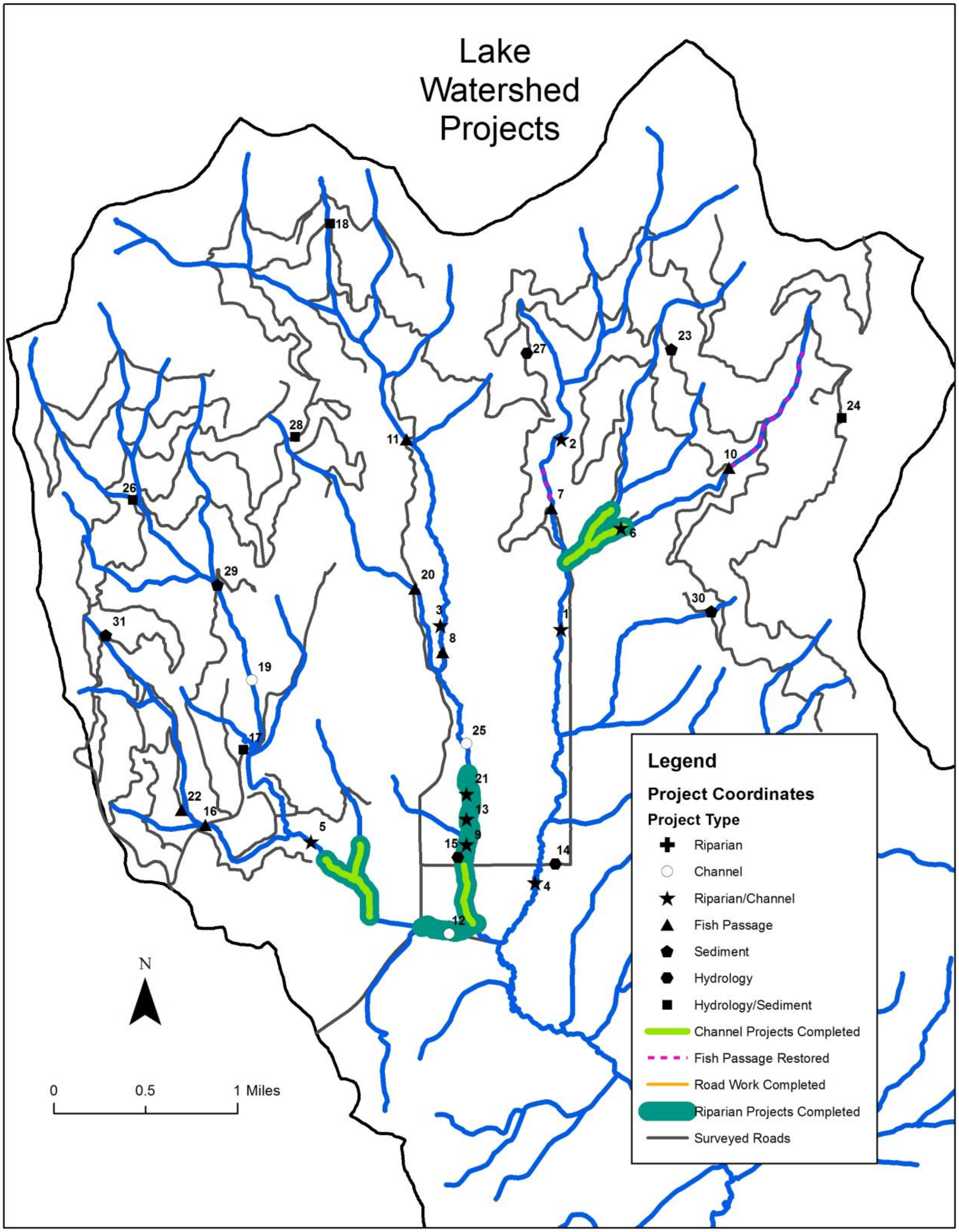


Figure 17. Locations of identified and completed projects in the Lake Creek watershed. Project numbers are cross-referenced to the descriptive list of projects found in Appendix E.

4.3 Summary of Implemented Actions

Implementation of restoration and enhancement activities occurred in the Benewah and Lake creek watersheds during 2013 and 2014. All activities completed during the period June 1, 2013 through December 31, 2014 are summarized below in a format that provides a detailed site characterization, description of limiting factors (problem statement), project objectives, summary of activities and relationship to the contracted scope of work.

A brief explanation of the project ID that is used in the summary table and in the detailed descriptions is warranted here. The project ID is an alphanumeric code that corresponds to the location of individual treatments in relation to the river-mile of the drainage network for the watersheds of interest. The first digit of the code signifies the watershed that the treatment is located in, using the first letter in the watershed name (e.g., B=Benewah Creek, L=Lake Creek, etc.). The series of numbers that follow correspond to the position in the river network (in kilometers) at the downstream end of treatment sites. River kilometer is tabulated in an upstream direction from mouth to headwaters and treatments that are located in tributary systems have river kilometer designations separated by a forward slash (/). For example, the downstream end of project L_8.2/0.7 is located in the Lake Creek watershed 0.7 kilometers up a tributary that has its confluence with the mainstem 8.2 kilometers from the mouth. This nomenclature is intended to indicate the spatial relationship of treatments to the mainstem and tributary aquatic habitats having significance to the target species. Furthermore, it readily conveys information about the relationship of multiple treatments by indicating the distance to common points in the drainage network.

Project B_21.5/2.1 – Instream/Channel Enhancement: WF Benewah Creek wood additions

Project Location:

Watershed: Benewah Creek

Sub Basin (River KM): 21.5/2.1

Legal: T45N R4W S27 NW; T45N R4W S26 SW

Lat: 47.215613 N Long: -116.821011 W

Site Characteristics:

Slope/gradient: 2-4%

Aspect: NE

Elevation: 960 m

Valley/Channel type: II/B3 & B4

Proximity to water: Instream and adjacent floodplain

Other: Large wood was placed in 700 meters of WF Benewah Creek and in 650 m of the SF of the WF Benewah Creek to increase habitat complexity and improve connectivity.

Problem Description: A wood recruitment study was conducted in 2007 and 2008 to examine the capacity of riparian areas to provide wood to streams over time, measure existing instream wood quantities and describe the complex relationship between riparian management, wood and aquatic habitat within local streams. Significant wood related habitat functions were associated with wood loading rates that exceeded 6 m^3/100 m (Duck Creek Associates 2008). Subsequently, stream segments with wood loads falling below this threshold were prioritized for treatment. Furthermore, riparian areas that lacked the capacity to meet this target over time were identified so that alternative management practices could be developed in cooperation with various private landowners to meet habitat objectives (Firehammer et al. 2011).

Currently, approximately 30% of the total stream length within the WF Benewah Creek subwatershed falls below the target threshold for wood loading of 6 m^3/100 m. The 2012 removal of a fish passage barrier located at rkm 1.7 opened 3390 m of additional habitat in the upper watershed to cutthroat trout. Habitat surveys completed in 2012 and 2013 confirmed that most of these newly accessible streams reaches also had a paucity of instream wood (mean = 2.13 m^3/100 m). As such, these reaches represent good opportunity for improving the habitat attributes that can contribute in the short term to increasing fish productivity (Table 12).

Table 12. Physical habitat attributes measured at 100 m sites in the West Fork Benewah Creek and the SF of the WF Benewah Creek in 2012 and 2013.

	Mean percent fines		Large woody debris		Pool habitat	
River km index	Bankfull	Wetted	Count (#/100 m)	Volume (m^3/100 m)	Percent pool	Mean residual depth (m)
21.5/1.9	18	5	16.2	0.84	33	0.24
21.5/2.1	41	9	7.0	1.27	29	0.18
21.5/2.6	49	11	4.9	0.23	11	0.41
21.5/2.35	35	12	9	0.69	37	0.25
21.5/2.9	45	6	7	0.81	22	0.15
21.5/1.0/0.3	39	14	8.1	0.60	42	0.23
21.5/1.0/0.8	55	31	19.9	3.80	55	0.19
21.5/1.0/0.5/0.4	79	63	13.9	8.80	50	0.19
Mean	**45**	**19**	**11**	**2.13**	**35**	**0.23**

Description of Treatment: Large wood was placed in WF Benewah Creek between river kilometer 2.1 and 2.8 where instream wood volume ranged between 1.27 and 0.81 m^3/100 m prior to treatment (see project #1 Figure 16; appendix E – Project descriptions). Wood was also added to 650 m of the SF of the WF Benewah Creek where wood loading was considerably higher on average, but still fell below the target volume of 6m^3/100 m (see project #25 Figure 16; appendix E – Project descriptions).

A Cat 320 excavator equipped with a rotating grapple was used to place approximately 71 cubic meters (30 MBF) of large wood (ranging in size from 0.2 – 0.7 m diameter, 3 - 10 m long) in a variety of configurations within the bankfull channel and floodplain. Placements included (in relation to the bankfull channel) parallel, transverse, bridged, partial- and fully-buried, as well as single and multiple log structures. Approximately 250 individual log placements were completed. Some placements were admittedly random, however, most were intended to create specific hydraulic effects (e.g., scour, deposition, gravel sorting); increase bank stability or provide grade control (i.e., vertical/horizontal stability); or simply provide overhead and instream hiding cover for fish (Photo 1). The configurations were largely determined using a fit-in-the-field approach during construction, based on habitat features and channel conditions readily observed at the scale of 3-5 times the bankfull channel width. Existing vegetation was preserved as much as possible, and especially mature woody vegetation, which was often used to provide stable anchor points for wood placements. After all wood placements were completed, a total of 500 deciduous trees and 2000 herbaceous grass plugs comprising 18 native species were planted in disturbed areas. These same areas were hand-seeded with a native grass mixture applied at a rate of 18 kg/ha.


Photo 1. An excavator equipped with a rotating grapple (inset) was used to place wood in a variety of configurations within 1350 m of the WF Benewah Creek subwatershed.

Project Timeline: A landowner agreement was negotiated and signed in 2012. Permits and NEPA compliance documentation were received in early 2013. Wood was placed in August and September, followed by planting in October.

Project Goals & Objectives: Increase instream wood quantities and associated wood related habitat function to meet a wood loading target of 6 m^3/100 m. Improvements are anticipated for pool frequency and quality, gravel sorting and spawning gravel retention, hiding cover for fish, bed and bank stability, and stream/floodplain connectivity.

Relationship to Scope of Work: This work fulfills the Program commitments for WE H in the 2014 Scope of Work and Budget Request (CR-234578) for the contract period June 1, 2013 - May 31, 2015.

Project Benewah 15.2/2.0 - Instream/Fish Passage: Whitetail Creek fish passage improvement

Project Location:

Watershed: Benewah Creek	Legal: T45N R4W S12 NW NE
Sub Basin (River km):15.2/2.0	Lat: 47.262421 N Long: -116.783010 W

Site Characteristics:

Slope/gradient: 3%	Aspect: NW	Elevations: 878 m
Valley/Channel type: C4/C4	Proximity to water: In-stream and adjacent floodplain	

Other: An undersized culvert was replaced to improve fish passage. A series of 5 cross-vanes were installed to create grade control within the project reach. Native trout will gain improved access to 4500 meters of potential rearing and spawning habitat.

Problem Description: Whitetail Creek is an important spawning and rearing stream for resident and adfluvial westslope cutthroat trout in the Benewah watershed. This stream crossing was identified as an adult and juvenile fish barrier in the Forest Road and Fish Passage Assessment completed in 2008 (Duck Creek Associates 2009). The existing 36" diameter culvert was undersized and perched 0.45 m above the stream channel where bankfull width is 3.38 m. A prioritization process completed by the Fisheries program ranked the replacement of this stream crossing as a high priority. The project will restore connectivity with the upper Whitetail Creek watershed, including access to 4500 meters of potential rearing and spawning habitats with a drainage area of 482 ha.

Description of Treatment: We collected data describing existing culvert size, length, road characteristics, flow line characteristics, floodplain information, and ground elevations using a Sokkia 530R total station. This information was imported into AutoCAD Civil 3D for analysis. In addition, cross-section information was collected to identify bankfull width and depth. Engineering drawings and specifications were developed for the new stream crossing structure using a variety of computer software. The Idaho Streamstats Website was used to derive discharge values at the site for a variety of flow regimes. The Federal Highway Administration's HY-8 Culvert Hydraulic Analysis Program was used to size the culvert. Once the culvert size and shape was determined, we used Fish Xing software to examine its characteristics for fish passage. ArcGIS was used to develop location maps and site maps.

The design called for replacing the existing undersized pipe with a new 64" x 43" x 50' arch pipe that more closely matched the bankfull channel width. The new pipe was countersunk to provide natural substrate in the bottom of the culvert and eliminate the outlet drop. Five grade control structures, each comprised of 20-25 large boulders, were constructed to form a series of step-pools that improve passage into the new culvert and provide more uniform channel grade in the vicinity of the of the stream crossing. The grade control structures were designed following specifications for cross-vanes developed by Rosgen (1996). One-hundred fifty feet of stream channel was affected by these structures. A total of 0.02 ha of wetland was disturbed during construction. An existing 24" culvert was left in place to provide additional flood relief at the road crossing (Photo 2).

The following construction phases were the focus of restoration work in summer 2013:

Phase 1: Replace existing culvert. A Cat 320 excavator was used to remove the undersized culvert and install the new 64" x 43" arch pipe. Before installing the new pipe, bedding material consisting of ¾" minus gravel was placed in the excavated pipe trench and compacted. The new pipe was delivered in 3 separate sections that were connected during construction. The used culvert was recycled at a local facility. The existing roadbed was capped with imported gravel. Rock rip-rap was placed around the new pipe to help protect the inlet and outlet of the new pipe. Large cobbles and small boulders were hand placed in the pipe to help accumulate gravel and create fish habitat.

Phase 2: Install grand control and reshape stream. Five drop structures were installed to connect the upstream and downstream stream reaches. These structures will create grade control as well as provide fish habitat.

Phase 3: Planting. A total of 500 1 gallon woody plants and 2,000 herbaceous grass plugs were planted along the stream channel and within the new riparian and upland areas created by removing sections of the abandoned road. Disturbed areas were seeded with native grass seed at a rate of 18 kg/ha.

Photo 2. The former Whitetail Creek stream crossing was identified as a fish barrier (left panel). The new Whitetail Creek culvert is shown during spring runoff in 2014 (right panel).

Project Timeline: NEPA compliance documentation and a landowner agreement were completed in early 2013. Construction was completed in August and planting occurred in September 2013.

Project Goals & Objectives: The goal is to restore connectivity with the upper Whitetail Creek subwatershed by removing a barrier to fish passage. Native trout will have access to 4,500 meters of prime rearing and spawning habitats upstream of the new culvert.

Relationship to Scope of Work: This work fulfills the Program commitments for WE F in the 2013 Scope of Work and Budget Request (CR-234578) for the contract period June 1, 2013 - May 31, 2014.

Project B_21.5/1.0/0.5/0.4 – Upland/Road: Reduce sediment delivery to Benewah Creek

Project Location:

Watershed: Benewah Creek	Legal: T45N R4W S27 SE NE, NE SE
Sub Basin (River KM): 21.5/1.0/0.5/0.4	Lat: 47.214451 N Long: -116.812811 W

Site Characteristics:

Slope/gradient: 3%	Aspect: E	Elevations: 926 m
Valley/Channel type: E3/C4	Proximity to water: hydrologically connected roads	

Other: Hydrologically connected road segments totaling 670 m were resurfaced to decrease sediment delivery to the West Fork Benewah and South Fork Benewah subwatersheds. An additional 400 m of stream parallel road was removed and converted back to riparian forest.

Problem Description: The West Fork Benewah Creek and South Fork Benewah Creek are important spawning and rearing streams for resident and adfluvial westslope cutthroat trout. A Forest Road and Fish Passage Assessment completed in 2008 identified road segments in the Benewah watershed that directly contribute sediment to these streams (Duck Creek Associates 2009). A prioritization process subsequently completed by the Fisheries program identified areas where additional drainage improvements and road resurfacing was needed (Firehammer et al. 2011). This work is part of the on-going effort by the tribe to improve fish habitat and water quality by managing roads in watersheds that encompass priority streams.

Description of Treatment: This project involved doing road improvements to roads within the West Fork/South Fork Benewah Creek subwatersheds. Previous road work in this area included removing a fish passage barrier along West Fork Benewah Creek at km 21.5/1.7 that opened up 3,390 meters to fish passage.

The following construction phases were the focus of restoration work in summer 2013:

Phase 1: Road resurfacing was completed for a total of 670 meters of native surface road. Three hydrologically connected road segments were resurfaced; two draining to West Fork Benewah Creek and one draining to the South Fork Benewah Creek. Prior to resurfacing, road segments were re-graded and ditches repaired using a Bobcat T-320 tracked skidsteer. Two rock sources were used to resurface the road: a base of courser 6" minus rock was placed first, followed by a surface cover of ¾" minus rock. A total of three culverts were installed using a Cat 303 mini-excavator to cross drain the resurfaced road segments and prevent water accumulation in roadside ditches. Two 18" cross-drains were installed along the resurface road segment in the South Fork Benewah drainage. In the West Fork Benewah drainage, a new 24" CMP culvert was installed at the location of a perennial spring to prevent water from saturating the road base.

Phase 2: An existing stream parallel, native surface road extending 400 meters along a tributary to the West Fork Benewah Creek was removed and reclaimed. A Cat 330DL excavator was used to rip the highly compacted surface of the old road bed. Tank traps and rolling dips were put in place to discourage future vehicle use and provide proper drainage. After the road was roughened 220 woody plants and 1000 herbaceous grass plugs were planted along the reclaimed roadbed. Disturbed areas were seeded with native grass seed at 18 kg/ha.

Photo 3. A high gradient road segment in the South Fork of Benewah Creek Watershed before and after resurfacing with gravel.

Photo 4. Road section along a tributary to the West Fork of Benewah Creek during road removal.

Project Timeline: NEPA compliance documentation and landowner agreement were completed in 2013. Construction for the project was completed in July 2013 and planting occurred in September of 2013.

Project Goals & Objectives: Reduce sediment delivery and improve drainage along road segments that are hydrologically connected and delivering sediment to important spawning and rearing streams.

Relationship to Scope of Work: This work fulfills the Program commitments for WE G in the 2013 Scope of Work and Budget Request (CR-234578) for the contract period June 1, 2013 - May 31, 2014.

Project L_13.6/0.0 – Upland/Planting: Lake Creek afforestation of former cropland

Project Location:

Watershed: Lake Creek	Legal: T48N R6W S12 NW; T48N R6W S1 SW
Sub Basin (River Kilometer): 13.6/0.0	Lat: 47.525564 N Long: -117.036149 W

Site Characteristics:

Slope/gradient: 3-25%	Aspect: Various	Elevations: 780 m
Valley/Channel type: VIII/E5	Proximity to water: Upland	

Other: Project treats approximately 21.4 ha (53.1 acres) of previously farmed uplands with highly erodible soils adjacent to 1447 m of streams in the upper watershed.

Problem Description: The project site consists of 21.4 hectares of uplands that variously drain to the mainstem of Lake Creek between river km 13.6 and 14.4 and to WF Lake Creek between river km 13.6/0.0 and 13.6/0.6. The forest was cleared from this area beginning in the 1920's and had a history of cropping and grazing up until the late 1990s. Soils in 33% of the area are classified as highly erodible. Sheet and rill erosion from these areas generated an estimated 15.1 tons/acre (total 262 tons/yr) of sediment annually with a delivery rate to streams of 10% under the historical cropping scenarios (US EPA 2005). Soils in the remaining 67% of the area are classified as moderately erodible due to their lower gradient. The single pass density index for age 1+ cutthroat trout in this area is quite variable based on the history of channel disturbance and lower than in adjacent upriver reaches. An index site within the more disturbed part of the project area supported trout densities in the range of 1.6-6.6 trout/100m, while a less disturbed site had densities of 9.8-34.1 trout/100m (this report). Abatement of sediment from upland sources is an important factor in maintaining the productivity of aquatic resources within this reach.

Previous work conducted on the project site consisted of 450m of stream wood additions to Lake Creek and a series of riparian planting projects completed between 1998 and 2001 (Vitale et al 2003). The established stream buffer was subsequently enrolled in the Conservation Reserve Program offered by the NRCS. The Coeur d'Alene Tribe ultimately facilitated purchase of the properties encompassing the project site to mitigate for wetlands impacts associated with construction of US Hwy 95. In 2012, the Idaho Transportation Department deeded the property to the Tribe and a conservation agreement protects the wetlands and other natural resources values in perpetuity.

Description of Treatment: In April 2014, a total of 15,915 conifers (ponderosa pine, western larch, western white pine, lodgepole pine and douglas fir) were planted on 21.4 hectares at an average density of 757 trees/hectare. Herbicide was also applied as a shielded spot spray using Atrazine 4L and glyphosate to control the grass and weeds in a 1.5m diameter circle around each seedling. In wetter portions of the planting area, Polaris SP replaced the Atrazine in the tank mix to protect ground water. A soil scalp adequate to prevent sprayed vegetation from brushing against seedlings was completed before planting.

Project Timeline: Initial site preparation occurred in April and trees were planted in May 2014, followed by the herbicide treatment.

Project Goals & Objectives: Restore prior converted agricultural lands back to a native forest community. Reduce sheet and rill erosion and increase water retention on site. Improve wetland function and values associated with sediment/nutrient/toxicant retention and removal, wildlife usage, uniqueness and cultural value. Achieve a minimum stocking rate after 5 years of 200 trees/acre on at least 70% of the planted areas. Survival surveys will monitor stocking in first, second and fifth years after planting. Further replanting would be scheduled where survival surveys indicate that the minimum acceptable stocking rate is not achieved.

Relationship to Scope of Work: This project fulfills the Program commitments for WE E in the 2013 Scope of Work and Budget Request (Contract #234578) for the contract periods dating June 1, 2013 through May 31, 2014.

Project L_13.4/4.0/0.1 - Instream/Channel Enhancement: EF Bozard Creek wood additions

Project Location:

Watershed: Lake Creek	Legal: T49N R5W S36 NW NW
Sub Basin (River KM):13.4/4.0	Lat: 47.552723 N Long: -117.020617 W

Site Characteristics:

Slope/gradient: 4%	Aspect: NE	Elevations: 829 m
Valley/Channel type: C4/E3	Proximity to water: Instream and adjacent floodplain	

Other: Large wood was placed along 600 meters of channel in 2014 to create fish habitat and increase connectivity with the adjacent floodplain.

Problem Description: A wood recruitment study was conducted in 2007 and 2008 to examine the capacity of riparian areas to provide wood to streams over time, measure existing instream wood quantities and describe the complex relationship between riparian management, wood and aquatic habitat within local streams. Significant wood related habitat functions were associated with wood loading rates that exceeded 6 m^3/100 m (Duck Creek Associates 2008). Subsequently, stream segments with wood loads falling below this threshold were prioritized for treatment. Furthermore, riparian areas that lacked the capacity to meet this target over time were identified so that alternative management practices could be developed in cooperation with various private landowners to meet habitat objectives (Firehammer et al. 2011).

East Fork Bozard Creek is an important spawning and rearing tributary for westslope cutthroat trout. Currently, only 14% of the total stream length within the Bozard Creek subwatershed meets the target threshold for wood loading of 6 m^3/100 m (Figure 18). Additional data collection in 2013 at two sites illustrated the importance of large wood in the drainage (Table 13). Site 1 is located on the lower East Fork Bozard Creek in a forested canyon while site 2 is located on the North Fork of the East Fork of Bozard Creek. Sampling these sites using single pass electrofishing returned 70 trout in site 1 where wood volume was 7.4 m^3/100 m, while 31 trout were caught in site 2 where wood loading was significantly lower at 1.13 m^3/100 m. Higher wood volume also contributed to a greater abundance and quality of pool habitats.

Table 13. Measured fish and habitat data for two sites in the East Fork Bozard Creek watershed, 2013.

	Fish Population	Large Woody Debris		Pool Habitat	
River km index	Total Count	Count (#/100 m)	Volume (m^3/100 m)	Percent Pool	Mean residual depth (m)
Site 1	70	14	7.4	49	0.21
Site 2	31	14	1.13	27	0.18

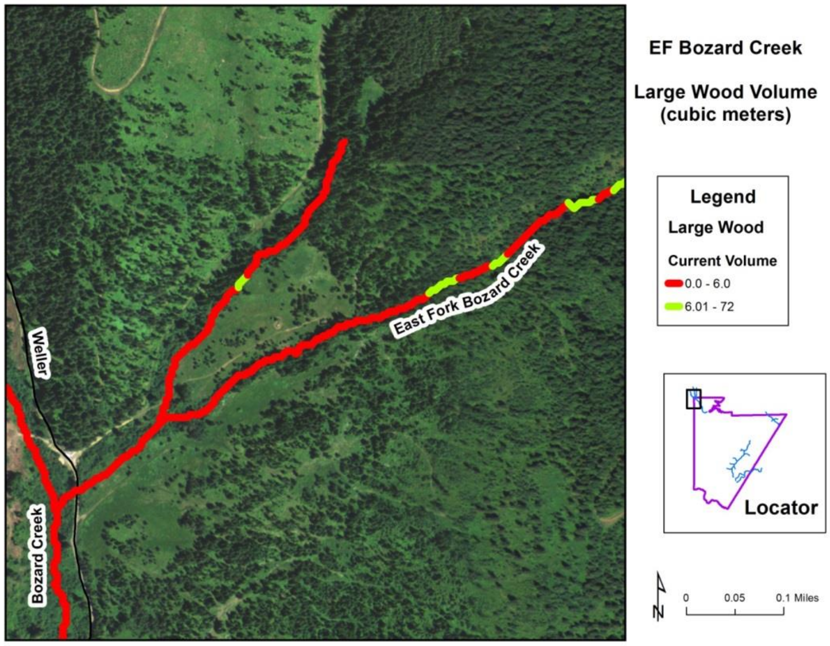


Figure 18. The results of a 2007 Wood Recruitment Study shows the current volume of instream large wood for the lower section of the East Fork of Bozard Creek falls below the target threshold set by the Tribe.

Description of Treatment: Large wood was placed in 500 m of theEast Fork of Bozard Creek and 100 m of the lower North Fork of the East Fork of Bozard Creek to increase wood abundance and wood related habitat function to meet a target volume of $6m^3$/100 m (Photo 5; Photo 6). A Cat 320DL excavator equipped with a rotating grapple was used to place approximately 28 cubic meters (12 MBF) of large wood (ranging in size from 0.2 – 0.7 m diameter, 3 - 10 m long) in a variety of configurations within the bankfull channel and floodplain. Placements included (in relation to the bankfull channel) parallel, transverse, bridged, partial- and fully-buried, as well as single and multiple log structures. Often portions of the logs were buried below the predicted depth of scour to act as stable anchors for the structures and provide grade control. Placements were intended to create specific hydraulic effects (e.g., scour, deposition, gravel sorting); increase bank stability or provide grade control (i.e., vertical/horizontal stability); or simply provide overhead and instream hiding cover for fish. The configurations were largely determined using a fit-in-the-field approach during construction, based on habitat features and channel conditions readily observed at the scale of 3-5 times the bankfull channel width. After all wood placements were completed, a total of 115 deciduous trees and 210 herbaceous grass plugs comprising 13 native species were planted in disturbed areas. These same areas were hand-seeded with a native grass mixture applied at a rate of 18 kg/ha.

Project Timeline: NEPA compliance documentation and landowner agreement were completed in early 2014. Construction for the project was completed in September and planting occurred in October.

Project Goals & Objectives: Increase instream wood quantities and associated wood related habitat function to meet a wood loading target of 6 m^3/100 m. Improvements are anticipated for pool frequency and quality, gravel sorting and spawning gravel retention, hiding cover for fish, bed and bank stability, and stream/floodplain connectivity.

<u>Relationship to Scope of Work</u>: This work fulfills the Program commitments for WE I in the 2014 Scope of Work and Budget Request (CR-272576) for the contract period June 1, 2014 - May 31, 2015.

Photo 5. Typical stream conditions on the East Fork of Bozard Creek prior to treatment. Very little wood, pool habitat and spawning gravel is present.

Photo 6. A large wood complex (left) and single log placements with parallel and bridged configurations (right) in the East Fork of Bozard Creek following construction in September 2014.

Project L_13.4/4.5 – Instream/Fish Passage: Bozard Creek fish passage improvement

Project Location:

Watershed: Lake Creek

Sub Basin (River km): 13.4/4.5

Legal: T49N R6W S36 NE NE

Lat: 47.555569 N Long: -117.025163 W

Site Characteristics:

Slope/gradient: 5%

Aspect: S

Elevations: 829 m

Valley/Channel type: B4/E4

Proximity to water: In-stream and adjacent floodplain

Other: An undersized culvert was replaced to improve fish passage. A series of 3 cross-vanes were installed to create grade control within the project reach. Native trout will have access to 450 m of potential rearing and spawning habitat upstream.

Problem Description: Bozard Creek is an important spawning and rearing stream for resident and adfluvial westslope cutthroat trout in the Lake watershed. This stream crossing was identified as an adult and juvenile fish barrier in the Forest Road and Fish Passage Assessment completed in 2008 (Duck Creek Associates 2009). The existing 48" diameter culvert was undersized and perched 0.24 m above the stream channel where bankfull width is 2.65 m. A prioritization process completed by the Fisheries program ranked the replacement of this stream crossing as a high priority (Firehammer et al. 2011). Native trout will have access to 450 meters of potential rearing and spawning habitats upstream (drainage area of 497 ha).

Description of Treatment: We collected data describing existing culvert size, length, road characteristics, flow line characteristics, floodplain information, and ground elevations using a Sokkia 530R total station. This information was imported into AutoCAD Civil 3D for analysis. In addition, cross-section information was collected to identify bankfull width and depth. Engineering drawings and specifications were developed for the new stream crossing structure using a variety of computer software. The Idaho Streamstats Website was used to derive discharge values at the site for a variety of flow regimes. The Federal Highway Administration's HY-8 Culvert Hydraulic Analysis Program was used to size the culvert. Once the culvert size and shape was determined, we used Fish Xing software to examine its characteristics for fish passage. ArcGIS was used to develop location maps and site maps.

The design called for replacing the existing undersized pipe with a new 77" x 52" arch pipe that more closely matched the bankfull channel width. The new pipe was countersunk to provide natural substrate in the bottom of the culvert and eliminate the outlet drop. Three grade control structures, each comprised of 20-25 large boulders, were constructed to form a series of step-pools that improve passage into the new culvert and re-establish the channel grade downstream of the stream crossing. The grade control structures were designed following specifications for cross-vanes developed by Rosgen (1996). One hundred feet of stream channel was affected by these structures. A total of 0.01 ha of wetland was disturbed during construction.

The following construction phases were the focus of restoration work in summer 2014:

Phase 1: Replace existing culvert. A Cat 320DL excavator was used to remove the undersized culvert and install the new 40 feet long 77” x 52” arch pipe. Before installing the new pipe, bedding material consisting of ¾” minus gravel was placed in the excavated pipe trench. The new pipe was delivered in 3 separate sections that were connected during construction. The used culvert was recycled at a local facility. The existing roadbed was capped with imported gravel. Rock rip-rap was placed around the new pipe to help protect the inlet and outlet of the new pipe. Large cobbles and small boulders were hand placed in the pipe to help accumulate gravel and create fish habitat.

Phase 2: Install Drop Structures and reshape stream. Three drop structures were installed to connect the upstream and downstream stream reaches. These structures will create grade control and as well as create fish habitat.

Phase 3: Planting. A total of 50 woody plants and 100 herbaceous grass plugs were planted along the stream channel and within the new riparian and upland areas created by removing sections of the abandoned road. Disturbed areas were seeded with native grass seed at 18 kg/ha.

Project Timeline: NEPA compliance documentation and landowner agreement were completed in 2014. Construction for the project was completed in September and planting occurred in October.

Project Goals & Objectives: This project will restore connectivity with the upper Bozard watershed by removing a barrier to fish passage. Native trout will have access to 450 meters miles of prime rearing and spawning habitats upstream of the new culvert.

Relationship to Scope of Work: This work fulfills the Program commitments for WE E in the 2014 Scope of Work and Budget Request (CR-272576) for the contract period June 1, 2014 - May 31, 2015.

Photo 7. Former Bozard Creek stream crossing that was identified as a fish barrier (left panel) and the new culvert (right panel).

Project L_13.4/4.0/1.67 - Instream/Fish Passage: EF Bozard Creek fish passage improvement

Project Location:

Watershed: Lake Creek	Legal: T49N R5W S29 SE SE
Sub Basin (KM): 13.4/4.0/1.67	Lat: 47.558748 N Long:-117.004449 W

Site Characteristics:

Slope/gradient: 5%	Aspect: NE	Elevations: 926 m
Valley/Channel type: E3/C4	Proximity to water: In-stream and adjacent floodplain	

Other: An undersized culvert was replaced to improve fish passage. Three cross-vanes were installed to create grade control within the project reach. Native trout will have access to 1,320 m of potential rearing and spawning habitat upstream.

Problem Description: East Fork Bozard Creek is an important spawning and rearing stream for resident and adfluvial westslope cutthroat trout in the Lake watershed. This stream crossing was identified as a juvenile fish barrier in the Forest Road and Fish Passage Assessment completed in 2008 (Duck Creek Associates 2009). The existing 54" diameter culvert was undersized and perched 0.18 m above the stream channel where bankfull width is 3.38 m. A prioritization process completed by the Fisheries program ranked the replacement of this stream crossing as a moderate priority (Firehammer et al. 2011). Native trout will have access to 1320 meters of potential rearing and spawning habitats upstream (drainage area of 391 ha).

Description of Treatment: We collected data describing existing culvert size, length, road characteristics, flow line characteristics, floodplain information, and ground elevations using a Sokkia 530R total station. This information was imported into AutoCAD Civil 3D for analysis. In addition, cross-section information was collected to identify bankfull width and depth. Engineering drawings and specifications were developed for the new stream crossing structure using a variety of computer software. The Idaho Streamstats Website was used to derive discharge values at the site for a variety of flow regimes. The Federal Highway Administration's HY-8 Culvert Hydraulic Analysis Program was used to size the culvert. Once the culvert size and shape was determined, we used Fish Xing software to examine its characteristics for fish passage. ArcGIS was used to develop location maps and site maps.

The design called for replacing the existing undersized pipe with a new 77" x 52" arch pipe that more closely matched the bankfull channel width. The new pipe was countersunk to provide natural substrate in the bottom of the culvert and eliminate the outlet drop. Three grade control structures, each comprised of 20-25 large boulders, were constructed to form a series of step-pools that improve passage into the new culvert and re-establish the channel grade downstream of the stream crossing. The grade control structures were designed following specifications for cross-vanes developed by Rosgen (1996). One hundred twenty feet of stream channel was affected by these structures. A total of 0.01 ha of wetland was disturbed during construction.

The following construction phases were the focus of restoration work in summer 2014:

Phase 1: Replace existing culvert. A Cat 320DL excavator was used to remove the perched culvert and install the new 40 foot long 77" x 52" arch pipe. The new stream crossing will allow for passage of all size classes of trout. Before installing the new pipe, bedding material consisting of ¾" minus gravel was placed in the excavated pipe trench and compacted. The new pipe was delivered in 2 separate sections that were connected during construction. The used culvert was recycled at a local facility. The existing roadbed was capped with imported gravel. Rock rip-rap was placed around the new pipe to help protect the inlet and outlet of the new pipe. Large cobbles and small boulders were hand placed in the pipe to help accumulate gravel and create fish habitat.

Phase 2: Install drop Structures and reshape stream: Three drop structures were installed to connect the upstream and downstream stream reaches. These structures will create grade control and as well as create fish habitat.

Phase 3: Planting: A total of 50 woody plants and 100 herbaceous plugs were planted along the stream channel and within the new riparian and upland areas created by removing sections of the abandoned road. Disturbed areas were seeded with native grass seed at 18 kg/ha.

Photo 8. Former East Fork Bozard Creek stream crossing that was identified as a fish barrier (left panel) and the new culvert with downstream grade control structures (right panel).

Project Timeline: NEPA compliance documentation and landowner agreement were completed in 2014. Construction for the project was completed in September and planting occurred in October.

Project Goals & Objectives: This project will restore connectivity with the upper Bozard watershed by removing a barrier to fish passage. Native trout will have access to 1,320 meters of prime rearing and spawning habitats upstream of the new culvert.

Relationship to Scope of Work: This work fulfills the Program commitments for WE F in the 2014 Scope of Work and Budget Request (CR-272576) for the contract period June 1, 2014 - May 31, 2015.

4.4 Lessons Learned and Adaptive Management

Refining the Approach for Beaver Aided Restoration

In Benewah Creek, we postulated that a positive feedback cycle may exist where historic beaver trapping and removal of trees and shrubs used by beaver resulted in local extirpation or significant reductions in beaver population size (Firehammer et al. 2013). In this event, neither beaver populations nor beaver-generated fish habitat will fully recover until riparian vegetation is restored (Pollock et al. 2004). Recovery of beaver-generated floodplain wetlands and their wet meadow, scrub–shrub, and forested plant communities is dependent upon the restoration of lost hydraulic linkages between the channel and its floodplain through annual flood pulses and a locally high water table (Westbrook et al. 2006). However, water availability may not be sufficient in environments like Benewah Creek to support riparian plant establishment and growth. In such circumstances, beaver were likely the historic mechanism that supplied riparian vegetation with sufficient water to establish and maintain trees and shrubs. Importantly, successful beaver recolonization and riparian vegetation restoration may require long periods of time when the positive feedback mechanism described above has been activated.

We developed and implemented a simple approach that emulates the ecosystem engineering effects of beaver. The approach involves constructing log flow-choke structures that mimic the hydraulic function of a stable natural beaver dam during flooding (DeVries et al. 2012). By placing these structures throughout the stream reach at locations promoting increased frequency of flood connection with floodplain swales and relict channels, we set the stage to restore the riparian corridor and floodplain more quickly than could be achieved through revegetation alone. We coupled this with several more passive approaches, where 1) vertical posts were used to reinforce active dams, and 2) large wood was placed in the channel and partially buried to provide a stable framework for beaver to build on; approaches that have more recently been referred to as Beaver Dam Analogues (BDAs) (MacCracken et al. 2005; Pollock et al., 2015). Together we hoped these methods would provide an ecosystem "kick-start" that emulates the mechanisms driving natural floodplain connectivity and restoring both fish habitat and floodplain vegetation more rapidly than simply revegetating and waiting for the riparian zone to mature.

Between 2009 and 2012, treatments were applied in 30 locations affecting 57 percent of stream habitats within 3,138 m of the upper mainstem of Benewah Creek (Figure 19). We have documented overbank flows across the valley bottom at discharges equal to the 1.5-year return interval flood in the vicinity of our structures, whereas other reaches without stable beaver dams require much higher discharge for overbank flow. Thus, from the riparian floodplain restoration perspective, we are already seeing some of the intended results, where floodplain flow path swales and relict channels are more frequently engaged and those that have been replanted are showing improved survival and growth. However, in the same timeframe we documented a 79 percent reduction in the direct influence by beaver on aquatic habitats in the reach, which we speculated would significantly affect the overall trajectory and scale for recovery of watershed processes (Firehammer et al. 2013). And this trend has worsened more recently with loss of all the remaining natural dams in the reach. Concurrent with the widespread loss of natural beaver dams we have observed less channel inundation and lower summer water tables, and by inference, less hyporheic exchange, a contraction in wetland area and an overall decrease in the complexity of the stream ecosystem. Moreover, establishing riparian plantings at a scale that can support beaver populations and shade stream channels in the future has continued to be a real challenge.

Rather than abandon the investments made during implementation of past projects, the absence of beaver activity in the reach suggests several opportunities for refining the restoration approach. In fact, monitoring data reinforces the need for such an adaptive approach. For example, seasonal movements have been detected showing fish utilizing mainstem reaches during summer and fall rearing periods and moving downstream into restored sections of the upper Benewah mainstem in winter (this report). The movements illustrate the importance of protecting or restoring seasonal habitats in these watersheds. The past mapping and monitoring of beaver dams in upper Benewah Creek identifies nearly 50 specific locations where construction of BDAs may be appropriate. Starter dams have already been established in five of these locations, wherein a line of wooden posts was installed using a hydraulic post pounder, followed by weaving branches in between the posts, after Pollock et al. (2012). In all cases the posts have remained intact across several high flow periods, and several dams that were constructed by hand functioned in much the same manner as log flow-choke structures that mimic the hydraulic function of stable natural beaver dams during flooding. The addition of BDAs in this manner should increase both the abundance and life span of natural dams if/when beaver should return, which in turn should promote reconnection of floodplain surfaces on a larger scale. Such longer lived, less transient dams should become building blocks for resilient and dynamic beaver dam complexes that support thriving colonies of beaver. In addition, the 17 locations where engineered flow choke structures have been built in Benewah Creek could also be modified to function more like natural dams. Currently these structures slow the movement of high-flow waters, increasing upstream flooding and creating temporary ponding, but during low flows they provide little functionality that is similar to a beaver dam. The weir opening in these stable structures could be "plugged" using natural materials in much the same manner as the starter dams described above. Less permeable plugs could effectively increase channel inundation and raise summer water tables thereby providing more viable planting locations. Consistent with the original intent of this work, these refinements would be very low impact and cost effective, requiring investments primarily in manual labor.

Lessons Learned: As a restoration approach, beaver assisted design seemingly is most appropriate and can be most successful in settings where beaver or evidence of beaver activity is present in successive years. However sufficient research and resources have been compiled to support the use of beaver in restoration and conservation; some of which is based on the real-life experience of restoration practitioners who are conducting ongoing experiments on using beaver to restore habitat. The movements of cutthroat further illustrate the importance of protecting or restoring the seasonal habitats that are influenced by beaver in these watersheds.

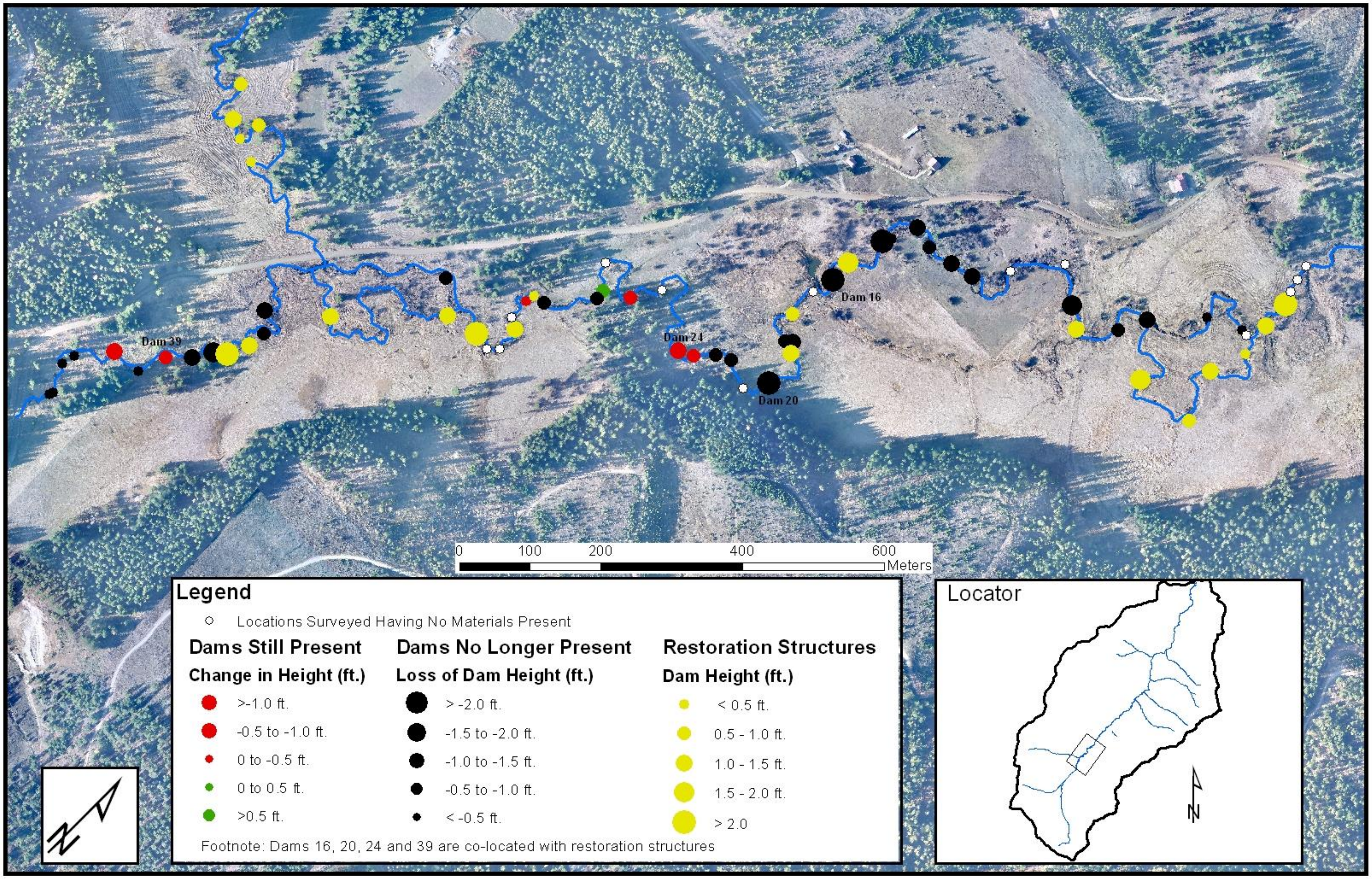


Figure 19. Disposition of natural dams and restoration structures surveyed during 2010 through 2012 in the D2 reach of the Ełumish Project in upper Benewah Creek. Potential locations of Beaver Dam Analogues (BDAs) are indicated by surveyed point locations lacking dam materials or active dams.

Evaluating the Efficacy of Restoration Planning

The planning exercise completed in 2011 resulted in prioritization of restoration actions within the tributaries that encompass the upper watersheds and identification of 105 projects in the Benewah Creek and Lake Creek watersheds. This list was subsequently revised as additional project scoping could take place, resulting in a refined list of 65 and 31 projects in Benewah and Lake watersheds, respectively. Collectively these projects affect approximately 21 km of road, 28 km of riparian and stream habitats (many of these projects overlap) and 18 fish passage projects. Contemplating the implementation of such a comprehensive scope of work can be intimidating, but on the other hand, it provides a clear road map for achieving project objectives that can be tracked over time and greatly facilitates the planning and coordination that leads to putting projects on the ground. For example, by looking at land ownership associated with these projects we saw that 49% of projects were situated on lands owned by just 4 industrial forest landowners and another 39% of projects were situated on lands owned by just 18 small private landowners. This puts the longer term work plan into perspective and it effectively highlights where strategic partnerships lie, as well as suggests opportunities for improving the efficiency and cost-effectiveness of project implementation (e.g., by scheduling implementation of adjacent projects).

Significant progress has been made to implement these projects since we went through this planning exercise. Agreements have been negotiated to implement projects with all the industrial landowners and with Benewah County, as well as with several smaller private landowners. These agreements help to build relationships that will facilitate implementation well into the future. In the Benewah Creek watershed, 11 projects have been completed since 2012, representing approximately 20 percent of the projected scope of work for the watershed. While three projects have been completed in the Lake Creek watershed, representing nearly 10 percent of the projected scope of work for that watershed. If similar resources are available to implement this scope of work into the foreseeable future, one can anticipate that 12 to 15 years may be required to achieve the restoration goals associated with these projects at an estimated cost of approximately $3,690,000.

There is some discrepancy to note between projected and actual restoration metrics as projects are implemented. For example, for the completed projects described above, projected metrics developed during the scoping exercise estimated treatments for 5.54 km of stream and riparian habitats, 1.75 km of roads, and 14 km of stream habitats with improved fish passage. The actual metrics for these same projects as reported after implementation was 2.6 km of stream and riparian treatments, 1.1 km of road improvements, and 11.1 km of stream habitats with improved fish passage. These differences stem from a number of issues, including: 1) overlap in project types, primarily between riparian and channel projects, that overestimate the scope of treatments during the planning phase; 2) changes in on-the-ground conditions and habitat needs between the time that assessments were completed and projects were implementation; and 3) discrepancy between mapped versus measured habitat attributes. Nevertheless, including project metrics as part of the initial planning exercise was an important component of the prioritization process and this discussion simply illustrates the value in tracking these metrics as projects are implemented.

Lessons Learned: A comprehensive restoration effort that is well focused to benefit aquatic resources and native fishes at the scale of whole watersheds can be accomplished over time

with the participation and support of a variety of stakeholders. Fractionated land ownership presents a challenge to meeting project goals, but it is not an insurmountable challenge, particularly where restoration programs are designed and intended to remain in place over a long period of time. This longevity allows for adaptive planning to better inform the process of restoration in addressing the priorities that are suggested by monitoring and evaluation. It also allows for relationships to develop with stakeholders that better reflect the spirit of collaboration in working toward project goals.

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APPENDIX A – DETAILED RME METHODS

Adfluvial adult cutthroat abundance

The number of adults ascending upstream of the trap, or approaching the trap site, was estimated as follows:

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

where:

N= the abundance estimate;
M= number of marked adults, or interrogated adults downstream of the trap;
C= number of adults captured; and
R= number of marked or interrogated adults recaptured.

The variance estimate of N was calculated as follows:

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

An approximate 95% confidence interval was then calculated as $N \pm 1.96\sqrt{v(N)}$.

Adfluvial juvenile outmigrant abundance

The number of juveniles moving downstream during each release trial period was calculated using the following equation:

$$U_h = \frac{(u_h)(M_h+1)}{m_h+1},$$

where:

U_h = outmigrant abundance, excluding recaptured fish, in trial period *h*;
u_h = number of untagged fish in trial period *h;*
M_h = number of tagged fish available for recapture in trial period *h*; and
m_h = number of tagged fish recaptured in trial period *h*.

The variance estimate of U_h was calculated as follows:

$$v(U_h) = \frac{(M_h+1)(u_h+m_h+1)(M_h-m_h)(u_h)}{(m_h+1)^2(m_h+2)}.$$

Total outmigration abundance (U) and variance ($v(U)$) were then calculated as the sum of the respective estimates across all trial periods. An approximate 95% confidence interval was then calculated as:

$U \pm 1.96\sqrt{v(U)}$.

Physical habitat protocol

Pool habitat

Pools were identified according to criteria that comported with other regional habitat monitoring protocols (Peck et al. 2006; AREMP 2007; Heitke et al. 2008), though methodologies varied depending on whether surveys were conducted in smaller tributary reaches or larger mainstem reaches. In a tributary reach, each pool was measured from tail crest to its upstream end, and depths were recorded at the tail crest and the deepest point for calculating residual pool depth. Percent pool habitat and mean residual pool depth were calculated for each site. In a mainstem reach, pools were identified and measured along their length using the following criteria. A habitat type was classified as a pool if the maximum depth minus the tail-crest, or control point, depth was greater than one foot of residual pool depth. If a pool was identified, then the upstream and downstream boundaries, demarcated to measure overall pool length, were those locations at which residual pool depth equaled one foot. Each pool was divided into four sections by selecting the following three locations along its length: 1) half-way between maximum depth and the downstream end of the pool, 2) the point of maximum depth, and 3) half-way between the maximum depth and the upstream end of the pool. At each of the three locations, stream widths were collected that only included the portion of the channel where the water depth was greater than one foot of residual depth. Finally, at each stream width, three depth measurements were collected equidistant across the measured width. Stream widths, average depths, and stream lengths were used to calculate pool volume for each section, and summed over all four sections to generate an overall pool volume. For each site, a collective pool volume and a mean residual pool depth were calculated.

Substrate composition

Wolman pebble counts (Wolman 1954) were completed at riffles and pool tailouts along the survey reach. At each of these points a measuring stick or finger was placed on the substrate and the one particle the tip touched was picked up and the size measured. Particle size was determined as the length of the "intermediate axis" of the particle; that is the middle dimension of its length, width and height. A total of 50 particles were counted across bankfull at each location, and a total of five riffle and two pool tailout locations distributed across the reach were sampled. Particles were noted whether they were sampled within or without the wetted channel width. Pebble count data were input into spreadsheets to graph the distribution of particle sizes and calculate pertinent descriptive criteria such as percent fines for each habitat type.

Canopy cover

Vegetative canopy density (or shade) was determined using a conical spherical densiometer, as described by Platts et al. (1987). The densiometer determines relative canopy "closure" or canopy density, which is the amount of the sky that is blocked within the closure by vegetation. Canopy cover over the stream was determined at ten equidistant locations distributed throughout the survey reach. At each location, densiometer readings were taken one foot above the water surface at the following stations: once facing the left bank, once facing upstream at the middle of the channel, once facing downstream at the middle of the channel and once facing the right bank. Percent density was calculated collectively over these four readings for each of the ten locations with an overall mean calculated for the reach.

Large woody debris

Large woody debris (LWD) was surveyed throughout the entire site. All LWD that was greater than 4 inches in diameter at the small end and 4 ft in length was counted. In addition to these criteria, LWD also had to be either partially located within bankfull or suspended across the channel above the water surface. Living trees and shrubs, however, did not qualify as LWD. For all pieces, the mean diameter and length were estimated and tallied in appropriate size ranges. Size classes were 4-8, 8-12, 12-18, 18-24, and >24 inches for mean diameter. Size classes were 4-10, 10-15, 15-20, 20-25, and >25 feet for length. In addition to the first five pieces of qualifying LWD encountered, the mean diameter and length were measured for every 5th piece of LWD to calibrate the accuracy of the visual length and diameter estimates. Volume of each piece was calculated using the mid-point values of the length and diameter categories to which the piece was assigned. Total volume and density of LWD was calculated for each site and expressed per meter of stream length. In addition to measuring the volume of LWD, data denoting the function and position of each identified piece were also collected to aid in describing how LWD was providing habitat and influencing channel form within the site. Function categories included: accumulating sediment, forcing a pool to form upstream or downstream, providing in-stream cover, or providing bank stabilization. More than one category could be assigned to individual wood pieces. Categories to describe the position of the identified piece in relation to the stream included: elevated above the bankfull channel, one end within and the other end outside bankfull channel, completely within bankfull channel but exposed, or within bankfull channel but partially buried.

Beaver dam survey

The list of available categories that were used describe the type of dam surveyed and the materials used to build the dam. Active dams were considered those in which a presence of fresh material (e.g., green stems) was detected.

Attribute	**Categories**
Dam type	Acitve single dam with large wood
	Active dam complex composed of multiple dams utilizing large wood and/or mid-channel islands
	Active single dam without large wood
	Inactive single dam with large wood
	Inactive dam complex composed of multiple dams utilizing large wood and/or mid-channel island
	Inactive single dam without large wood
Dam materials	Key pieces (> 4 inches in diameter; length >= bankfull width)
	Other large wood (> 4 inches in diameter)
	Large wood with root wad
	Small wood (< 4 inches in diameter)
	Herbaceous plant material
	Mud
	Other

Sub-drainage abundance of cutthroat trout

For each of the WFB, SFB, and Windfall sub-drainages, abundance estimates within each stratum were calculated using the following formula:

$$N_x = L\left(\frac{\Sigma n}{\Sigma l}\right)$$

where:

N_x = Abundance in stratum (x)
L = Length of stratum (x)
n = Abundance estimate at each site sampled in stratum (x)
l = Length of each site sampled in stratum (x)

The standard error was calculated as the square root of the total variance:

$$se(N_x) = \sqrt{\left\{\left(\frac{L}{\sum l}\right)\left(\sum var(r)\right) + \left[\frac{\left(\left(\frac{L}{\sum l}\right)(t)\right)\left(\left(\left(\frac{L}{\sum l}\right)(t)\right) - t\right)\left(\sum varC(y)\right)}{(t)(t-1)}\right]\right\}}$$

where:

$\left(\frac{L}{\sum l}\right)\left(\sum var(r)\right)$ = Measurement Variance

and:

$\left[\frac{\left(\left(\frac{L}{\sum l}\right)(t)\right)\left(\left(\left(\frac{L}{\sum l}\right)(t)\right) - t\right)\left(\sum varC(y)\right)}{(t)(t-1)}\right]$ = Sampling Variance

where:
$\sum var(r)$ = Total variance summed across mark-recapture sites in stratum (x)
t = # of sites sampled within stratum (x)
$\sum varC(y)$ = Calculation used to generate sampling variance among sites sampled in stratum (x)

where:

$varC(y) = l^2((y_i - \hat{y}))^2$, and

y_i = Density estimate at site i

$\hat{y}$ = Mean density within stratum (x)

APPENDIX B – GENERATED EFFICIENCIES FOR PIT ARRAYS, ELECTROFISHING PASSES, AND OUTMIGRANT TRAPS

Table B-1. Detection efficiencies generated for directional PIT arrays during high and moderate flow periods in the upper Benewah Creek and upper Lake Creek watersheds, 2013-2014. Detection efficiencies were computed using the methodology described by Connolly et al (2008).

	2013				2014			
	High Flows		Moderate Flows		High Flows		Moderate Flows	
Location (River Km)	**Detections**	**Efficiency**	**Detections**	**Efficiency**	**Detections**	**Efficiency**	**Detections**	**Efficiency**
Upper Benewah Creek Watershed								
Benewah Creek, 9-mile (14.2)	174	0.90	200	0.93	100	0.86	331	0.94
Benewah Creek, 12-mile (19.1)	5	1.00	16	0.99	26	0.70	32	0.96
Windfall Creek mouth (18.6)	4	1.00	25	1.00	27	1.00	36	1.00
Benewah Creek, confluence of south and west forks (21.5)	5	1.00	10	1.00	15	0.90	22	0.98
Upper Lake Creek Watershed								
Bozard Creek mouth (13.4)	13	0.95	45	1.00	34	0.99	123	1.00
Lake Creek, confluence of upper and west forks (13.8)	4	0.67	45	0.99	19	1.00	121	1.00

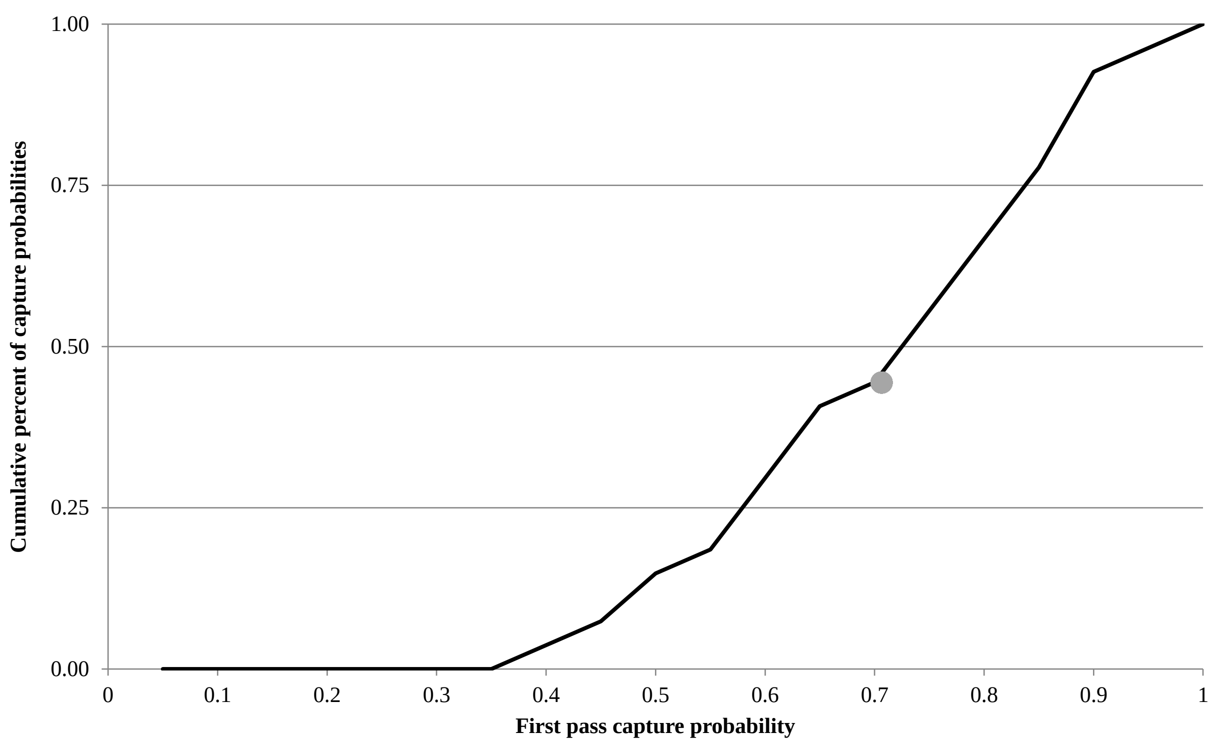

Figure B-1. Cumulative distribution of first pass capture probabilities generated for mark-recapture sites (n=27) in South Fork Benewah, West Fork Benewah and Windfall sub-drainages, 2013-2014. Filled grey circle denotes the mean first pass capture probability of 0.71.

Table B-2. Trap efficiency trials conducted in Lake Creek in 2013. Number (%) of fish recaptured after their respective trial period and detected at distant upstream PIT-tag arrays is also displayed.

Trial period	Fish released	Trap efficiency estimate	Abundance estimate	Recapped after trial period (%)	Detected at PIT antennae (%)
24-Apr -27-Apr	42	0.60	125	4 (10)	0 (0)
27-Apr -30-Apr	34	0.17	274	0 (0)	0 (0)
30-Apr -02-May	47	0.13	384	0 (0)	1 (2)
02-May -08-May	40	0.19	294	3 (8)	0 (0)
08-May -10-May	58	0.50	149	14 (24)	8 (14)
10-May -14-May	49	0.59	228	3 (6)	6 (12)
14-May -16-May	70	0.58	178	9 (13)	17 (24)
16-May -18-May	60	0.52	142	10 (17)	16 (27)
18-May -21-May	57	0.37	101	9 (16)	17 (30)
21-May -23-May	36	0.16	300	0 (0)	7 (19)
23-May -30-May	50	0.18	632	3 (6)	12 (24)
30-May -04-Jun	66	0.16	988	2 (3)	9 (14)
04-Jun -14-Jun	40	.	.	0 (0)	12 (30)

Table B-3. Trap efficiency trials conducted in Lake Creek in 2014. Number (%) of fish recaptured after their respective trial period and detected at distant upstream PIT-tag arrays is also displayed.

Trial period	Fish released	Trap efficiency estimate	Abundance estimate	Recapped after trial period (%)	Detected at PIT antennae (%)
24-Mar - 27-Mar	11	0.60	97	2 (18)	0 (0)
27-Mar - 31-Mar	32	0.66	99	1 (3)	0 (0)
31-Mar - 04-Apr	29	0.54	92	5 (17)	0 (0)
04-Apr - 07-Apr	29	0.57	111	3 (10)	0 (0)
07-Apr - 11-Apr	32	0.51	106	2 (6)	0 (0)
11-Apr - 13-Apr	30	0.52	127	2 (7)	0 (0)
13-Apr - 15-Apr	33	0.53	154	3 (9)	0 (0)
15-Apr - 18-Apr	30	0.48	165	1 (3)	0 (0)
18-Apr - 21-Apr	31	0.45	357	0 (0)	1 (3)
21-Apr - 23-Apr	31	0.50	188	0 (0)	0 (0)
23-Apr - 27-Apr	27	0.21	378	0 (0)	0 (0)
27-Apr - 30-Apr	30	0.52	246	1 (3)	0 (0)
30-Apr - 02-May	31	0.52	152	2 (6)	1 (3)
02-May - 05-May	29	0.27	439	0 (0)	0 (0)
05-May - 07-May	33	0.42	203	0 (0)	1 (3)
07-May - 09-May	30	0.42	122	0 (0)	0 (0)
09-May - 12-May	24	0.56	175	0 (0)	0 (0)
12-May - 14-May	30	0.46	51	1 (3)	1 (3)
14-May - 21-May	73	0.19	1689	1 (1)	0 (0)
21-May - 23-May	35	0.66	223	2 (6)	1 (3)
23-May - 25-May	30	0.39	457	0 (0)	0 (0)
25-May - 27-May	30	0.13	1043	0 (0)	1 (3)
27-May - 30-May	30	0.19	1157	0 (0)	0 (0)
30-May - 01-Jun	30	0.22	151	0 (0)	0 (0)

Table B-4. Trap efficiency trials conducted in Benewah Creek in 2013. Number (%) of fish recaptured after their respective trial period is also displayed.

Trial period	Fish released	Trap efficiency estimate	Abundance estimate	Recapped after trial period (%)
15-Mar -18-Mar	9	0.49	66	0 (0)
18-Mar -21-Mar	16	0.64	22	1 (6)
21-Mar -26-Mar	10	0.73	19	2 (20)
26-Mar -29-Mar	9	0.42	44	1 (11)
29-Mar -01-Apr	18	0.53	162	1 (6)
01-Apr -03-Apr	30	0.68	118	0 (0)
03-Apr -05-Apr	30	0.55	56	3 (10)
05-Apr -08-Apr	30	0.67	65	0 (0)
08-Apr -11-Apr	30	0.58	60	0 (0)
11-Apr -15-Apr	30	0.80	78	1 (3)
15-Apr -19-Apr	19	0.54	49	0 (0)
19-Apr -22-Apr	26	0.52	166	0 (0)
22-Apr -25-Apr	30	0.71	70	1 (3)
25-Apr -30-Apr	41	0.52	101	1 (2)
30-Apr -03-May	28	0.65	26	0 (0)
03-May -06-May	14	0.38	15	0 (0)

Table B-5. Trap efficiency trials conducted in Benewah Creek in 2014. Number (%) of fish recaptured after their respective trial period is also displayed.

Trial period	Fish released	Trap efficiency estimate	Abundance estimate	Recapped after trial period (%)
20-Mar - 24-Mar	30	0.69	137	2 (7)
24-Mar - 27-Mar	16	0.42	119	0 (0)
27-Mar - 31-Mar	30	0.76	140	0 (0)
31-Mar - 03-Apr	30	0.70	85	3 (10)
03-Apr - 07-Apr	29	0.74	141	1 (3)
07-Apr - 10-Apr	31	0.42	80	0 (0)
10-Apr - 14-Apr	29	0.65	29	0 (0)
14-Apr - 18-Apr	10	0.63	66	0 (0)
18-Apr - 21-Apr	33	0.59	115	1 (3)
21-Apr - 24-Apr	30	0.43	87	0 (0)
24-Apr - 28-Apr	34	0.63	148	0 (0)
28-Apr - 02-May	30	0.67	78	0 (0)
02-May - 06-May	30	0.50	130	0 (0)
06-May - 09-May	25	0.49	54	0 (0)
09-May - 12-May	11	0.18	127	0 (0)
12-May - 14-May	22	0.13	42	0 (0)

APPENDIX C – PHOTOS OF MONITORING SITES AND EQUIPMENT

Photo 9. Adult migrant trap at Lake Creek. Pictured on the left is the series of interconnected picket panels that are supported underneath by a structure that can be manually raised or lowered. Pictured on the right is the winch that is used to adjust the panels, and the livebox for holding captured fish.

Photo 10. The fixed panel trap used in Lake Creek in 2013 to intercept downstream moving juveniles and post-spawn adults. The inset picture in the upper right depicts a pop-out inner panel that can be removed under high flows to relieve pressure on the trap.

Photo 11. Series of three side-by-side 5’x5’ FDX antennas that span the channel immediately downstream of the adult trap in Lake Creek.

APPENDIX D – PUBLISHED NORTHERN PIKE MANUSCRIPT

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Trophic Ecology of Nonnative Northern Pike and their Effect on Conservation of Native Westslope Cutthroat Trout

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ARTICLE

Trophic Ecology of Nonnative Northern Pike and their Effect on Conservation of Native Westslope Cutthroat Trout

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Abstract
Westslope Cutthroat Trout *Oncorhynchus clarkii lewisi* in Coeur d'Alene Lake, Idaho, have declined in recent years; predation by Northern Pike *Esox lucius*, a nonnative sport fish, is thought to be a causative mechanism. The goal of this study was to describe the seasonal food habits of Northern Pike and determine their influence on Westslope Cutthroat Trout in Coeur d'Alene Lake by using a bioenergetics modeling approach. Fish were sampled monthly from March 2012 to May 2013 using pulsed-DC electrofishing and experimental gillnetting in four bays. Northern Pike catch rates from electrofishing were generally low but increased slightly each season and were highest in the southern portion of the lake; catch rates from gillnetting were approximately 50% higher during the two spring sampling periods compared with the summer and fall. Seasonal growth and food habits of 695 Northern Pike (TL = 16.2–108.0 cm; weight = 24–9,628 g) were analyzed. Diets primarily consisted of kokanee *O. nerka*, Westslope Cutthroat Trout, and Yellow Perch *Perca flavescens*. Results of a bioenergetics model estimated that Westslope Cutthroat Trout represented approximately 2–30% of the biomass consumed by age-1–4 Northern Pike. Total Westslope Cutthroat Trout biomass consumed by Northern Pike (2008–2011 year-classes) across all seasons sampled was estimated to be 1,231 kg (95% CI = 723–2,396 kg), and the total number consumed was 5,641 (95% CI = 3,311–10,979). The highest occurrence of Westslope Cutthroat Trout in Northern Pike diets was observed during spring. Thus, reducing Northern Pike predation on Westslope Cutthroat Trout would be one tool worth considering for conserving Westslope Cutthroat Trout populations in Coeur d'Alene Lake.

The Cutthroat Trout *Oncorhynchus clarkii* historically had one of the most widespread distributions of any North American salmonid; however, Cutthroat Trout populations have been declining since the 19th century and are now a major focus of management and conservation (Gresswell 1988; Dunham 2002). A primary factor contributing to the decline of Cutthroat Trout is a reduction in habitat quality and quantity (Liknes and Graham 1988; Marnell 1988; Shepard et al. 2005; Gresswell 2011). The construction of dams has created movement barriers that interfere with spawning and other important life history events (Liknes and Graham 1988). Many populations also exist in watersheds with extensive agriculture, where channel dewatering and sedimentation are common (Moeller 1981; Liknes and Graham 1988). Changes in water quality and damage to riparian habitat from livestock grazing have been shown to exert negative effects on Cutthroat Trout populations

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(Peterson et al. 2010). In addition, the Cutthroat Trout was among the most common fish species encountered by European settlers in the 19th century and as a result was important for subsistence and commerce (Behnke 1988). The high catchability of Cutthroat Trout and a lack of harvest regulations for this species caused many populations to be overexploited in less than 100 years (Behnke 1988).

Nonnative fishes have been shown to negatively affect Cutthroat Trout populations through competition, predation, and hybridization (Rich 1992; Shepard et al. 2005; Tabor et al. 2007; Muhlfeld et al. 2008). As populations of Cutthroat Trout have become less abundant, water bodies have often been stocked with nonnative species to create or supplement fisheries. One of the greatest factors contributing to the decline of Cutthroat Trout is their interaction with nonnative Rainbow Trout *O. mykiss*, which compete and hybridize with Cutthroat Trout (Marnell 1988; Allendorf et al. 2004; Shepard et al. 2005; Muhlfeld et al. 2009). Many remaining genetically pure populations of Westslope Cutthroat Trout *O. clarkii lewisi* exist only in headwater streams where movement barriers protect them from nonnative species (Rasmussen et al. 2010). In fact, Westslope Cutthroat Trout populations known to be genetically pure currently inhabit less than 10% of this subspecies' historic distribution in the United States and less than 20% of its historic distribution in Canada (Shepard et al. 2005). Other species, such as Brown Trout *Salmo trutta* in large streams, Brook Trout *Salvelinus fontinalis* in small streams, and Lake Trout *Salvelinus namaycush* in lake systems, have also replaced Cutthroat Trout across the species' distribution (Behnke 2002; Quist and Hubert 2004). In addition to salmonids, various warmwater and coolwater species have been introduced into systems containing Cutthroat Trout, primarily to diversify recreational angling opportunities. Some of these species include Smallmouth Bass *Micropterus dolomieu*, Largemouth Bass *M. salmoides*, Northern Pike *Esox lucius*, Walleye *Sander vitreus*, and Sauger *Sander canadensis*. Nonnative top-level predators not only have an influence on native fishes but also can greatly alter prey population structure and dynamics (Tabor et al. 2007; Muhlfeld et al. 2008).

Introductions of nonnative species have contributed to declines in Cutthroat Trout populations, particularly Westslope Cutthroat Trout, across much of the Pacific Northwest (Rich 1992; Naughton et al. 2004; Tabor et al. 2007; Muhlfeld et al. 2008). In Idaho, Westslope Cutthroat Trout are native to the Kootenai, Pend Oreille, Spokane, Clearwater, and Salmon River systems in the northern part of the state. Historically, Westslope Cutthroat Trout were abundant in Idaho and as a result were important for subsistence and commerce (Wallace and Zaroban 2013). In addition, Westslope Cutthroat Trout have cultural significance to Native Americans. In the past, the Coeur d'Alene Tribe in northern Idaho relied on Westslope Cutthroat Trout for subsistence, harvesting roughly 42,000 fish per year from Coeur d'Alene Lake and the St. Joe River (Firehammer et al. 2012). However, Westslope Cutthroat Trout in Coeur d'Alene Lake have declined drastically, and conservation efforts have been initiated.

Over the last 10–15 years, the Coeur d'Alene Tribe has implemented restoration practices in Lake and Benewah creeks (i.e., two tributaries to Coeur d'Alene Lake) to recover populations of adfluvial Westslope Cutthroat Trout. The Coeur d'Alene Tribe is focused on restoring stream spawning and rearing habitat by increasing sinuosity, creating deep pools, enhancing large woody debris, and reconnecting streams to their floodplains (Firehammer et al. 2012). Stream renovations were initiated to increase instream survival, but there is a critical knowledge gap associated with the survival of adfluvial Westslope Cutthroat Trout once they out-migrate to Coeur d'Alene Lake as juveniles and return to spawn as adults. Recently, the Coeur d'Alene Tribe embarked on an intensive PIT-tagging study to better understand juvenile survival and adult return rates. Of the 5,300 out-migrating juveniles that were tagged during 2005–2010, only 1.7% returned as adults to Lake Creek and 2.3% returned to Benewah Creek (Firehammer et al. 2012). These juvenile-to-adult return rates are 8–12 times lower than estimates obtained using similar techniques in comparable systems (Huston et al. 1984; Stapp and Hayward 2002; Muhlfeld et al. 2009). The mechanism responsible for the poor survival of adfluvial Westslope Cutthroat Trout is unknown, but it is hypothesized to be the result of predation by nonnative species, particularly Northern Pike, in Coeur d'Alene Lake (Rich 1992; Naughton et al. 2004; Tabor et al. 2007; Muhlfeld et al. 2008).

Northern Pike are top-level predators with a circumpolar distribution. Due to their popularity in recreational fisheries, Northern Pike have been introduced into systems across North America (Crossman 1978). In addition to being stocked for sport fishery enhancement, Northern Pike have also been introduced to reduce densities of "nuisance" species, such as the Common Carp *Cyprinus carpio* and Gizzard Shad *Dorosoma cepedianum* (Pflieger 1997). Northern Pike are ambush predators that require littoral habitat with abundant vegetation for successful spawning (Crossman 1978; Casselman and Lewis 1996). They are also opportunistic predators that prefer soft-rayed fishes (Eklöv and Harrin 1989).

In the Coeur d'Alene River basin of northern Idaho, shallow, vegetated habitat and sloughs are common where tributaries enter Coeur d'Alene Lake. Juvenile adfluvial Westslope Cutthroat Trout out-migrate to Coeur d'Alene Lake during spring and must pass through habitat that is highly suitable for Northern Pike. Thus, there is the potential for spatial and temporal overlap between Westslope Cutthroat Trout and Northern Pike in areas where tributaries enter the lake. Given the need to better understand factors influencing Westslope Cutthroat Trout in Coeur d'Alene Lake, our objectives were to describe the seasonal food habits of Northern Pike in the lake and to estimate their consumption of Westslope Cutthroat Trout and other prey taxa.

METHODS

Coeur d'Alene Lake is the second-largest natural lake in Idaho, with a surface area of 12,700 ha (Figure 1). The lake has a mean depth of approximately 24 m and a maximum depth of 61 m (Rich 1992; Vitale et al. 2004). Primary tributaries to Coeur d'Alene Lake are the Coeur d'Alene and St. Joe rivers; many small streams also contribute to the system. Post Falls Dam was constructed on the outlet of Coeur d'Alene Lake in 1906 and raised the water level of the lake by 2.5 m, creating an abundance of shallow, vegetated habitats (Rich 1992). The lake has been classified as mesotrophic based on nutrient concentrations; however, heavy metals from 100 years of mining and ore processing in the watershed limit biological production (National Research Council 2005). Fisheries in Coeur d'Alene Lake are co-managed by the Coeur d'Alene Tribe and the Idaho Department of Fish and Game.

Native sport fish species in Coeur d'Alene Lake include Westslope Cutthroat Trout, Bull Trout *Salvelinus confluentus*, and Mountain Whitefish *Prosopium williamsoni*. Currently, sport fishes are primarily nonnative species, such as kokanee *O. nerka*, Chinook Salmon *O. tshawytscha*, Rainbow Trout, Brook Trout, Largemouth Bass, Smallmouth Bass, Black Crappie *Pomoxis nigromaculatus*, Pumpkinseed *Lepomis gibbosus*, Yellow Perch, Brown Bullhead *Ameiurus nebulosus*, Black Bullhead *Ameiurus melas*, and Northern Pike. Other notable native species in the basin include Northern Pikeminnow *Ptychocheilus oregonensis* and Longnose Sucker *Catostomus catostomus*. Tench *Tinca tinca*, a nonnative species in North America, is also common in Coeur d'Alene Lake.

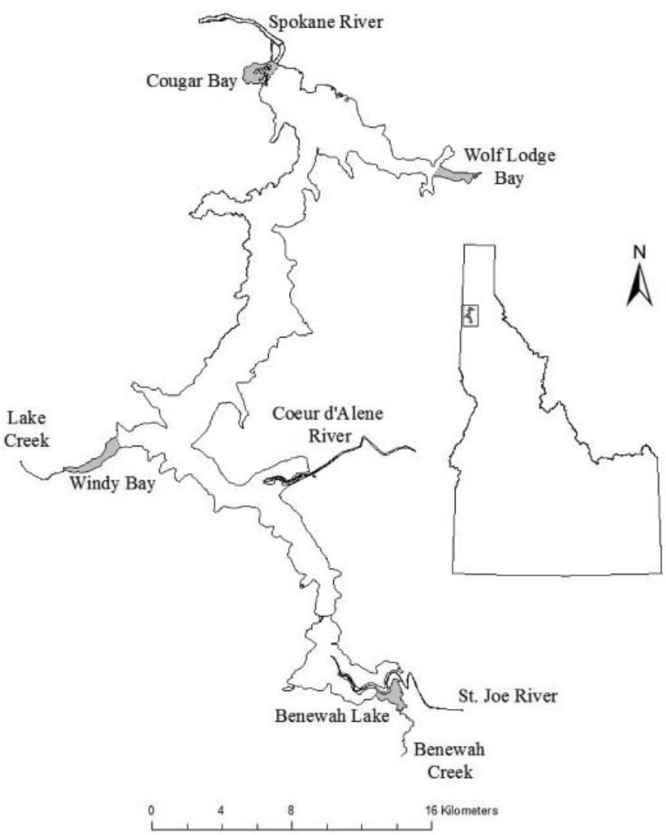

FIGURE 1. Coeur d'Alene Lake, located in northern Idaho. The Idaho Department of Fish and Game manages the lake north of the Coeur d'Alene River mouth; the Coeur d'Alene Tribe manages the lake south of the river mouth as well as the Lake Creek watershed. Sampling sites were located in Cougar Bay, Wolf Lodge Bay, Windy Bay, and Benewah Lake.

Four major bays (i.e., Wolf Lodge Bay, Cougar Bay, Windy Bay, and Benewah Lake) in Coeur d'Alene Lake were selected for this study because they are the primary areas where Northern Pike are common or because they represent important areas for sport fish management (Figure 1; Rich 1992; Firehammer et al. 2012). Stratified random sampling was used to select sampling sites by dividing the shoreline of each bay into 300-m sections and randomly assigning a gear type to a section. A sampling event consisted of sampling 18 nonoverlapping sections composed of 12 gillnetting sites and 6 electrofishing sites. Sampling occurred once per month in Cougar and Wolf Lodge bays from March 2012 to May 2013. Windy Bay and Benewah Lake were sampled once per month during June–November 2012 and twice per month from March to May in both 2012 and 2013. Spring biweekly sampling was performed to increase the resolution in Windy Bay and Benewah Lake, where the Coeur d'Alene Tribe is intensely monitoring Westslope Cutthroat Trout in tributaries (i.e., Lake and Benewah creeks). Hazardous lake conditions prevented us from sampling during winter (December 2012–February 2013).

Northern Pike were sampled using pulsed-DC electrofishing and experimental gill nets. Electrofishing was conducted using a 5,000-W generator mounted in an aluminum boat with Smith-Root equipment (Smith-Root, Inc., Vancouver, Washington). Power output was standardized to 2,750–3,250 W based on ambient water conductivity (μS/cm; Miranda and Boxrucker 2009). In an effort to minimize mortality and prey digestion, gill nets (46 × 1.8 m, with panels of 2.5-, 3.2-, 3.8-, 4.4-, and 5.0-cm bar-measure mesh) were fished for 1.5–2.0 h. Kobler et al. (2008) found that Northern Pike movement was more homogeneous during winter months than in other months, with slightly higher movement occurring during the day. Those authors also reported that Northern Pike were most active at dawn and dusk during the summer. Therefore, we conducted sampling at dusk in May–September and during the day in October–April. Additionally, operation of a boat at night with low water levels and ice became hazardous during fall and winter.

All Northern Pike were measured for TL to the nearest millimeter and were weighed to the nearest gram. Each Northern Pike was marked by completely removing the left pelvic fin (Nielson 1992; Guy et al. 1997). Age structures (i.e., left pelvic fin ray) were collected from 10 fish per centimeter length-group (Laine et al. 1991; Quist et al. 2012). Fin rays were placed into coin envelopes and were allowed to air dry before processing (Koch and Quist 2007). Cleithra from Northern Pike were collected to corroborate ages from pelvic fin rays. Agreement between cleithrum ages and pelvic fin ray ages was 100%.

Half of the captured Northern Pike were tagged by using an individually numbered, nonreward FD-94 T-bar anchor tag (7.6 cm; Floy Tag, Inc., Seattle) inserted near the posterior end of the dorsal fin. All other Northern Pike were tagged with an individually numbered, nonreward Carlin dangler tag (0.6 × 1.6 cm; Floy Tag; Quist et al. 2010) in the caudal peduncle. Individually numbered tags were used to obtain individual recapture histories, which were used to estimate Northern Pike population abundance in Program MARK (Cooch and White 2010).

Stomach contents were obtained via gastric lavage from 5 fish per centimeter length-group during each sampling event in each bay. A 12-V, 14.4-L/min pump (Fimco, North Sioux City, South Dakota) equipped with a pressure gauge, changeable hose fittings, and a pressure-release valve was used to flush stomachs (Light et al. 1983; Bowen 1996; Venturelli and Tonn 2006). Large prey items that were not flushed from the stomach were removed using forceps. Filtered water held in an on-board container was used for the lavage process to ensure that samples were not contaminated with organisms from the lake. Before a fish was released, a gastroscope was inserted through the esophagus and into the stomach to ensure the removal of all prey items, water, and air. If prey items were observed, the lavage process was repeated until the stomach was empty. Stomach contents were fixed with 10% buffered formalin (Garvey and Chipps 2012). The efficiency of removing all prey items from stomachs with the pulsed gastric lavage technique was evaluated by dissecting mortalities and examining their stomachs for any remaining content; efficiency was 98%. Stomach contents were also scanned for PIT tags by using an Allflex ISO compact reader (Allflex, San Antonio, Texas), as adfluvial Westslope Cutthroat Trout in Lake and Benewah creeks are PIT-tagged.

In the laboratory, vertebrate diet items were counted and identified to species, and invertebrate diet items were counted and identified to order. Lengths of prey items were measured to the nearest 0.002 cm by using a caliper (Mitutoyo, Aurora, Illinois). Wet and dry weights were measured to the nearest milligram. For partially digested items, total lengths and weights were estimated from hard structures (e.g., vertebrae and head capsules) by using published length–weight equations (Duke and Crossley 1975; Dumont et al. 1975; Smock 1980; Evenson and Kruse 1982; Rust 1991; Garvey and Stein 1993; Ganihar 1997; Altindag et al. 1998; Behnke et al. 1999; Sabo et al. 2002; Anders et al. 2003; Baumgartner and Rothhaupt 2003; Wigley et al. 2003).

Relative weight (W_r) was used to evaluate body condition of Northern Pike:

$$W_r = \left(\frac{W}{W_s}\right) \times 100,$$

where W is the weight of an individual and W_s is the standard weight from a species-specific length–weight regression (Neumann et al. 2012). A W_r value greater than 100 indicates above-average body condition.

Food habits data were pooled by season based on water temperature: spring (March–May), summer (June–August), and fall (September–November). All data were summarized by Northern Pike year-class for those year-classes that were represented by at least five individuals in each season (i.e., the 2008–2011 year-classes). Frequency of occurrence, percent by number, percent energy contribution, and prey-specific energy contribution were used to summarize the diet data (Garvey and Chipps 2012). Percent energy contribution was estimated by multiplying the weight of a taxon by its caloric value and then dividing the total energy of that taxon by the total energy of all prey items. Prey-specific energy contribution was the percentage of energy contributed by a prey taxon to total energy (all taxa) for only those stomachs in which the prey taxon occurred (Amundsen et al. 1996). Only Northern Pike with identifiable prey items in their stomachs were used in the food habits analysis. Unidentifiable prey items were rare ($<1\%$) and therefore removed from further analysis.

To gain insight on prey importance, feeding strategy, and components of diet niche width for Northern Pike in Coeur d'Alene Lake, we used a modification of the Costello method, which plots the prey-specific energy contribution of a prey taxon against its frequency of occurrence (Amundsen et al. 1996). Feeding strategies can be defined as follows: (1) rare taxa occur at low frequencies, contribute little energy, and are typical of a generalist diet; (2) prey taxa that occur at high frequencies and that contribute substantial amounts of energy indicate specialization at the population level; and (3) prey taxa with low frequencies of occurrence and high prey-specific energy contributions indicate specialization by individuals (Amundsen et al. 1996).

Bioenergetics modeling conducted with Fish Bioenergetics 3.0 (Hanson et al. 1997) was used to estimate the weights of various taxa consumed by Northern Pike. Bioenergetics models are popular for understanding the growth and trophic ecology of fishes and are based on the generalized equation

$$C = (R + A + S) + (F + U) + (\Delta B + G),$$

where C = consumption, R = respiration, A = active metabolism, S = specific dynamic action, F = egestion, U = excretion, ΔB = somatic growth, and G = gonad production (Hanson et al. 1997). The simulation covered 440 d (from March 15, 2012, to May 31, 2013) with a daily time step and

TABLE 1. Biomass (g) of individual prey types consumed by Northern Pike in Coeur d'Alene Lake, Idaho, as estimated with bioenergetics models. Estimates are provided for each Northern Pike year-class (2008–2011) and each season. Months were grouped together based on water temperature: spring (March–May), summer (June–August), and fall (September–November).

	2011 year-class				2010 year-class			
Taxon	Spring 2012	Summer 2012	Fall 2012	Spring 2013	Spring 2012	Summer 2012	Fall 2012	Spring 2013
Invertebrates								
Annelida	28.88	0.00	0.00	0.05	0.00	0.00	0.00	0.01
Coleoptera	0.00	0.00	0.00	0.00	0.07	0.90	0.00	0.00
Decapoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hymenoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Odonata	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00
Fish								
Catostomidae								
Largescale Sucker	7.04	0.00	0.00	0.00	30.31	1.47	58.50	0.00
Centrarchidae								
Black Crappie	30.20	0.00	0.00	1.18	0.00	0.00	8.67	29.42
Bluegill	0.00	0.00	549.67	4.82	0.00	0.00	18.02	0.00
Largemouth Bass	0.00	87.63	0.00	0.00	0.00	0.08	7.66	0.00
Unknown species	0.00	0.00	0.00	0.00	0.00	0.00	12.38	0.00
White Crappie *Pomoxis annularis*	0.00	0.00	0.00	0.41	0.00	0.00	0.00	0.00
Clupeidae								
Pacific Herring *Clupea pallasii*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.81
Cottidae								
Sculpin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyprinidae								
Northern Pikeminnow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tench	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Esocidae								
Northern Pike	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
Ictaluridae								
Brown Bullhead	0.00	17.82	0.00	0.00	17.77	0.00	17.27	0.74
Percidae								
Yellow Perch < 15.0 cm	24.50	134.96	264.77	32.25	46.59	19.33	97.55	196.65
Yellow Perch ≥ 15.0 cm	0.00	0.00	0.00	155.60	106.07	92.76	174.83	77.91
Salmonidae								
Kokanee	0.00	0.00	0.00	94.53	238.26	55.03	108.86	98.50
Unknown species	0.00	0.00	0.00	0.68	0.00	0.00	0.00	3.88
Westslope Cutthroat Trout	0.00	0.00	0.00	26.80	216.79	345.48	0.00	96.55
Other								
Idaho giant salamander *Dicamptodon aterrimus*	0.00	0.00	0.00	0.00	0.00	0.00	1.99	0.00
Detritus	32.99	46.24	0.00	0.00	0.00	12.23	0.01	0.00

was divided into four periods (i.e., spring, summer, and fall 2012; and spring 2013) to better represent seasonal trends in consumption and growth for each Northern Pike year-class. Bioenergetics models were not developed for winter (i.e., December 1, 2012–March 14, 2013) because no sampling occurred during that period.

The two most common uses of bioenergetics models are for estimating how environmental conditions affect growth and estimating the weight of prey consumption by predators (Hartman and Kitchell 2008). The models require water temperature data, prey energy densities, predator energy densities, and cohort-specific information on diet proportions, initial weights, final weights, and physiological parameters for the focal species (e.g., Hanson et al. 1997; Muhlfeld et al. 2008). Water temperature was recorded by three Onset temperature loggers (Model H08-001-02; Onset, Cape Cod, Massachusetts)

TABLE 1. Extended.

Taxon	2009 year-class Spring 2012	2009 year-class Summer 2012	2009 year-class Fall 2012	2009 year-class Spring 2013	2008 year-class Spring 2012	2008 year-class Summer 2012	2008 year-class Fall 2012	2008 year-class Spring 2013
Invertebrates								
Annelida	0.24	0.00	0.00	64.88	0.21	0.00	0.00	0.00
Coleoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapoda	0.00	196.72	0.00	0.00	0.00	0.00	0.00	0.00
Hymenoptera	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00
Odonata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish								
Catostomidae								
Largescale Sucker	0.00	0.00	35.57	19.95	0.00	0.00	0.00	0.00
Centrarchidae								
Black Crappie	0.00	0.00	53.73	0.00	0.21	0.00	0.00	22.87
Bluegill	0.00	0.00	53.05	0.00	0.00	0.00	0.00	0.00
Largemouth Bass	18.63	0.00	230.66	0.00	0.00	0.00	0.00	0.00
Unknown species	0.00	0.00	0.00	0.00	0.00	0.00	9.76	64.19
White Crappie *Pomoxis annularis*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Clupeidae								
Pacific Herring *Clupea pallasii*	0.00	0.00	0.00	113.99	0.00	0.00	0.00	0.00
Cottidae								
Sculpin	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.00
Cyprinidae								
Northern Pikeminnow	0.00	0.00	44.36	12.82	0.00	0.00	0.00	0.00
Tench	0.00	0.00	0.00	125.10	36.29	0.00	0.00	0.00
Esocidae								
Northern Pike	0.00	0.00	0.00	0.00	13.16	0.00	0.00	0.00
Ictaluridae								
Brown Bullhead	18.05	217.82	38.88	0.00	0.05	0.00	0.00	16.56
Percidae								
Yellow Perch < 15.0 cm	76.59	3.68	210.26	95.65	41.55	0.00	0.22	0.00
Yellow Perch ≥ 15.0 cm	50.40	118.98	29.73	87.16	16.76	73.15	160.93	129.20
Salmonidae								
Kokanee	233.62	186.63	339.03	181.87	80.85	786.76	296.44	178.93
Unknown species	13.44	0.00	0.00	0.00	37.31	0.00	56.42	0.00
Westslope Cutthroat Trout	142.29	4.80	128.28	52.04	74.39	18.66	287.11	160.69
Other								
Idaho giant salamander *Dicamptodon aterrimus*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Detritus	0.00	0.00	0.02	0.00	0.00	36.72	0.00	0.00

in each of the four bays. Temperature loggers were placed at depths varying from 0.9 to 10.7 m across bays and recorded the temperatures that were likely to be experienced by Northern Pike. The loggers recorded a water temperature (°C) every 6 h to generate a mean daily temperature. Caloric densities for prey items and predators were obtained from the published literature (Cummins and Wuycheck 1971; Yule and Luecke 1993; Bryan et al. 1996; Hanson et al. 1997; Liao et al. 2004; Antolos et al. 2005; Muhlfeld et al. 2008). Dietary information for each sampling day was aggregated across all individual Northern Pike by year-class and was input into the model as the proportion by weight of prey taxa consumed. Initial and final weights of Northern Pike for each period and year-class were estimated using the median weights of individuals from each year-class. If an initial or final weight was less than the previous value, the weight was assumed to be the same as that recorded for the previous period. Physiological parameters from Bevelhimer et al. (1985) were developed for

TABLE 2. Total biomass (g) of individual prey types consumed by Northern Pike in Coeur d'Alene Lake, as estimated with bioenergetics models. Estimates are presented for each Northern Pike year-class (2008–2011) as well as summed across year-classes.

	Year-class				
Taxon	2011	2010	2009	2008	Total
Invertebrates					
Annelida	28.93	0.01	65.12	0.21	94.27
Coleoptera	0.00	0.97	0.00	0.00	0.97
Decapoda	0.00	0.00	196.72	0.00	196.72
Hymenoptera	0.00	0.00	0.00	0.04	0.04
Odonata	0.00	0.04	0.00	0.00	0.04
Fish					
Catostomidae					
Largescale Sucker	7.04	90.27	55.52	0.00	152.83
Centrarchidae					
Black Crappie	31.39	38.09	53.73	23.08	146.29
Bluegill	554.49	18.02	53.05	0.00	625.57
Largemouth Bass	87.63	7.74	249.29	0.00	344.66
Unknown species	0.00	12.38	0.00	73.95	86.33
White Crappie	0.41	0.00	0.00	0.00	0.41
Clupeidae					
Pacific Herring	0.00	3.81	113.99	0.00	117.80
Cottidae					
Sculpin	0.00	0.00	0.00	0.52	0.52
Cyprinidae					
Northern Pikeminnow	0.00	0.00	57.18	0.00	57.18
Tench	0.00	0.00	125.10	36.29	161.39
Esocidae					
Northern Pike	0.00	0.02	0.00	13.16	13.17
Ictaluridae					
Brown Bullhead	17.82	35.78	274.75	16.61	344.96
Percidae					
Yellow Perch < 15.0 cm	486.48	360.13	386.19	41.77	1,274.56
Yellow Perch ≥ 15.0 cm	155.60	451.57	286.28	380.04	1,273.48
Salmonidae					
Kokanee	94.53	500.65	941.14	1,342.98	2,879.31
Unknown species	0.68	3.88	13.44	93.73	111.73
Westslope Cutthroat Trout	26.80	658.82	327.40	540.85	1,553.86
Other					
Idaho giant salamander	0.00	0.35	0.00	0.00	0.35
Detritus	79.23	12.24	0.02	36.72	128.22
All prey	1,571.02	2,196.74	3,198.94	2,599.93	

Northern Pike varying from 12.8 to 22.7 cm TL and from 9.5 to 53.2 g. Bean (2010) demonstrated that there is a risk of overestimating consumption when the parameters developed by Bevelhimer et al. (1985) are applied to larger individuals (i.e., >22.7 cm). Therefore, to correct inaccuracies for larger individuals, Bean (2010) developed parameters for Northern Pike varying from 25.0 to 71.8 cm TL and from 86 to 2,146 g. Thus, physiological parameters from Fish Bioenergetics 3.0 (i.e., Bevelhimer et al. 1985) were used for the 2011 year-class, whereas parameters from Bean (2010) were used for the 2008–2010 year-classes. Bioenergetics models were not developed for the 2005–2007 year-classes, as fewer than five individuals were captured during each season.

After all species- and site-specific data were entered, the proportion of maximum consumption (P_c) was calculated as

$$P_c = \frac{C}{(C_{max} \times r_c)},$$

where C is the estimated consumption, C_{max} is the maximum consumption of a specific ration at a given temperature, and r_c

TABLE 3. Estimates of total Westslope Cutthroat Trout (WCT) biomass consumed by Northern Pike (2008–2011 year-classes) in Coeur d'Alene Lake from March 15, 2012, to May 31, 2013 (excluding December 1, 2012–March 15, 2013). Northern Pike age composition percentages were derived from an age–length key. The 95% CIs are shown in parentheses for Northern Pike abundance (*N*) and total WCT biomass.

Year-class	Age composition (%)	Northern Pike *N*	Total WCT biomass (kg)
2011	19.5	637 (358–1,240)	17.1 (9.6–33.2)
2010	31.4	1,026 (576–1,997)	676.1 (379.8–1,315.8)
2009	30.8	1,007 (565–1,959)	329.6 (185.1–641.4)
2008	11.8	386 (217–751)	208.6 (117.2–405.9)
Total	93.5	3,056 (1,717–5,947)	1,231.3 (691.7–2,396.4)

is a temperature-dependent proportional adjustment of the consumption rate (Hanson et al. 1997). In the present model, P_c was estimated by solving the equation with observed growth and temperature data.

Program MARK (Cooch and White 2010) was used to estimate the population abundance of Northern Pike in each of the study bays in Coeur d'Alene Lake by using closed-population capture–recapture models. Closed capture models include a single mixture, so only two parameters are used: the capture probability (p_i) and the recapture probability (c_i). We used this method to estimate population abundance with four models: M_0, M_b, M_t, and M_{tb}. Model M_0 was the null model, with constant detection probabilities. Model M_b assumed that p_i was equal to c_i. Model M_t also assumed that c_i and p_i were equal, but the values were allowed to vary through time. In model M_{tb}, p_i and c_i were modeled as constant offsets of one another. The four candidate models were compared in an information theoretic framework by using Akaike's information criterion corrected for small sample size (Burnham and Anderson 2002). The abundance of Northern Pike in each bay was aggregated to estimate the total population abundance. Total abundance of Northern Pike in each year-class was calculated by multiplying the estimated total population abundance by the percent age composition derived from an age–length key.

The total weight of Westslope Cutthroat Trout consumed seasonally by Northern Pike was estimated as follows: (population abundance of Northern Pike [2008–2011 year-classes]) × (the corresponding estimate of Westslope Cutthroat Trout biomass consumed by an individual Northern Pike). The estimated total number of Westslope Cutthroat Trout consumed by Northern Pike was derived from the Westslope Cutthroat Trout's (1) estimated total consumed biomass, (2) length–weight relationship, and (3) frequency of consumption.

RESULTS

Sampling was performed on 138 d, and 15,645 individual fish representing 24 species were captured. Electrofishing effort totaled 62.4 h, and 638 gill nets were fished for 1,166.0 h. In total, 58 Northern Pike were sampled with electrofishing and 678 were sampled with gillnetting. Although electrofishing catch rates varied greatly among season and among bays, Northern Pike catch rates were consistently higher in Benewah Lake than in the other bays (Figure 2). Northern Pike catch rates from gillnetting during the two spring sampling periods were twice as high as the catch rates observed during summer and fall. The data suggest that body condition (W_r) of Northern Pike decreased between summer and fall and increased the following spring (Figure 3). Additionally, Northern Pike in Windy Bay tended to be in better condition than those in the other bays across all seasons. Among the 736 Northern Pike captured, 573 were marked, 98 were recaptured, and 73 were mortalities. The recapture rate of Northern Pike was highest (38%) in Windy Bay, whereas the recapture rate in the other bays was roughly 9%.

Seasonal growth and food habits were analyzed from 695 Northern Pike (including recaptures) varying from 16.2 to 108.0 cm TL and from 24 to 9,628 g. Age of Northern Pike varied from 1 to 7 years; approximately 95% of individuals were ages 1–4. In general, the majority of growth occurred between fall and spring for most of the Northern Pike year-classes (Figure 4).

The proportion of empty stomachs varied among year-classes and seasons but was highest for most year-classes during spring 2012 (Figure 5; Appendix Table A.1). For Northern Pike belonging to the 2011 year-class, the diet was dominated by warmwater species (i.e., Yellow Perch, Bluegills *Lepomis macrochirus*, and Brown Bullheads). Salmonids became an important prey taxon for the 2011 year-class during the spring of 2013 and accounted for approximately 40% of the total energy consumed by that year-class. For older Northern Pike (2008–2010 year-classes), the diets were dominated by salmonids (i.e., kokanee and Westslope Cutthroat Trout). Throughout the year, kokanee represented the highest frequency of occurrence, percent by number, and energy contribution to the diet. Kokanee were consumed at the highest rate during summer, accounting for 87% of the total energy consumed. Northern Pike consumption of Westslope Cutthroat Trout was highly variable among seasons. During spring 2012, Westslope Cutthroat Trout occurred in approximately 25% of Northern Pike stomachs but contributed roughly 75% of the total energy consumed (Figure 5). During summer and fall,

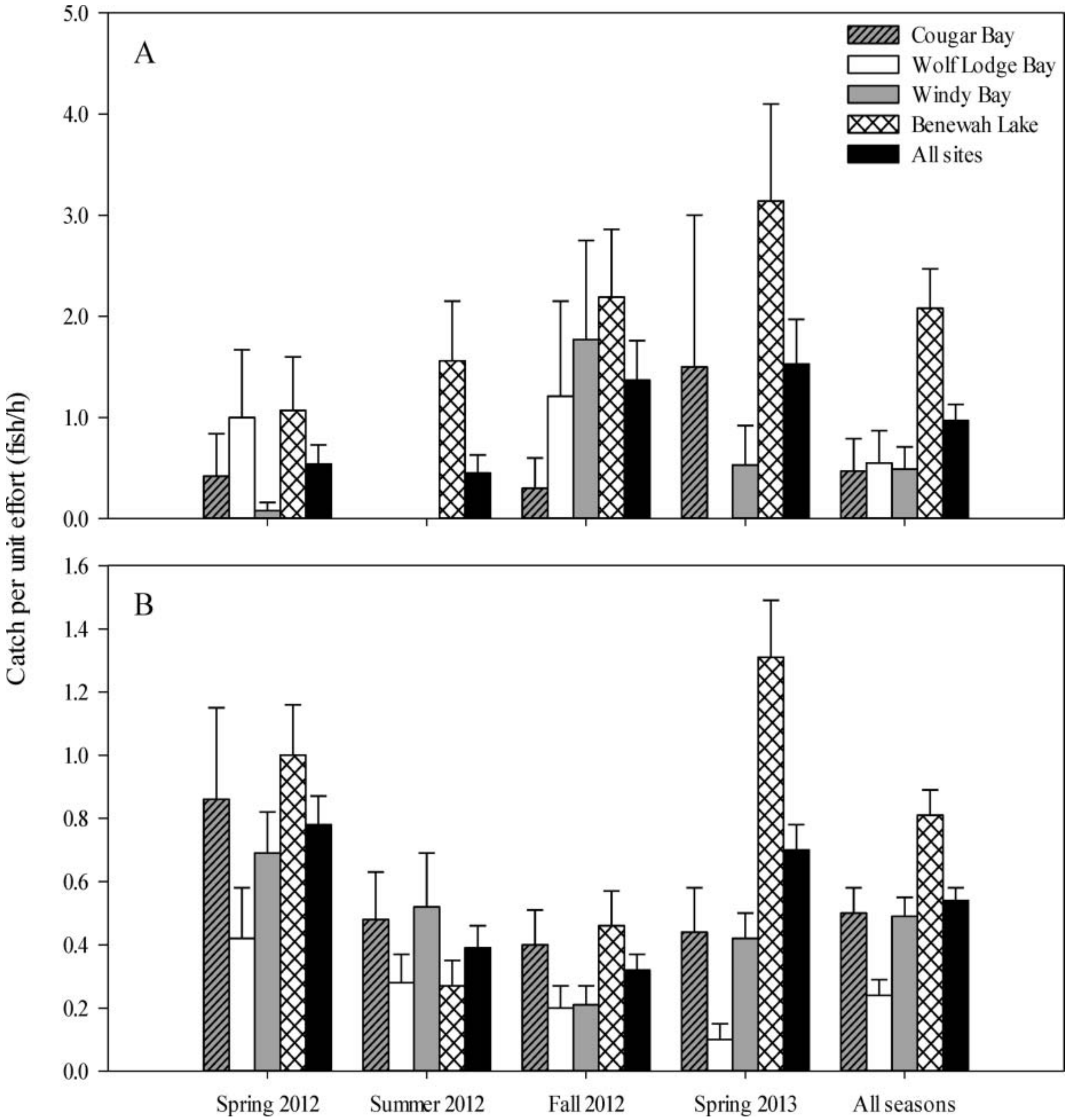

FIGURE 2. Mean (+SE) Northern Pike catch per unit effort (fish/h) with **(A)** electrofishing and **(B)** gillnetting by season in Coeur d'Alene Lake from March 2012 to May 2013. Months were grouped together based on water temperature: spring (March–May), summer (June–August), and fall (September–November).

percent occurrence and energy contribution of Westslope Cutthroat Trout in the diet decreased by about 50%. In spring 2013, the occurrence of Westslope Cutthroat Trout in Northern Pike diets increased again relative to summer and fall (Figure 5). The bioenergetics models estimated that Westslope Cutthroat Trout contributed approximately 2–30% of the biomass consumed by age-1–4 Northern Pike (Tables 1, 2). Seasonal P_c values for Northern Pike in Coeur d'Alene Lake were generally highest during spring and lowest during summer (Figure 6).

The estimate of Northern Pike abundance generated by the best candidate model was 3,268 fish (95% CI = 2,000–6,361) across the four study bays. For the Northern Pike year-classes used in the bioenergetics model (i.e., the 2008–2011 year-classes), abundance was estimated at 3,056 fish (95% CI = 1,793–5,947; Table 3). The TL of Westslope Cutthroat Trout consumed by Northern Pike varied from 8.7 to 43.7 cm and averaged 25.0 cm (Figure 7). The TLs of Westslope Cutthroat Trout consumed by Northern Pike were highly variable across seasons and generally increased with Northern Pike TL

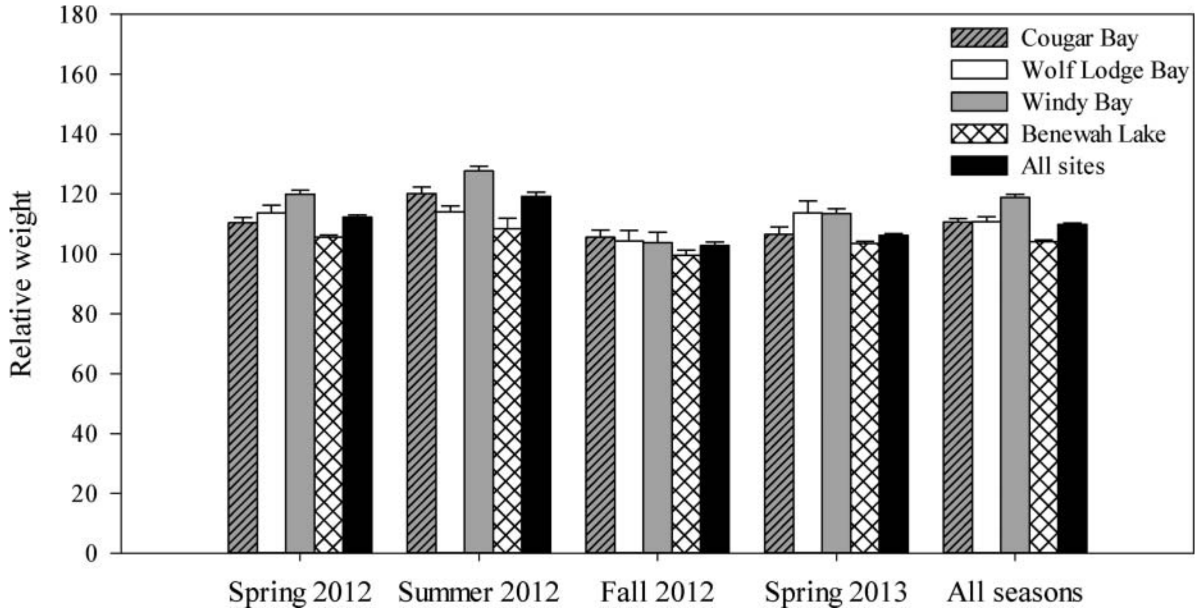

FIGURE 3. Mean (+SE) relative weights of Northern Pike captured in four bays of Coeur d'Alene Lake from March 2012 to May 2013. Means were calculated for each season as well as for each site across all seasons. Months were grouped together based on water temperature: spring (March–May), summer (June–August), and fall (September–November).

(Figure 8). The total Westslope Cutthroat Trout biomass consumed seasonally by Northern Pike (2008–2011 year-classes) in the four bays was estimated to be 1,231 kg (95% CI = 723–2,396 kg), and the total number of Westslope Cutthroat Trout consumed was estimated at approximately 5,641 fish (95% CI = 3,311–10,979).

DISCUSSION

Northern Pike have been introduced into many watersheds to create recreational fishing opportunities throughout North America, including Coeur d'Alene Lake. Unfortunately, many studies have found that Northern Pike can have detrimental effects on native fishes (Muhlfeld et al. 2008; Sepulveda et al. 2013). Therefore, an understanding of the effects of Northern Pike on native fishes is critical for developing management strategies to balance recreational sport fisheries with efforts to conserve native fishes, particularly species like the Westslope Cutthroat Trout.

The food habits of Northern Pike have been extensively studied throughout the species' distribution; although Northern Pike are generally piscivorous, they are highly opportunistic (Frost 1954; Soupir et al. 2000; Venturelli and Tonn 2006). For example, Soupir et al. (2000) reported that invertebrates were common in Northern Pike diets when the availability and abundance of fish were low in six lakes within Voyageurs National Park, Minnesota. Similarly, in three eutrophic lakes in northeast Alberta that lacked prey fishes, introduced Northern Pike consumed leeches and other invertebrates (Venturelli and Tonn 2006). Northern Pike in the current study consumed a diversity of food items, including invertebrates, fish, and salamanders. Invertebrates were consumed sporadically throughout the year but contributed little to the overall amount of energy consumed by Northern Pike in Coeur d'Alene Lake. Rather, kokanee had the greatest energy contribution to the diets in each season. Westslope Cutthroat Trout were consumed at the highest frequency during spring. Northern Pike also preyed on spiny-rayed fishes (e.g., Yellow Perch and Black Crappies) throughout the year, with the highest occurrence in fall 2012 and spring 2013, likely a result of prey availability. Eklöv and Harrin (1989) reported that Northern Pike preferred soft-rayed fishes and that Northern Pike switched to spiny-rayed fishes or cannibalism when preferred prey types were unavailable.

Ontogenetic changes in the diet are common for Northern Pike (Frost 1954; Miller and Kramer 1971). The only exception appears to be in systems with simple fish assemblages (Soupir et al. 2000). In Coeur d'Alene Lake, ontogenetic shifts in the food habits of Northern Pike were apparent, particularly between ages 1 and 2. For the 2011 year-class, diets primarily consisted of Yellow Perch less than 15.0 cm, Brown Bullheads, and centrarchids during fall 2012. In spring 2013, the diets of the 2011 year-class shifted toward large Yellow Perch (i.e., $\geq$15.0 cm) and salmonids. Although the data suggest that Northern Pike undergo an ontogenetic shift in feeding habits toward salmonids at a young age, factors such as prey availability, habitat, and gape size also likely play a role in the shift (Nilsson and Bronmark 2000).

Growth of Northern Pike in Coeur d'Alene Lake varied among year-classes and among seasons. Most year-classes

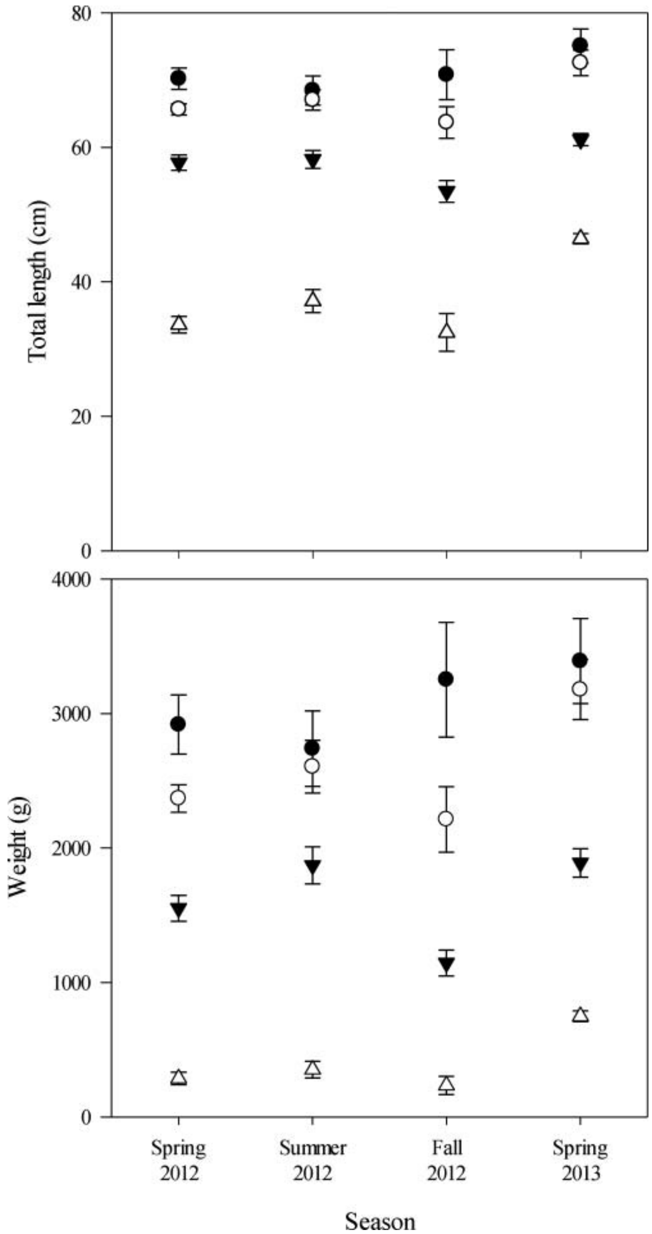

FIGURE 4. Mean (±SE) TLs and weights of Northern Pike from four year-classes (black shaded circles = 2008; open circles = 2009; black shaded triangles = 2010; open triangles = 2011) sampled in Coeur d'Alene Lake from March 2012 to May 2013. Months were grouped together based on water temperature: spring (March–May), summer (June–August), and fall (September–November).

increased in weight from spring to summer, but weight then decreased in the fall. Interestingly, about 50% of the annual growth in weight was achieved between fall and the beginning of the next spring. Headrick and Carline (1993) reported similar results, with Northern Pike losing weight from May to October and then gaining weight from October to March. Other coolwater species have also been observed to exhibit the majority of their growth in the fall. For example, Quist et al. (2002) reported that for Walleyes in Glen Elder Reservoir, Kansas, approximately 80% of length and weight was achieved between August and October.

Percentage of C_{max} reflects the intensity of predation and prey availability (Rice et al. 1983). Seasonal P_c values were consistently highest for the 2011 year-class of Northern Pike in Coeur d'Alene Lake, likely due to the increased metabolic demand in juveniles (Bean 2010). We also observed a seasonal pattern in which estimates of P_c were generally highest during spring for all cohorts. The high estimates of P_c for spring likely reflect the availability of salmonids as prey and the post-spawn feeding intensity of Northern Pike. Low P_c values for Northern Pike in the summer and fall are probably attributable to a decrease in prey availability and the lower metabolic rates achieved by Northern Pike as they move to cooler water during those seasons (Bevelhimer et al. 1985).

As concerns over nonnative species increase, many such species have been the focus of removal or suppression efforts (Mueller 2005; Spens and Ball 2008; Kolar et al. 2010). However, a high density of other nonnative species may actually assist in the recovery of native fish populations. When a predator's preferred prey is depleted, predators often switch to another prey type, thereby allowing the preferred prey type to recover (Sinclair et al. 2006). The current study suggests that some nonnative species may act as a predation buffer for Westslope Cutthroat Trout throughout much of the year. Specifically, kokanee and Yellow Perch (nonnative species) each accounted for 30% of the total annual biomass consumed by Northern Pike. The occurrence of a predation buffer has also been reported for other aquatic systems. Stapanian and Madenjian (2007) determined that when Sea Lampreys *Petromyzon marinus* began preying on Lake Trout in Lake Erie, Burbot *Lota lota* increased in abundance.

Nonnative prey species may create a predation buffer for Westslope Cutthroat Trout, but numerous studies in the Pacific Northwest have shown that Northern Pike consume large quantities of Westslope Cutthroat Trout when present. For example, Muhlfeld et al. (2008) estimated that Northern Pike in the upper Flathead River system, Montana, consumed approximately 13,000 Westslope Cutthroat Trout annually. Similarly, Rich (1992) reported that Westslope Cutthroat Trout contributed about 45% of the prey weight consumed by Northern Pike in Killarney Lake, Idaho. More importantly, the ability of Northern Pike to consume large quantities of Westslope Cutthroat Trout suggests that high densities of Westslope Cutthroat Trout may not be feasible in a system that contains Northern Pike. An exception was provided by Sepulveda et al. (2013), who reported that salmonid escapement objectives were met in Wood River Lake, Alaska, despite a high level of predation by Northern Pike. Sepulveda et al. (2013) hypothesized that salmonid and Northern Pike habitats were spatially segregated.

Northern Pike predation on Westslope Cutthroat Trout in Coeur d'Alene Lake decreased in the summer and fall,

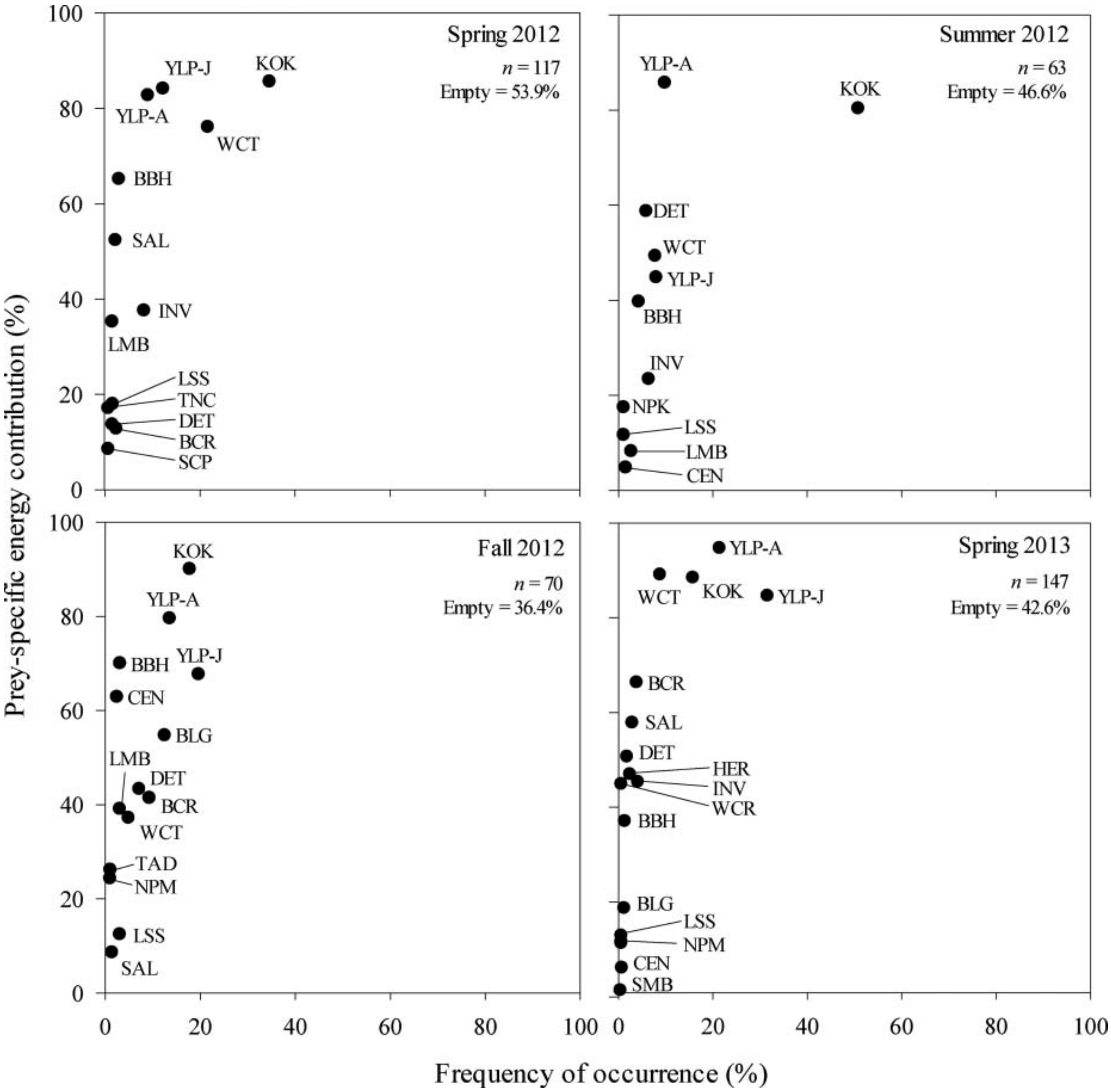

FIGURE 5. Frequency of occurrence and prey-specific energy contribution of prey types in the diets of Northern Pike sampled from Coeur d'Alene Lake during spring, summer, and fall 2012 and spring 2013. The seasonal frequency of empty stomachs and the sample size (*n*; the number of Northern Pike stomachs with diet contents) are also provided (INV = invertebrates; LSS = Largescale Sucker; BCR = Black Crappie; BLG = Bluegill; LMB = Largemouth Bass; WCR = White Crappie; CEN = Centrarchidae; HER = Pacific Herring; SCP = sculpin; NPM = Northern Pikeminnow; TNC = Tench; NPK = Northern Pike; BBH = Brown Bullhead; YLP-A = Yellow Perch ≥ 15.0 cm; YLP-J = Yellow Perch < 15.0 cm; KOK = kokanee; WCT = Westslope Cutthroat Trout; SAL = Salmonidae; DET = detritus; TAD = tadpole; SMB = Smallmouth Bass).

suggesting habitat segregation during those periods. Habitat segregation between salmonids and Northern Pike is possible because salmonids typically spend minimal time in the shallow, vegetated areas commonly occupied by Northern Pike (D'Angelo and Muhlfeld 2013). Unfortunately, the increased occurrence of Westslope Cutthroat Trout in Northern Pike diets during spring may negate any benefits obtained from habitat segregation during other time periods. Although the period of spatial overlap appears to be relatively short (i.e., April and May) based on Northern Pike diets, previous research has shown that Northern Pike can consume large quantities of prey over a short time period. In a study of the Danish River, Denmark, Jepsen et al. (1998) found that Northern Pike predation over a 3-week period was responsible for 56% of Atlantic Salmon *Salmo salar* smolt mortalities. In Coeur d'Alene Lake, approximately 80% of the predation on Westslope Cutthroat Trout in 2012 occurred during spring. However, the potential effects of Northern Pike predation on Westslope Cutthroat Trout varied depending on the study location. Although only 29% of the Northern Pike were captured in

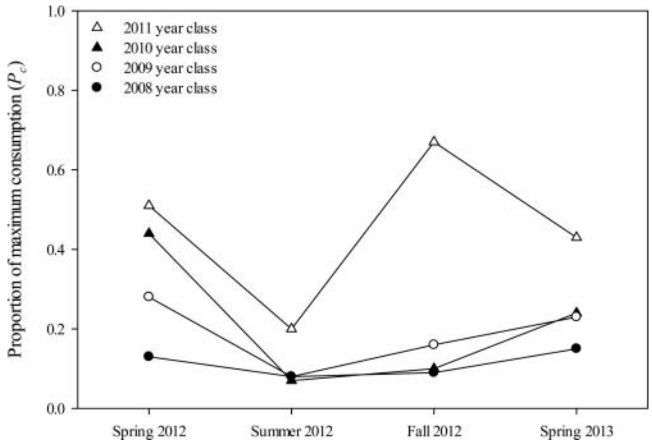

FIGURE 6. Proportion of maximum consumption (P_c) from the bioenergetics model used to estimate consumption and growth of four year-classes of Northern Pike in Coeur d'Alene Lake from March 2012 to May 2013. Months were grouped together based on water temperature: spring (March–May), summer (June–August), and fall (September–November).

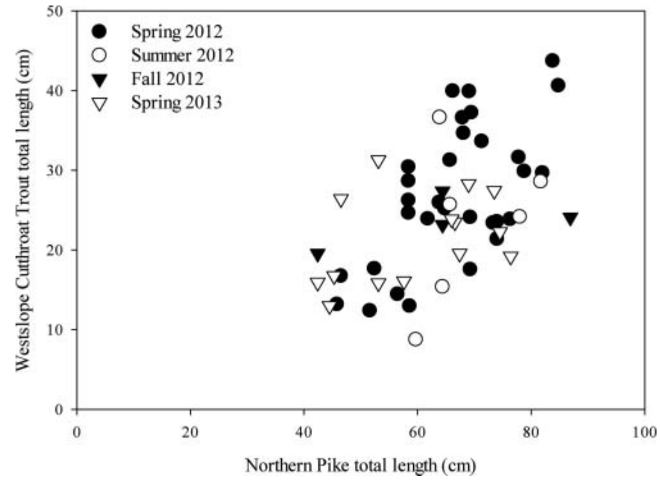

FIGURE 8. Relationship between Northern Pike TL (cm) and the TLs of Westslope Cutthroat Trout consumed seasonally in Coeur d'Alene Lake from March 15, 2012, to May 31, 2013.

Windy Bay, those fish accounted for 75% of the Westslope Cutthroat Trout that were consumed. Based on our estimates of abundance and consumption, Northern Pike consumed approximately 335 adult Westslope Cutthroat Trout (≥30.0 cm) in Windy Bay during spring 2012. In Lake Creek, the tributary that enters Windy Bay, the estimated abundance of spawning adult Westslope Cutthroat Trout was 410 fish (SE = 85; Firehammer et al. 2012). Similar estimates are not available for 2013 or for tributaries of the other bays. Estimates of Westslope Cutthroat Trout consumption by Northern Pike are also conservative since no sampling occurred during winter. Nevertheless, the observed predation by Northern Pike is of concern and may explain the low juvenile-to-adult return rates of Westslope Cutthroat Trout (Firehammer et al. 2012). Fortunately, intense seasonal predation on Westslope Cutthroat Trout might be alleviated by reducing Northern Pike densities near the tributaries used by spawning Westslope Cutthroat Trout.

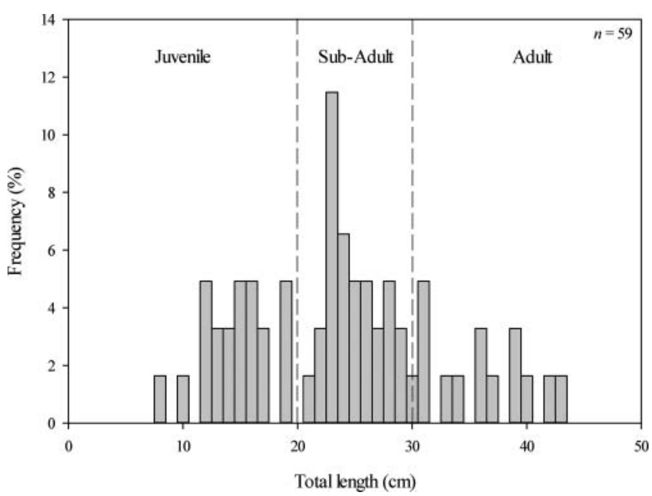

FIGURE 7. Length frequency histogram of adfluvial Westslope Cutthroat Trout consumed by Northern Pike in Coeur d'Alene Lake from March 2012 to May 2013. Dashed lines delineate the TL (cm) classes corresponding to juvenile, subadult, and adult Westslope Cutthroat Trout.

Various mechanical removal methods have been used or recommended to reduce densities of nonnative predators (Broughton and Fisher 1981; Mann 1985; Kulp and Moore 2000; Mueller 2005). Suppressing a nonnative predator such as Northern Pike may be important for conserving salmonids and other native fish species. However, desired effects from suppression efforts are usually diminished because the remaining individuals of the target species typically display compensatory increases in recruitment, survival, and growth (Kolar et al. 2010). Additionally, the amount of resources needed to reduce piscivore biomass in larger systems is generally prohibitive (Goeman et al. 1993). In some systems, complete eradication of nonnative piscivores is required for achieving viability of salmonid populations (Spens and Ball 2008); however, eradication of Northern Pike from large systems has been unsuccessful (Aguilar et al. 2005). Additionally, the Northern Pike is an important sport fish in Coeur d'Alene Lake, and anglers are likely to show substantial opposition to a removal plan. Future research should focus on management strategies (i.e., harvest regulations) that might be used in Coeur d'Alene Lake to reduce Northern Pike densities at small spatial and/or temporal scales.

Results of the present study have important implications for the management of Northern Pike and the conservation of Westslope Cutthroat Trout. The primary limitation of our study was the inability to estimate the lakewide abundance of Westslope Cutthroat Trout. Unfortunately, given the size of the lake and its major tributaries, attempts to estimate absolute abundance of Westslope Cutthroat Trout are unlikely.

Nevertheless, we determined that Northern Pike consumption of Westslope Cutthroat Trout varies across seasons and that Westslope Cutthroat Trout could account for up to 30% of the total biomass consumed by Northern Pike. High spatial and temporal overlap between these two species during spring resulted in relatively large quantities of Westslope Cutthroat Trout being consumed in some areas. Thus, the Coeur d'Alene Tribe's management objective—to restore Westslope Cutthroat Trout to a level that allows for subsistence harvest, maintains genetic diversity, and increases the probability of persistence despite anthropogenic influences—might be achieved if predation by Northern Pike near tributaries used by adfluvial Westslope Cutthroat Trout can be reduced during the spring.

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Appendix: Taxonomic Composition and Energy Contribution of Prey Consumed by Northern Pike in Coeur d'Alene Lake

TABLE A.1. Frequency of occurrence (%*O*), percent by number (%*N*), and percent energy contribution (%EC) of prey types consumed by Northern Pike from four year-classes (YC) in Coeur d'Alene Lake, Idaho, March 2012–May 2013. Sample size (*n*) and the percentage of empty stomachs are presented for each YC and season.

	2011 YC			2010 YC			2009 YC			2008 YC		
Variable or taxon	%*O*	%*N*	%EC	%*O*	%*N*	%EC	%*O*	%*N*	%EC	%*O*	%*N*	%EC
Spring 2012												
Sample size	17			54			129			36		
Empty	64			44			57			44		
Invertebrates												
Annelida	17	29	[a]	0	0	0	6	3	[a]	8	5	[a]
Coleoptera	0	0	0	6	10	[a]	0	0	0	0	0	0
Decapoda	0	0	0	0	0	0	0	0	0	0	0	0
Hymenoptera	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0	0	0	0	0	0	0
Odonata	0	0	0	3	4	[a]	2	1	[a]	0	0	0
Fish												
Catostomidae												
Largescale Sucker	17	14	76	3	1	[a]	0	0	0	0	0	0
Centrarchidae												
Black Crappie	17	14	3	0	0	0	0	0	0	4	3	[a]
Bluegill	0	0	0	0	0	0	0	0	0	0	0	0
Largemouth Bass	0	0	0	0	0	0	3	2	1	0	0	0
Unknown species	0	0	0	0	0	0	0	0	0	0	0	0
White Crappie	0	0	0	0	0	0	0	0	0	0	0	0
Clupeidae												
Pacific Herring	0	0	0	0	0	0	0	0	0	0	0	0
Cottidae												
Sculpin	0	0	0	0	0	0	0	0	0	4	3	[a]
Cyprinidae												
Northern Pikeminnow	0	0	0	0	0	0	0	0	0	0	0	0
Tench	0	0	0	0	0	0	0	0	0	4	3	20
Esocidae												
Northern Pike	0	0	0	0	0	0	0	0	0	4	3	2
Ictaluridae												
Brown Bullhead	0	0	0	3	1	[a]	3	2	1	4	3	[a]
Percidae												
Yellow Perch < 150 mm	33	29	21	6	2	[a]	15	12	1	8	5	0
Yellow Perch ≥ 150 mm	0	0	0	11	3	5	6	4	2	8	13	3
Salmonidae												
Kokanee	0	0	0	51	71	68	35	61	54	28	45	36
Unknown species	0	0	0	0	0	0	3	2	9	4	3	3
Westslope Cutthroat Trout	0	0	0	17	7	26	26	14	31	20	13	36
Other												
Idaho giant salamander	0	0	0	0	0	0	0	0	0	0	0	0
Detritus	17	14	[a]	0	0	0	0	0	0	4	3	[a]
Summer 2012												
Sample size	9			47			37			15		
Empty	44			53			46			33		

(Continued on next page)

TABLE A.1. Continued.

Variable or taxon	2011 YC %O	2011 YC %N	2011 YC %EC	2010 YC %O	2010 YC %N	2010 YC %EC	2009 YC %O	2009 YC %N	2009 YC %EC	2008 YC %O	2008 YC %N	2008 YC %EC
Invertebrates												
Annelida	0	0	0	3	1	[a]	0	0	0	0	0	0
Coleoptera	0	0	0	3	72	[a]	0	0	0	0	0	0
Decapoda	0	0	0	0	0	0	4	3	[a]	0	0	0
Hymenoptera	0	0	0	0	0	0	0	0	0	10	27	[a]
Isopoda	0	0	0	0	0	0	0	0	0	0	0	0
Odonata	0	0	0	3	2	0	0	0	0	0	0	0
Fish												
Catostomidae												
Largescale Sucker	0	0	0	3	1	3	0	0	0	0	0	0
Centrarchidae												
Black Crappie	0	0	0	0	0	0	0	0	0	0	0	0
Bluegill	0	0	0	0	0	0	0	0	0	0	0	0
Largemouth Bass	20	20	11	3	1	[a]	0	0	0	0	0	0
Unknown species	0	0	0	0	0	0	0	0	0	0	0	0
White Crappie	0	0	0	0	0	0	0	0	0	0	0	0
Clupeidae												
Pacific Herring	0	0	0	0	0	0	0	0	0	0	0	0
Cottidae												
Sculpin	0	0	0	0	0	0	0	0	0	0	0	0
Cyprinidae												
Northern Pikeminnow	0	0	0	0	0	0	0	0	0	0	0	0
Tench	0	0	0	0	0	0	0	0	0	0	0	0
Esocidae												
Northern Pike	0	0	0	3	1	[a]	0	0	0	0	0	0
Ictaluridae												
Brown Bullhead	20	20	57	0	0	0	9	7	1	0	0	0
Percidae												
Yellow Perch < 150 mm	20	20	31	10	2	[a]	4	3	[a]	0	0	0
Yellow Perch ≥ 150 mm	0	0	0	7	1	2	9	7	2	20	13	4
Salmonidae												
Kokanee	0	0	0	50	17	80	65	72	93	50	47	90
Unknown species	0	0	0	0	0	0	0	0	0	0	0	0
Westslope Cutthroat Trout	0	0	0	10	2	14	9	7	3	10	7	6
Other												
Idaho giant salamander	0	0	0	0	0	0	0	0	0	0	0	0
Detritus	40	40	[a]	3	1	[a]	0	0	0	10	7	[a]
Fall 2012												
Sample size	8			41			34			19		
Empty	50			22			50			37		
Invertebrates												
Annelida	0	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0	0	0	0	0	0	0
Decapoda	0	0	0	0	0	0	0	0	0	0	0	0
Hymenoptera	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0	0	0	0	0	0	0
Odonata	0	0	0	0	0	0	0	0	0	0	0	0

(Continued on next page)

TABLE A.1. Continued.

Variable or taxon	2011 YC			2010 YC			2009 YC			2008 YC		
	%O	%N	%EC	%O	%N	%EC	%O	%N	%EC	%O	%N	%EC
Fish												
Catostomidae												
Largescale Sucker	0	0	0	2	1	2	8	7	7	0	0	0
Centrarchidae												
Black Crappie	0	0	0	16	19	2	8	7	[a]	0	0	0
Bluegill	60	67	63	9	28	1	13	25	0	0	0	0
Largemouth Bass	0	0	0	2	1	1	8	7	[a]	0	0	0
Unknown species	0	0	0	2	1	[a]	0	0	0	8	8	1
White Crappie	0	0	0	0	0	0	0	0	0	0	0	0
Clupeidae												
Pacific Herring	0	0	0	0	0	0	0	0	0	0	0	0
Cottidae												
Sculpin	0	0	0	0	0	0	0	0	0	0	0	0
Cyprinidae												
Northern Pikeminnow	0	0	0	0	0	0	4	4	8	0	0	0
Tench	0	0	0	0	0	0	0	0	0	0	0	0
Esocidae												
Northern Pike	0	0	0	0	0	0	0	0	0	0	0	0
Ictaluridae												
Brown Bullhead	0	0	0	5	3	3	4	4	1	0	0	0
Percidae												
Yellow Perch < 150 mm	40	33	37	28	25	10	8	7	1	8	8	[a]
Yellow Perch ≥ 150 mm	0	0	0	14	8	33	13	11	10	25	23	7
Salmonidae												
Kokanee	0	0	0	9	6	48	21	18	63	33	38	82
Unknown species	0	0	0	0	0	0	0	0	0	8	8	5
Westslope Cutthroat Trout	0	0	0	0	0	0	8	7	10	17	15	5
Other												
Idaho giant salamander	0	0	0	0	0	0	0	0	0	0	0	0
Detritus	0	0	0	12	7	[a]	4	4	[a]	0	0	0
Spring 2013												
Sample size	112			93			28			16		
Empty	41			46			32			44		
Invertebrates												
Annelida	3	2	[a]	2	1	[a]	5	8	[a]	0	0	0
Coleoptera	0	0	0	0	0	0	0	0	0	0	0	0
Decapoda	0	0	0	0	0	0	0	0	0	0	0	0
Hymenoptera	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda	3	5	[a]	0	0	0	0	0	0	0	0	0
Odonata	0	0	0	0	0	0	0	0	0	0	0	0
Fish												
Catostomidae												
Largescale Sucker	0	0	0	0	0	0	5	2	15	0	0	0
Centrarchidae												
Black Crappie	4	3	[a]	4	4	1	0	0	0	13	8	14
Bluegill	3	4	[a]	0	0	0	0	0	0	0	0	0
Largemouth Bass	0	0	0	0	0	0	0	0	0	0	0	0
Unknown species	0	0	0	0	0	0	0	0	0	13	8	[a]
White Crappie	1	3	[a]	0	0	0	0	0	0	0	0	0

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TABLE A.1. Continued.

Variable or taxon	2011 YC			2010 YC			2009 YC			2008 YC		
	%*O*	%*N*	%EC	%*O*	%*N*	%EC	%*O*	%*N*	%EC	%*O*	%*N*	%EC
Clupeidae												
Pacific Herring	0	0	0	2	4	1	14	27	3	0	0	0
Cottidae												
Sculpin	0	0	0	0	0	0	0	0	0	0	0	0
Cyprinidae												
Northern Pikeminnow	0	0	0	0	0	0	5	19	1	0	0	0
Tench	0	0	0	0	0	0	5	2	3	0	0	0
Esocidae												
Northern Pike	0	0	0	0	0	0	0	0	0	0	0	0
Ictaluridae												
Brown Bullhead	0	0	0	2	1	[a]	0	0	0	13	8	5
Percidae												
Yellow Perch < 150 mm	41	42	8	31	30	2	19	8	1	0	0	0
Yellow Perch ≥ 150 mm	23	16	51	20	19	13	14	10	6	25	15	10
Salmonidae												
Kokanee	12	19	24	19	23	73	19	17	68	25	46	65
Unknown species	1	1	1	6	4	3	0	0	0	0	0	0
Westslope Cutthroat Trout	5	5	15	11	9	6	14	6	4	13	15	6
Other												
Idaho giant salamander	0	0	0	2	2	[a]	0	0	0	0	0	0
Detritus	3	2	[a]	2	2	[a]	0	0	0	0	0	0

[a]Frequency < 1%.

APPENDIX E – PROJECT DESCRIPTIONS

Table E-1. Descriptive list of projects for the Benewah Creek watershed. Highlighted projects have been completed to date, while other projects are proposed. Project numbers are cross-referenced to the locations found in Figure 16.

Project number	Project title	Project description	Process Impairment	Priority Score	Project type [1]	Ownership type [2]	Project metrics [3]
1	WF Benewah Creek LWD/Riparian Assessment	Inventory and assess stream and riparian condition related to wood recruitment potential, rkm 1.6-3.2	High	97	R	I	1600
2	WF Benewah Creek culvert replacement	Improve fish passage on WF Benewah Creek at adult fish barrier, 3799_110	High	87	P	I	3390
3	Whitetail Creek culvert replacement	Improve fish passage on Whitetail Creek at adult fish barriers, 3200_9184 and 3200_9205	Moderate	87	P	I	4740
4	Schoolhouse Creek Culvert Replacement	Replace fish barrier on Schoolhouse Creek	High	87	P	I	837
5	School House Creek LWD addition and riparian planting	Add LWD, rkm 0.3-0.7, to address 300m of non-forested channel w/ 150 yr wood loading deficits	High	84	C	P	300
6	SF Benewah Creek culvert replacement	Improve fish passage on SF Beneawh Creek at adult fish barrier, 3100_5662	High	84	P	C	6118
7	WF Benewah Creek culvert replacement	Replace WF Benewah Creek Culvert	High	84	P	C	6871
8	Windfall Creek LWD addition	Add LWD and stabilize channel, rkm 0.0-1.2, to address 650m of channel instability and 750m of channel w/ 150 yr wood loading deficits	High	83	C	T	1400
9	Windfall Creek riparian planting	Riparian planting, rkm 0.0-0.9	Moderate	83	R	T	900
10	School House Creek riparian management prescriptions	Develop silvicultural prescription, rkm 0.7-2.2, for increasing growth and recruitment	High	82	R	I	1500
11	WF Hart Creek culvert replacement	Improve fish passage on WF Hart Creek at adult fish barrier, 3143_6535	High	82	P	I	781
12	Whitetail Creek riparian management prescriptions	Develop silvicultural prescription, rkm 1.7-2.6, for increasing growth and recruitment	Moderate	82	R	I	900
13	EF Hodgson Creek LWD addition	Add LWD, rkm 0.0-0.8, to address 580m of channel w/ 50 yr wood loading deficits	High	81	C	P	580
14	SF Windfall Creek culvert replacement	Improve fish passage on SF Windfall Creek at fish barrier, 3158_235	Moderate	80	P	I	1352
15	Hodgson Creek Culvert Replacement	Improve fish passage on Hodgson Creek at adult fish barrier, road 3724_945.	Low	79	P	I	930
16	SF Benewah Creek riparian planting	Riparian planting, rkm 0.8-1.5	Moderate	79	R	P	700
17	SF Windfall Creek culvert replacement	Improve fish passage on SF Windfall Creek at fish barrier, 3155_3045	Moderate	79	P	I	853
18	Improve road drainage and reduce sediment delivery	Install cross drains on road 3700.	Low	78	H	C	104
19	Whitetail Creek LWD addition	Add LWD, rkm 1.7-2.6, to address 342m of channel w/ 50 yr wood loading deficits	High	78	C	I	342
20	School House Creek LWD addition	Add LWD, rkm 0.0-0.3, to address 225m of channel w/ 150 yr wood loading deficits	High	76	C	I	225

Project number	Project title	Project description	Process Impairment	Priority Score	Project type [1]	Ownership type [2]	Project metrics [3]
21	SF Benewah Creek LWD addition	Add LWD, rkm 0.5-1.4, to address 670m of channel w/ 150 yr wood loading deficits	High	76	C	P	670
22	SF Benewah Creek riparian management prescriptions	Develop silvicultural prescription, rkm 1.5-3.2, for increasing growth and recruitment	High	76	R	P	1700
23	Windfall Creek riparian management prescriptions	Develop silvicultural prescription, rkm 1.2-2.6, for increasing growth and recruitment	High	76	R	P	1400
24	Windfall Creek culvert replacement	Improve fish passage on Windfall Creek at fish barrier, road 3169_110	Moderate	76	P	P	1057
25	SF of WF Benewah Creek LWD addition	Add LWD in SF of WF Benewah Creek, rkm 0.3-1.6, to address possible wood needs	High	76	C	P	1647
26	Hart Creek culvert replacement	Improve fish passage on Hart Creek at juvenile fish barrier, 3143_6080	High	75	P	I	643
27	Hodgson Creek LWD addition	Add LWD, rkm 0.2-1.2, to address 350m of channel w/ 50 yr wood loading deficits	High	74	C	P	350
28	Improve road drainage and reduce sediment delivery	Install cross drains and resurface 833m of roads 3100, 3101, 3102	High	73	HS	I	1320
29	Reduce sediment delivery	Resurface 367m of roads 3205, 3204, and 3203	Low	73	S	I	367
30	Improve road drainage and reduce sediment delivery	Install 7 cross drains on road 3700 (Benewah Road) near Lolo Pass.	High	73	H	C	3057
31	Reduce sediment delivery	Replace stream crossing at 3701_3090.	Moderate	72	S	P	20
32	WF Benewah Creek LWD addition	Add LWD, rkm 1.0-1.6, to address 300m of channel w/ 50 yr wood loading deficits	High	72	C	I	300
33	Improve road drainage and reduce sediment delivery	Replace stream crossing at 3142_460 and 3145_680, install cross drains and resurface 798m of roads 3140, 3142 and 3143	High	72	HS	I	1219
34	Whitetail Creek LWD addition	Add LWD, rkm 2.6-3.0, to address 226m of channel w/ 50 yr wood loading deficits	High	72	C	I	226
35	Whitetail Creek riparian planting	Riparian planting, rkm 0.5-1.1	Moderate	72	R	P	600
36	Hodgson Creek LWD addition	Add LWD, rkm 1.2-2.1, to address 256m of channel w/ 50 yr wood loading deficits	High	71	C	P	256
37	SF Benewah Creek LWD addition	Add LWD, rkm 0-0.5, to address 340m of channel w/ 150 yr wood loading deficits	High	71	C	P	340
38	Improve road drainage and reduce sediment delivery	Replace culverts (4 non-fish bearing), install cross-drains, and resurface 1072m of road, 3103_0-1950 and 3118_0-1570	High	71	HS	P	1659
39	Whitetail Creek LWD addition	Add LWD, rkm 0.5-1.1, to address 270m of channel w/ 50 yr wood loading deficits	High	71	C	P	270
40	Whitetail Creek riparian management prescriptions	Develop silvicultural prescription, rkm 2.6-3.0, for increasing growth and recruitment	Moderate	71	R	I	400
41	Improve road drainage and reduce sediment delivery	Install cross drain and resurface up to 390m of road 3155	High	70	HS	I	450
42	Improve road drainage and reduce sediment delivery	Replace ford crossings with culverts at 3156_600 and 3156_783, and resurface 681m of roads 3151 and 3156	Moderate	69	S	I	741
43	Hodgson Creek LWD addition	Add LWD, rkm 2.1-2.7, to address 100m of channel w/ 50 yr wood loading deficits	High	68	C	P	100
44	IDL Creek LWD addition	Add LWD, rkm 1.0-1.9, to address 400m of channel w/ 150 yr wood loading deficits	High	68	C	I	400
45	Improve road drainage on Fletcher Rd.	Install cross drains on 304m of road, 3100_1950-2950	High	68	H	C	304

Project number	Project title	Project description	Process Impairment	Priority Score	Project type [1]	Ownership type [2]	Project metrics [3]
46	Improve road drainage and reduce sediment delivery	Replace stream crossing 3178_23156, install cross drains and resurface 905m of roads 3178 and 3185	High	68	HS	P	1111
47	Reduce sediment delivery	Resurface 274m of road 3702	Low	67	S	P	274
48	Improve road drainage and reduce sediment delivery	Replace stream crossing at 3003_7480	Low	67	S	S	20
49	Improve road drainage and reduce sediment delivery	Install cross drainson road 3530 and 3532, resurface 76m of road 3532 and replace stream crossing at 3503_4430	Moderate	67	HS	I	324
50	Improve road drainage and reduce sediment delivery	Install cross drains and resurface 481m of road 3105	High	67	HS	I	366
51	WF Benewah Creek LWD addition	Add LWD, rkm 0.0-0.5, to address 100m of channel w/ 150 yr wood loading deficits	High	67	C	P	100
52	Improve road drainage and reduce sediment delivery	Install cross drains and resurface 246m of roads 3203 and 3205	Moderate	67	HS	I	367
53	Windfall Creek LWD addition	Add LWD, rkm 1.2-2.6, to address 460m of channel w/ 50 yr wood loading deficits	High	66	C	P	460
54	Reduce sediment delivery	Resurface 152m of road 3711	Low	65	S	I	152
55	SF Benewah Creek LWD addition	Add LWD, rkm 1.4-3.2, to address 850m of channel w/ 50 yr wood loading deficits	High	65	C	P	850
56	WF Benewah Creek LWD addition	Add LWD, rkm 0.5-1.0, to address 320m of channel w/ 150 yr wood loading deficits	High	65	C	P	320
57	Improve road drainage and reduce sediment delivery	Replace stream crossing 3175_300 and resurface 180m of road 3175	Moderate	65	S	I	240
58	Improve road drainage and reduce sediment delivery	Resurface 182m of roads 3511, 3512 and 3543, install cross-drains on road 3530	Moderate	64	HS	I	285
59	Improve road drainage and reduce sediment delivery	Install cross drains and resurface 231m of road 3126 and 3127	High	64	HS	M	474
60	Improve road drainage and reduce sediment delivery	Install cross drains and resurface 807m of road 3160	High	64	HS	S	1614
61	Reduce sediment delivery	Replace undersize culvert, install cross-drains and resurface 59m of road 3203_990	Moderate	63	HS	I	118
62	Improve road drainage and reduce sediment delivery	Replace stream crossings at 3160_10550 and 3169_745, add cross drains and resurface 715 ft of road 3160, 450 ft of road 3169 and an additional 845 ft of road 3169	High	63	HS	P	1427
63	Improve road drainage and reduce sediment delivery	Install cross drains on road 3521	Moderate	61	H	I	205
64	Reduce road sediment delivery	Replace ford crossing with a culvert on unnamed tributary, 3150_2800	High	61	S	I	60
65	Reduce sediment delivery	Resurface 102m of road 3200	Low	58	S	I	102

[1] Project Type: C=channel; H=hydrology; P=passage; R=riparian; S=sediment

[2] Ownership Type: C=county; I=industrial; P=private; S=state

[3] Project metrics are specific to project type and are summarized as follows: P= length (m) of low gradient habitat (<10%) available upstream of barrier; R= length (m) of stream channel treated; C= length (m) of channel treated; H= length (m) of treated road directly delivering sediment; S= length (m) of treated road

Table E- 2. Descriptive list of projects for the Lake Creek watershed. Highlighted projects have been completed to date, while other projects are proposed. Project numbers are cross-referenced to the locations found in Figure 17.

Project number	Project title	Project description	Process impairment	Priority score	Project type [1]	Ownership type [2]	Project metrics [3]
1	Bozard Creek riparian planting and LWD addition	Riparian planting and LWD addition, rkm 1.4-3.5, to address 1463m of channel w/ 150 yr wood deficits	High	87	RC	P	732
2	Bozard Creek riparian management prescriptions and LWD addition	Develop silvicultural prescription and add LWD, rkm 3.5-6.1, to address 1792m of channel w/50-150 yr wood deficits	High	87	RC	I	896
3	Upper Lake Creek riparian planting and LWD addition	Riparian planting and LWD addition, rkm 1.8-3.9, to address 1464m of channel w/ 150 yr wood loading deficits	High	87	RC	P	732
4	Bozard Creek riparian planting and LWD addition	Riparian planting and LWD addition, rkm 0.0-1.4, to address 994m of channel w/ 150 yr wood deficits	High	86	RC	P	497
5	WF Lake Creek riparian management and LWD addition	Riparian management and LWD addition, rkm 0.9-2.3, to address 667m of channel w/ 150 yr wood loading deficits	High	86	RC	S	334
6	EF Bozard Creek riparian management prescriptions and LWD addition	Develop silivicultural prescription and add LWD, rkm 0.1-1.0, to address 932m of channel w/50-150 yr wood deficits	High	84	RC	P	466
7	Bozard Creek culvert replacement	Improve fish passage on Bozard Creek at adult fish barrier, 4510_7430	Moderate	83	P	I	3855
8	Lake Creek culvert replacement	Improve fish passage on Lake Creek at adult fish barrier, MSL_235	High	83	P	P	3381
9	Upper Lake Creek riparian planting and LWD addition	Riparian planting and LWD addition, rkm 0.6-0.8, to address 214m of channel w/ 150 yr wood loading deficits	High	76	RC	P	107
10	EF Bozard Creek culvert replacement	Improve fish passage on EF Bozard Creek at fish barrier, road 4505_5105	Moderate	75	P	I	593
11	Lake Creek culvert replacement	Improve fish passage on Lake Creek at adult fish barrier, road 4515_14800	High	75	P	P	1482
12	WF Lake Creek LWD addition	Add LWD, rkm 0.0-0.5, to address 345m of channel w/ 150 yr wood loading deficits	High	75	C	P	345
13	Upper Lake Creek riparian planting and LWD addition	Riparian planting and LWD addition, rkm 0.8-1.0, to address 182m of channel w/ 150 yr wood loading deficits	High	73	RC	P	91
14	Improve drainage and reduce sediment delivery	Install cross drains on road 4514	Moderate	72	H	C	132
15	Improve road drainage and reduce sediment delivery	Install cross drains on road 4514	Low	72	H	C	157
16	Olsen Creek culvert replacement	Improve fish passage on Olsen Creek at fish barrier, 4600_2090	Low	69	P	C	1480
17	Improve road drainage and reduce sediment delivery	Add cross-drains and resurface 609m of road 4600	Moderate	68	HS	P	850
18	Improve road drainage and reduce sediment delivery	Replace stream crossing at 4000_12615, install cross drains on road 4001, and resurface 457m of roads 4000, 4001, and 4003	Low	67	HS	I	533
19	WF Lake Creek LWD addition	Add LWD, rkm 2.3-3.9, to address 1136m of channel w/ 50 yr wood loading deficits	High	67	C	P	1136
20	WF of Upper Lake Creek culvert replacement	Improve fish passage on WF of Upper Lake Creek at fish barrier, road 4515_10360	High	66	P	P	1529
21	Upper Lake Creek riparian planting and LWD addition	Riparian planting and LWD addition, rkm 1.0-1.4, to address 420m of channel w/ 150 yr wood loading deficits	High	66	RC	P	210

Project number	Project title	Project description	Process impairment	Priority score	Project type [1]	Ownership type [2]	Project metrics [3]
22	Olsen Creek culvert replacement	Improve fish passage on Olsen Creek at adult fish barrier, 4303_5630	Low	66	P	P	390
23	Improve road drainage and reduce sediment delivery	Replace stream crossing at 4500_13590, and resurface 365m of roads 4925, 4920, 4505 and 4500	Moderate	63	S	I	425
24	Improve road drainage and reduce sediment delivery	Replace stream crossing at 4920_10805, add cross-drains to road 4920, and resurface 396m of roads 4920 and 4923	Moderate	63	HS	I	487
25	Upper Lake Creek LWD addition	Add LWD, rkm 1.4-1.8, to address 441m of channel w/ 150 yr wood loading deficits	High	63	C	P	441
26	Improve road drainage and reduce sediment delivery	Replace stream crossing at 4014_5490, resurface 914m of roads 4010, 4014 and 4015, and install cross drains on 4014	Moderate	63	HS	I	974
27	Improve road drainage and reduce sediment delivery	Install cross drains and resurface 365m of roads 4500 and 4510	Moderate	61	H	I	512
28	Improve road drainage and reduce sediment delivery	Install cross drains on road 4023 and resurface up to 213m of roads 4023 and 4022	Low	60	HS	I	278
29	Reduce sediment delivery	Resurface 457m of road 4301	Moderate	58	S	P	457
30	Reduce sediment delivery	Replace stream crossing at 4506_1255	Moderate	57	S	I	20
31	Reduce sediment delivery	Resurface 304m of roads 4303, 4302 and 4017	Moderate	54	S	I	304

[1] Project Type: C=channel; H=hydrology; P=passage; R=riparian; S=sediment

[2] Ownership Type: C=county; I=industrial; P=private; S=state

[3] Project metrics are specific to project type and are summarized as follows: P= length (m) of low gradient habitat (<10%) available upstream of barrier; R= length (m) of stream channel treated; C= length (m) of channel treated; H= length (m) of treated road directly delivering sediment; S= length (m) of treated road