Coeur d'Alene Tribe
Fisheries Program

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

2009 ANNUAL REPORT

Coeur d'Alene Tribe Department of Natural Resources
Fisheries Program
401 Annie Antelope Road
Plummer, ID 83851-0408

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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 populations of westslope cutthroat trout in the Coeur d'Alene basin. This report summarizes RME data collected during 2009 that describe the status and trends of cutthroat trout in target watersheds and the response of stream habitats and trout populations to implemented habitat restoration and non-native fish extraction measures. The report also describes the in-stream and riparian restoration actions that were implemented in 2009 and outlines a strategic prioritization exercise that was conducted to create a list of prospective restoration projects to address additional habitat deficiencies in our watersheds.

Research, monitoring, and evaluation summary

An abundance estimate of 175 (± 10) adfluvial cutthroat trout spawners was generated for the Lake Creek watershed. In Benewah Creek, an abundance estimate was not attainable because of the inability to capture upriver adult migrants; 30 post-spawn adults, however, were captured moving back downriver. Given that the precision of the estimate in Lake Creek was primarily due to changes in our trapping and sampling techniques, similar modifications will be made to sampling procedures in Benewah Creek in 2010. Further, such precision will allow us to reliably track adult spawners over time in both watersheds.

Abundance estimates of 2859 (± 111) and 442 (± 154) were generated for outmigrating juvenile cutthroat trout in Lake and Benewah creeks in 2009, respectively. The lower estimate in upper Benewah Creek likely reflects the lower number of spawning adfluvial adults in Benewah than in Lake Creek. However, estimates were likely biased low in both watersheds given that large numbers of juvenile cutthroat trout were typically captured soon after traps were deployed. Because accurate juvenile outmigrant abundance estimates are required to reliably track watershed-scale changes in in-stream productivity of our adfluvial cutthroat trout populations, modifications to sampling protocol and trapping techniques are being considered that will address this concern. Of the juvenile cutthroat trout that were captured in Lake and Benewah watersheds in 2009, 696 (28%) and 97 (62%) were PIT-tagged, respectively.

Detection data from juveniles that had been PIT-tagged in Lake Creek from 2005 to 2007 indicate that less than 2% have returned to spawn as adults. This return rate translates into an annual in-lake juvenile survival rate of 14-15% which is two to three times less than empirical survival estimates generated for juvenile cutthroat trout in other lacustrine systems. In addition, fish that have returned to spawn as adults in Lake Creek have generally been larger and outmigrated earlier when tagged as juveniles than those that have not been found to return. Our results indicate that processes operating in Lake Coeur d'Alene are likely impacting survival of juvenile cutthroat trout and that the strength of these processes may be dependent on behavioral or morphological attributes of juveniles at the time of outmigration. Our results also lend support to the need to further investigate whether predation is a predominant mechanism regulating survival rates given the established presence of several non-native piscivorous fish species in the lake.

Results from electrofishing surveys conducted at index sites in 2009 across target watersheds revealed spatial patterns of cutthroat trout distribution that were consistent with surveys conducted in previous years. Cutthroat trout of ages one and older were observed at moderate densities (mean of 33.5 fish/100 m) across mainstem reaches in Evans Creek. In contrast, densities of similar aged cutthroat trout in Alder Creek were generally less than 5 fish/100 m and constrained to the lowermost reaches of the watershed. In our adfluvial watersheds, densities of age one and older cutthroat trout were substantially greater in tributaries than in mainstem reaches. In Benewah Creek, mean densities of 30.1 fish/100 m were observed across tributaries that were able to be effectively sampled; densities in mainstem reaches were typically less than 10 fish/100 m. In Lake Creek, the highest densities of cutthroat trout were also typically found in tributaries, with a mean value of 57.4 fish/100 m calculated for sites sampled in upper reaches of tributaries. However, densities in lower reaches of Lake Creek tributaries were comparably much lower (mean of 4.8 fish/100 m).

Significant temporal trends in cutthroat trout densities, estimated from our index site electrofishing surveys, were detected over the past seven years at large spatial scales in both the Evans and upper Benewah watersheds. Though synchronous trends in the Evans watershed were mostly cyclical, the abundance trajectory in the upper Benewah watershed displayed a more prominent linear increase over time. The results observed in the Benewah watershed may have been a collective response to the large-scale habitat restoration and the aggressive brook trout suppression program that have proceeded in this watershed since 2004. In contrast to the Evans and Benewah watersheds, a watershed-scale trend in cutthroat trout abundance was not apparent in the Lake Creek watershed.

Results from our trend analysis also indicated that first pass catch data provided similar interpretations of watershed-wide changes in abundance as did estimates generated from our multi-pass depletion methodology. Moreover, results from a mark-recapture study conducted across a subsample of index sites in 2009 provided evidence that not only did depletion estimates underestimate true abundance, but a single-pass estimator of abundance would have the capability of tracking true abundance over time. These results lend support to using first-pass catch as an index of abundance to examine long-term trends in our watersheds.

Habitat surveys conducted in 2009 revealed that physical features markedly changed in those reaches that have received restorative treatments, but most commonly as a direct result of our intervention. In the mainstem reach of the upper Benewah watershed that was treated in 2008, large woody debris loadings substantially increased as a direct result of the introduction of large wood for bank stabilization and fish cover. In addition, both the re-activation of channel meanders and the elevation of the channel bed in incised reaches to create new riffles have increased the amount of deep pool habitat in this reach. Thermal refugia, however, were less prevalent in deepened pools along this reach than in other downstream restored reaches that have been surveyed in previous years.

Habitat surveys conducted in 2009 along the mainstem reach of the upper Benewah watershed that is currently receiving treatment as part of Phase 2 restoration revealed the extensive presence of beaver activity. We documented a frequency of dams that ranged from 11.3 – 13.4 per km over survey periods. Changes in metrics associated with this beaver dam complex were observed and indicated evidence of considerable building activity between summer and fall survey periods. During the summer survey, approximately two-thirds of the 39 documented dams were considered inactive, whereas in the fall only 11% of the 47 dams were deemed inactive. Further, median dam height doubled from 0.6 to 1.34 ft over the survey periods, with concomitant significant seasonal increases in backwatered surface area, pool volume, and residual pool depth. However, only approximately a quarter of the documented dams were built with or upon stable materials, which confers a degree of instability to the dam complex.

Much of the expected benefits of our Phase 2 approach is predicated on the stability of persistent wood aggregations and beaver dams that will more effectively maintain pool habitat throughout the year, impede and attenuate flows, aggrade the streambed over time, and progressively enhance floodplain connectivity through backwater effects. Notably, the observed engagement of stream flows with the floodplain in the Phase 2 reach in 2009 may have played a role in regulating summer stream temperatures in this reach in 2009 relative to past years, and lends support to our restoration goals that aim to reduce rearing temperatures for cutthroat trout by increasing water retention in upper mainstem reaches. The current approaches that we are using to support the desired stability in upper mainstem reaches are less intrusive than Phase 1 tactics, and consequently, physical habitat responses to Phase 2 restoration likely will proceed more gradually than that which has been measured in response to Phase 1 restoration.

Responses of cutthroat trout to various restoration actions implemented across our watersheds were variable. Cutthroat trout were found to exhibit a rapid, localized increase in abundance in response to the placement of in-stream structures in lower Evans Creek, with mean densities increasing from 12.8 to 93.3 fish/100 m. However, we have yet to detect a direct positive response by cutthroat trout to the large-scale channel reconstruction that has occurred in the upper Benewah watershed over the past four years. The lack of an immediate detectable response may be due to the degree of disturbance imposed by our channel reconstruction actions on stream processes and the persistence of limiting factors in reaches adjacent to those restored which may be inhibiting dispersal from core rearing tributaries. Both of these potential explanations are intended to be redressed by our less intrusive Phase 2 restoration actions. We also intend to modify the sampling techniques that are used in deep restored habitats, and to use PIT-tag technology to better understand the potential use of restored Benewah mainstem habitats during overwintering periods.

The brook trout suppression program that has been implemented in the upper Benewah watershed since 2004 has been effective at regulating numbers of brook trout at a manageable level. Densities of brook trout removed from a mainstem index reach were much lower in 2009 (250 fish/km) than during 2005 and 2006 (452-481 fish/km) when mainstem reaches were first targeted. Further, present densities are more than five times lower in most reaches in upper Benewah than in upper Alder Creek. However, though over 7000 brook trout have been removed since inception of the suppression program, an overall significant decline in densities has not been observed across all upper Benewah reaches. Densities have generally remained at low levels or have substantially declined in Whitetail, South Fork, and West Fork creeks, but have exhibited increases in both Windfall and Schoolhouse creeks. These differences may be explained by the proximity of the latter two tributaries to mainstem reaches that have consistently displayed the highest densities of adult brook trout during the spawning season. Our current approach aims to curb reproductive success in this mainstem reach by not only removing fish from this reach, but by installing a barrier to prevent other brook trout from ascending into and accessing these apparently suitable spawning habitats.

Restoration and enhancement activities

Both channel and riparian enhancement measures were implemented in the upper Benewah watershed in 2009 as part of our Phase 2 restoration strategy to reestablish floodplain connectivity. Channel restoration included the excavation of 439 m of an existing relict channel, that once activated, will result in 197 m of added channel length and reduce local stream gradient from 0.45 to 0.24%. An additional 371 m of an existing swale was re-graded to create a high-flow wetland swale that will serve as a nursery area for propagation of cottonwood and willow for future riparian restoration in the project area. Seven in-channel wood structures were also introduced into channel reaches to emulate flow obstruction effects of natural wood and beaver dams. The intent of these structures is to attenuate flows and increase backwater effects during floods such that the valley floor would become connected annually. Riparian treatments for stabilization involved the planting of a total of 14, 904 herbaceous plugs and 6,950 woody trees and shrubs along 969 m of streambanks and 0.78 hectares of associated floodplain that were disturbed during construction. Additional planting was conducted as part of an overall riparian enhancement strategy, utilizing black cottonwood's unique characteristics to rapidly change the current degraded state of the riparian ecosystem, that intends to re-establish a patchwork of native vegetation communities on the valley floor that will lay the foundation for a diverse forest ecosystem to develop over the next 25-50 years. A total of 10,058 herbaceous plugs, 4,634 deciduous trees, and 3,800 conifers were planted on 3.31 ha of floodplain and along 742 m of streambank as part of this enhancement strategy.

Channel and riparian enhancement measures to address severe channel incision and bank erosion were implemented in the West Fork of Lake Creek in 2009 as part of a strategy to create a new channel segment that is hydraulically connected with the adjacent floodplain. Channel construction involved the creation of 106 m of new channel length excavated into 2 hectares of newly graded floodplain habitat. Imported gravels and logs were used to create streambed and streambanks in the newly constructed channel. Logs were also placed on the new floodplain to provide roughness to prevent erosion. Riparian enhancement in 2009 followed the vegetation plan that was developed for the site and involved the planting of 300 herbaceous plugs along 100 m of newly built streambank, and the planting of 800 conifers and 450 deciduous trees along 1.01 ha of adjacent floodplain habitat to re-establish native vegetation.

We utilized previous watershed assessments and data from our status and trend monitoring to aid in the identification and prioritization of restoration actions that will have the greatest potential to improve habitat that is limiting the recovery of cutthroat trout in our watersheds. First, we developed objectives and criteria for describing the relative degree of impairment to the following processes in our watersheds: sediment delivery, flood hydrology, riparian processes and wood recruitment potential, water quality, and biological productivity. Watershed assessments and monitoring data were then used to assign a relative impairment ranking (i.e., low, medium, high) for each of the aforementioned processes to three subbasins in Lake Creek and nine sub-basins in Benewah Creek. Collectively, the impairment rankings of all processes were used to assign an overall impairment ranking to each sub-basin, which permitted the identification of those sub-basins that should be prioritized for restoration. For each high priority sub-basin, a list of spatially-explicit restoration projects was then developed which addressed the highlighted impairments, described locations of implementation, and outlined levels of projected effort required for completion. Projects were then scored based on several criteria including the degree to which the action addresses causal processes, the uncertainty associated with projected outcomes and with biological responses to the action, and how the project accommodates local socioeconomic goals. Total scores were then used to delineate those projects that were considered to have the most potential in achieving restoration goals and providing benefits for cutthroat trout recovery.

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 removed 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 (Mallet 1969; Scholz et al. 1985; Lillengreen et al. 1993). These factors included the construction of Post Falls Dam in 1906, major changes in land cover types, impacts from agricultural activities, and introduction of exotic fish species.

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 both resilience and resistance 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 to historical levels.

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 tributaries; and potential survival bottlenecks in Coeur d'Alene Lake.

In 1994, the Northwest Power Planning Council adopted the recommendations set forth by the Coeur d'Alene Tribe to improve the Reservation fishery (NWPPC Program Measures 10.8B.20). These recommended actions included: 1) Implement habitat restoration and enhancement measures in Alder, Benewah, Evans, and Lake Creeks; 2) Purchase critical watershed areas for protection of fisheries habitat; 3) Conduct an educational/outreach program for the general public within the Coeur d'Alene Reservation to facilitate a "holistic" watershed protection process; 4) Develop an interim fishery for tribal and non-tribal members of the reservation through construction, operation and maintenance of five trout ponds; 5) Design, construct, operate and maintain a trout production facility; and 6) Implement a monitoring program to evaluate the effectiveness of the hatchery and habitat improvement projects. These activities provide partial mitigation for the extirpation of anadromous fish resources from usual and accustomed harvest areas and Reservation lands.

Since that time, much of the mitigation activities occurring within the Coeur d'Alene sub-basin have had a connection to the BPA project entitled "Implement 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. Further, most of the aforementioned limiting factors are being addressed by this project either through habitat enhancement and restoration techniques, biological control, or with monitoring and evaluation that will provide data to refine future management decisions. This annual report summarizes previously unreported data collected during the 2009 calendar year 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:

- Monitoring and evaluation. This section comprises monitoring results for biological and physical indicators that describe the status and trends of trout populations and in-stream habitat features in our target watersheds. In addition, this section summarizes data that evaluate the effectiveness of implemented management actions in our watersheds, including recent channel restoration activities and the brook trout suppression program.
- Implementation of restoration and enhancement projects. This section comprises descriptions of the channel and riparian restoration projects that were implemented in 2009. Included in the action descriptions are summaries of the immediate effects that the restoration measures had on channel features.

To provide consistency between project objectives around which past reports have been structured and the work element format adopted by Pisces, relevant work elements and/or milestones found in our statement of work are referenced within each section.

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.

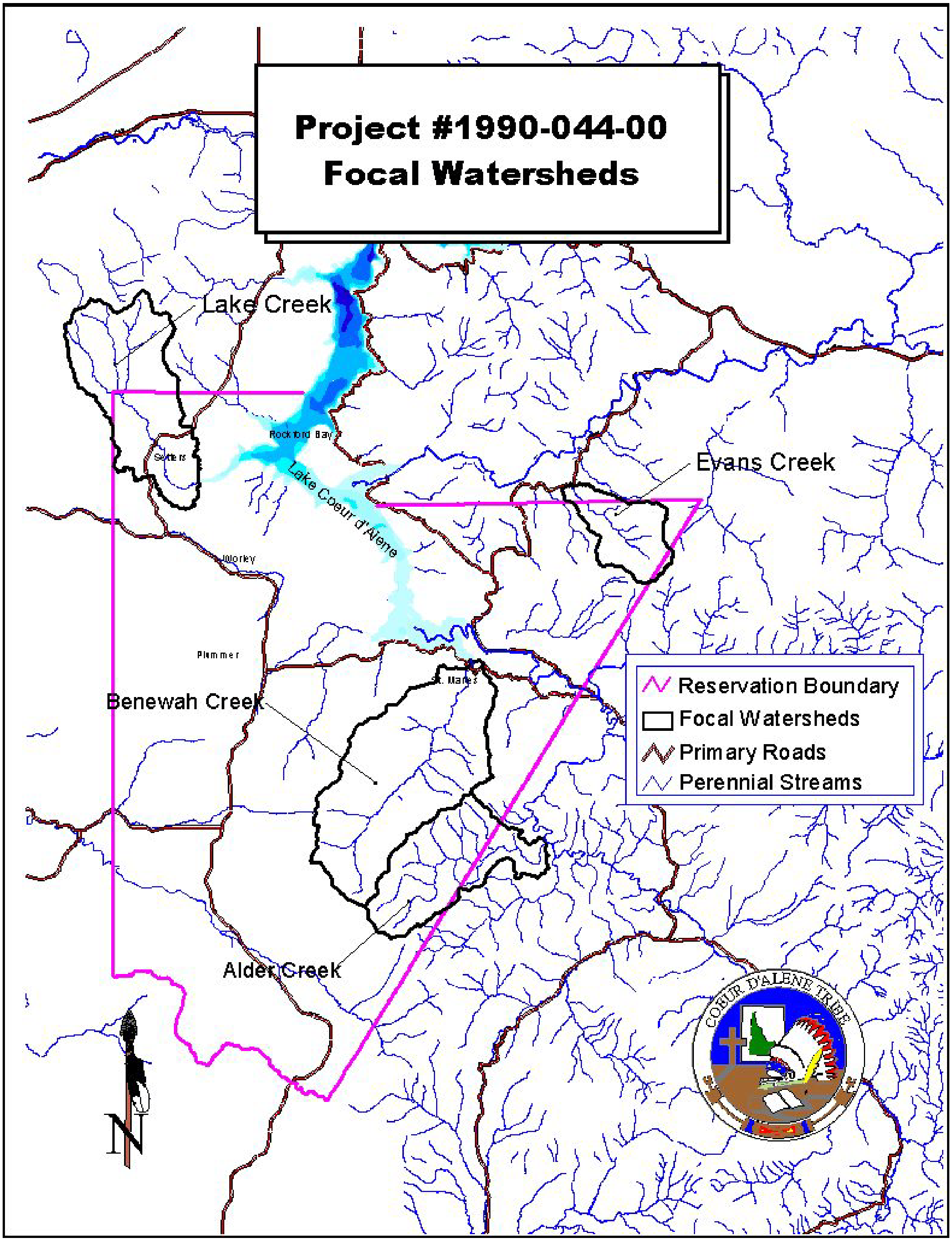

Figure 1. Locations of BPA Project 90-044-00 Focal Watersheds on the Coeur d'Alene Indian Reservation.

3.0 MONITORING AND EVALUATION

3.1 Introduction

Salmonid populations and habitat features are monitored annually at index sites distributed across tributary and mainstem reaches to track trends within our four target watersheds (Vitale et al. 2002). Abundance trajectories for both native westslope cutthroat trout and non-native brook trout at index sites permits an examination of whether conditions are improving for either species and if improvements are operating at a local subbasin or a regional watershed scale. Further, the detection of declining trends may signal potential localized degradation or deficiencies in habitat conditions that need to be addressed. Trend monitoring also permits a description of temporal changes in spatial distributions to assess expansion and contraction rates of our salmonid populations to examine whether newly created suitable habitat is undergoing colonization. We not only assess relative changes in abundance at the reach scale, but also monitor overall trends at the watershed scale by tracking number of juvenile outmigrants and returning adults in watersheds that support the adfluvial life-history. In addition to our salmonid populations, we also track annual trends in temperatures given that high water temperatures during summer rearing periods have been considered to be a major factor limiting cutthroat trout production in our watersheds.

Effectiveness monitoring (Is the project achieving desired habitat and population benefits?) is also conducted in watersheds that are currently receiving treatments that address factors limiting cutthroat trout recovery. We are monitoring the response of salmonids and physico-chemical habitat features to action implementation by measuring indicator variables in both treated and control reaches or watersheds. Effectiveness monitoring is currently being conducted in the upper Benewah watershed to evaluate responses to large-scale channel construction activities and non-native brook trout control.

From 2005 to 2008, 2524 m of mainstem channel habitat was reconstructed in the upper Benewah watershed upriver of 9-mile bridge to address dysfunctional stream processes and structure, including channel incision, unstable streambanks and accelerated sedimentation, lack of habitat complexity, and elevated summer rearing temperatures from low stream canopy closure and reduced groundwater connection with adjacent floodplains (Vitale et al. 2007, Vitale et al. 2008; Firehammer et al. 2009, Firehammer et al. 2010). This main-channel reach was targeted because it had the potential to increase carrying capacity and production of juvenile cutthroat trout given its proximity and connectivity to important spawning tributaries. Channel reconstruction during these four years entailed reactivating meanders previously lost to channel avulsions; elevating riffle streambeds to promote overbank flooding and increase pool volume; adding large wood to in-stream habitats to provide cover, create pools, and aid in bank stabilization; and planting vegetation along channel margins and riparian zones for shade, bank stablilization, and future woody debris recruitment. Monitoring the biological response to these enhancement actions included examining changes in trout abundances before and after habitat restoration in treated reaches relative to control reaches. Temperature responses were monitored by examining changes in the availability of thermal refugia in pool habitats before and after restoration. Physical responses to mainstem restoration were monitored by examining changes in large woody debris volume, substrate composition, canopy cover, and residual pool depth and volume.

A brook trout removal program was initiated in 2004 to suppress the numbers of brook trout found in mainstem and tributary habitats in the upper portion of the 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. 2004a; Shepard 2004). However, unlike other brook trout removal projects that have focused on chemical eradication and subsequent preventative re-colonization measures, such as passage barriers (Shepard et al. 2003), we have used less intrusive methods (e.g., electrofishing, trapping) to annually control brook trout. Our approach was tempered by the desire to maintain connectivity with the lake to promote the migratory life-history variant of our cutthroat trout population and its concomitant high productivity potential. We felt that the benefits of unimpeded access and the expression of the cutthroat adfluvial life-history greatly outweighed the benefits of brook trout eradication in isolated tributaries (Peterson et al. 2008a). Further, eradication treatments have not always proven entirely successful, and, within our watershed, would require large-scale chemical treatments that may receive public opposition and an extensive trapping and hauling program to supply migratory adult cutthroat trout to the various isolated spawning tributaries. Monitoring the success of the removal program is conducted by examining changes in brook trout abundances estimated at our index sites in the upper Benewah watershed relative to those monitored at index sites in our control watershed, Alder Creek.

The objectives of the monitoring and evaluation section with corresponding BPA Pisces scope of work elements are as follows:

1) Assess temporal and spatial changes in cutthroat trout abundances and distribution
    a) Measure the productivity of the adfluvial life-history of cutthroat trout by analyzing data collected from migration traps and PIT tag systems installed in Lake and Benewah creek watersheds (Work Elements L,M,N,O,Q,R)
    b) Conduct electrofishing population surveys at index sites to assess relative changes in the distribution and abundance of salmonids in mainstem and tributary reaches within the four target watersheds (Work Elements P,Q,S)

2) Collect and summarize longitudinal trends in water temperatures by deploying loggers within monitored watersheds (Work Elements U,X)

3) Evaluate effectiveness of habitat restoration in the upper Benewah watershed
    a) Assess differences in trout abundance between restored treatment sites and unrestored control sites in mainstem reaches (Work Element S)
    b) Assess differences in thermal heterogeneity in pool habitats in treated mainstem reaches before and after restoration (Work Elements V,X)
    c) Assess differences in physical habitat indicators measured at treatment and control sites (Work Elements T,W,X)

4) Reduce the abundance and distribution of non-native brook trout in the upper Benewah watershed
    a) Remove brook trout from Benewah Creek (Work Element J)
    b) Test the effectiveness of the removal program by examining trends in brook trout abundances over the course of program implementation in both treated and control watersheds (Work Element K)

3.2 Methods

3.2.1 Trend and status monitoring

3.2.1.1 Adfluvial cutthroat trout migration

Migration traps were installed in 2009 in both Lake and Benewah creeks to collect abundance and life-history information on adfluvial cutthroat trout. Resistance board weir (RBW) traps (Tobin 1994; Stewart 2002) were used in both watersheds to intercept adult cutthroat migrating upriver. This style of migrant trap has proven successful in capturing adult fish in past years during high spring discharge. However, periodic high-volume freshets have been observed to depress trap panels below the water surface, markedly reducing capture efficiency (Firehammer et al. 2010). As a result, modifications to the RBW design were incorporated into the trap installed in Lake Creek in 2009 to improve trap performance. A cabled pulley system was secured to the structure so that trap panels could be manually lowered or raised to maintain their height above the water surface. RBW traps in both systems were installed in late winter after ice out but early enough to attempt to capture the majority of the spawning run.

To capture post-spawn adults and outmigrating juveniles, a modified fence-weir design was used in both watersheds as the downriver trap (DN). The design incorporated pop-out panels that could be removed during periods of high flow to relieve pressure on the trap. Downriver traps were installed in the spring in both systems as early as possible under amenable discharge levels. In both watersheds, traps were positioned downriver of principal spawning tributaries and of most of the recently implemented and projected habitat restoration projects. The RBW trap on the Benewah Creek mainstem was installed at river kilometer (rkm) 14.5, with the DN trap located immediately upstream (Figure 3); the RBW trap on the Lake Creek mainstem was installed at rkm 6.0, with the DN trap located approximately 0.13 km upriver (Figure 5). Traps were checked and cleaned frequently during periods of operation, with checks occurring typically daily during high discharge and associated peak movement periods from March through early June to ensure proper trap performance and to assess migration timing and relative abundance.

PIT-tag arrays have been installed immediately downstream of the RBW traps in both the Lake (~ 10 m downstream) and Benewah (~2 m downstream) systems. Detections by these arrays permit an evaluation of adult return rates from prior outmigrating cohorts and allow an in-season examination of trap performance. The Lake Creek array spans the entire stream channel and consists of three side-by-side 5x5 ft antennas; two side-by-side 10x4 ft antennas constitute the array in Benewah Creek and span the entire wetted width of the channel under most flows. Both systems were calibrated and started on February 24. Logged detection data were downloaded several times a week to monitor both adult and juvenile fish passage throughout the migratory period. The Benewah Creek PIT-tag system was shut down on July 13 because of a lack of fish detections and the absence of fish captured in the DN migratory trap. On March 5, during an early spring freshet, apparently an ice dam or a large timber dislodged the Lake Creek PIT-tag array structure from the Old H95 bridge to which it was secured. Consequently, because all three antennas were damaged beyond repair, the Lake Creek array was not operational during 2009. A new, similarly configured array system (3 side-by-side 5x5 ft antennas) was installed at the same location under the Old H95 bridge in Lake Creek on August 25, 2009.

Total lengths (TL, mm), weights (Wt, g), and scales were collected and condition factors (estimated as $10{,}000 \cdot Wt / TL^3$) calculated from all captured adult cutthroat trout. In 2009, adults captured in the RBW received a hole punch along the outer margin of the right opercle to serve as a mark that would be used in recapture events at the DN trap to generate an estimate of the abundance of upriver migrating adults. Given the cold water temperatures and the relatively short period of time spent by fish on the spawning grounds (Firehammer et al. 2010), the punch was not expected to rapidly heal over and thus remain recognizable until recapture. Adult abundance was estimated using Chapman's modification of the Petersen index:

$$N = \frac{(M+1)(C+1)}{(R+1)} - 1, \ (\textit{Equation 1})$$

where:

- N= the abundance estimate;
- M= number of adults that received a mark;
- C= number of adults captured in the DN trap; and
- R= number of adults captured in the DN trap that had been marked.

The variance estimate of N was calculated as follows:

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

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

Adults in both traps were also scanned for the presence of PIT-tags using a hand-held wand. In addition, all adults captured in the RBW that had not received a PIT-tag as a juvenile, received a PIT-tag that was inserted into the muscle tissue immediately posterior to the insertion of the right pelvic fin; tag insertion into the body cavity was not considered lest they would become expelled on the spawning grounds (Peterson et al. 2004a). Short-term tag retention for these fish was assessed during their recapture in the DN trap using the opercle punch as a double-tag.

Lengths were collected from all outmigrating juvenile cutthroat trout captured in DN traps. In addition, at least 25% of the captured juveniles in each system received intra-peritoneal PIT tags following the Pacific States Marine Fish Commission PTAGIS guidelines. Weights and scales were collected from these tagged fish, and the adipose fin was clipped to identify its tagged status for recapture events. Attempts were made to representatively tag juvenile fish throughout the entire outmigration period, with subsamples of PIT-tagged juveniles used in trap efficiency trials to estimate outmigrant abundance. In addition, subsamples of PIT-tagged fish used in efficiency trials were held for a day in a PVC-framed net pen upriver of the DN trap before their release to permit estimates of post-implantation survival and tag retention rates. Outmigration estimates for each release trial period were derived from recaptured fish enumerated at the trap using the following equation (Carlson et al. 1998):

$$U_h = \frac{(u_h)(M_h+1)}{m_h+1}, \ (\textit{Equation 3})$$

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 released 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:

$$v(U_h) = \frac{(M_h + 1)(u_h + m_h + 1)(M_h - m_h)(u_h)}{(m_h + 1)^2 (m_h + 2)}. \quad (\textit{Equation 4})$$

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

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

Because observed rates of trap passage varied considerably for tagged fish released above the DN trap, all marked fish did not have an equal probability of being caught during a release trial's recapture period. Because of this mark-recapture model violation, a modification of the stratified design used by Carlson et al. (1998) was used to estimate release trial abundances. During each trial period, only those tagged fish available for recapture were used in calculations rather than all tagged fish released during the trial period (i.e., M_h in the equation above). The number of tagged fish considered available for recapture during each trial period was calculated as the number of tagged fish released in that period discounted by those that were enumerated at the trap during subsequent release trial periods.

3.2.1.2 Summer trout abundance surveys

The channel types delineated during prior pilot habitat surveys (Lillengreen et al. 1996) served as basic geomorphic units for selecting sample index sites for conducting fish population surveys. In these early surveys, stream reaches were stratified into relatively homogeneous types according to broad geomorphologic characteristics of stream morphology, such as channel slope and shape, channel patterns and channel materials, as defined by Rosgen (1994). Stream reaches were further stratified by basin area to ensure that both mainstem and tributary habitats were represented in the stratification scheme. Sample index sites within each reach stratum were randomly selected in proportion to the total reach length (Figure 2-5). The length of each index site was standardized to 61 meters to encompass at least 20 channel widths for most sites.

Sites were electrofished between mid-July and mid-October to quantify the abundance and distribution of salmonids during base flow conditions. Electrofishing was conducted using a Smith-Root Type VII pulsed-DC backpack electrofisher, and followed established guidelines and procedures to standardize capture efficiency (Reynolds 1983). Block nets were placed at the upstream and downstream boundaries of each site to prevent immigration and emigration during sampling. Typically, three passes were conducted at a site. At other sites, time constraints or habitat conditions only afforded two passes, though catch was adequately reduced to permit estimation of abundance.

Captured salmonids, including westslope cutthroat trout and brook trout *(Salvelinus fontinalis)* were identified, enumerated, and measured for total length. Weights and scales were collected from a subsample of 8-10 fish within each 10 mm length group for each species and watershed. Based on age keys derived from previously collected scale samples, cutthroat and brook trout respectively greater than 70 and 75 mm were considered to be at least one year of age. Other species, such as dace (*Rhinichthys* spp.), redside shiner (*Richardsonius balteatus*), longnose sucker (*Catostomus catostomus*), and sculpin (*Cottus* spp.), were considered incidental catch and were only counted during the initial electrofishing pass.

Index site abundances were estimated for fish of all ages and for those considered at least one year of age (hereafter referred to as age 1+) separately for each salmonid species using the removal-depletion method (Zippen 1958; Seber and LeCren 1967). For sites in which only two passes were conducted, site estimates were calculated using the following equation (Armour et al. 1983):

$$N = \frac{U_1}{1-(U_2/U_1)}, \quad (\textit{Equation 5})$$

where:

N = estimated population size;
U_1 = number of fish collected in the first pass; and
U_2 = number of fish collected in the second pass.

The standard error of the estimate (*se(N)*) was calculated as:

$$se(N) = \sqrt{\frac{M(1-M/N)}{A-\left[(2p)^2(U_2/U_1)\right]}}, \quad (\textit{Equation 6})$$

where:

M = $U_1 + U_2$;
A = $(M/N)^2$; and
p = $1-\frac{U_2}{U_1}$.

Site estimates for three pass removals were calculated using the following equation (Armour et al. 1983):

$$N = \frac{M}{1-(1-p)^t}, \quad (\textit{Equation 7})$$

where:

N = estimated population size;
M = sum of all removals ($U_1 + U_2 + \ldots.U_t$);
t = the number of removal occasions;
U_i = the number of fish in the i^{th} removal pass;
C = $(1)U_1 + (2)U_2 + (3)U_3 + \ldots..(t)U_t$;
R = $(C-M)/M$;
p = $(a_0)1 + (a_1)R + (a_2)R^2 + (a_3)R^3$; and
a_i = Polynomial coefficient (Armour et al. 1983).

The standard error of the estimate (*se(N)*) was calculated as:

$$se(N) = \sqrt{\frac{N(N-M)M}{M^2 - \frac{N(N-M)(tp)^2}{(1-p)}}} \quad (\textit{Equation 8})$$

The approximate 95% confidence interval for each abundance estimate was then calculated as follows:

$$95\%CI = N \pm 1.96 * se(N)$$

In some cases, few fish were captured during each subsequent pass but numbers were not adequately reduced to reliably generate an estimate. We determined that if the total fish captured was ten or less over three passes, or six or less over two passes, the estimated abundance would be considered the total number of fish caught without an accompanying confidence interval.

Mark-recapture results to evaluate efficacy of 1st pass index

In 2009, a study was conducted within the purview of our annual sampling regime to examine the feasibility of using a single-pass abundance index rather than a depletion estimator to track abundance in our watersheds. Various authors have cautioned against the use of depletion-removal estimates as unbiased measures of fish abundance for salmonids in small stream systems because they have been found to overestimate capture probability during subsequent passes and consequently underestimate population size (Riley and Fausch 1992; Peterson et al. 2004b). The multipass-depletion technique can also be time-consuming, especially in our watersheds where the relatively large amount of fine sediment leads to much time expended between passes waiting for water clarity to improve. In addition, others have found single-pass indices to perform well in predicting abundances for salmonid populations in small-streams (Strange et al. 1989; Jones and Stockwell 1995; Kruse et al. 1998; Mitro and Zale 2000).

To evaluate the predictive abilities of a single-pass index, we selected 27 of our index sites, distributed across all four watersheds, which varied in levels of mean salmonid density (estimated from past surveys). For each site, block nets were placed at the upstream and downstream boundaries, and age 1+ fish that were captured by a single pass were marked by a fin-clip and released within the blocked-off site. The next day the site was re-visited and sampled again using our multipass-depletion removal protocol, and both numbers of marked and unmarked fish captured during each subsequent pass were recorded.

Depletion estimates for marked age 1+ fish (see *equations 5-8*) were generated and compared to the actual number of marked fish released at each site. In addition, depletion estimates for all age 1+ trout generated from the recapture event were compared to those estimates generated by using a mark-recapture model (see *equations 1 and 2*). Marked and unmarked fish captured only in the first pass, and over all three passes, were used in mark-recapture models to generate two estimates for each site for comparative purposes. The precision of the relationship between marked fish captured during the first pass and known marked fish released at each site was also examined across all sampled sites.

Repeated measures analysis for examining cutthroat trout trends

Temporal trends in age 1+ cutthroat trout in target watersheds were examined using our annual index site survey data. To address potential dependency among proximate sites, trout depletion abundance estimates and first pass catch data were first aggregated over sites within tributaries or within longitudinal reaches that shared similar geomorphic characteristics, habitat features, or historical trout abundances (Table 1). For each of the composite reaches, aggregate values comprised annual data from at least two sites and were expressed as fish/100 m to permit standardization over years and across reaches. Noticeably, several sites within each watershed were not included in composite reaches. In the Alder Creek watershed, mainstem sites 1-10 were omitted from these analyses given the consistently low numbers of both cutthroat and brook trout captured in these reaches. In the Benewah Creek watershed, Coon Creek was omitted due to the lack of available abundance estimates. In addition, the mainstem reach that has been restored or is targeted for restoration upstream of 9-mile bridge was omitted because of the inability to effectively sample fish and provide reliable abundance estimates in restored habitats, in addition to the fact that many of the sites had not been sampled before 2007. The unrestored mainstem reach upriver of the Windfall confluence was also omitted given that only one site was available for inclusion for most of the monitored years. In Lake Creek, the lowermost composite mainstem reach was also omitted because of lack of site replicates (i.e., only one index site).

Initially, all 24 composite reaches from Benewah, Evans, and Lake creeks, were included in a global model to examine age 1+ cutthroat trout trends over the time period from 2003-2009. In this model, watershed was included as a grouping factor to examine potential differences in trends among the three watersheds. Significant interactions were found between watershed and year for both the depletion abundance estimates ($p = 0.001$) and the first pass catch data ($p = 0.003$), indicating that temporal trajectories behaved differently among watersheds, and consequently supported conducting trend analyses separately for each watershed. A similar analysis was also conducted for the Benewah watershed, in which the ten composite reaches were initially grouped by their location relative to 9-mile bridge (Table 1), to account for potential trend differences between those reaches that have and have not received treatments over the last five years (e.g., brook trout suppression and large-scale channel restoration upstream of 9-mile bridge).

Significant differences among years were evaluated using an ANOVA repeated measures model. First, assumptions of compound symmetry (i.e., synchronous differences among reaches over time) were evaluated by examining the Huynh-Feldt statistic. If the assumptions were violated, then the less powerful multivariate statistic, Wilk's lambda, was used to evaluate significance (the multivariate analysis does not require compound symmetry). Lastly, single degree of freedom polymomial tests were examined to evaluate the type of trend (e.g., linear, quadratic, cubic, etc.) that significantly explained the detected variability across years. Repeated measures models were constructed for series of depletion estimates and first pass catch to draw comparisons between the two abundance indices.

3.2.1.3 Longitudinal stream temperatures

Stream temperatures were continuously monitored every 30 minutes at fixed locations along mainstem reaches and in major tributaries of upper Benewah and Lake creek watersheds using HOBO Temp Pro (Onset Computer Corp.) digital temperature dataloggers (accurate to ±0.2 °C). In the upper mainstem of Benewah Creek, dataloggers were placed in main channel locations, in connected side-channels influenced by springbrooks, and in isolated springbrooks. Air temperatures were also recorded using HOBO H8 Pro Series loggers (Onset Computer Corp.) at a forested and open meadow site in both upper Benewah and Lake creek watersheds. Daily mean and maximum water temperatures, and the percent time in which logged temperatures exceeded 17°C were computed for each HOBO logger. The threshold value of 17°C was used because it has been considered to be a 95% upper limit for optimal cutthroat trout growth (Bear et al. 2007). Daily temperature metrics were used to calculate monthly mean values for July and August to permit comparisons within watersheds and across years.

Table 1. Composite reaches in four target watersheds over which index site trout densities were aggregated. Benewah creek was differentiated by upper and lower sections given that large-scale recovery actions have been implemented in the upper watershed over the last five years.

Composite reach	Sites
Alder Creek watershed	
Mid-upper Alder Creek	11,12,13,14
Upper Alder Creek	15,16,17
Lower North Fork Creek	1,2
Mid North Fork Creek	3,4,5
Upper North Fork Creek	6,7,8
Benewah Creek - lower watershed	
Lower Benewah Creek	1,2
Lower-mid Benewah Creek	3,4,5,6,7,8
Mid Benewah Creek	9,10,11,12,13
Mid-upper Benewah Creek	14L,14,14U
Bull Creek	1,2
Benewah Creek - upper watershed	
Schoolhouse Creek	1,2
Whitetail Creek	1,2
Windfall Creek	1,2
South Fork Creek	1,2,3
West Fork Creek	1,2
Evans Creek watershed	
Lower Evans Creek	1,2,3
Lower-mid Evans Creek	4,5,6,7
Mid Evans Creek	8,9
Mid-upper Evans Creek	10,11,12
Upper Evans Creek	13,14,15,16
Evans Creek tributaries	E. Fork 1; Rainbow Fork 1; S. Fork 1,2
Lake Creek watershed	
Lower-mid Lake Creek	2,3,4,5
Mid Lake Creek	6,7,8
Mid-upper Lake Creek	9,10
Upper Lake Creek	11,12,13,14
Lower Bozard Creek	1,2
Upper Bozard Creek	3,4; E. Fork 1
Lower West Fork Creek	1,2,3
Upper West Fork Creek	4,5

3.2.2 Effectiveness monitoring – Response to restoration activities

3.2.2.1 Evaluating physical and biological responses to reach-specific restoration

We evaluated the response of habitat and trout populations to reach-specific restoration measures by comparing metrics collected at treated and control sites before and after implementation of habitat enhancement activities. Physical attributes, which have been linked to the quality of trout habitat, were typically measured within established 152 m long sites, and included large woody debris volume, canopy cover, substrate composition, and pool depth and volume. Standardized electrofishing sites (i.e., 61 m) were typically encompassed by the habitat sites for the evaluation of relative changes in cutthroat trout abundance between restored and control reaches. Methods used to measure physical attributes are described in detail below.

Stream typing

The classification of stream channel types followed guidelines presented by Rosgen (1996) and used data collected during the thalweg profile, cross section profile and sinuosity surveying efforts. The objective of classifying streams on the basis of channel morphology was to use discrete categories of stream types to develop consistent, reproducible descriptions of the stream reaches. These descriptions must provide a consistent frame of reference to document changes in the stream channels over time and to allow comparison between different streams. The dominant substrate type (i.e., slit/clay, sand, gravel, or cobble) was included as a modifier to the channel type. The numbering for this is 1 for bedrock, 2 for boulder, 3 for cobble, 4 for gravel, 5 for sand and 6 for silt and clay. The delineative criteria included entrenchment ratio, width-to-depth (W/D) ratio, sinuosity and slope.

Longitudinal thalweg profile

The first effort to be undertaken upon arrival at a monitoring site was to determine the location of the downstream end of the previously surveyed reach. Once this was found, the location was flagged with surveyors' ribbon. Bank pins were established on the banks of the channel above the high water mark at major changes in the channel planform. When the 500-foot mark was reached this marked the end of the reach. Profile surveys involved the determination of water depth, and water surface and channel bottom elevations along the thalweg of each 500-foot study reach using methods modified from Peck et al. (2001). Elevation measurements were made relative to a fixed benchmark, assigned an arbitrary elevation of 100.00 ft. All measurements were recorded as distances along the longitudinal profile. A sufficient number of measurements were taken to capture all changes in bed and water surface slope and habitat types along the reach. A SET 530R Sokkia Total Station was used to collect longitudinal profile data at most sites, in place of an autolevel, which had been used in previous surveys. Survey data was recorded on a Recon Pocket PC. After the survey was complete, data was downloaded into a text file and imported into Microsoft excel for analysis.

Cross section profiles

Cross section profiles were measured using a surveyor's level and rod at six locations along each studied reach. All but one of the sites had cross-sections that had been previously established in 2002 or 2003. All cross sections were monumented with permanent pins (rebar), stakes, lathe and flagging to allow for repeat surveying of the profiles in the future. In some cases, survey pins had to be reset because they had been moved or "lost". The benchmark established for the longitudinal profile was also used as the reference point for each of the six cross sections.

The cross section profiles were used to verify the bankfull depth and to calculate the bankfull cross sectional area, wetted perimeter, average and maximum depth and width-to-depth ratio. The flood-prone width, which is defined as the valley width at twice the maximum depth at bankfull, and entrenchment ratio, defined as the flood-prone width divided by the bankfull width, were determined by using floodplain cross-section information collected with the total station if it was collected. Survey data was input into the Reference Reach Spreadsheet.

Bed-form differencing

Identifying pool and riffle habitats is important in monitoring changes in bedform and fish habitat. Residual pool depth (RPD) is a particularly important habitat indicator because it can be accurately measured independent of discharge (Kershner et al 2004) and increasing RPD is generally associated with increased salmonid biomass (Hogel 1993; Binns 1994). A macrohabitat identification technique called the Bed Form Differencing was applied to each of the longitudinal profiles collected to minimize the error in identifying pools and riffles due to acknowledged inconsistencies associated with field identification (Kershner et al 2004) and to facilitate comparisons across datasets (Arend 1999). This method was developed by O'Neill and Abrahams (1984) as a way to objectively identify bedforms in a survey reach.

Four types of bedforms are identified using this method: absolute maximums (riffles), absolute minimums (pools), local maximums, and local minimums. The tolerance value is determined by taking the standard deviation of all of the "differences" and multiplying it times a coefficient. If habitat units exceed this value they are classified as either a minimum or a maximum. If they do not exceed this value they are identified as not being a bedform. If a maximum is followed by a minimum then it is a absolute maximum (riffle). If a maximum is followed by another maximum, it is identified as a local maximum. If a minimum is followed by a maximum, it is defined as an absolute minimum (pool). A bed differencing program was developed in Microsoft Excel using Visual Basic. Residual pool depths were calculated by running a program that sorts the bedforms that are either absolute maximums or absolute minimums, then identifies the first "riffle" and starts calculating residual pools by subtracting the elevation of the absolute minimum from the adjacent downstream absolute maximum. The sample spacing is assumed to be equal to channel width though shorter spacing can be used. The resolution of our data is at a much tighter interval. As a result, we have modified our data in order to achieve spacing closer to bankfull width by running the program twice. After the first run is complete, the sign designation of each point is examined. If there is a series of more than two increasing or decreasing points, the intermediate points are deleted, then the program is ran again.

Pool volume

A reduced longitudinal survey was introduced in 2008 in order to collect detailed pool information at habitat survey sites. Pools were identified by first measuring the depth at the downstream control point. The maximum depth of the pool was calculated from measuring the depth at the deepest part of the pool. If the maximum depth minus the minimum depth was greater than one foot residual depth, the habitat unit was classified as a pool. For each pool, three stream widths were measured: 1) half-way between maximum depth and the downstream end of the pool, 2) the point of max depth, and 3) half-way between the maximum depth and the upstream end of the pool. Three depth measurements were taken where each channel width was measured. Channel widths only included the portion of the channel where the water depth was greater than the minimum depth plus one foot. Pool lengths and stationing of each width location were collected so that a pool volume could be determined. In addition, information about the type of pool and the mechanism forming the pool was also collected. Pool forming mechanisms include boulder (B), meander (M), wood (W), and other (O). Types of pools include dammed pools (D), scour pools (S), and other types of pools (T). The aim with this methodology is to examine the quantity and quality of pool habitats that can be used at baseflow conditions.

Channel substrate

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. Pebble count data was input into the Reference Reach Spreadsheets, which automatically graphed the distribution of particle sizes and calculated pertinent descriptive criteria such as percent by substrate class (size) and a particle size index (D value) for each habitat type for which data was collected.

Canopy density

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, and this is measured in percent. Canopy density can change drastically through the year if the canopy vegetation is deciduous. Canopy cover over the stream was determined at randomly selected locations throughout the survey reach. At each selected location, densiometer readings were taken one foot above the water surface at the following locations: 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. The adjusted density readings were then averaged for the entire reach.

Large woody debris

The organic materials survey transect was walked along the thalweg starting at the downstream end of the reach. All woody debris that was greater than 4 inches in diameter at the small end and 3 ft in length was tallied and measured whether or not it crossed the line of the transect. This included material, other than living trees and shrubs, suspended above the water surface or partially located outside of the wetted stream width. Small and large end diameters (in) and lengths (ft) were recorded for each piece of LWD. If roots were attached, the large end diameter was measured immediately above the roots. Total volume and density of LWD within bankfull width was calculated for each habitat site.

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 (AS), forcing a pool to form upstream or downstream (FP), providing in-stream cover (HC), providing bank stabilization (BS), or none of the above (N). More than one category could be assigned to individual wood pieces. Categories to describe the position of the indentified piece in relation to the stream included: elevation above the bankfull channel (1), one end within and the other end outside bankfull channel (2), completely within bankfull channel but exposed (3), or within bankfull channel but partially buried (4).

Reach-specific restoration projects

In 2009, habitat surveys were conducted at sites in reaches of lower Evans Creek to evaluate whether changes in physical attributes had occurred four years after a habitat enhancement project was implemented to increase in-stream complexity. Prior to restoration, the targeted reach lacked sufficient permanent pools and structure. Although the landowner would construct temporary rock dams each summer using available small cobbles, which would create shallow residual pools utilized by fish during periods of low flow, these 'rock dams' provided little cover and would wash away during higher flows in the winter and spring. To create more permanent habitat, 4 MBF of natural wood and 16 ELWD™ (Type 20 N) structures were introduced along 152 m of Evans Creek (i.e., site 3) in October of 2005 (Picture 1). Approximately 44 pieces of natural wood were placed in the site, these consisted of pulp logs that came in a variety of sizes as large as 10 m long and 0.6 m in diameter. The ELWd™ structures were formed from eight smaller diameter logs to form structures that were approximately 63-68 cm in diameter and 6 m long. The ELWd™ structures were cabled to nearby cottonwood trees after construction. Objectives of this restoration project were to create pools, provide cover, and increate channel complexity. To evaluate achievement of objectives, habitat attributes and trout density at the restored site were compared to similar metrics at nearby control reaches.

Picture 1. Example of the ELWD™ structure placed at site 3 in Evans Creek in 2005. This structure moved in 2008.

Immediate changes to habitat attributes due to restoration activities were also evaluated at a Benewah mainstem site that was located within a 650 m reach that underwent large-scale channel reconstruction in 2008. Along this restored reach, large woody debris was introduced to both stabilize banks and create structure in pool habitats, deep pools were created both through the re-meandering of lost channel length and the concomitant elevating of riffle habitats, and large substrate was imported into designated riffles. Data collected during the 2009 habitat survey were compared to that collected prior to restoration in 2008 to evaluate immediate changes due to implementation. Comparisons of trout data were not conducted to the inability to effectively sample the newly restored deep pool habitats in this reach.

3.2.2.2 Evaluating thermal refugia in restored Benewah reaches

Thermal heterogeneity at fine-scale, riffle/pool sequences was assessed in upper Benewah mainstem reaches in mid-summer using a rapid-response digital thermistor probe (Cooper Instruments model TM99A-E, accurate to within ±0.1 °C). The thermistor probe was attached to a surveying rod, permitting simultaneous measurements of depth and temperature. While wading upstream, water temperature and depth (m) were recorded both at a riffle and at the deepest part of the associated pool upstream. The relationship between residual pool depth and the calculated riffle-pool temperature difference was examined to evaluate changes in the availability of thermal refugia in upper mainstem reaches in Benewah Creek before and after restoration.

3.2.2.3 Monitoring beaver dams in upper Benewah mainstem reaches

Beaver dams were surveyed during two different time periods along a 3.5 km reach of the upper Benewah mainstem that is currently receiving treatment as part of Phase 2 restoration implementation. The first survey occurred from late June to early July, and the latter survey occurred during early October; the duration of each survey typically lasted 7-10 d. Various attributes that described dam morphology and in-stream habitat influenced by the dam were measured and recorded at each dam surveyed in each time period. Dam morphology attributes included dam type, which indexed the apparent stability, complexity, and derelict state of the dam; the materials used to build the dam; and the dam width and height (Table 2). The in-stream habitat influenced by the dam was considered to be that channel length that was backwatered by the dam (i.e., the length of channel upstream over which water surface elevation did not change). Attributes evaluated along the backwatered channel length included the inundated surface area, pool surface area, pool volume, and mean residual pool depth. Inundated surface area was calculated by multiplying the backwatered channel length by the average of five wetted channel widths measured at equidistant intervals along the channel length. Pools were identified and measured along the backwatered length using the criteria and protocol described above (see *Pool volume*). Pool lengths and their respective measured widths and depths were used to calculate the collective pool surface area and volume, and the mean residual depth for pools associated with each dam. Paired data collected at dams surveyed in both time periods were used to examine seasonal differences in mean values for dam height, inundated surface area, pool surface area, pool volume, and mean residual pool depth.

Table 2. List of categories that describe available dam types and dam-building materials. Active dams are considered those in which a presence of fresh material (e.g., green stems, recently placed mud) has been 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

3.2.3 Effectiveness monitoring - Responses to brook trout removal in Benewah

In late summer and early fall, single-pass electrofishing was used to remove non-native brook trout from select upper mainstem reaches in the Benewah watershed. Removal efforts occurred after population surveys were completed in the upper Benewah watershed to prevent the removal activities from biasing index site abundance estimates. Compared with previous years of suppression, electrofishing efforts were reduced in 2009 to concentrate sampling along a 2 km mainstem reach from the 12-mile bridge upstream to the confluence of the West and South Forks. High densities of adult brook trout have consistently been found in this reach, and suitable spawning habitat is seemingly much more prevalent in this reach than in mainstem reaches downriver that are of lower gradient and dominated by beaver dam pools. In addition, a temporary trap was installed immediately upriver of 12-mile bridge to intercept ascending brook trout and hence prevent access to habitat upriver. The trap consisted of a downriver fixed weir that spanned most of the channel width but maintained a narrow opening along one bank to allow passage. Another fixed weir spanning the entire channel width and obstructing further upriver movement was installed approximately 25 m upriver. Periodically, the 25 m of enclosed stream length was shocked to remove any brook trout that had entered. This alternative approach was expected to reduce our removal efforts given the ease with which the trap enclosure could be shocked compared with the inordinate amount of time that has been allocated during past efforts to shocking the deeper, pool habitats from 9-mile bridge to 12-mile bridge. The RBW trap at 9-mile bridge also remained deployed in 2009 from the end of spring trapping through the end of the removal efforts to prevent brook trout from ascending into the upper watershed.

Trends in brook trout abundance were examined using various indices to evaluate the population response to the suppression program. Changes in numbers of total brook trout, adult brook trout, and brook trout greater than 150 mm in length, removed from the 2 km reach were examined over the period from 2005 to 2009 given that this reach had been consistently sampled in all five years. Because maturation data were not collected from sacrificed brook trout in 2009, maturation probability models derived from the 2008 data were used to assign adult status to fish removed in 2009 based on their measured length.

Temporal trends in age 1+ brook trout in tributaries of the upper Benewah watershed were examined over the years 2003-2009, and compared to those trends observed in the upper Alder Creek watershed over the same time period. Initially, all ten composite reaches from upper reaches of both watersheds were included in a global ANOVA repeated measures model to evaluate potential differences in trajectories among watersheds (Table 1). Only upper Benewah composite reaches were used given the lack of brook trout captured in reaches in the lower watershed. Significant interactions between watershed and year supported separate analyses by watershed. Repeated measures models were constructed for both the depletion abundance estimates and the first pass catch to compare interpretations of model results between the two abundance indices (see *Repeated measures analysis for examining cutthroat trout trends* for details on analytical methods).

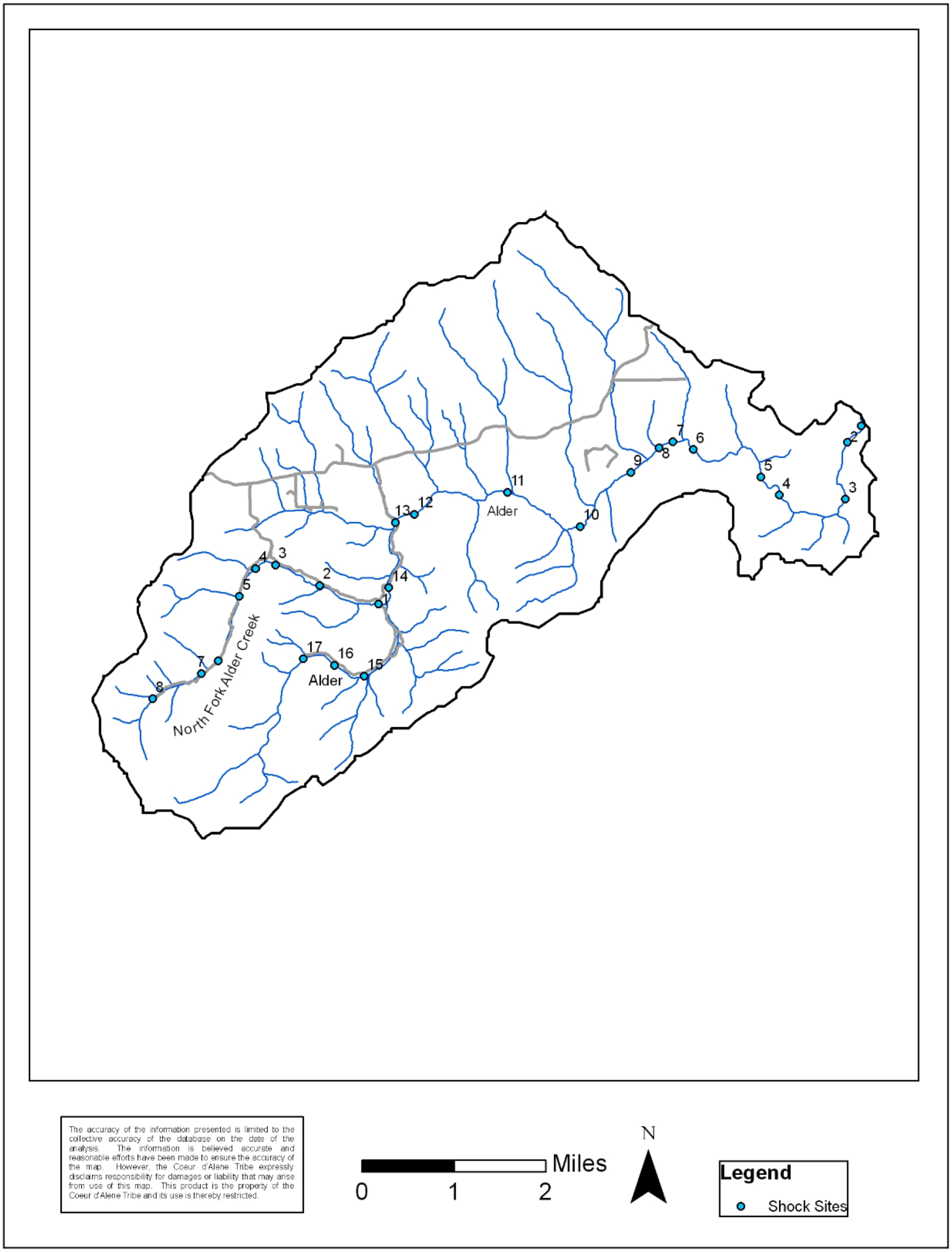

Figure 2. Map of Alder Creek depicting index sites sampled during salmonid population surveys in 2008.

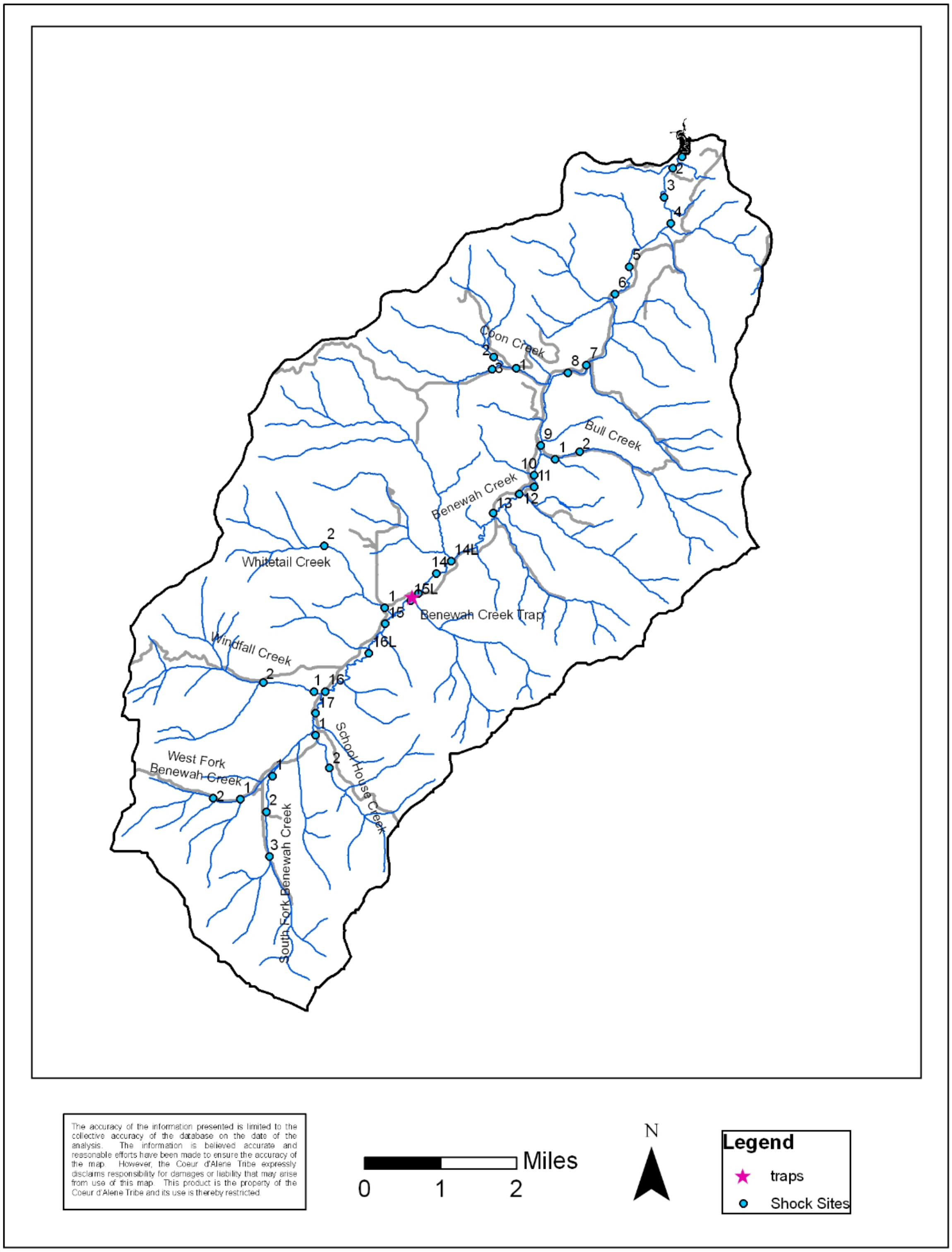

Figure 3. Map of Benewah Creek depicting index sites sampled during salmonid population and habitat surveys in 2008. The location of the traps and PIT-tag array is indicated by the star.

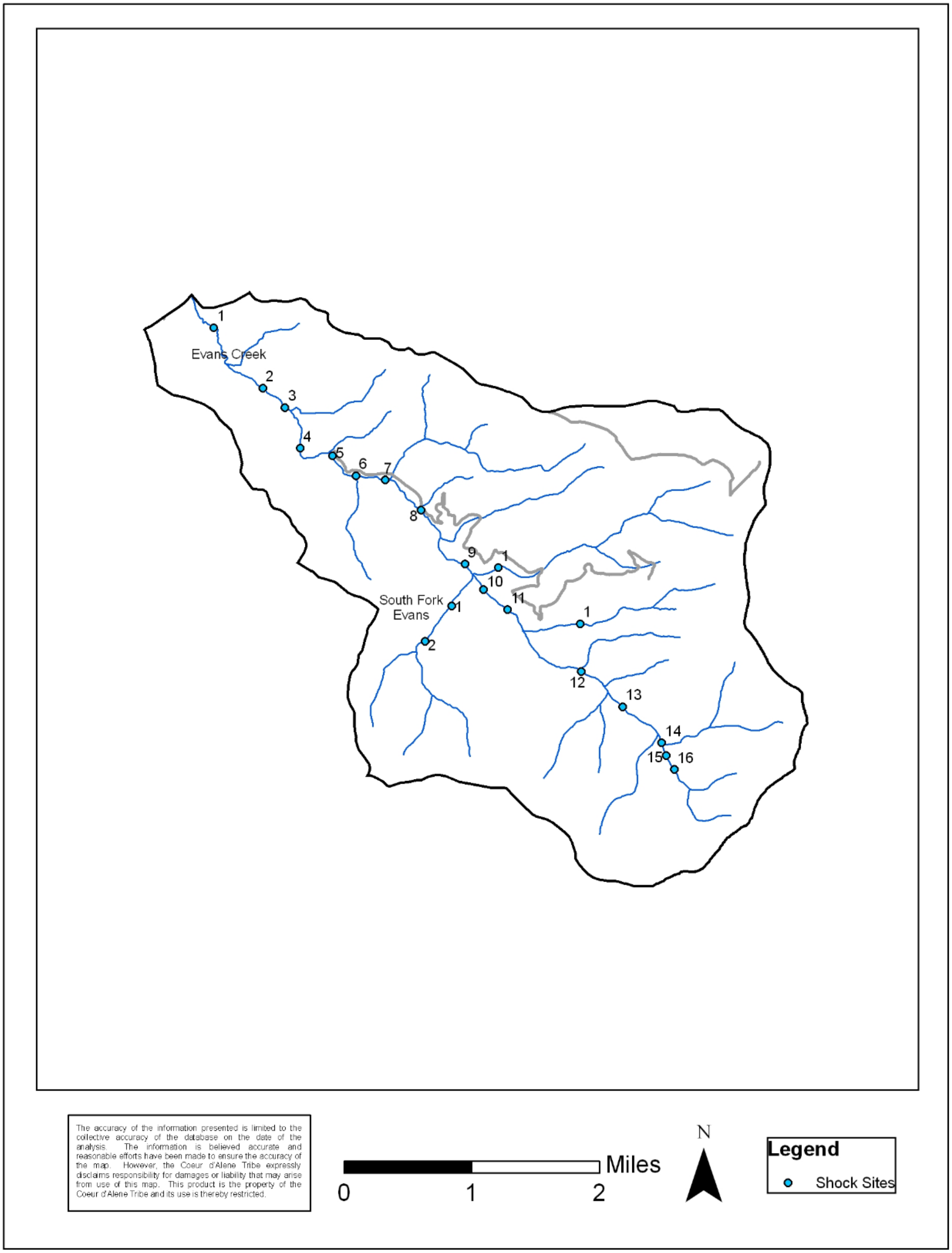

Figure 4. Map of Evans Creek depicting index sites sampled during salmonid population surveys in 2008.

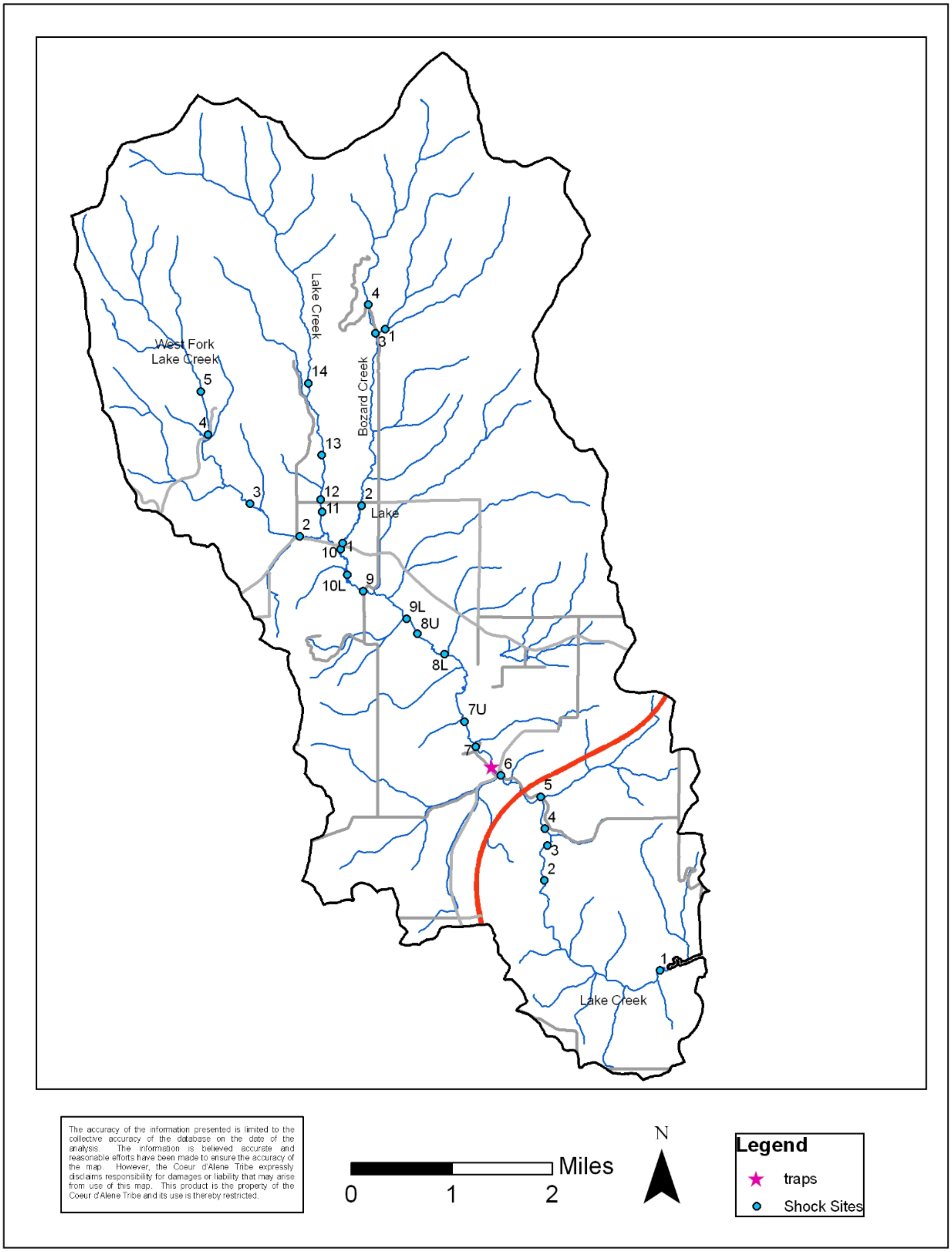

Figure 5. Map of Lake Creek depicting index sites sampled during salmonid population surveys in 2008. The location of the traps and PIT-tag array is indicated by the star.

3.3 Results

3.3.1 Trend and status monitoring – Biological indices

3.3.1.1 Lake Creek adult adfluvial cutthroat trout migration

The RBW trap was installed in the mainstem of Lake Creek on March 14 and was removed on May 29 in 2009, yielding an operable period of 77 d. During the operable period, the trap was checked a total of 65 d (84% of the days), and was considered fishing approximately 87% of the time that it was being monitored. The trap was considered compromised, with water flowing over the trap panels, during a heavy flow event that lasted from March 20 to March 25, and during brief freshets on April 6-9 and April 13 that were part of a more sustained high flow period from April 4 to April 18 (Figure 6). The DN trap was installed in Lake Creek on April 27, after high discharge periods had ceased, and was removed on July 8 in 2009, yielding an operable period of 73 d (Figure 6). During this time, the trap was checked a total of 42 d (58% of the days); more frequent monitoring occurred during the first 46 days of operation (75% of the time). Throughout the period in which it was monitored, the DN trap was considered effectively fishing 100% of the time.

A total of 127 adfluvial adult cutthroat trout was captured in the RBW trap (Table 3). Ninety-five of these were identified as females (75%) with a mean length and weight of 378 mm and 526 g, respectively. Thirty-one of the fish were identified as males with a mean length and weight of 401 mm and 577 g, respectively. Though adults were captured throughout April and the first half of May, 67 of the 127 fish (53%) were captured from April 17 to April 22 after the period of sustained high flows (Figure 7). Of the 127 adults captured at the trap, 121 received opercle punches and 105 received PIT-tags. Fifteen of the 127 did not have an adipose fin indicating that they had been tagged in previous years; five of the 15 (33%) did not scan.

A total of 133 adfluvial adults was captured in the DN trap, in addition to five other fish, presumed to be post-spawn outmigrants, that were captured by shocking the reach between the DN and RBW traps after DN trap installation (Table 3). Of these 138, 95 were identified as females (mean length of 379 mm; mean weight of 491 g) and 42 as males (mean length of 398 mm; mean weight of 559 g). Noticeably, the mean condition factor was significantly lower (t = 7.5, $p < 0.001$) for females captured in the DN trap (0.87) than for females caught in the RBW trap (0.95), indicating that many of the outmigrating females likely spawned (Table 3). Generally, catch rates of outmigrating adults declined gradually throughout the time period in which the DN trap was operable (Figure 7). However, given that the largest daily catch rate of 15 fish was observed two days after trap installation, it was likely that a portion of those fish that had spawned and outmigrated early were not captured. Eighty-one of the PIT-tagged adults that had either been tagged or detected at the RBW were detected moving back downriver. Mean elapsed period between detections for these fish was greater for males, 18.5 d, than for females, 13 d.

Nintety-two of the 133 adults captured at the DN trap had a detectable opercle punch, yielding a spawner abundance estimate of 175 fish (± 10). Only 22 of the 41 males (54%) compared with 69 of the 91 females (76%) captured in the DN trap had an opercle punch indicating that more males than females had escaped capture at the RBW trap. Of the adult fish captured moving downriver, 10 of the 85 that had both an opercle punch and the presence of an adipose fin (indicating that the fish had been PIT-tagged this year at the RBW trap) did not scan, which yielded an estimated percent tag loss of 11.7%.

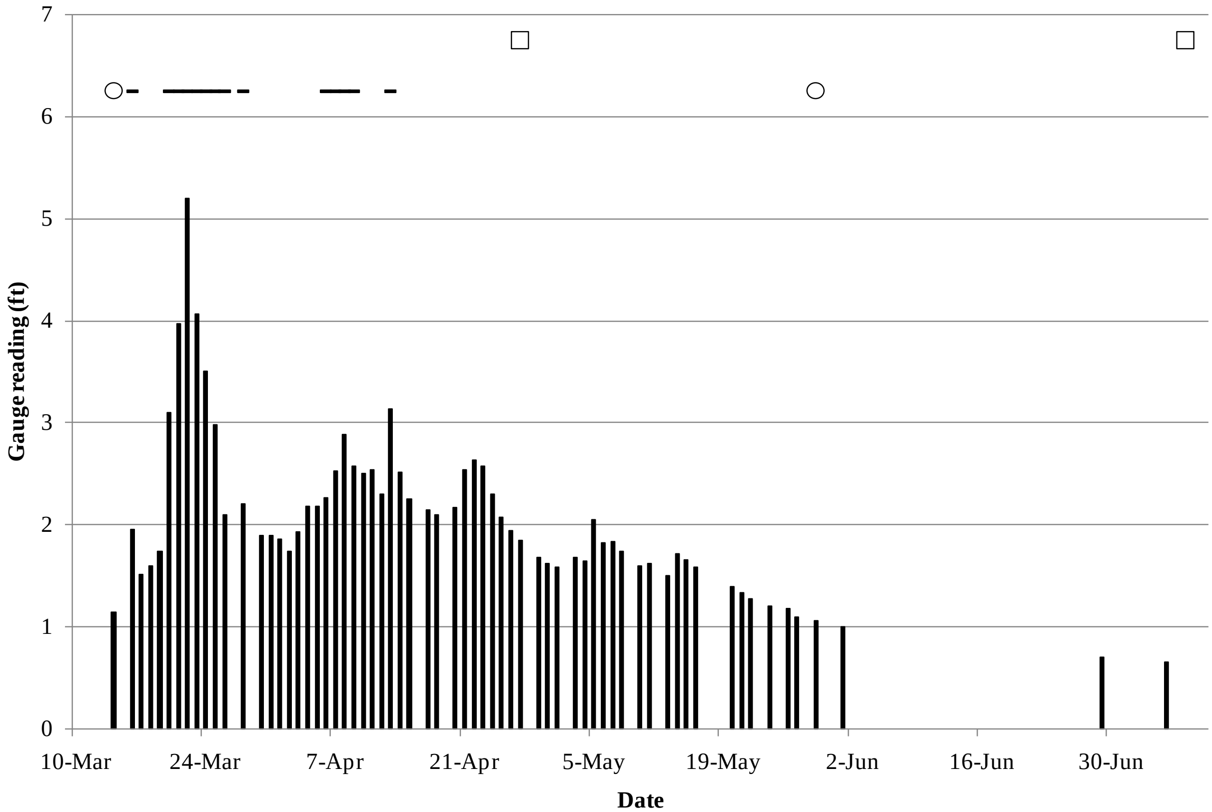

Figure 6. Gauge height readings (ft) collected at the old H95 bridge during the 2009 migratory period in Lake Creek. Solid bars at the top indicate periods when the RBW trap was compromised. Open circles and squares at the top represent installation and removal dates for the RBW and DN traps, respectively.

Table 3. Length, weight and condition factor means and standard deviations (SD) for adult adfluvial cutthroat trout captured during their upriver and downriver migrations in Benewah and Lake creeks in 2009.

		Total length (mm)			**Weight (g)**		**Condition Factor**	
Gender	**N**	**Range**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
			Benewah Creek downriver [a]					
Female	20	329 - 430	369.6	28.4	412.3	81.3	0.81	0.05
Male	8 [b]	360 - 520	386.5	54.3	430.2	29.8	0.87	0.05
			Lake Creek upriver [c]					
Female	95	321 - 560	378.3	33.3	526.3	178.0	0.95	0.07
Male	31	333 - 451	401.0	24.9	576.8	86.1	0.90	0.08
			Lake Creek downriver [c]					
Female	95	310 - 568	379.3	39.0	490.6	191.6	0.87	0.08
Male	42	334 - 471	398.2	28.6	559.0	127.5	0.87	0.06

[a] Two fish of undetermined sex also captured

[b] Seven of the eight fish ranged from 360 to 379 mm in length; mean weight calculated from these fish

[c] One fish of undetermined sex also captured

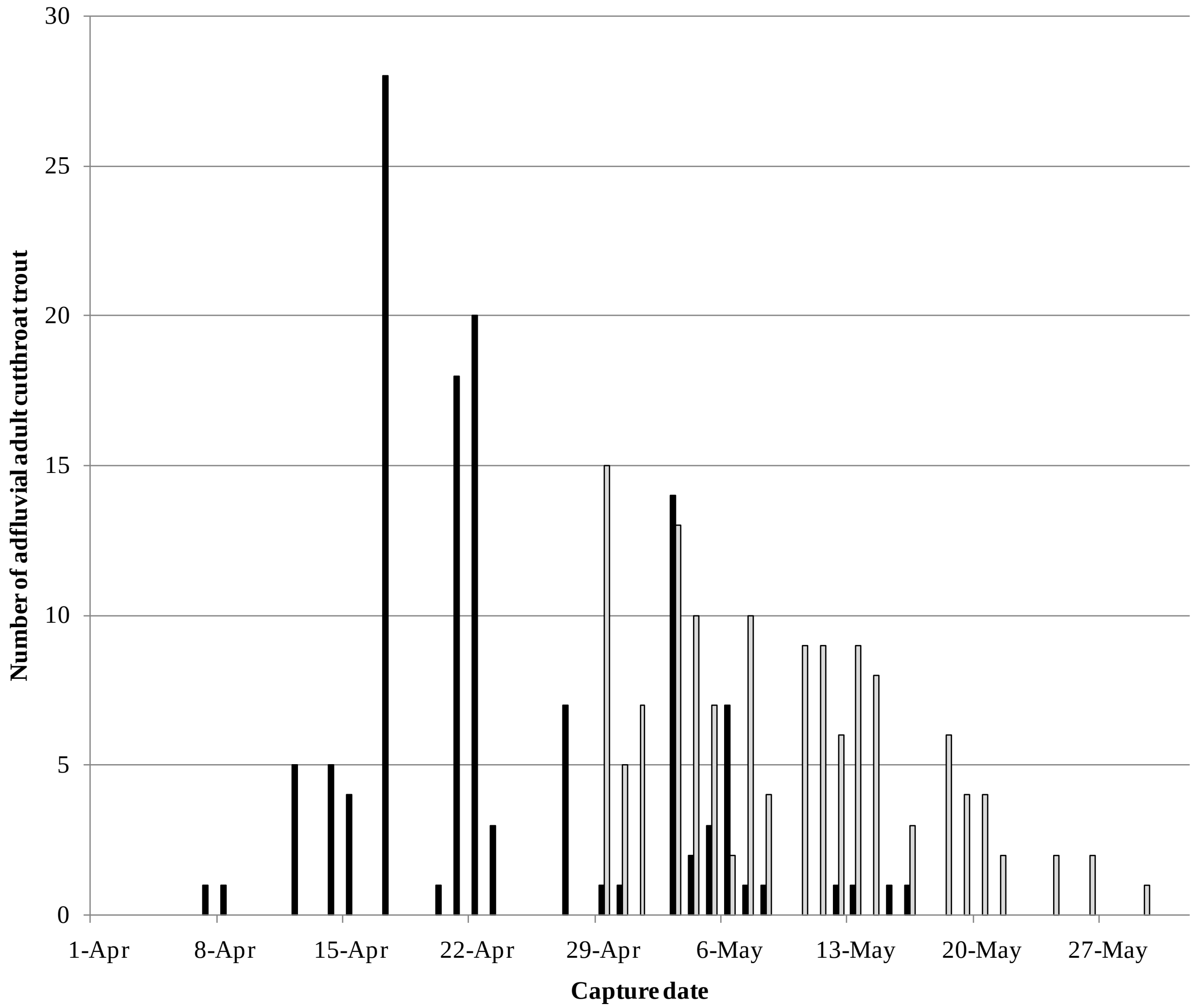

Figure 7. Timing of adult adfluvial cutthroat trout captured during their upriver (black bars) and downriver (light gray bars) migrations in Lake Creek, 2009.

Eighteen adult cutthroat trout that had been tagged as juveniles in previous years were detected in either the RBW or DN traps in 2009 (Table 4). Two, four, nine, and three were tagged as juveniles in 2005, 2006, 2007, and 2008, respectively. All four of the females that were tagged as juveniles in 2005 and 2006 had also been detected in either 2007 or 2008, with three of the four detected last year, and one fish detected in both years. The three fish tagged in 2008 that were all captured in the DN trap on May 18 were inadvertently mistaken for tagged fish from 2009 release trials, and consequently were likely to be of similar size to outmigrating juveniles. Notably, all three of these fish were less than 125 mm when tagged in 2008. Fish from the 2007 tagging group displayed two-year growth increments that ranged from 144 to 215 with a mean value of 184. Fish that had been at large for 3 and 4 years since tagging respectively displayed mean total length changes of 230 and 220 mm, indicating that annual body length increments likely decrease markedly with age after maturation. Indeed, the female that had been detected in traps over the last three years only increased in length between trappings by 15 and 1 mm, respectively.

Table 4. Morphometric data for adfluvial cutthroat trout PIT-tagged in previous years and captured in Lake Creek traps in 2009. Detection data in previous years, either by the array (i.e., no size data available) or in the trap, are also provided.

	Tagging information		2009 morphometric data			Juvenile to adult data		2008 Detection information			2007 Detection information		
Sex	Year	Total length (mm)	Total length (mm)	Weight (g)	Location	Years elapsed	Length change (mm)	Detected	Total length (mm)	Weight (g)	Detected	Total length (mm)	Weight (g)
F	2005	146	373	464.0	RBW [a]	4	227	Y	372	424.3	Y	357	372.4
F	2005	175	388	568.6	RBW	4	213	.	.	.	Y	346	338.0
F	2006	174	392	601.2	RBW	3	218	Y	.	.	.	.	.
F	2006	170	397	582.0	DN	3	227	Y	382	491.8	.	.	.
M	2006	163	399	561.0	DN	3	236	.	.	.	.	.	.
M	2006	163	403	575.0	DN	3	240	.	.	.	.	.	.
F	2007	145	351	362.0	DN	2	206	.	.	.	.	.	.
F	2007	164	352	427.0	RBW [a]	2	188	.	.	.	.	.	.
F	2007	173	362	477.9	RBW [a]	2	189	.	.	.	.	.	.
F	2007	181	351	434.7	RBW [a]	2	170	.	.	.	.	.	.
F	2007	210	396	578.0	RBW [a]	2	186	.	.	.	.	.	.
F	2007	184	355	434.0	RBW	2	171	.	.	.	.	.	.
M	2007	187	375	502.5	RBW	2	188	.	.	.	.	.	.
M	2007	177	392	543.0	DN	2	215	.	.	.	.	.	.
M	2007	190	334	.	DN [a]	2	144	.	.	.	.	.	.
.	2008	95	.	.	DN [b]	1	.	.	.	.	.	.	.
.	2008	118	.	.	DN [b]	1	.	.	.	.	.	.	.
.	2008	123	.	.	DN [b]	1	.	.	.	.	.	.	.

[a] Captured and detected during both upriver and downriver migrations

[b] Captured on May 18 but presumed to be a 2009 release trial recapture and consequently not measured for length

Over the time period from 2005-2007, 2272 cutthroat trout have been PIT-tagged during spring outmigration periods and were deemed alive upon release. Of these fish, only 41 (1.8%) have been uniquely detected either by the array or in the traps after at least one year post-release. Detected fish generally were larger and tagged earlier as juveniles than those PIT-tagged fish that have not been detected. For example, only approximately 15% of the fish had exceeded 160 mm in length at time of tagging. However, of those fish that have been detected, 65% were at least 160 mm when tagged (Figure 8). In a similar manner but not as dramatic, approximately 50% of all PIT-tagged fish had been tagged prior to May 4 (Julian date of 124), whereas 75% of those that have been detected had been tagged before this date (Figure 9).

3.3.1.2 Lake Creek juvenile cutthroat trout migration

A total of 2526 juvenile cutthroat trout was captured by the DN trap in Lake Creek in 2009. Fish were captured throughout the month of May and into June at variable rates with capture rates markedly decreasing after the first week in June (Figure 10). Approximately a third of the fish, 810 juvenile migrants, was captured during the first week in June. Moreover, more than 100 juveniles were processed on several other occasions, May 1, 10, 14, and 21, with periods of low trap capture either preceding or following these high capture events. Given the lack of a definable distribution of outmigration times for juveniles throughout the early period of trap operation and the large number of fish captured soon after trap installation (e.g., 124 on May 1), it is likely that a portion of the early part of the outmigration was not sampled.

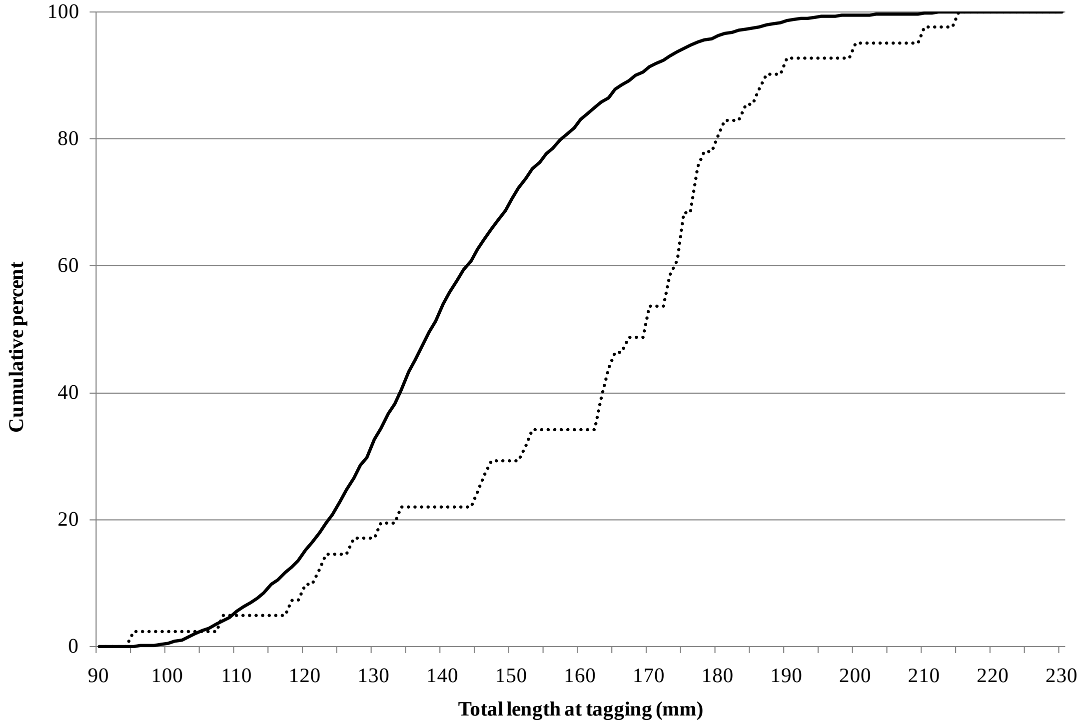

Figure 8. Cumulative distribution curves of length at PIT-tagging for all cutthroat trout tagged from 2005-2007 (solid line) and for cutthroat trout detected at least one year later (dotted line).

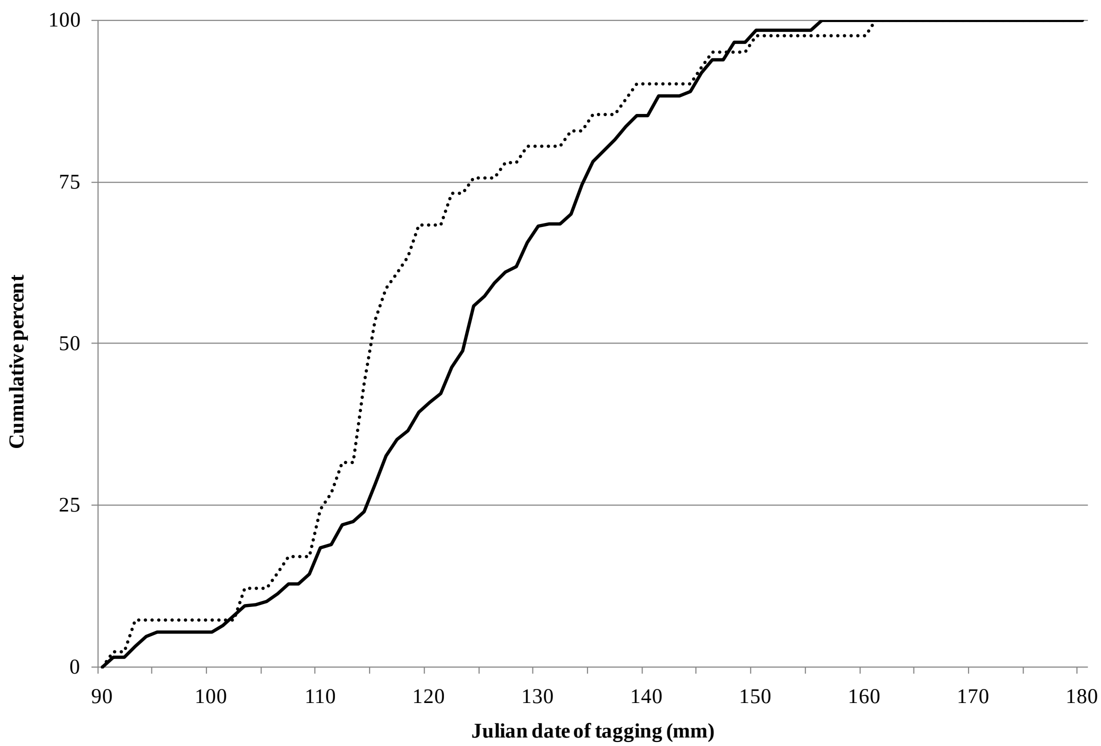

Figure 9. Cumulative distribution curves of date at PIT-tagging for all cutthroat trout tagged from 2005-2007 (solid line) and for cutthroat trout detected at least one year later (dotted line).

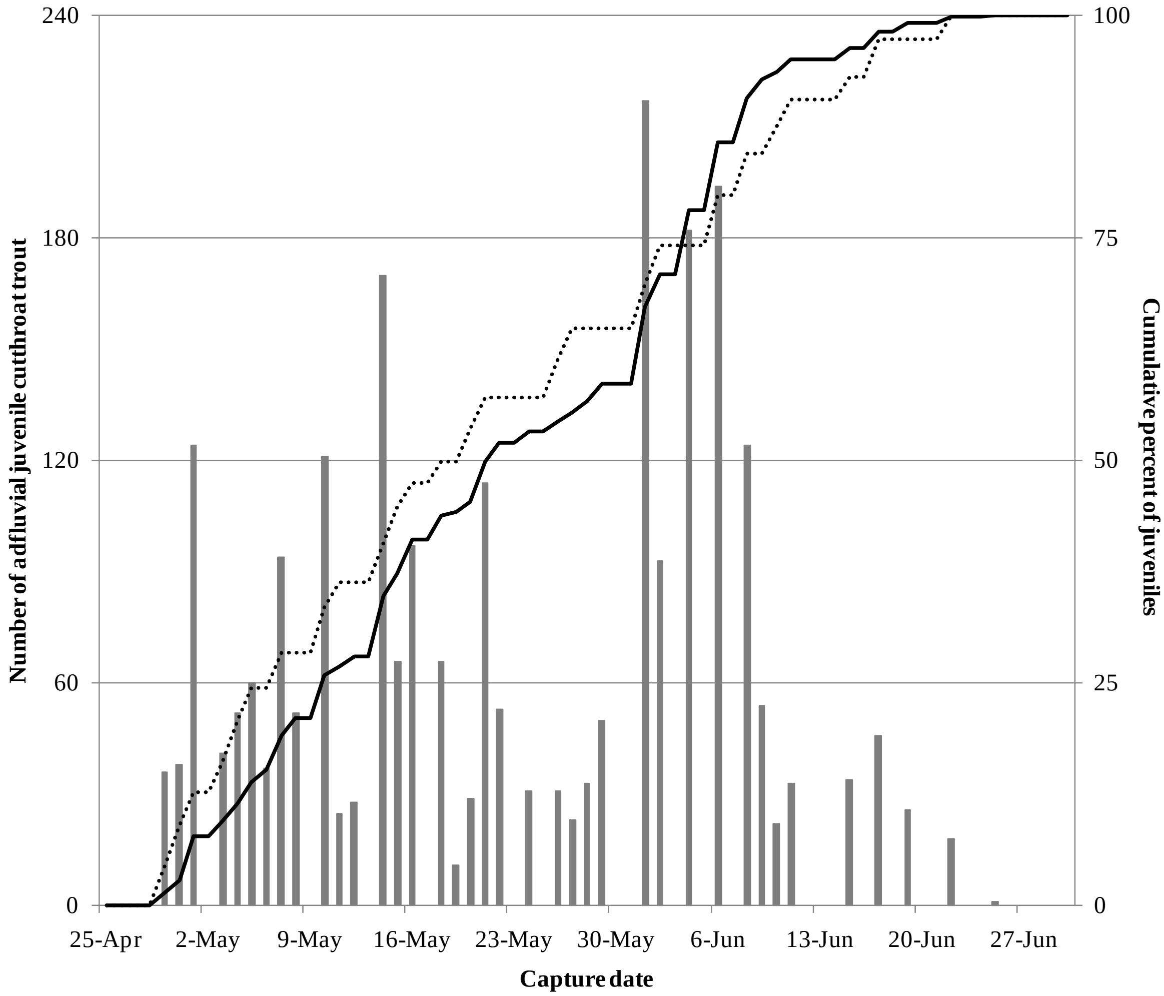

Figure 10. Timing of juvenile adfluvial cutthroat trout captured in the downriver trap during their outmigration in Lake Creek, 2009. Numbers of juveniles (gray bars) along with the cumulative distribution curves of all captured juveniles (solid line) and PIT-tagged juveniles (dotted line) are presented.

A difference in the size distribution of captured outmigrating juveniles was detected with the mean total length increasing from 138 mm before May 23 to 144 mm thereafter (Figure 11). However, given that we were unable to sample throughout most of April, the mean size of fish captured early by our trap may not accurately reflect the size distribution of all early outmigrants. In addition to those juveniles considered to be actively outmigrating to the lake, 64 other fish captured in the DN trap were classified as likely residents given their external markings. Mean total length of these 64 fish was 179 mm.

Of the 2526 juveniles captured, 696 (28%) received PIT tags. Generally, fish were tagged representatively throughout most of their outmigration as supported by the similarity in the cumulative distribution curves for PIT-tagged juveniles and all captured juveniles (Figure 10). In addition, the length distribution of PIT-tagged adfluvial juveniles was similar to that for all juveniles captured in the DN trap ($\chi^2 = 7.0$, $p = 0.32$; Table 5), with approximately 80% of both groups ranging between 121 and 160 mm. Nineteen of the 64 fish that were classified as resident cutthroat trout also received PIT tags.

Table 5. Number and relative percent of adfluvial juvenile cutthroat trout captured and PIT-tagged of different length groups in Lake and Benewah creeks, 2009.

	Lake Creek				Benewah Creek			
Length	All fish captured		Tagged fish		All fish captured		Tagged fish	
group (mm)	Number	Percent	Number	Percent	Number	Percent	Number	Percent
81-100	9	0.4	0	0.0	5	3.2	0	0.0
101-120	193	7.7	55	7.9	38	24.4	16	16.5
121-140	1052	41.7	266	38.2	58	37.2	37	38.1
141-160	992	39.3	285	40.9	39	25.0	31	32.0
161-180	241	9.6	80	11.5	14	9.0	11	11.3
181-200	28	1.1	7	1.0	2	1.3	2	2.1
>200	7	0.3	3	0.4	0	0.0	0	0.0

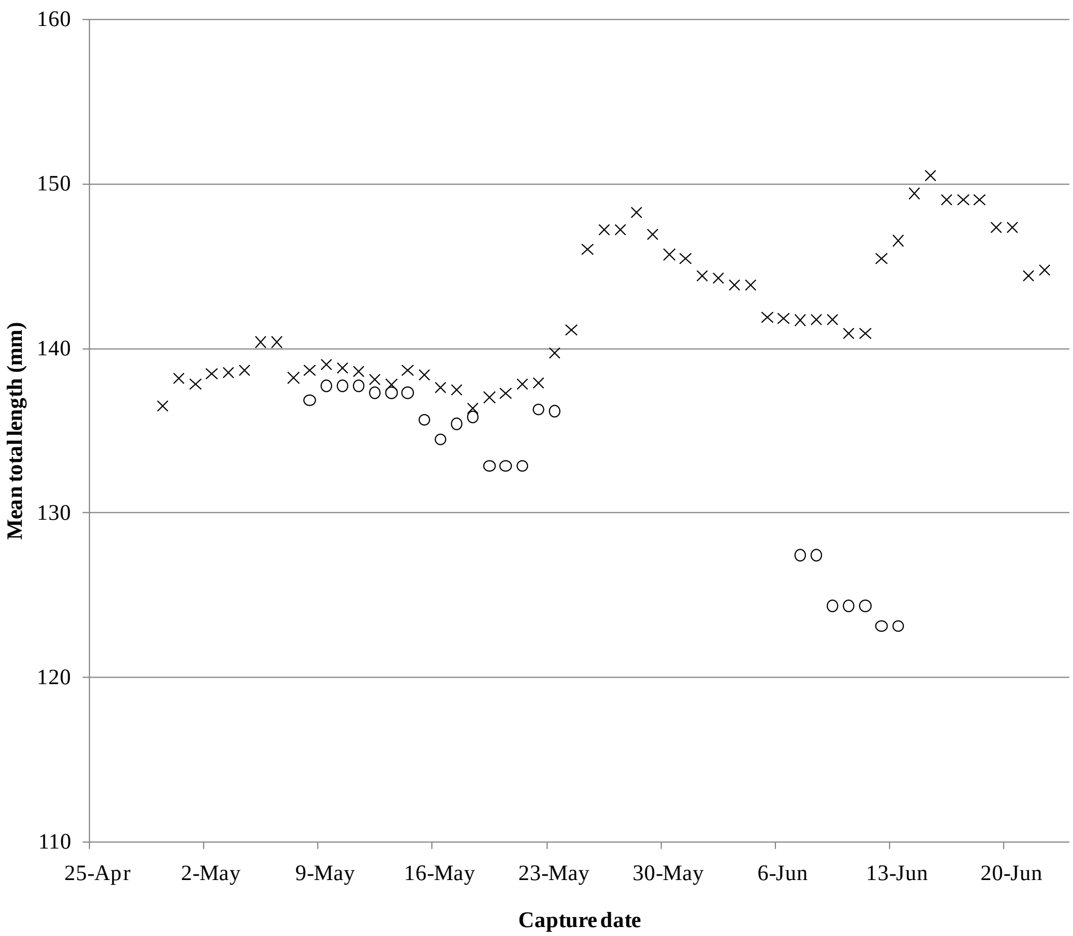

Figure 11. Seven-day daily moving averages of total length (mm) for adfluvial juvenile cutthroat trout captured in DN traps in Lake (x) and Benewah (o) creeks in 2009. For each day, a mean was calculated only if more than 20 fish were captured over the period that encompassed the 3 days before and after the given day.

An overall juvenile outmigrant abundance estimate of 2859 ±111 was generated for Lake Creek in 2009 using the data from nine release trials conducted from April 30 to June 25 (Table 6). Release trial periods typically lasted 5-6 d with an average of approximately 60 tagged fish released in each trial. In addition, mortality/retention trials were conducted in association with the first eight release trials in which an average of 33 tagged fish were held overnight for each trial; all 264 fish were found to retain their tags and survive the trial before their release. Estimated trapping efficiencies were very high, exceeding 90%, throughout most of the trial periods, until June when estimated efficiencies decreased over time from 98 to 51%. Generally, other than the first trial period, released fish were recaptured in the trap during the trial period of their release, as evidenced by similar values for number of fish released and number of fish available for recapture (which is discounted by those captured in subsequent trial periods). After adjusting for trial-specific trap efficiencies, the estimated mean total length of outmigrating adfluvial juveniles in Lake Creek was 141 mm in 2009 (Figure 12).

Table 6. Abundance estimates for juvenile westslope cutthroat trout outmigrating in Benewah and Lake creeks, 2009. Tagged fish were released on the day denoted by the beginning of the trial period. The number of tagged fish available for recapture within each trial period was discounted by those captured during subsequent periods.

Trial period	Total fish captured	Tagged fish released	Tagged fish available for recapture	Tagged fish recaptured	Trap efficiency estimate	Abundance estimate	95% confidence interval
			Benewah Creek				
May-12 - May-16	83 [a]	35	28	10	0.38	219	115 - 323
May-16 - May-21	25	20 [b]	18	3	0.20	119	19 - 218
May-21 - May-27	12	15	13	11	0.85	14	10 - 18
May-27 - Jun-05	8	7	7	2	0.35	21	2 - 41
Jun-05 - Jun-11	22	4	4	3	0.79	28	16 - 39
Jun-11 - Jun-22	7	11	11	1	0.15	42	-7 - 91
Overall						**442**	**289 - 596**
			Lake Creek				
Apr-30 - May-05	351 [c]	63	48	46	0.96	366	344 - 388
May-05 - May-11	329	58	57	53	0.93	353	327 - 380
May-11 - May-16	361	57	56	56	1.00	361	361 - 361
May-16 - May-21	220	50	48	45	0.94	234	216 - 253
May-21 - May-27	138	52	49	44	0.90	153	137 - 169
May-27 - Jun-02	393	56	55	54	0.98	400	385 - 415
Jun-02 - Jun-08	500	66	66	51	0.78	644	558 - 730
Jun-08 - Jun-17	189	73	73	53	0.73	259	219 - 299
Jun-17 - Jun-25	45	30	30	15	0.51	87	54 - 121
Overall						**2859**	**2748 - 2969**

[a] Included fish captured from May 8 to May 16

[b] One fish was found dead on the panel so was discounted from those available for recapture

[c] Included fish captured from April 29 to May 5

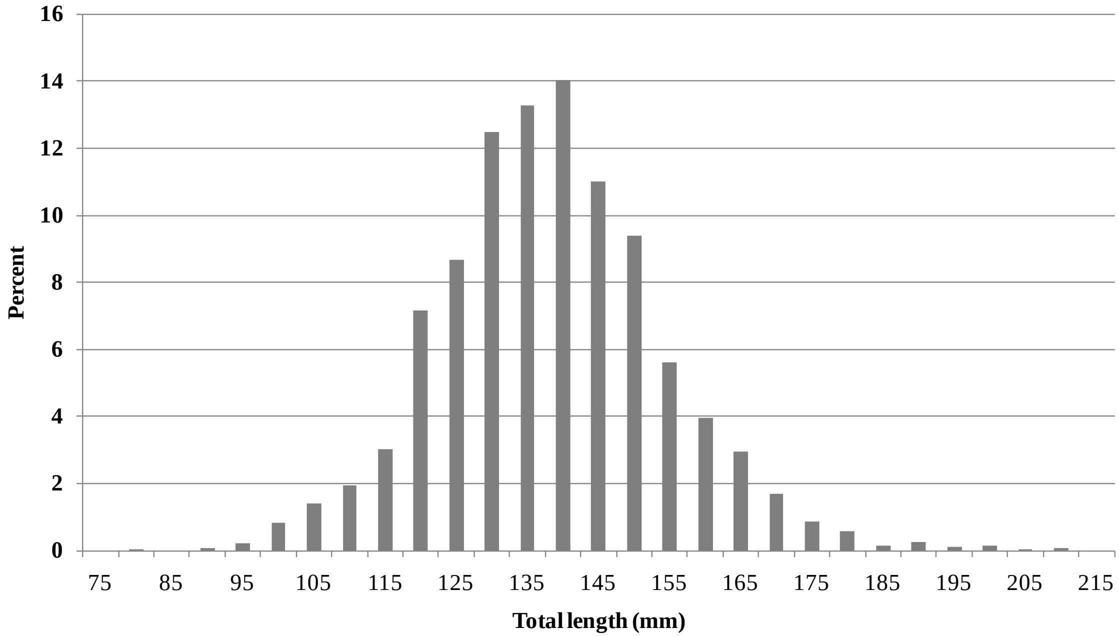

Figure 12. Relative length distribution of outmigrating adfluvial juvenile cutthroat trout in Lake Creek, 2009. Numbers of fish captured were adjusted by trial period specific estimated capture efficiencies.

3.3.1.3 Benewah Creek adult adfluvial cutthroat trout migration

In Benewah Creek in 2009, the RBW was installed on February 20 and was no longer monitored after June 10 because of the absence of fish in the trap's live box (111 d). The trap was considered fishing 88% of the time over the 61 d that it was monitored. However, periodically throughout March and April brief freshets compromised the trap performance, in which panels were observed to be depressed below the water surface (Figure 13). Only one cutthroat trout measuring 233 mm in length was captured by the RBW on May 27. Given the date on which the fish was captured and its size, it was difficult to determine whether this fish was a small adfluvial adult actively moving upriver or a foraging resident fish that had been intercepted. The DN trap in Benewah Creek was installed on May 7 and removed on June 26, yielding an operable period of 51 d. During this time, the trap was checked a total of 21 d (41% of the time), and over the period in which it was monitored was considered to be effectively fishing 100% of the time.

Twenty-one adult adfluvial cutthroat trout were captured in the DN trap, in addition to nine other fish presumed to be post-spawn outmigrants that were captured by shocking the reach between the two traps on May 6 and 8 (Table 3). Of these 30, 20 were identified as females with a mean length of 370 mm and mean weight of 412 g. Notably, the mean weight value was considerably lower than that computed for outmigrating females in Lake Creek. The mean condition factor of 0.81 for females, again appreciably lower than that recorded for Lake Creek females, suggests that many of the fish had likely spawned (incidentally, 7 of the 9 fish captured by shocking were females with a mean condition factor of 0.82). Eight fish were classified as males with a mean length of 387 mm; a value heavily influenced by the one fish of 520 mm. The mean length and weight of the other seven males was 367 mm and 430 g, respectively. Over 50% of the adults (17 of 30) were captured from May 6 to May 11, coincident with trap installation, indicating that a portion of the post-spawn outmigration could have been missed (Figure 14).

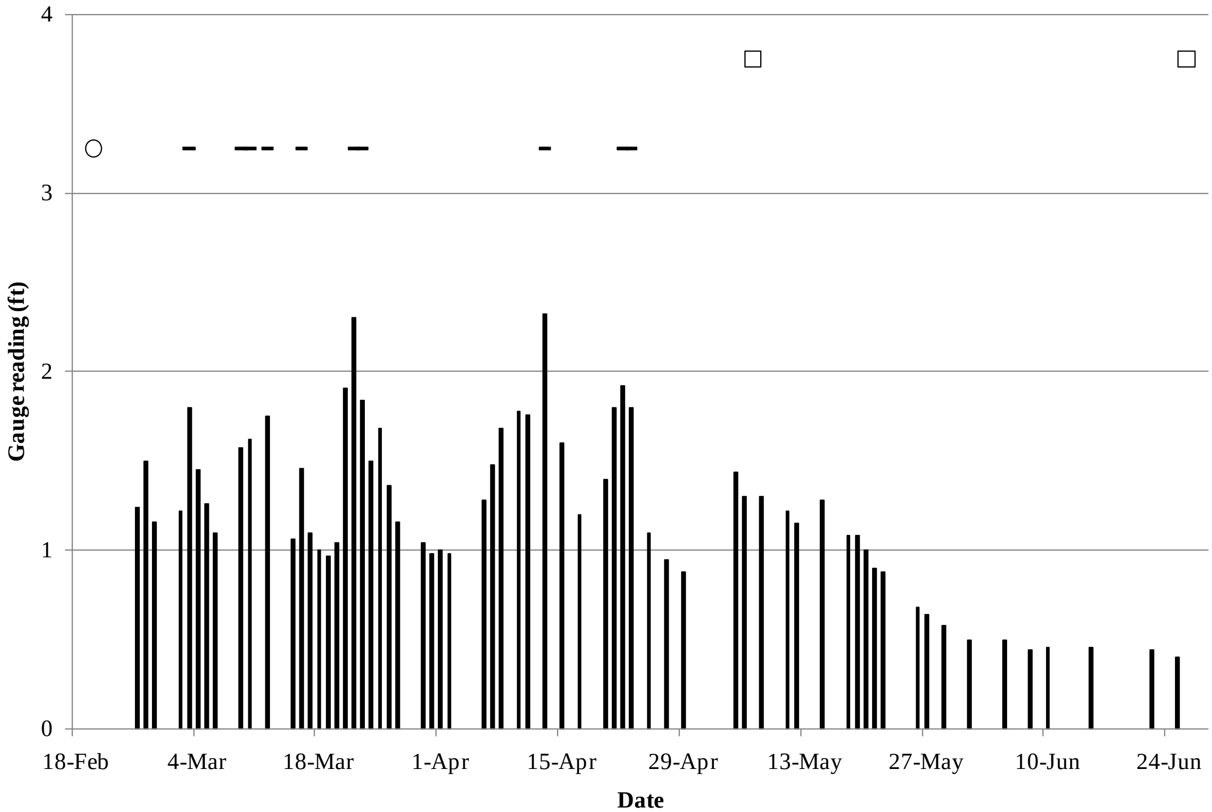

Figure 13. Gauge height readings (ft) collected at 9-mile bridge during the 2009 migratory period in Benewah Creek. Solid bars at the top indicate periods when the RBW trap was compromised. Open circles and squares at the top represent installation and removal dates for the RBW and DN traps, respectively. Note that the RBW was not removed but left intact during the summer to prevent ascension by large mature brook trout.

3.3.1.4 Benewah Creek juvenile cutthroat trout migration

A total of 157 adfluvial juvenile cutthroat trout was captured in the DN trap in Benewah Creek from May 8 to June 22 in 2009. Approximately half of the fish (83 of 157) were captured in the first 8 d of trap operation (Figure 15), suggesting that a portion of the early part of the outmigration was not sampled. A noticeable difference in the size distribution of captured juveniles was observed with the mean total length decreasing from 136 mm before May 23 (a value similar to the computed mean of total length for juveniles captured in Lake Creek during the same time period) to 126 mm thereafter (Figure 11). Notably, the length distribution of captured adfluvial juveniles was significantly different ($\chi^2 = 79$, $p = <0.001$) between watersheds, with a larger percentage of fish in the 101-200 mm range but a smaller percentage in the 141-160 mm range in Benewah Creek than in Lake Creek (Table 5). Only two of the 157 (total lengths of 147 and 149 mm) had exterior markings (e.g., faint red slash, dense spotting pattern on anterior portion of flank) that resembled those of a cutthroat trout hybridized with a rainbow trout. Seven other cutthroat trout captured in the DN trap were classified as likely residents given their external markings; mean total length of these 7 fish was 187 mm. Other trout that were captured in the DN trap included two fish with total lengths of 224 and 231 mm that were considered to be either resident hybrids or rainbow trout, and four brook trout with lengths ranging between 134 and 153 mm.

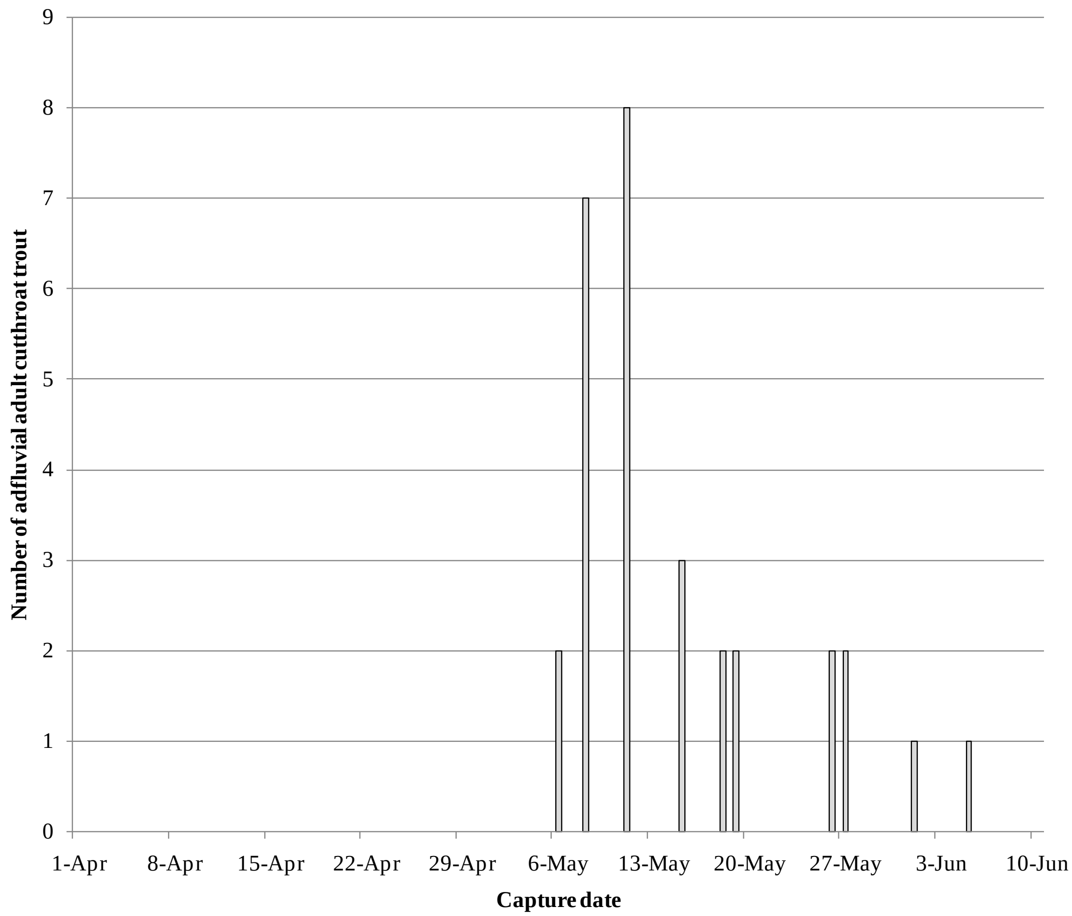

Figure 14. Timing of adult adfluvial cutthroat trout captured during their downriver migration in Benewah Creek, 2009

Of the 157 adfluvial juveniles captured, 97 (62%) received PIT tags. Fish were generally tagged representatively throughout the outmigration period as supported by the similarity in the cumulative distribution curves for PIT-tagged juveniles and all captured juveniles (Figure 15). In addition, the length distribution of PIT-tagged adfluvial juveniles was similar to that for all juveniles captured in the DN trap ($\chi^2 = 6.5$, $p = 0.37$; Table 5), with approximately 85% of both groups ranging between 101 and 160 mm in total length. Four of the seven fish classified as residents received PIT tags.

Nine fish that had been tagged as juveniles in 2008 were detected either by the PIT-tag array or in the DN trap in 2009 (Table 7). Three of the nine fish were captured in the DN trap, with two of these classified as resident fish based on their external markings and size (i.e., > 180 mm). Five of the other six fish detected were all less than 130 mm in total length at time of tagging in 2008, and were typically detected briefly by the array during abbreviated time periods from March 19 to April 16.

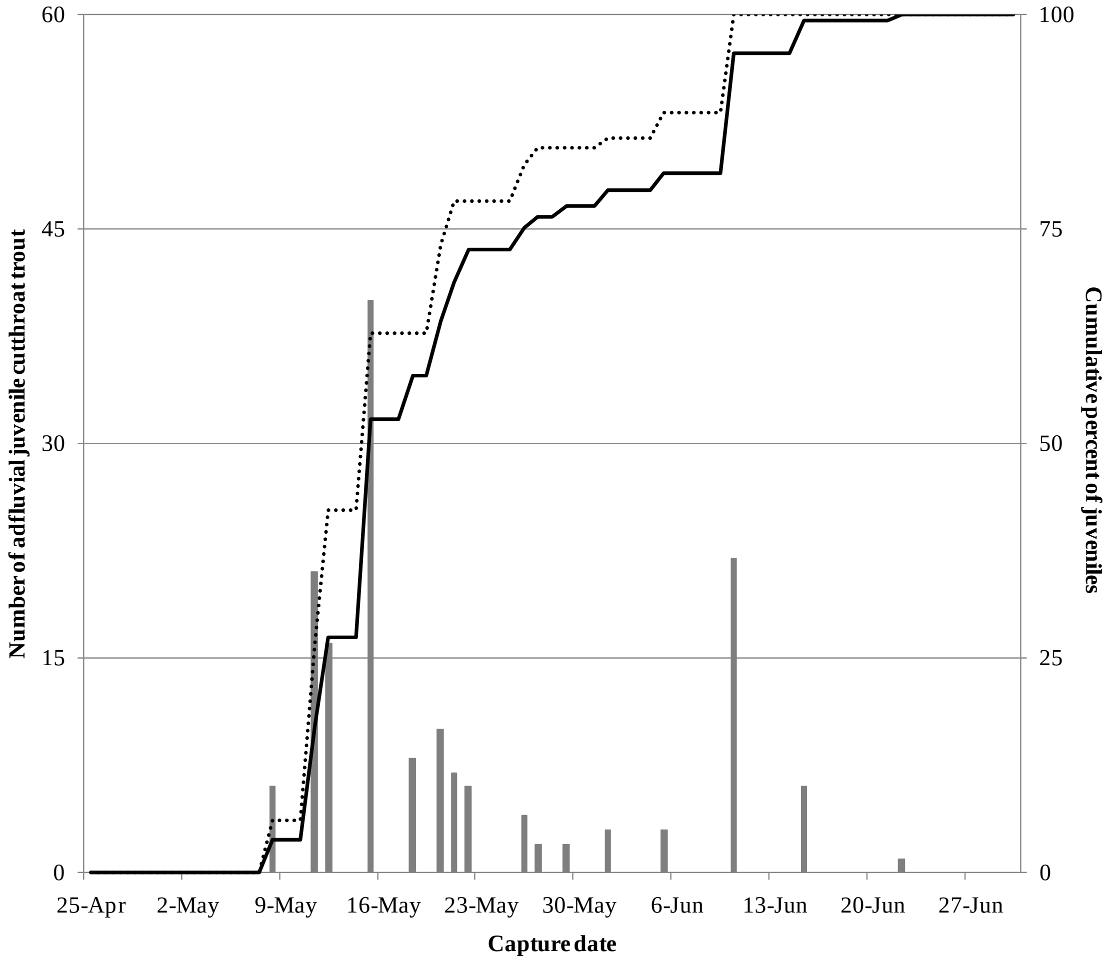

Figure 15. Timing of juvenile adfluvial cutthroat trout captured in the downriver trap during their outmigration in Benewah Creek, 2009. Numbers of juveniles (gray bars) along with the cumulative distribution curves of all captured juveniles (solid line) and PIT-tagged juveniles (dotted line) are presented.

An overall juvenile outmigrant abundance estimate of 442 ±154 fish was generated for Benewah Creek in 2009 using the data from six release trials conducted from May 12 to June 22, a value considerably less than that generated for the Lake Creek watershed (Table 6). Release trial periods ranged from 4 to 11 d in length, with variable numbers of fish released during each period. Numbers of released fish ranged from 4 to 35 and were highly dependent upon the numbers of captured outmigrants available to be tagged. Five mortality/retention trials were conducted in association with the first four and the last release trials; all 65 fish were found to retain their tags and survive the trial before their release. Estimated trap efficiencies varied substantially across the release trials, with estimates ranging between15 and 85% (Table 6). Sample size apparently did not influence efficiency estimates, as the two largest release trials yielded estimates less than 38%, whereas an estimate of 79% was generated for the trial in which only 4 tagged fish were released.

Table 7. Detection information for cutthroat trout either captured in the downriver trap or scanned by the PIT-tag array in Benewah Creek, 2009. For fish captured in the downriver trap, data for 'Last detection' and 'Number of days detected' are for the period before trap capture.

2008 tagging information			Capture information from downriver trap		PIT-tag array detection information		
Date tagged	**Total length (mm)**	**Weight (g)**	**Date**	**Total length (mm)**	**First detection**	**Last detection**	**Number of days detected**
21-May	110	11.5	.	.	19-Mar	19-Mar	1
23-May	129	20.1	.	.	6-Apr	10-Apr	2
25-May	140	24.5	1-Jun	229	16-Apr	16-Apr	1
25-May	170	46.3	.	.	20-May	22-May	2
27-May	101	9.0	.	.	16-Apr	16-Apr	1
3-Jun	120	17.2	29-May [a]	.	8-Apr	8-Apr	1
6-Jun	106	11.2	.	.	5-Apr	5-Apr	1
16-Jun	134	22.3	11-May	181	12-Mar	6-May	9
16-Jun	117	16.5	.	.	10-Apr	15-Apr	5

[a] Fish was presumed to be a 2009 release trial recapture and consequently not measured for length

3.3.1.5 Trout abundances at surveyed index sites

Time constraints during the monitoring season, because of the effort invested in the study to evaluate the feasibility of a single pass abundance index, permitted only a subsample of index sites to be surveyed within each watershed. Fifteen, thirty-four, eleven, and twenty sites were sampled in Alder, Benewah, Evans, and Lake creek watersheds, respectively. In Alder and Evans creeks, sites were subsampled to ensure adequate longitudinal spatial coverage in both mainstem and tributary habitats. In Lake and Benewah creeks, mainstem sites were subsampled to ensure a representative spatial distribution, whereas all tributary index sites were surveyed. In addition, all mainstem sites in the upper Benewah watershed that served as either control or treatment sites for evaluating the effectiveness of restoration activities were sampled. Incidentally, in each watershed, those sites that were not surveyed in the 2008 assessment were sampled this year (Firehammer et al. 2010). Cutthroat trout were found in all four watersheds, and brook trout were captured only in Alder and Benewah creeks.

In Alder Creek, the distribution of age 1+ cutthroat trout was generally constrained to lower mainstem reaches with low overall densities, a result consistent with that documented in previous annual surveys (Table 8). Except for two mainstem sites, which yielded densities of 13.1 and 27.2 fish/100 m, estimates of cutthroat trout were less than 5.0 at index sites,. Furthermore, there was an absence of cutthroat trout at those sites distributed in the uppermost reaches of the watershed. As indicated by the similarities in abundance estimates of age 1+ fish and fish of all ages within sites, age-0 cutthroat were generally not captured at index sites.

Brook trout in the Alder Creek watershed displayed distribution patterns that were opposite of those displayed by cutthroat trout, and generally were much more abundant (Table 9). In lower reaches (i.e., mainstem sites 1-6), age 1+ brook trout were relatively absent, with density estimates of less than 3.3 fish/100 m for all but one of the sites. However, density estimates were over ten times greater at sites in the upper reaches of the watershed (i.e., sites upstream of site 10), with an average density of 82.8 fish/ 100 m (range, 36.6 - 150.2). In addition, age-0 fish were often abundant at sites in the upper watershed that had elevated densities of age 1+ fish. For example, at five of the six uppermost index sites, age-0 fish comprised a mean of 27% (range, 15-44) of the total abundance estimate.

Table 8. Total fish caught and depletion-removal abundance estimates for cutthroat trout sampled by multipass electrofishing at mainstem (M) and tributary (T) index sites in the Alder Creek watershed in 2009. Ordering of index sites corresponds to relative longitudinal position within either mainstem or tributary habitat from downstream to upstream. Abundance estimates without associated confidence intervals were obtained by summing fish captured over all passes.

		All ages		Age 1+			
Index site	**Channel type**	**Total captured**	**Abundance estimate**	**Total captured**	**Abundance estimate**	**95% CI**	**Density (fish/100 m)**
Alder 1	M	0	0	0	0	.	0
Alder 2	M	3	3	3	3	3-3	4.9
Alder 3	M	4	4	3	3	3-3	4.9
Alder 4	M	18	18	16	17	16-19	27.2
Alder 5	M	3	3	3	3	3-4	5
Alder 6	M	0	0	0	0	.	0
Alder 8	M	0	0	0	0	.	0
Alder 10	M	9	9	8	8	8-8	13.1
Alder 12	M	0	0	0	0	.	0
Alder 14	M	0	0	0	0	.	0
Alder 16	M	0	0	0	0	.	0
North Fork 1	T	0	0	0	0	.	0
North Fork 3	T	0	0	0	0	.	0
North Fork 5	T	0	0	0	0	.	0
North Fork 7	T	0	0	0	0	.	0

In the Benewah watershed, cutthroat trout were captured in high numbers primarily in tributary reaches, a result consistent with that found in prior survey years (Table 10). Other than sites in Coon Creek where heavy rains obscured visibility and likely decreased capture efficiency, density estimates of age 1+ fish at 8 of the 13 tributary index sites averaged 26.4 fish/ 100 m (range, 19.0 - 34.6), with elevated estimates of 57.6 and 72.6 fish/100 m at two other sites in lower Bull Creek and upper Windfall Creek, respectively. Although a reliable estimate could not be generated for the lower West Fork site because numbers of fish were not depleted substantially over subsequent passes, the number of age 1+ fish captured would have also yielded a density estimate of at least 29.5 fish/100 m. For all tributaries except Whitetail Creek, age 1+ fish comprised a mean percent of 92 (range, 75 – 100) of the total abundance at sites in downstream reaches. In comparison, the mean percent of the total abundance constituted by age-1+ fish was only 35 (range, 14 - 61) at uppermost sites in all tributaries except Windfall. Age-0 fish were also prevalent at the lower Whitetail site, comprising 63% of the total abundance. In contrast to tributaries, age 1+ densities estimated along mainstem reaches were generally low with values of less than 10 fish/100 m at most sites (Table 10). Estimated densities did not exceed 3.5 fish/100 m for any of the four sites distributed along the mainstem reach that was restored from 2005-2008 (i.e., sites 15L - 2008), and further upstream, in unrestored mainstem reaches, densities averaged only 6.6 fish/100 m (range, 0 – 12.1). Age-0 fish were prevalent at some mainstem sites, including the two sites in the uppermost sampled mainstem reach where over 20 age-0 fish were captured at each site comprising over 64% of the respective total catch.

Table 9. Total fish caught and depletion-removal abundance estimates for brook trout sampled by multipass electrofishing at mainstem (M) and tributary (T) index sites in the Alder Creek watershed in 2009. Ordering of index sites corresponds to relative longitudinal position within either mainstem or tributary habitat from downstream to upstream. Abundance estimates without associated confidence intervals were obtained by summing fish captured over all passes.

		All ages		Age 1+			
Index site	**Channel type**	**Total captured**	**Abundance estimate**	**Total captured**	**Abundance estimate**	**95% CI**	**Density (fish/100 m)**
Alder 1	M	0	0	0	0	.	0
Alder 2	M	2	2	2	2	.	3.3
Alder 3	M	1	1	1	1	1-1	1.6
Alder 4	M	6	8	6	8	6-14	12.4
Alder 5	M	1	1	1	1	1-1	1.6
Alder 6	M	1	1	1	1	1-1	1.6
Alder 8	M	13	14	13	14	13-17	22.8
Alder 10	M	25	31	25	31	25-42	50.1
Alder 12	M	29	30	29	30	29-31	48.5
Alder 14	M	119	121	101	103	101-107	150.2
Alder 16	M	38	39	22	22	22-24	36.6
North Fork 1	T	101	105	86	88	86-92	144.4
North Fork 3	T	49	49	35	35	35-37	57.9
North Fork 5	T	69	73	48	51	48-56	83.5
North Fork 7	T	38	39	35	36	35-38	58.6

Densities of age1+ brook trout were variable but more abundant at both mainstem and tributary sites in the upper than in the lower portion of the Benewah watershed in 2009 (Table 11). Brook trout were virtually absent from sites sampled in lower mainstem reaches and at sites sampled in Bull Creek. Also, densities estimated at Phase 1 restoration sites were extremely low, with values not exceeding 3.6 fish/100 m. However, at upper mainstem sites (sites 16L – 18), age 1+ brook trout densities were much higher than those calculated for cutthroat trout, with an average of 31.1 fish/100 m (range, 23.0 – 44.7) at 3 of the sites with reliable estimates, in addition to a value of 125 fish/100 m calculated for site 16. In 2009, Site 16 was truncated to a channel length of only 30.5 m, because of the inability to effectively sample the upper half of the site, and consisted of one long pool. Densities of age 1+ brook trout also differed both among and within tributaries (Table 11). Whereas densities were generally low (< 4.0 fish/ 100 m) in West Fork and upper reaches of Whitetail and South Fork creeks, downstream index sites in these latter two tributaries yielded respective estimates of 13.7 and 19.9 fish/100 m, albeit values that were lower than those estimated for cutthroat trout. In comparison, numbers of age1+ brook trout captured in Schoolhouse and Windfall creeks were relatively high, with densities of 22.8 and 31.5 fish/100 m estimated in Windfall creek. Age-0 brook trout were most prevalent at those mainstem sites that had elevated densities of age 1+ fish, comprising 36-61% of all brook trout captured at four of the five upper mainstem sites (i.e., all those sites except site 16).

Table 10. Total fish caught and depletion-removal abundance estimates for cutthroat trout sampled by multipass electrofishing at mainstem (M) and tributary (T) index sites in the Benewah Creek watershed in 2009. Ordering of index sites corresponds to relative longitudinal position within either mainstem or tributary habitat from downstream to upstream. Abundance estimates without associated confidence intervals were obtained by summing fish captured over all passes.

		All ages		Age 1+			
Index site	**Channel type**	**Total captured**	**Abundance estimate**	**Total captured**	**Abundance estimate**	**95% CI**	**Density (fish/100 m)**
Benewah 1	M	3	3	3	3	3-3	4.9
Benewah 3	M	4	4	4	4	.	6.6
Benewah 5	M	8	10	8	10	8-16	15.8
Benewah 7	M	32	33	15	15	15-16	22.7
Benewah 9	M	0	0	0	0	.	0
Benewah 10	M	3	3	1	1	.	1.6
Benewah 14L	M	5	5	3	3	3-4	5
Benewah 14	M	4	4	3	3	.	4.9
Benewah 14U	M	6	6	2	2	2-4	3.6
Benewah 15L	M	2	2	2	2	2-2	3.3
Benewah 2006	M	1	1	1	1	1-1	1.6
Benewah 15	M	1	1	1	1	.	1.6
Benewah 2008	M	0	0	0	0	.	0
Benewah 16L	M	7	7	7	7	7-9	12.1
Benewah 2010	M	8	8	7	7	.	9.2
Benewah 16	M	0	0	0	0	.	0
Benewah 17	M	33	40	12	. [a]	.	.
Benewah 18	M	29	29	4	4	4-5	5.1
Coon 1	T	0	0	0	0	.	0
Coon 2	T	0	0	0	0	.	0
Coon 3	T	0	0	0	0	.	0
Bull 1	T	46	47	35	35	35-36	57.6
Bull 2	T	152	154	21	21	21-22	34.6
Whitetail 1	T	46	51	18	19	18-21	30.8
Whitetail 2	T	22	22	11	12	11-14	19
Windfall 1	T	10	12	10	12	10-17	19.2
Windfall 2	T	47	49	42	44	42-49	72.6
Schoolhouse 1	T	13	16	13	16	13-26	26.5
Schoolhouse 2	T	10	11	3	3	.	4.9
South Fork 1	T	17	17	16	16	16-17	26.5
South Fork 2	T	17	17	15	15	15-17	25.2
South Fork 3	T	31	31	19	19	19-20	29.1
West Fork 1	T	19	. [a]	18	. [a]	.	.
West Fork 2	T	41	42	9	9	9-10	15.1

[a] Reliable abundance estimate could not be generated using the depletion model

Table 11. Total fish caught and depletion-removal abundance estimates for brook trout sampled by multipass electrofishing at mainstem (M) and tributary (T) index sites in the Benewah Creek watershed in 2009. Ordering of index sites corresponds to relative longitudinal position within either mainstem or tributary habitat from downstream to upstream. Abundance estimates without associated confidence intervals were obtained by summing fish captured over all passes.

		All ages		**Age 1+**			
Index site	**Channel type**	**Total captured**	**Abundance estimate**	**Total captured**	**Abundance estimate**	**95% CI**	**Density (fish/100 m)**
Benewah 1	M	1	1	1	1	1-1	1.6
Benewah 3	M	0	0	0	0	.	0
Benewah 5	M	0	0	0	0	.	0
Benewah 7	M	0	0	0	0	.	0
Benewah 9	M	0	0	0	0	.	0
Benewah 10	M	0	0	0	0	.	0
Benewah 14L	M	16	17	5	5	5-5	8.2
Benewah 14	M	12	14	6	7	6-9	10.7
Benewah 14U	M	7	8	2	2	2-4	3.6
Benewah 15L	M	5	6	1	1	.	1.6
Benewah 2006	M	5	5	1	1	.	1.6
Benewah 15	M	15	21	2	2	2-4	3.6
Benewah 2008	M	4	4	1	1	1-1	1.6
Benewah 16L	M	27	.[a]	15	16	15-18	25.7
Benewah 2010	M	45	55	26	34	26-51	44.7
Benewah 16	M	35	45	31	38	31-52	125
Benewah 17	M	22	22	14	14	14-14	23
Benewah 18	M	41	.[a]	16	.[a]	.	.
Coon 1	T	0	0	0	0	.	0
Coon 2	T	0	0	0	0	.	0
Coon 3	T	0	0	0	0	.	0
Bull 1	T	0	0	0	0	.	0
Bull 2	T	0	0	0	0	.	0
Whitetail 1	T	7	8	7	8	7-14	13.7
Whitetail 2	T	0	0	0	0	.	0
Windfall 1	T	16	19	16	19	16-28	31.5
Windfall 2	T	13	14	13	14	13-17	22.8
Schoolhouse 1	T	18	.[a]	14	.[a]	.	.
Schoolhouse 2	T	6	8	6	8	6-14	12.4
South Fork 1	T	19	20	12	12	12-13	19.9
South Fork 2	T	4	4	1	1	1-1	1.6
South Fork 3	T	0	0	0	0	.	0
West Fork 1	T	1	1	1	1	1-1	1.6
West Fork 2	T	2	2	2	2	2-2	3.3

[a] Reliable abundance estimate could not be generated using the depletion model

Similar to the Benewah Creek watershed, densities of age 1+ cutthroat trout in Lake Creek were greatest in sampled tributaries in 2009, but only in the uppermost reaches of the tributaries, a pattern consistent with previous years (Table 12). Density (fish/100 m) estimates of age 1+ fish were 43.5 at Lake Creek 14, ranged between 62.4 and 69.1 at sites 4 and 5 in the West Fork subdrainage, and ranged between 41.9 and 42.7 at sites 2, 3, and 4, with an estimate of 100 at the East Fork site, in the Bozard subdrainage. In comparison, age 1+ densities were substantially lower at all other tributary index sites, with an average density of 4.8 fish/100 m (range, 0 - 10.7). In addition, the mean percent of the total abundance estimates constituted by age-1+ fish for the high-density tributary sites was 90 (range, 84 – 100) indicating the lack of age-0 fish captured at sites in upper reaches of tributaries. Density estimates in mainstem sites were generally lower than those estimated in the upper tributaries, with a relatively modest mean density of 31.3 fish/100 m in the lower mainstem reaches, and a low density of 8.2 fish/100 m in upper mainstem reaches (i.e., reaches upstream of old H95 bridge).

Table 12. Total fish caught and depletion-removal abundance estimates for cutthroat trout sampled by multipass electrofishing at mainstem (M) and tributary (T) index sites in the Lake Creek watershed in 2009. Ordering of index sites corresponds to relative longitudinal position within either mainstem or tributary habitat from downstream to upstream. Abundance estimates without associated confidence intervals were obtained by summing fish captured over all passes.

		All ages		Age 1+			
Index site	**Channel type**	**Total captured**	**Abundance estimate**	**Total captured**	**Abundance estimate**	**95% CI**	**Density (fish/100 m)**
Lake 2	M	30	36	26	28	26-34	46.5
Lake 4	M	13	17	11	15	11-30	25.2
Lake 6	M	16	17	13	14	13-15	22.1
Lake 8L	M	9	9	8	8	.	13.1
Lake 8U	M	4	4	3	3	3-3	4.9
Lake 9L	M	5	5	3	3	3-3	4.9
Lake 10L	M	6	6	6	6	.	9.8
Lake 11	T	4	4	4	4	4-5	6.6
Lake 12	T	0	0	0	0	.	0
Lake 14	T	24	28	21	27	21-39	43.5
West Fork 1	T	3	3	3	3	3-3	4.9
West Fork 2	T	6	7	6	7	6-9	10.7
West Fork 3	T	4	4	3	3	.	4.9
West Fork 4	T	44	57	37	42	37-51	69.1
West Fork 5	T	44	44	38	38	38-38	62.4
Bozard 1	T	3	3	1	1	1-1	1.6
Bozard 2	T	26	26	26	26	26-26	42.7
Bozard 3	T	25	26	25	26	25-27	41.9
Bozard 4	T	27	28	24	26	24-30	42
East Fork Bozard 1	T	71	73	59	61	59-65	99.9

In the Evans Creek watershed, cutthroat trout were found to be distributed across all sampled index sites, with moderate to high abundances exhibited at all mainstem sites (Table 13). Age 1+ densities averaged 33.5 fish/100 m in mainstem reaches, with the highest densities of 52.7 and 84.5 fish/100 m estimated for sites in the upper reaches. Moreover, age 1+ fish constituted a mean percent of 93 (range, 84 – 100) of the total abundance estimated for all mainstem sites. In comparison, the lowest age 1+ density estimates of 4.9 and 8.2 fish/100 m were calculated for the two sites in the South Fork tributary.

Table 13. Total fish caught and depletion-removal abundance estimates for cutthroat trout sampled by multipass electrofishing at mainstem (M) and tributary (T) index sites in the Evans Creek watershed in 2009. Ordering of index sites corresponds to relative longitudinal position within either mainstem or tributary habitat from downstream to upstream. Abundance estimates without associated confidence intervals were obtained by summing fish captured over all passes.

		All ages		**Age 1+**			
Index site	**Channel type**	**Total captured**	**Abundance estimate**	**Total captured**	**Abundance estimate**	**95% CI**	**Density (fish/100 m)**
Evans 2	M	10	10	10	10	.	16.4
Evans 3	M	32	33	29	29	29-31	48.3
Evans 4	M	9	9	8	8	8-9	13.3
Evans 5	M	12	13	12	13	12-15	20.7
Evans 8	M	13	15	12	15	12-25	24.9
Evans 10	M	17	18	16	17	16-20	27.8
Evans 12	M	58	61	47	51	47-59	84.5
Evans 14	M	31	34	30	32	30-37	52.7
Evans 16	M	9	9	8	8	8-9	13.3
South Fork 1	T	5	5	3	3	3-3	8.2
South Fork 2	T	4	4	3	3	3-3	4.9

Mark-recapture results to evaluate efficacy of 1st pass index

Twenty-three of the 27 sites selected to evaluate the efficacy of a single-pass index to reflect true abundance were included in analyses. Of the four that were omitted, trout were not captured during the marking event at one site, and at the other three sites nets were found to be compromised which could have biased mark-recapture estimates. For the remaining 23 sites, the number of marked trout varied substantially from a low of 2 fish at site 10L in the mainstem of Lake Creek to a high of 78 fish at site 1 in the North Fork of Alder Creek (Table 14). Numbers of marked fish included both cutthroat trout and brook trout, and were evaluated collectively in analyses.

For many of the 23 sites, the depletion-removal estimator underestimated the total number of marked trout that were released at the site (Figure 16). Only at three sites, Lake 14, Schoolhouse 1, and Windfall 2, did the 95% confidence interval of the estimator include the actual number of marked fish. In addition, the discrepancy between the estimated and actual number of marked trout tended to increase with numbers of marked trout, especially at those sites in which more than 20 trout were marked (i.e., sites to the right of Alder 12 on Figure 16). Incidentally, a reliable depletion-removal estimator for marked trout could not be generated for site 1 in the Benewah West Fork because numbers of marked trout were not substantially reduced over subsequent passes.

Table 14. Numbers of trout marked at twenty-three sites selected in 2009 to evaluate the efficacy of a first pass index to reflect abundance.

Watershed	Stream	Site	Marked fish
Lake	Lake	10L	2
Lake	Lake	8L	2
Evans	Evans	5	3
Benewah	South Fork	2	7
Benewah	Schoolhouse	2	8
Lake	Lake	14	8
Benewah	Benewah	17	10
Lake	Bozard	3	13
Benewah	Benewah	18	15
Benewah	West Fork	1	16
Benewah	Bull	2	17
Benewah	South Fork	1	17
Alder	Alder	12	18
Benewah	Schoolhouse	1	24
Lake	East Fork Bozard	1	25
Benewah	Bull	1	26
Alder	North Fork	3	27
Alder	North Fork	5	30
Evans	Evans	12	32
Benewah	Windfall	2	37
Lake	West Fork	5	39
Alder	Alder	14	66
Alder	North Fork	1	78

Underestimation of abundance was primarily the result of an overestimation of the overall capture probability and the fact that actual capture probabilities differed among passes (Figure 17). For example, for all but two of the sites (Schoolhouse 1 and Windfall 2) in which more than 20 trout were marked, actual capture probabilities of marked fish markedly decreased between the first pass and subsequent passes. Capture probabilities were relatively similar at Windfall 2 which gave rise to the accurate depletion-removal estimate of marked fish at that site. Further, not only at Schoolhouse 1, but at three other sites in which less than 20 fish were marked, Schoolhouse 2, Benewah 17, and West Fork Benewah 1, actual capture probabilities of marked fish were lower in the first pass than in either or both of the subsequent passes.

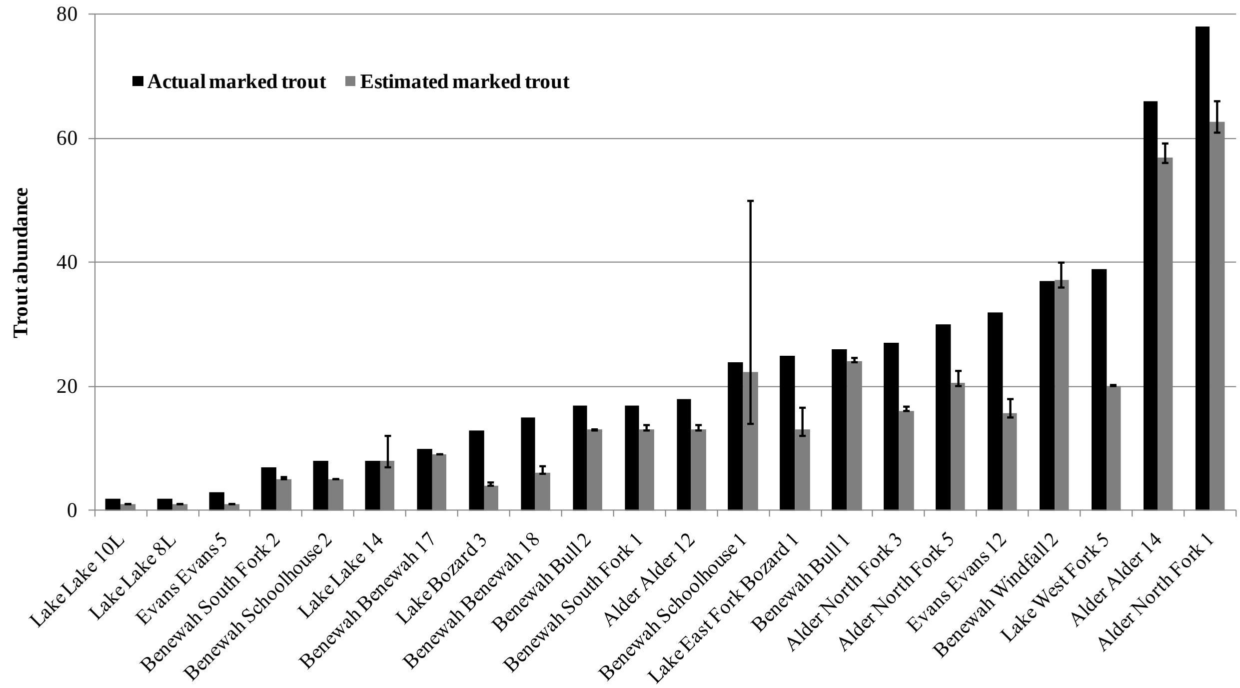

Figure 16. Abundance estimates and associated 95% confidence intervals for marked trout relative to actual numbers of marked trout at twenty-two sites sampled in 2009. Sites (labeled as watershed, stream, and site) are ordered left to right by numbers of trout marked.

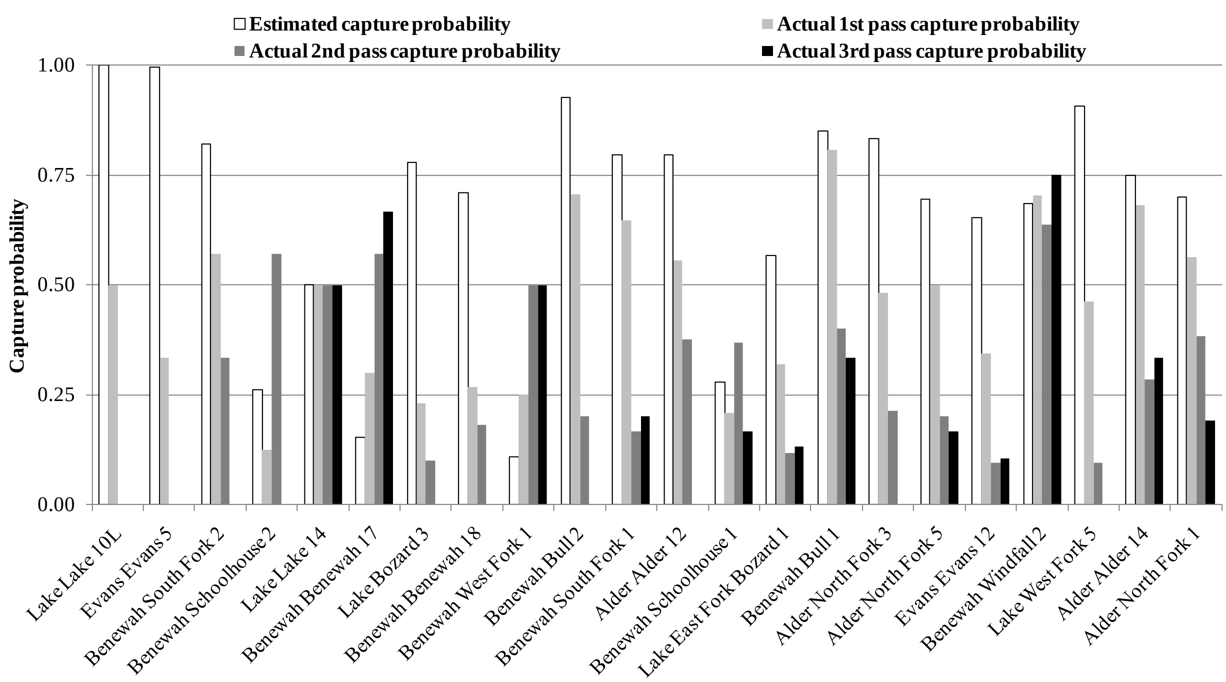

Figure 17. Estimated capture probabilities for marked trout using the removal-depletion model and actual 1^{st}, 2^{nd}, and 3^{rd} pass capture probabilities computed from the numbers of marked trout caught relative to those available for capture in each pass. Sites (labeled as watershed, stream, and site) are ordered left to right by numbers of trout marked.

Depletion-removal estimates were also generally lower than mark-recapture estimates generated for all age 1+ trout at sampled sites (Figure 18). Confidence intervals for both estimates did not overlap for six of the sampled sites when only first pass catch was used to generate the mark-recapture estimate, and for 15 of the sampled sites when catch accrued over all passes was used to generate the mark-recapture estimate. Further, when comparing the depletion-removal method to the mark-recapture method using catch over all passes, the largest discrepancies, in both the abundance estimates and the lack of overlap in confidence intervals, occurred at sites in which more than 20 fish were marked. Notably, a depletion-removal estimate of age 1+ trout could not be reliably generated for Benewah 18 because captured fish were not substantially reduced over subsequent passes.

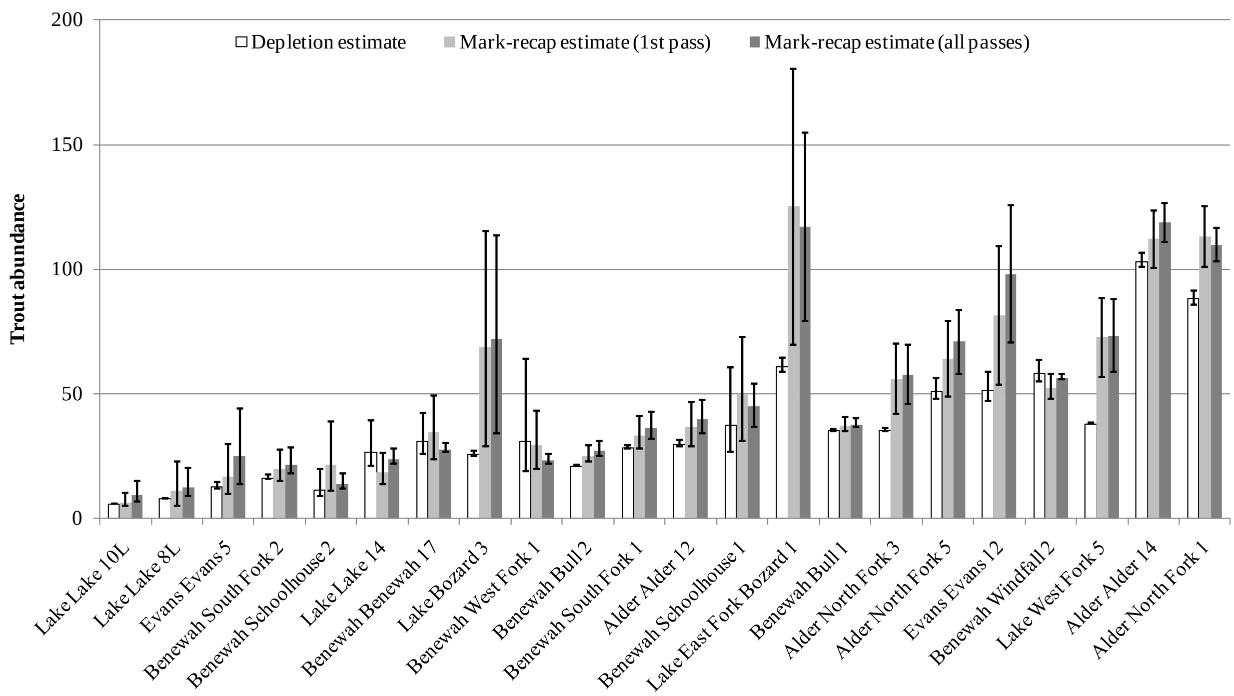

Figure 18. Comparison of removal-depletion estimates to estimates generated by mark-recapture methods when only fish captured during the first pass were used and when fish captured over all passes were used. 95% confidence intervals are also displayed for all three estimates. Sites (labeled as watershed, stream, and site) are ordered left to right by numbers of trout marked.

The precision of age 1+ trout abundance estimates also differed between methods, and across sites within each method (Figure 18). Confidence intervals generated for depletion-removal estimates were generally narrow, except for those generated at Schoolhouse 2, Lake 14, Benewah 17, Benewah West Fork 1, and Schoolhouse 1. Incidentally, other than Lake 14, these were the same sites in which actual capture probabilities of *marked* fish were greater after the first pass than during the first pass (Figure 17). Confidence intervals for mark-recapture estimates were generally wider than those generated for the depletion estimates. As expected given the greater number of marked fish recaptured, the precision of mark-recapture estimates generally improved, though not substantially, when all fish rather than just fish caught in the first pass were included in the model. Rather imprecise mark-recapture estimates, due to the lack of recaptured fish (i.e, low capture probabilities of marked fish, Figure 17), were generated at Bozard 3, East Fork Bozard 1, and Evans 12. However, for all these sites the lower 95% confidence bound of the mark-recapture estimate (fish from all passes included) still was greater than the depletion estimate.

A strong linear relationship existed when comparing numbers of marked trout recaptured in the first pass of the depletion event to those marked and released the day before across all sites (Figure 19; r = 0.95). Although there was a degree of variability around the fitted trend line at sites in which between 20 and 40 fish were marked, a large number of fish relative to those that were marked were still recaptured in the first pass for those two sites in which more than 60 fish were marked. Lastly, the number of age 1+ trout captured during the single pass marking event was compared with age 1+ trout captured the following day during the first pass of the recapture event. A high degree of consistency in first pass catch between days was found for many of the sites, as evidenced by the close-fitting relationship with the displayed line of unity slope (Figure 20). Only Benewah 17, Benewah 18, West Fork Benewah 1, and Schoolhouse 1 (open circles) displayed a greater than 50% change in the numbers of trout captured in the first pass on consecutive days; incidentally, these were the same sites for which age 1+ depletion estimates were either imprecise or could not be generated.

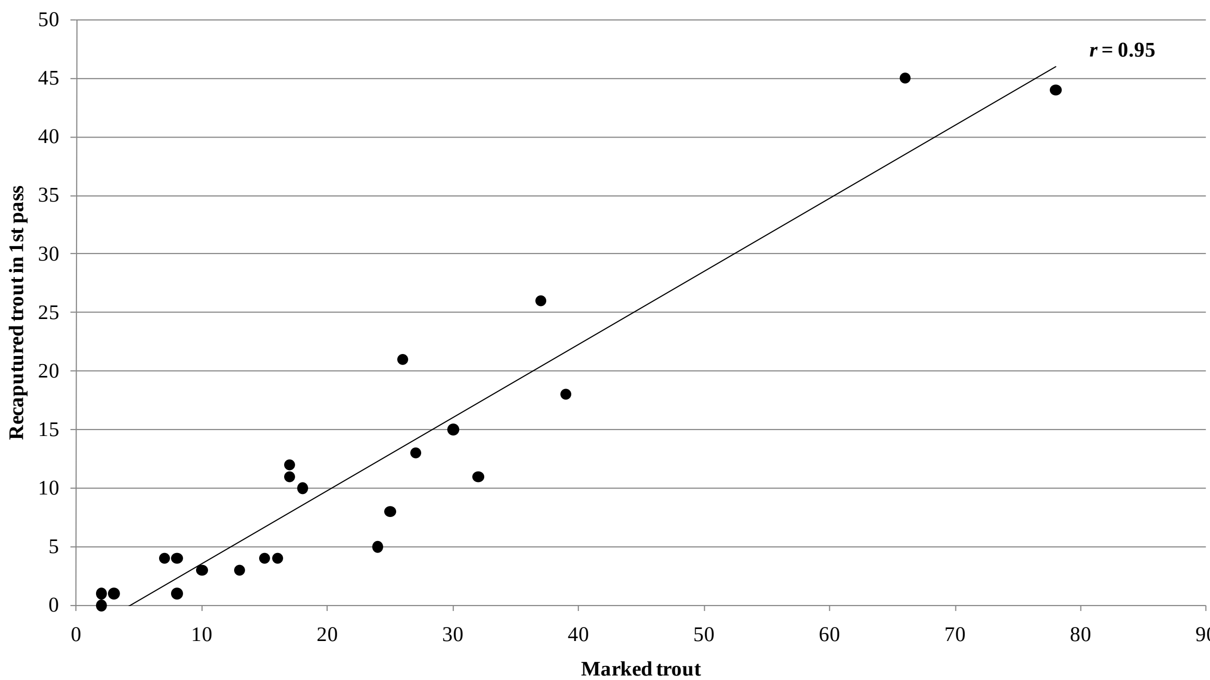

Figure 19. Numbers of trout recaptured during the first pass of the depletion event relative to those marked and released the day before at twenty-three sites in 2009.

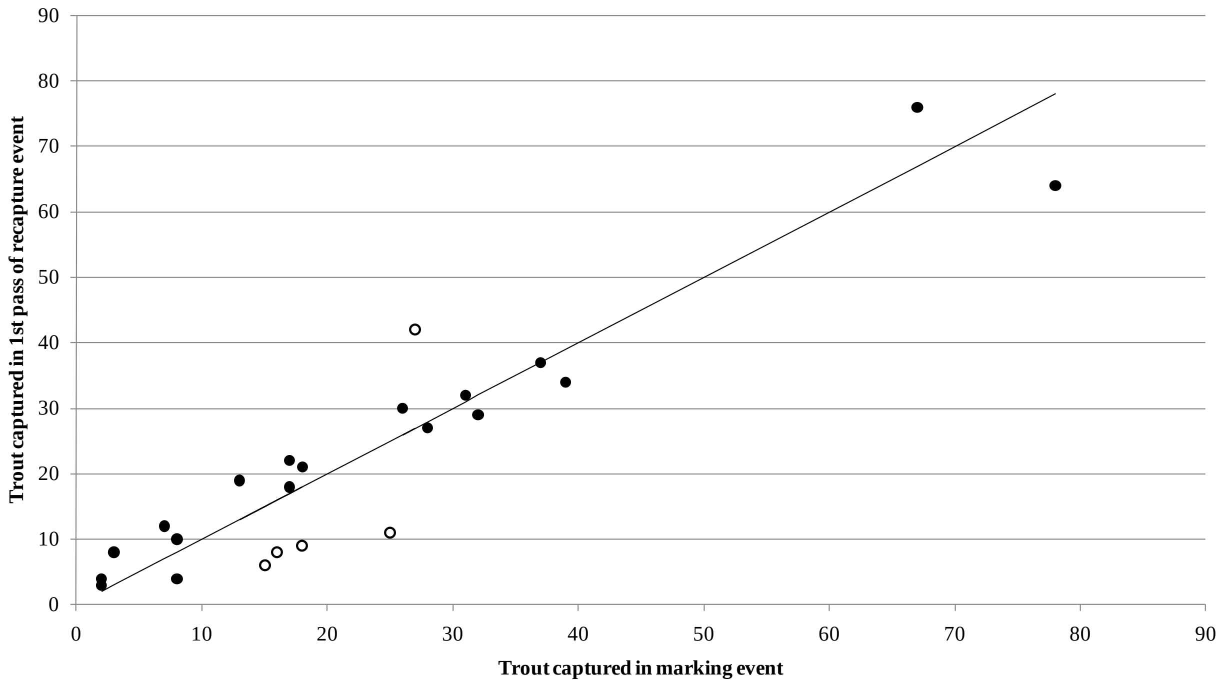

Figure 20. Numbers of age 1+ trout captured during the first pass of the recapture event relative to age 1+ trout captured during the single pass of the marking event the day before. Open circles designate those sites at which numbers of captured trout differed by at least 50% between events. Also, displayed for comparative reference is a line with a slope of unity.

Repeated measures analysis for examining cutthroat trout trends

Trajectories of depletion-removal estimates and 1st pass catch for age 1+ cutthroat trout over the period from 2003 to 2009 were similarly interpreted across composite reaches within watersheds, though trends were found to differ among analyzed watersheds. For the six composite reaches in the Evans Creek watershed, synchronous differences in depletion-removal estimates were significantly detected across the analyzed years (F = 8.19, p < 0.001; Table 15). Though a significant linear trend was evident in the data (p = 0.019), it only explained 29% of the variability among years. In comparison, the higher order cubic trend (p = 0.006) explained 55% of the annual variability, approximately twice that of the linear trend. The cubic trend is evident when examining the pattern of change in depletion-removal estimates across all six composite reaches (Figure 21). Densities generally decreased from 2003 to 2005, then increased markedly over the next two years, and declined thereafter. Similar results were obtained when using the time series of standardized first pass catch (Table 15). An overall significant difference was detected among years (F = 8.33, p < 0.001), with the cubic trend explaining approximately half of the variation (p = 0.006), and much more than that explained by the linear trend, which unlike the series of depletion estimates, was not determined to be significant (p = 0.09).

In the Lake Creek watershed, concurrent differences in age 1+ cutthroat trout depletion estimates were not detected among years across the eight composite reaches (p = 0.500; Table 15), and, furthermore, no watershed-scale trends were evident. In addition, composite reach trajectories did not exhibit similar patterns of change over time (i.e., Huynh-Feldt conditions not satisfied). For example, mainstem and upper Lake tributary reaches seemingly operated independent of one another over the analyzed time period (Figure 22). Likewise, the two Bozard reaches generally increased over the period from 2003 to 2007, whereas the lower and upper reaches in the West

Fork of Lake Creek were respectively decreasing and highly variable over the same time period (Figure 23). The repeated measures analysis using 1st pass catch data rendered a similar lack of detectable difference and absence of trend across years (Table 15). Notwithstanding the lack of trend observed in both the depletion estimate and first pass catch series, both series generally resembled one another as evident in the similar patterns of change within each of the four composite reaches in the Bozard and West Fork drainages (Figure 23 and Figure 24).

In Benewah Creek, trajectories of age 1+ cutthroat trout differed between the upper and lower reaches of the watershed. When using all 10 composite reaches and grouping by watershed location (i.e., location relative to 9-mile bridge), a significant interaction was detected between locations for the depletion estimate series (p = 0.026) and a moderately significant interaction was detected for the first pass catch series (p = 0.070). Given that these results indicated that trends may be operating differently among watershed locations, analyses were then conducted separately for each of the upper and lower watershed locations. For the composite tributary reaches in the upper part of the watershed, a synchronous significant difference among years was detected for both the depletion estimate (p = 0.001) and first pass catch series (p = 0.009; Table 15). Further, significant linear and cubic trends were detected in both series. However, though the linear trend explained more of the annual variation than the cubic trend in each of the two series, a stronger linear trend was apparent in the series of depletion estimates (67% of the variation; Figure 25) than in the series of first pass catch (44% of the variation). Notably, the presence of a stronger linear than cubic trend was opposite that observed in the Evans Creek data. In contrast to the upper watershed, neither concurrent differences nor detectable trends were apparent in composite tributary and mainstem reaches below 9-mile bridge for both series of depletion estimates (p = 0.110; Figure 26) and first pass catch (p = 0.421; Table 15).

Table 15. Summary of repeated measures analysis for series of standardized depletion estimates and first pass catch to detect trends in age 1+ cutthroat trout over the years 2003-2009.

	Depletion-removal estimate (fish/100 m)			**1st pass catch (fish/100 m)**		
Statistical test	***F***	***p***	**Percent explained by trend**	***F***	***p***	**Percent explained by trend**
		Evans Creek				
Difference among years	8.19	< 0.001	.	8.33	< 0.001	.
Linear trend	11.80	0.019	29	4.42	0.090 [a]	14
Cubic trend	21.40	0.006	55	20.31	0.006	48
5th order trend	9.35	0.028	14	29.71	0.003	32
		Lake Creek				
Difference among years	1.29	0.500 [b]	.	13.86	0.070 [b]	.
		Benewah Creek - downriver of 9-mile bridge				
Difference among years	2.08	0.110 [c]	.	1.04	0.421 [c]	.
		Benewah Creek - upriver of 9-mile bridge				
Difference among years	7.25	0.001	.	4.25	0.009	.
Linear trend	21.90	0.009	67	13.55	0.021	44
Cubic trend	13.80	0.021	24	10.08	0.034	40

[a] Though not significant, p-value provided for comparison to trend value obtained for series of depletion-removal estimates

[b] Huynh-Feldt conditions not satisfied and consequently a multivariate test statistic, Wilk's lambda, was used to evaluate significance. No significant trends were detected.

[c] Huynh-Feldt conditions not satisfied. No significant trends detected

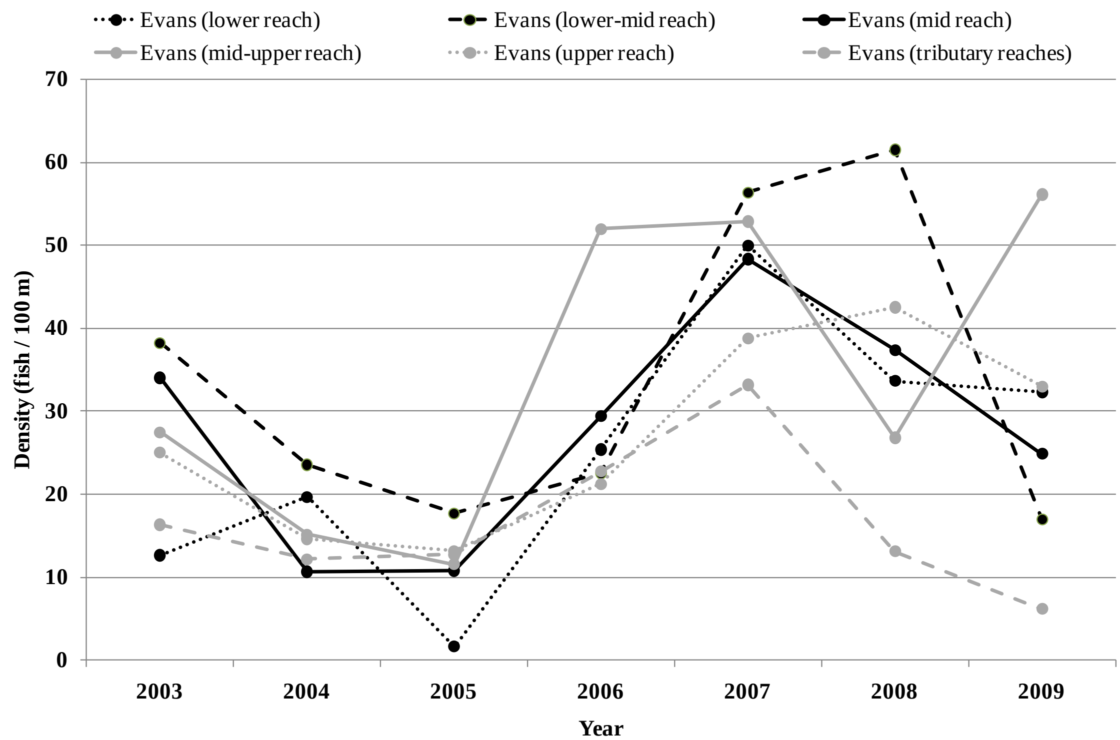

Figure 21. Depletion-removal estimates (fish/100 m) of age 1+ cutthroat trout for six composite reaches in the Evans Creek watershed, 2003-2009.

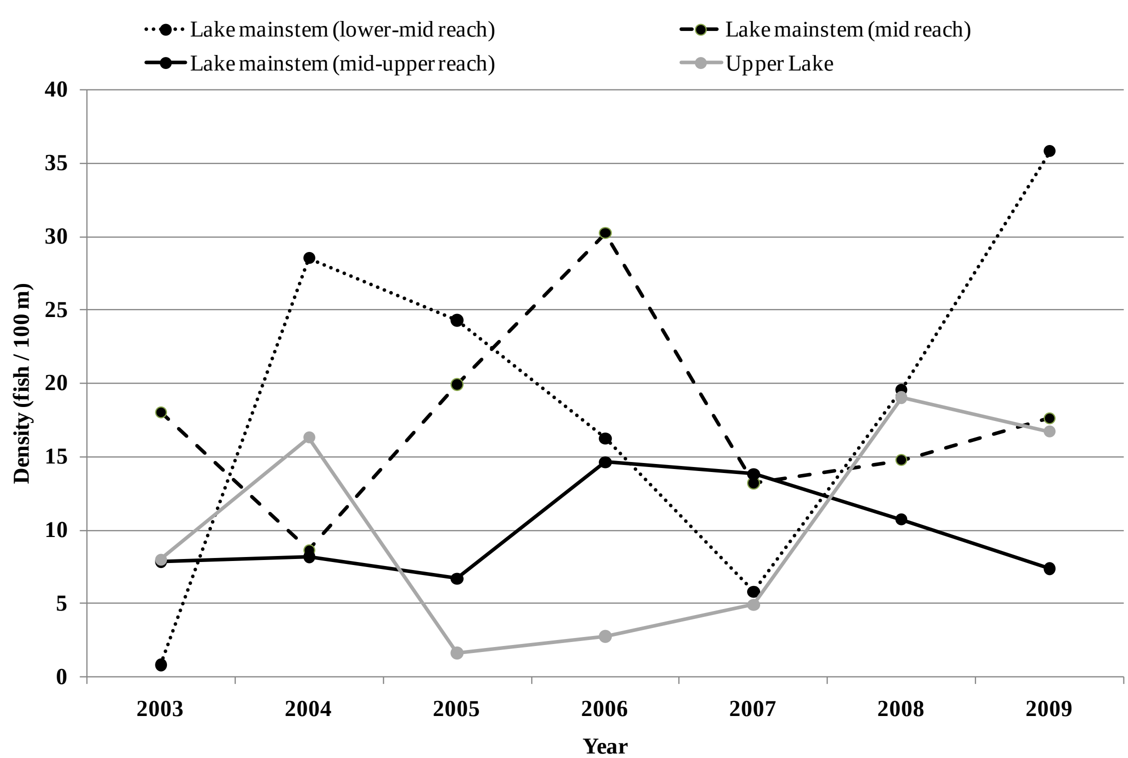

Figure 22. Depletion-removal estimates (fish/100 m) of age 1+ cutthroat trout for four composite reaches in the Lake Creek watershed, 2003-2009.

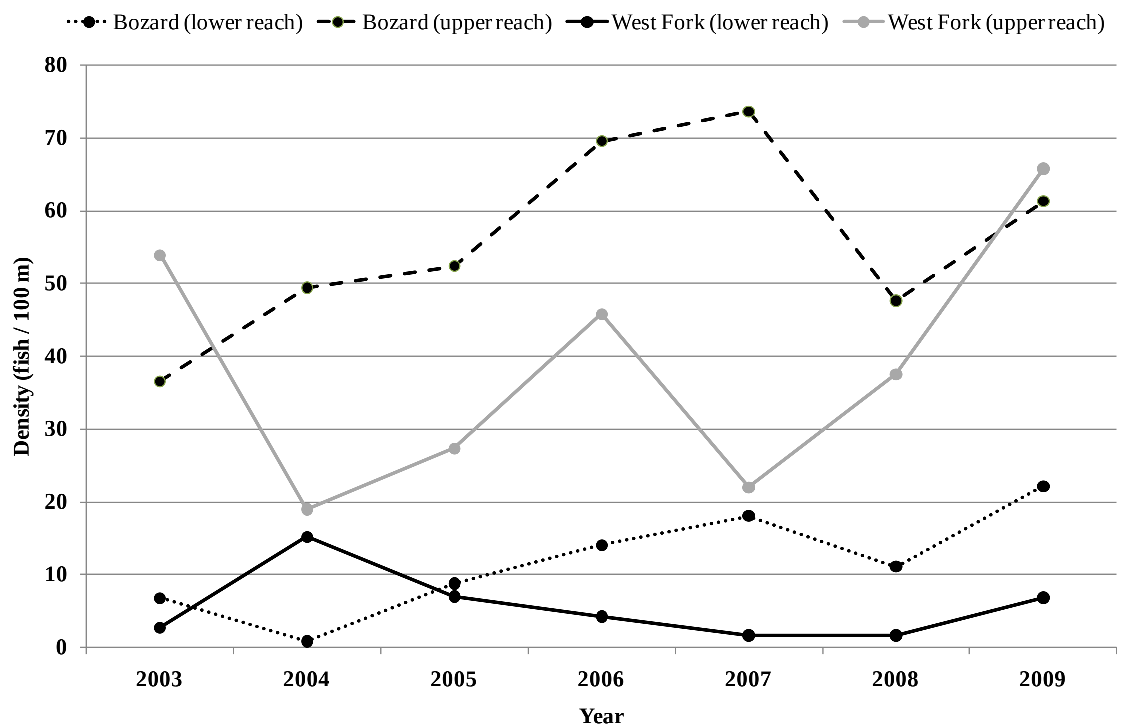

Figure 23. Depletion-removal estimates (fish/100 m) of age 1+ cutthroat trout for four composite reaches in Bozard and West Fork drainages in the Lake Creek watershed, 2003-2009.

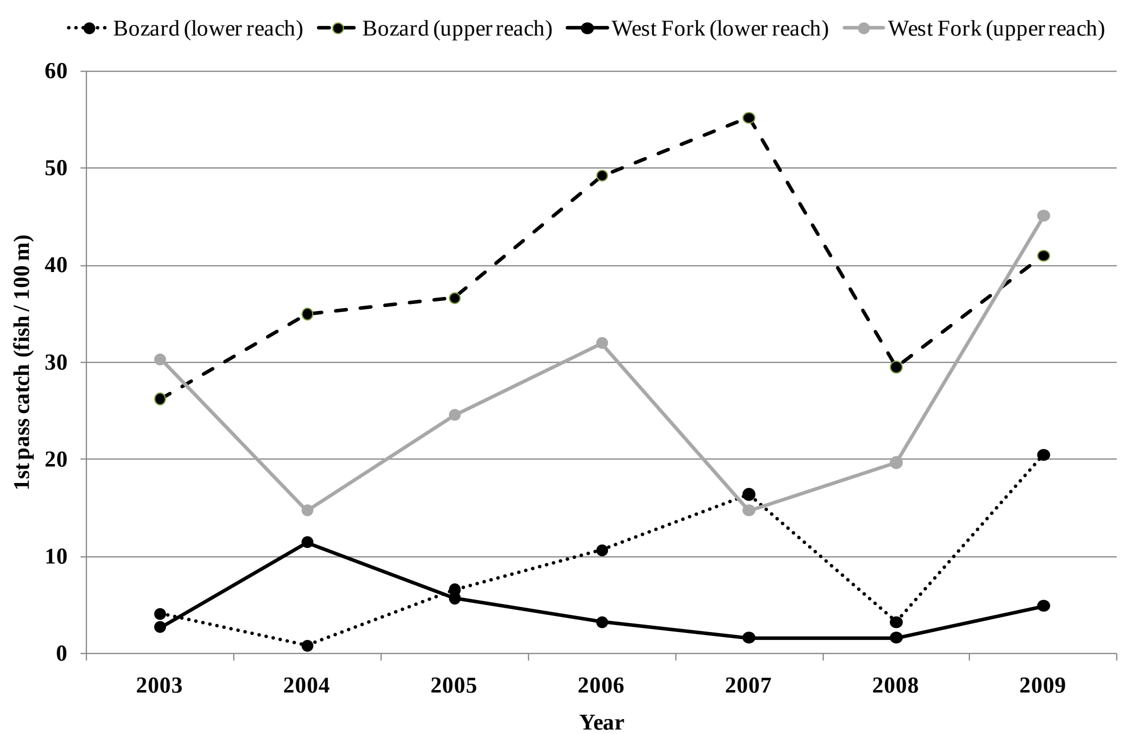

Figure 24. First pass catch (fish/100 m) of age 1+ cutthroat trout for four composite reaches in the Bozard and West Fork sub-drainages in the Lake Creek watershed, 2003-2009.

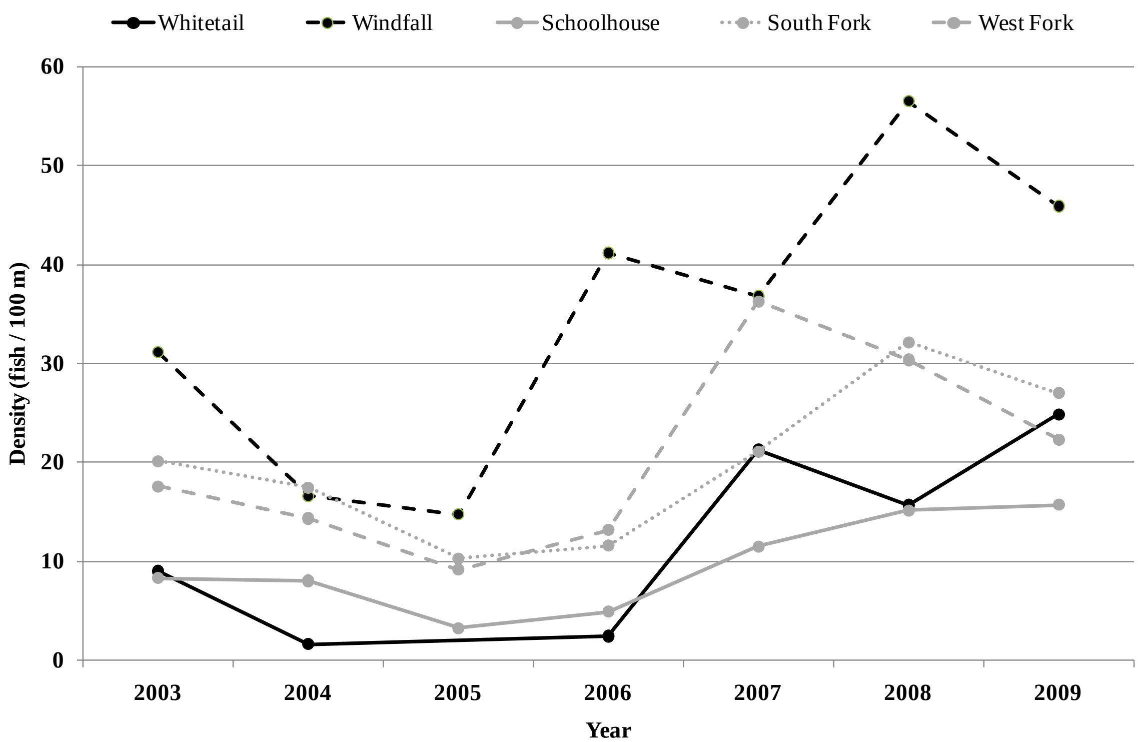

Figure 25. Depletion-removal estimates (fish/100 m) of age 1+ cutthroat trout for five composite tributary reaches in the upper Benewah watershed, 2003-2009.

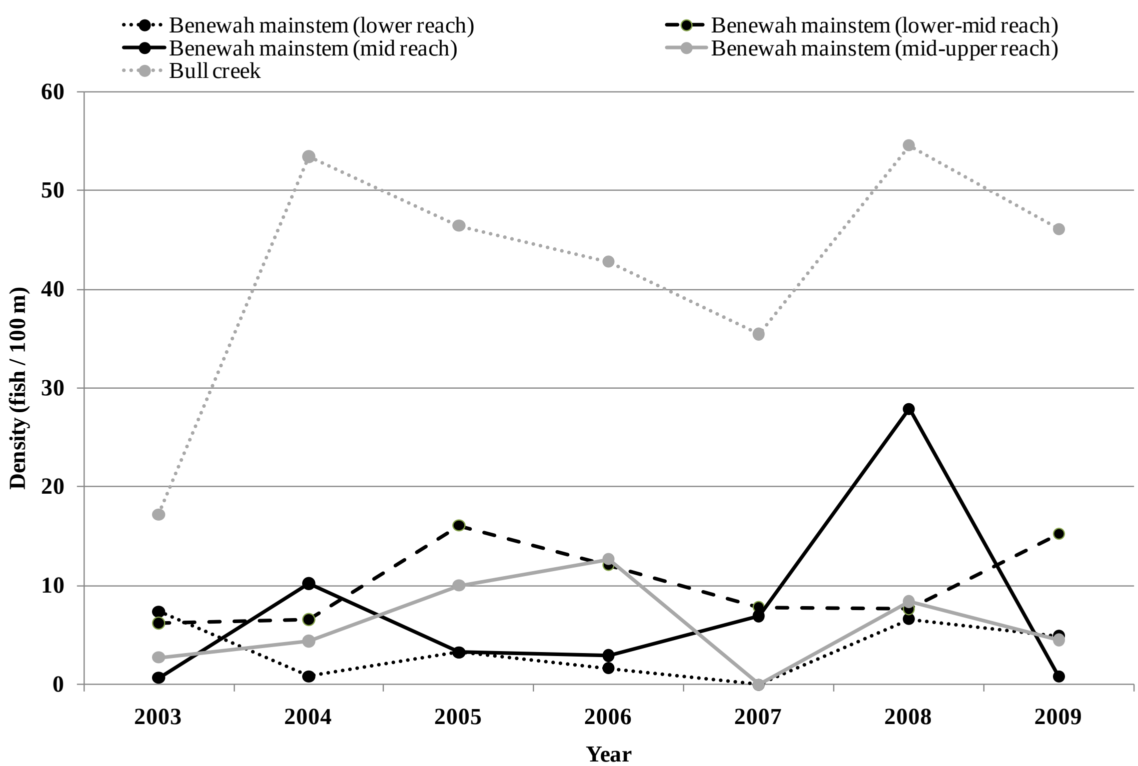

Figure 26. Depletion-removal estimates (fish/100 m) of age 1+ cutthroat trout for five composite reaches in the lower Benewah watershed, 2003-2009.

3.3.2 Trend and status monitoring – Stream temperatures

3.3.2.1 Benewah Creek temperatures

Ambient summer stream temperatures generally increased downstream over the 6.4 km section of the Benewah mainstem from the mouth of Schoolhouse Creek to 9-mile bridge in 2009, though the longitudinal temperature change was more gradual in upper than in lower reaches (Table 16; Figure 27, Figure 28). Monthly means of daily mean temperatures recorded by data loggers only increased 1.8ºC from 13.7 to 15.5ºC in July and 1.5ºC from 13.9 to 15.4ºC in August over the uppermost 3.2 km reach. In comparison, thermal changes doubled along the lowermost 3.2 km reach relative to the 3.2 km reach upstream, increasing 3.6ºC from 15.5 to 19.1ºC in July and 2.9ºC from 15.4 to 18.3ºC in August. Similarly, monthly means of maximum daily temperatures for both months displayed a general lack of trend over the mainstem reach 3.8 to 6.4 km above 9-mile bridge, whereas a general increasing trend was observed below this reach attaining highs of 21ºC and 20ºC in July and August, respectively. Furthermore, monthly means of daily maximum temperatures were at least 17ºC for all loggers positioned downstream but not upstream of the logger located 3.8.km upstream of 9-mile bridge.

Similar to the trends observed for mean and maximum temperatures, the percentage of time logged water temperatures exceeded 17ºC during July and August in 2009 were higher and increased more rapidly along the lower half than along the upper half of the 6.4 km reach of the upper Benewah mainstem (Table 16; Figure 27, Figure 28). Along the uppermost 3.2 km, daily stream temperatures exceeded 17ºC less than 25% of the time during July and August with percentages increasing downstream by only 23% and 17%, respectively. Conversely, percentages in the lowermost 3.2 km increased downstream a total of 57% from 25 to 82% in July, and 46% from 21 to 67% in August, an increase of approximately 2.5 times that observed in the uppermost 3.2 km within each month. Moreover, daily temperatures exceeded 17ºC over 50% of the time during July for loggers placed in reaches that had been restored from 2005-2008 (i.e., lowermost four loggers).

Summer stream temperatures along the 6.4 km section of the upper Benewah mainstem were generally cooler in 2009 than in 2007, but warmer than those recorded in 2008 (Table 17). In addition, temperature differences among years differed between the upper and lower 3.2 km reaches. Compared to 2007, July means of daily mean and maximum temperatures calculated in 2009 were on average only respectively 1.7ºC and 1.5ºC cooler for the four loggers positioned along the lower 3.2 km, but 2.4ºC and 2.8ºC cooler for the four loggers positioned along the upper 3.2 km. Similarly, the percent time in which July temperatures exceeded 17ºC was on average 24% less along the lower reach, but 43% less along the upper reach when comparing 2009 data to that recorded in 2007. Conversely, the opposite trend in reach differences was observed when comparing 2009 to 2008 data. Compared to 2008, July means of daily mean and maximum temperatures calculated in 2009 were on average respectively 0.9ºC and 1.2ºC warmer along the lower 3.2 km, but only 0.2ºC and 0.1ºC warmer along the upper 3.2 km. Additionally, when comparing 2009 to 2008, the percent time in which July temperatures exceeded 17ºC was on average 15% more along the lower reach, but only 6% more along the upper reach.

Table 16. Summary statistics for July and August water temperatures recorded by data loggers located in the main channel, in off-channel springbrooks, and in tributaries in the upper Benewah watershed in 2009. Rkm refers to the number of river kilometers above 9-mile bridge; loggers placed in tributaries were located < 0.1 km from their confluence with the Benewah mainstem, and in this case, Rkm refers to the relative position of the tributary mouth to 9-mile bridge. 17°C was considered the upper 95% confidence interval limit for optimal growth for westslope cutthroat trout (Bear et al. 2007).

Stream	Site	Rkm	Mean of daily means	Mean of daily maximums	Percent time > 17°C
		July temperatures			
Benewah	Main channel	0.1	19.1	21.5	81.9
Benewah	Main channel	0.4	18.9	21.3	80.0
Benewah	Main channel	1.1	17.8	20.8	60.3
Benewah	Main channel	1.6	17.5	20.4	56.4
Benewah	Main channel	2.6	16.1	18.9	37.0
Benewah	Main channel	3.2	15.5	17.9	24.9
Benewah	Main channel	3.8	15.1	16.4	10.4
Benewah	Main channel	4.2	15.0	16.1	9.1
Benewah	Main channel	5.2	15.0	16.4	10.8
Benewah	Main channel	5.4	14.3	16.6	8.7
Benewah	Main channel	6.0	14.1	16.4	8.3
Benewah	Main channel	6.4	13.7	15.3	2.0
Benewah	Springbrook	1.3	14.0	14.8	0.0
Benewah	Springbrook	2.5	11.5	11.9	0.0
Benewah [a]	Springbrook	3.8	8.2	8.3	0.0
Benewah	Springbrook	4.2	12.8	13.3	0.0
Whitetail	Tributary	1.1	12.0	12.8	0.0
Windfall	Tributary	5.3	13.7	15.4	0.9
Schoolhouse	Tributary	6.4	13.0	14.6	0.4
Unnamed tributary	Tributary	7.1	12.4	13.8	0.0
		August temperatures			
Benewah	Main channel	0.1	18.3	19.9	66.8
Benewah	Main channel	0.4	18.0	20.2	62.3
Benewah	Main channel	1.1	17.2	19.0	47.6
Benewah	Main channel	1.6	17.1	19.7	47.2
Benewah	Main channel	2.6	16.0	17.9	28.3
Benewah	Main channel	3.2	15.4	17.3	20.7
Benewah	Main channel	3.8	14.7	15.8	13.6
Benewah	Main channel	4.2	14.8	15.7	14.8
Benewah	Main channel	5.2	14.9	16.4	17.7
Benewah	Main channel	5.4	14.3	15.7	9.2
Benewah	Main channel	6.0	14.2	16.1	10.7
Benewah	Main channel	6.4	13.9	15.1	4.1
Benewah	Springbrook	1.3	13.2	13.8	0.0
Benewah	Springbrook	2.5	11.8	12.0	0.0
Benewah [a]	Springbrook	3.8	9.3	9.3	0.0
Benewah	Springbrook	4.2	12.7	13.1	0.0
Whitetail	Tributary	1.1	12.2	12.7	0.0
Windfall	Tributary	5.3	13.0	13.8	0.0
Schoolhouse	Tributary	6.4	13.2	14.6	1.7
Unnamed tributary	Tributary	7.1	12.8	13.9	0.0

[a] Springbrook was isolated from the main channel

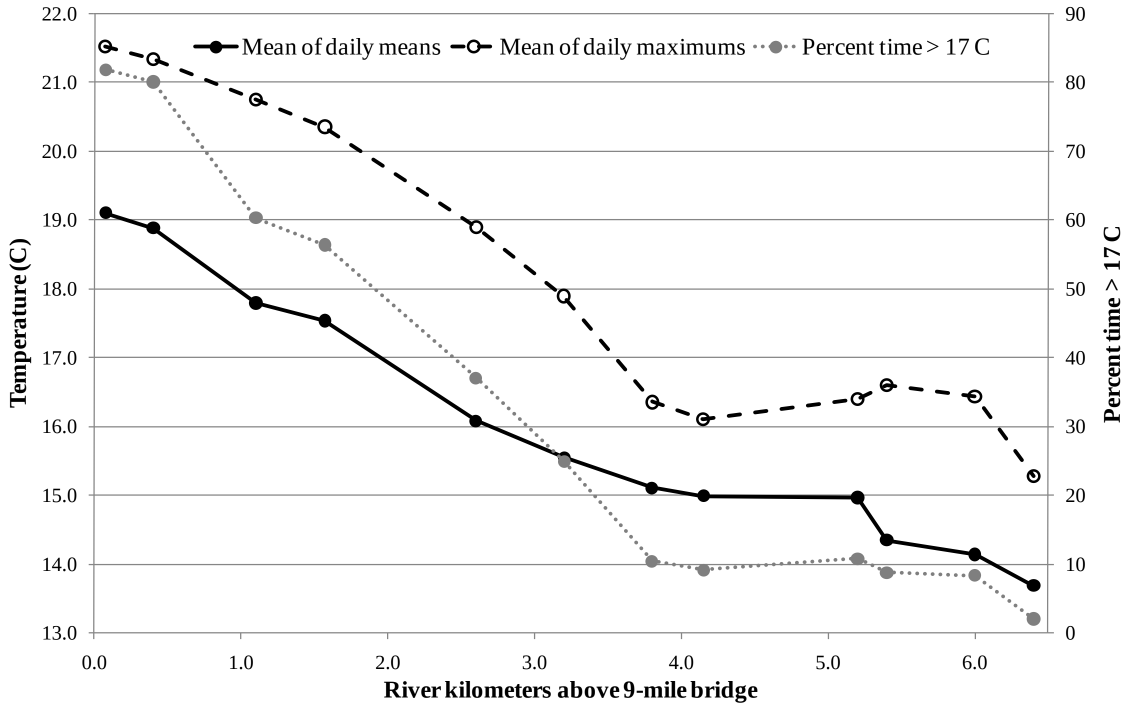

Figure 27. Longitudinal change in the July mean of daily mean and maximum ambient stream temperatures and of the percent time temperatures exceeded 17^{o}C over mainstem Benewah reaches above 9-mile bridge, 2009.

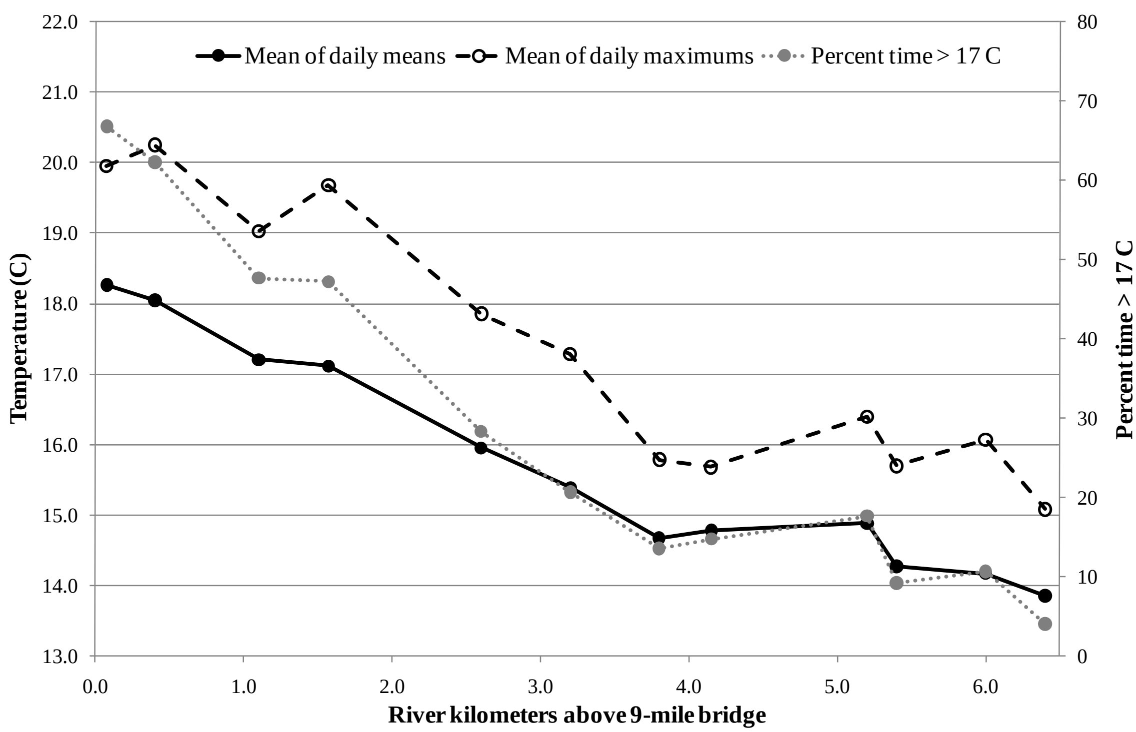

Figure 28. Longitudinal change in the August mean of daily mean and maximum ambient stream temperatures and of the percent time temperatures exceeded 17^{o}C over mainstem Benewah reaches above 9-mile bridge, 2009.

Table 17. Comparison of summary statistics among 2007, 2008, and 2009 for July temperatures recorded by data loggers in upper Benewah mainstem reaches. Rkm refers to the number of river kilometers above 9-mile bridge. 17°C was considered the upper 95% confidence interval limit for optimal growth for westslope cutthroat trout (Bear et al. 2007).

	Mean of daily means			**Mean of daily maximums**			**Percent time > 17°C**		
Rkm	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
0.1	21.4	18.2	19.1	24.7	20.8	21.5	95.2	68.1	81.9
1.1	18.8	16.8	17.8	20.5	19.5	20.8	86.6	45.8	60.3
1.6	18.5	16.4	17.5	20.8	18.9	20.4	78.9	37.5	56.4
2.6	18.6	15.5	16.1	21.5	17.8	18.9	71.5	23.5	37.0
3.2	17.8	15.1	15.5	20.3	16.8	17.9	64.5	10.5	24.9
4.2	17.4	14.8	15.0	18.8	16.1	16.1	62.3	3.3	9.1
5.4	16.7	14.2	14.3	18.6	16.4	16.6	47.2	4.7	8.7
6.4	16.4	13.8	13.7	19.1	16.1	15.3	42.5	2.8	2.0

Temperature indices were cooler in lower reaches of monitored tributaries than in mainstem reaches in the upper Benewah watershed in 2009 (Table 16). In July and August, monthly means of daily mean temperatures respectively ranged from 12.0 to 13.7ºC and from 12.2 to 13.2ºC, and monthly means of daily maximums respectively ranged from 12.8 to 15.4ºC and from 12.7 to 14.6ºC. These ranges were all lower than their respective counterparts in mainstem reaches. In addition, water temperatures barely exceeded 17ºC in monitored tributaries during the summer of 2009, with only one tributary logger in each month displaying a percent time greater than 17ºC of only 1-2%.

In addition to the tributaries in the upper mainstem of the Benewah watershed, various springbrooks also displayed temperature signatures during summer months in 2009 that were much cooler than those recorded in adjacent mainstem habitats (Table 16). At monitored connected springbrooks located 1.3, 2.5, and 4.2 km upstream of 9-mile bridge, July averages of daily mean temperatures were respectively 3.8, 4.6, and 2.2ºC less than those in proximate (i.e., less than 0.2 km) main channel reaches. Similarly, July averages of daily maximums were respectively 6.0, 7.0, and 2.8 ºC less than those in nearby main channel reaches. As expected, differences in mean values were greater for daily maximums than for daily means due to the moderating influence of springbrooks on diel temperature fluctuations. Further, differences in mean values for both indices were not as large for the pair of loggers located in the upper half of the monitored mainstem reach compared to the two paired loggers located downstream. August results displayed similar discrepancies in temperature metrics for all pairs of loggers. Notably, temperature metrics for the isolated springbrook that was located in the unconstrained valley reach were not only nearly identical, but were the lowest of all values recorded, with mean monthly values ranging between 8.2 and 9.3ºC. Temperatures recorded at connected and isolated springbrooks never exceeded 17ºC during July and August of 2009.

3.3.2.2 Lake Creek temperatures

Ambient stream temperatures were generally cool throughout most of the upper Lake Creek watershed during the summer of 2009 (Table 18). Monthly means of mean daily temperatures in July and August ranged from 14.2 to 15.4ºC for loggers located in reaches proximate to the confluence of the three upper forks. Loggers located further upstream in the Bozard subdrainage had calculated monthly means during these two months that ranged from 13.0 to 13.7ºC. Similar patterns emerged for the calculated monthly averages of daily maximum values. Averages for loggers located near the confluence of the three forks ranged from 15.2 to 17.0ºC, whereas averages for the group of loggers positioned further up the Bozard subdrainage ranged from 14.4 to 15.2ºC. However, summer temperatures recorded in the reach of the mainstem near the old H95 bridge (in close proximity to the location of the migrant traps) were much warmer than those recorded upstream. Monthly averages of daily maximum temperatures were 2.1 and 3.6ºC higher than the highest values calculated for upriver loggers during July and August, respectively.

The percentage of time recorded temperatures exceeded 17ºC was also generally low across the upper Lake Creek watershed during the summer of 2009 (Table 18). The percent of the time temperatures were greater than 17ºC in July and August was between 9 and 17 for the group of loggers positioned near the confluence of the three forks, and less than 4 for that group located in the upper Bozard subdrainage. In comparison, temperatures exceeded 17ºC approximately 52% of the time in the lower mainstem reach.

Table 18. Summary statistics for July and August water temperatures recorded by data loggers located in reaches of the upper mainstem of Lake Creek and of proximate tributaries in 2009. Logger locations are listed in order of relative longitudinal position in the watershed from lowermost to uppermost. 17^{o}C was considered the upper 95% confidence interval limit for westslope cutthroat trout optimal growth (Bear et al. 2007).

Logger location	**Mean of daily means**	**Mean of daily maximums**	**Percent time > 17^{o}C**
		July temperatures	
Lake Creek mainstem, near old H95 bridge	17.5	20.5	56.0
Lake Creek mainstem, downstream of Bozard Creek confluence	15.4	16.7	16.5
Bozard Creek, upstream of Lake Creek confluence	14.9	16.9	14.5
West Fork Lake Creek, upstream of Lake Creek confluence	15.4	16.8	17.4
Bozard Creek, downstream of East Fork Bozard confluence	13.1	14.6	0.4
East Fork Bozard, upstream of Bozard Creek confluence	13.0	14.4	0.0
Bozard Creek, upstream of East Fork Bozard confluence	13.2	15.0	1.3
		August temperatures	
Lake Creek mainstem, near old H95 bridge	16.9	19.1	48.1
Lake Creek mainstem, downstream of Bozard Creek confluence	15.1	16.5	15.3
Bozard Creek, upstream of Lake Creek confluence	14.7	17.0	14.2
West Fork Lake Creek, upstream of Lake Creek confluence	14.2	15.2	8.8
Bozard Creek, downstream of East Fork Bozard confluence	13.5	14.9	1.9
East Fork Bozard, upstream of Bozard Creek confluence	13.4	14.8	1.3
Bozard Creek, upstream of East Fork Bozard confluence	13.7	15.2	3.6

Similar to the results documented in the upper Benewah watershed, temperatures in the upper Lake Creek watershed in 2009 were cooler than in 2007 but slightly warmer than in 2008 (Table 19). July means of daily mean and maximum temperatures in monitored reaches were on average respectively 1.7 and 2.1ºC lower in 2009 than in 2007. Additionally, the percent time in which July temperatures exceeded 17ºC was on average 9% less for the group of loggers in the upper Bozard subdrainage, and 32% less for the rest of the loggers located downstream when comparing 2009 to 2007. Conversely, July averages of daily mean and maximum temperatures were on average respectively 0.7 and 0.8ºC higher in 2009 than in 2008. Further, the percent time in which July temperatures exceeded 17ºC was on average 11% more for the group of four loggers located most downstream in the watershed, and was approximately equivalent for the group in the upper Bozard subdrainage, when comparing 2009 to 2008.

Table 19. Comparison of summary statistics among 2007, 2008, and 2009 for July water temperatures recorded by data loggers located in reaches of the upper mainstem of Lake Creek and of proximate tributaries. Logger locations are listed in order of relative longitudinal position in the watershed from lowermost to uppermost. 17^{o}C was considered the upper 95% confidence interval limit for westslope cutthroat trout optimal growth (Bear et al. 2007).

	Mean of daily means			Mean of daily maximums			Percent time > 17^{o}C		
Logger location	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
Lake Creek mainstem, near old H95 bridge	19.7	16.5	17.5	22.8	19.3	20.5	81.6	42.7	56.0
Lake Creek mainstem, downstream of Bozard Creek confluence	17.3	14.8	15.4	19.5	16.4	16.7	58.6	6.1	16.5
Bozard Creek, upstream of Lake Creek confluence	17.1	14.1	14.9	20.4	15.8	16.9	50.3	2.2	14.5
West Fork Lake Creek, upstream of Lake Creek confluence	16.5	15.2	15.4	17.9	16.6	16.8	41.2	9.2	17.4
Upper Lake Creek, upstream of West Fork confluence [a]	17.0	15.4	.	19.5	16.4	.	48.6	9.5	.
Bozard Creek, downstream of East Fork Bozard confluence	14.6	12.3	13.1	16.4	13.7	14.6	8.9	0.0	0.4
East Fork Bozard, upstream of Bozard Creek confluence	14.5	12.1	13.0	16.0	13.4	14.4	5.8	0.0	0.0
Bozard Creek, upstream of East Fork Bozard confluence	14.8	12.6	13.2	16.9	14.3	15.0	14.8	0.0	1.3

[a] Logger could not be located in 2009

3.3.3 Effectiveness monitoring – Response to habitat restoration activities

3.3.3.1 Physical and biological response to habitat restoration in lower Evans Creek

Comparison of crosss-sectional data, 2003-2009

Habitat site cross-sections for sites in Evans Creek were compared between 2003 and 2009 to examine changes in channel form over time (see Appendix A for graphical illustrations for all sites). The cross section graphs display small changes to the bed and banks at the cross section locations. They show changes over time with regard to streambank erosion and lateral stability. Many of the changes in cross-section can be due to how the tape is stretched along the channel. Other changes could be due to the size of substrate lining the bottom of the channel. Also, some head pins on some of the cross-sections had to be re-established because the original rebar stake had become buried, bent, or had been removed. The following figures highlight some of the sites where moderate changes to channel bed and banks occurred due to erosion or deposition.

Depositional processes were illustrated by the comparative data collected at cross-section 2 at Evans site 4 (Figure 29). 1.02 m^2 of sediment was deposited in the main channel. In comparison, the channel dimensions of cross-section 3 at site 1 in Evans Creek displayed minimal changes over the 5-year period (Figure 29). Evans Creek site 1 is backwatered by the Coeur d'Alene River during part of the year which may help protect its banks from eroding.

Evans site 5 had cross-sections where erosion was widening the channel. From 2003 to 2009, Evans site 5 (cross-section 4;Figure 30) experienced bank erosion on the left bank looking downstream, resulting in an area of 1.7 m^2 of streambank that was lost. Comparative data collected at cross-section 2 at site 5 in Evans Creek showed bank erosion on the right bank (0.37 m^2 of erosion). In addition, the left bank showed some aggradation while the thalwag deepened slightly. The most change in any cross-section was due to changing head pins (Appendix A, Evans site 5, cross-section 1).

Figure 31 compares a cross-section profile at Evans site 3 from 2003 to 2009. Between 2003 and 2005, there was some scour on the right bank and aggradation on the channel bed in the main part of the channel. One year post construction, two ELWD structures are present in the cross-section. The channel bed is 0.3 ft above where the channel bed was located in 2005. The ELWD structures that were present in 2006 moved in 2008 so that both of the pieces were located on the left bank (only one structure was present in the cross-section). The deeper part of the pool associated with these two pieces of wood filled in with rock. Comparing the profile of 2009 with that of 2003, channel bed aggradation of approximately one foot has occurred at this cross-section. Given similar levels of bed aggradation at cross-sections at site 4 upriver, it is difficult to determine if the wood structures contributed to the collection and deposition of sediment, or if other watershed-related processes operating at larger spatial were responsible.

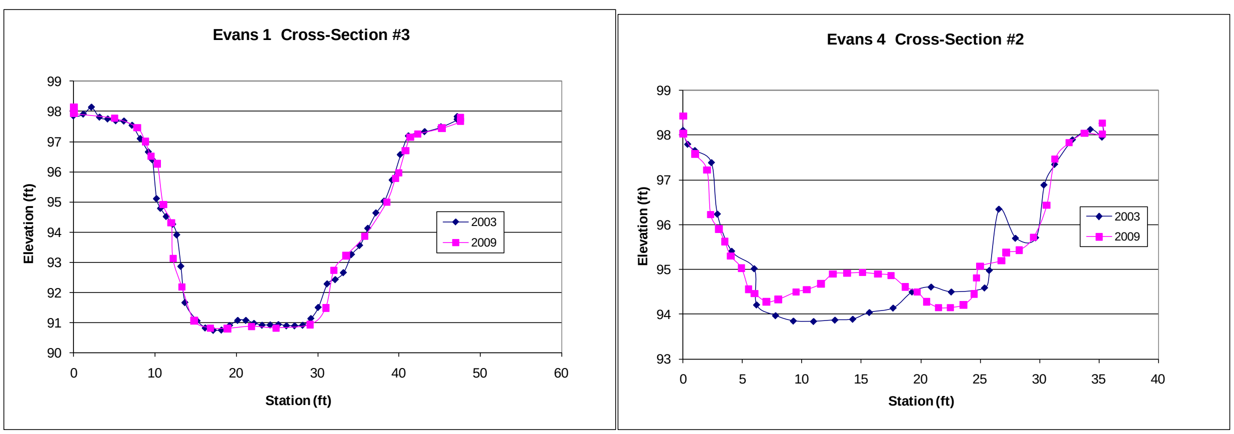

Figure 29. Comparisons of cross-sections at Evans Creek site 1 (left panel) and Evans Creek site 4 (right panel) between 2003 and 2009.

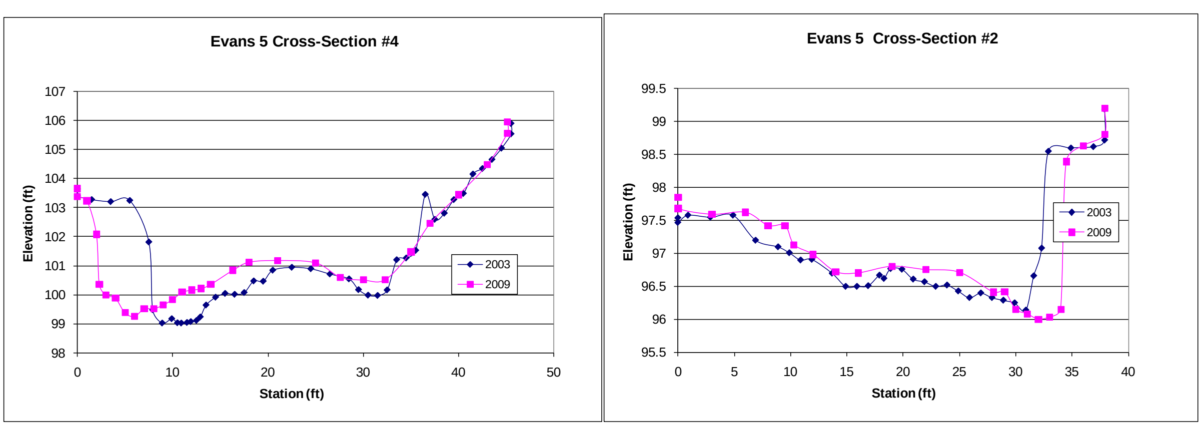

Figure 30. Comparisons of cross-sections at Evans Creek site 5 between 2003 and 2009.

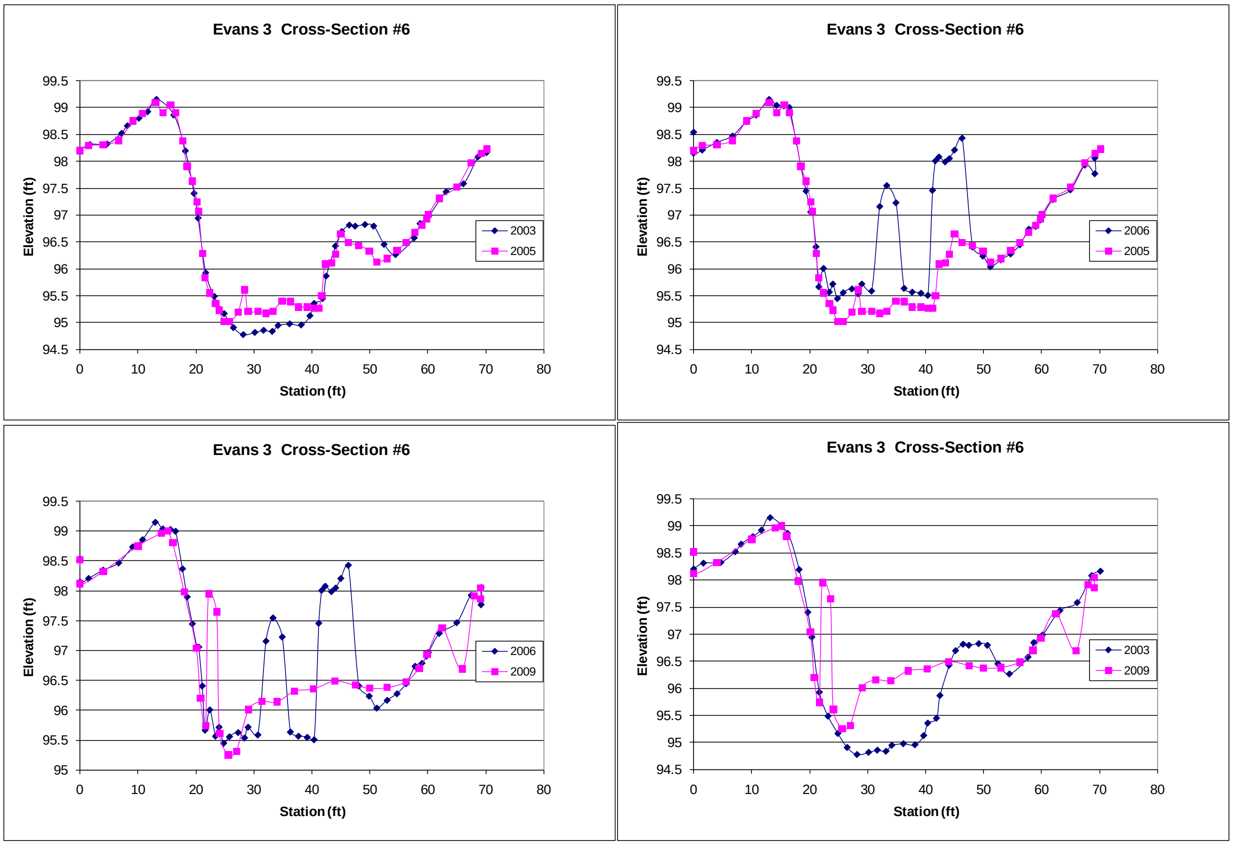

Figure 31. Comparisons of cross-section 6 at Evans site 3 for preconstruction, one-year post, 4 years post construction, and for all years during the period of 2003 to 2009.

Changes in physical and biological metrics at a restored site in lower Evans Creek

Large wood loading was greater in the restored than the control site in Evans Creek from 2003-2009 (Table 20). The density of large wood at Evans 3 in 2005 (pre-restoration) was 4.12 m^3/ 100 m while in 2006 (post-restoration) the density was 25.32 m^3/ 100 m. Part of the 2005 wood density was due to a large rootwad that had a volume of 3.97 m^3. This rootwad moved off the site in 2006. There was a substantial increase in the number of pieces of wood after restoration activities were completed. There were 10 pieces located at Evans 3 in 2005 and 144 pieces located there in 2006. A majority of the wood post-construction consisted of the 14 *ELWd*™ structures which each contain 8 logs. Wood loading decreased in 2009 compared to 2006 due to the force of high flows in intervening years causing some of the natural wood to be moved off site. However, cabled *ELWd*™ structures remained present, even though many had changed their orientation. Even while this was occurring, smaller pieces were continuing to accumulate behind a number of the *ELWd*™ structures resulting in more logs being present in 2009 compared to 2006. For the control site, wood loading increased slightly from 2.27 m^3/ 100 m in 2005 to 3.66 m^3/ 100 m in 2009. A decrease in the number of pieces of wood occurred at this site from 2003 to 2005, and an increase occurred in the number of pieces from 2005 to 2009. The wood loading at the restored site meets Tribal objectives of 9 m^3/ 100m. This objective was not met at the un-restored control site.

Pool metrics did not change substantially at Evans 3, relative to the control site, when comparing pre-treatment data with post-treatment data (Table 20). Though there was an increase in mean pool depth for both restored and un-restored sites from 2005 to 2009, the mean depth increased more in this time period at the un-restored Evans 4 site (0.15 m to 0.24 m) than it did at the restored site (0.23 m to 0.28 m). Similarly, the number of pools did not exhibit a persistent increase at the treated site over the same time period. Though pools did increase from 6 in 2005 to 9 in 2006 one year following treatment, a decrease back to 6 was documented in 2009; the number of pools recorded at the control site remained unchanged between surveys conducted in 2005 and 2009. Overall, a lack of deep pools is apparent in data collected in lower Evans. In 2009, only two pools greater than 0.3 m residual depth were recorded at each of the two sites, and no pools in any years at any site had residual depths greater than 1 meter.

Slight differences were seen in substrate composition between the restored and control sites in lower Evans Creek between 2003 and 2009 (Table 20). Control site 4 showed little change in substrate composition (particles less than 2 mm) between 2005 and 2009 with 15.71% and 15.11%, respectively. This is higher than the 2003 value of 1.64%. Values varied widely for substrate at Evans site 3, showing low numbers from 2003-2005 (pre-construction), the highest value of 21.64% in 2006, and then 3.81% in 2009. Currently, the performance objective of less than 15% fines in riffle/run habitats is being met at the restored Evans 3 site. Evans 4 was right at the threshold of 15% for 2005 and 2009.

Though trout densities were very similar in lower Evans creek from 1996 to 2002, extremely different trends were observed from 2003 to 2009 between the treated reach and two control reaches (Figure 32). Prior to restoration, from 2003 to 2005, the mean density of cutthroat trout at the treated site 3 was 12.8 fish/100 m. After restoration in 2005, mean density over the years 2006 to 2009 increased dramatically to 93.2 fish/100 m. Conversely, over the same time periods, mean densities decreased from 48.3 to 32.3 fish/100 m at downriver control site 2, and 30.8 to 21.1 fish/100 m at upriver control site 4. Evidently, the *ELWd*^{TM} structures provided important habitat at site 3 (Picture 2).

Table 20. Habitat indicator variables measured at Evans site 3(restored) and Evans site 4 (un-restored) for 2003-2009. The Evans 3 site was treated with large woody debris placements in 2005.

	Unrestored			Restored		Unrestored		
	Evans site 3					*Evans site 4*		
YEAR	2003	2004	2005	2006	2009	2003	2005	2009
Average of % < 2mm	0.00	0.00	2.29	21.64	3.81	1.64	15.71	15.11
Total count	11	6	10	144	156	32	9	24
Volume (m^3)	4.15	7.02	6.27	38.49	29.67	4.26	3.44	5.56
Loading (m^3/ 100 m)	2.73	4.62	4.12	25.32	19.52	2.80	2.27	3.66
Mean pool depth (m)	0.33	0.39	0.23	0.28	0.28	0.14	0.15	0.24
Max pool depth (m)	0.73	0.84	0.41	0.51	0.52	0.27	0.25	0.42
Min pool depth (m)	0.16	0.14	0.10	0.13	0.16	0.09	0.10	0.14
Number of pools	6	7	6	9	6	8	6	6

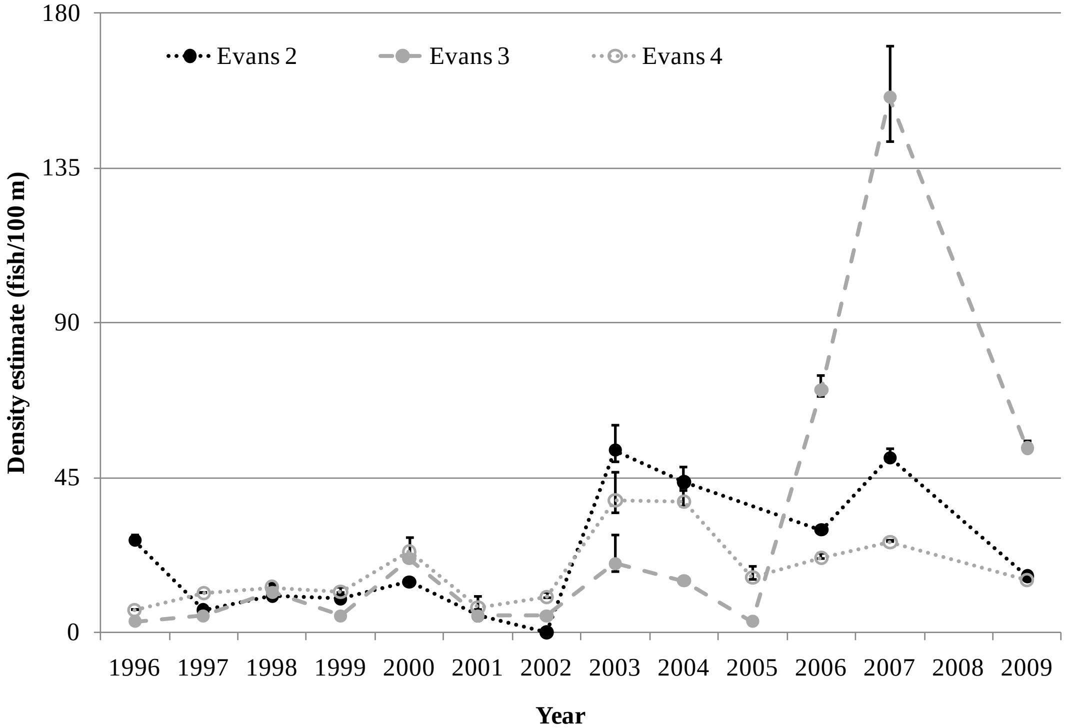

Figure 32. Density estimates and associated 95% confidence intervals for cutthroat trout at restored site 3 and unrestored sites 2 and 4 in lower Evans Creek, 1996-2009. In-channel habitat enhancement occurred at site 3 in fall of 2005 after fish sampling had occurred.

Picture 2. Westslope Cutthroat Trout using ELWd™ Structures.

3.3.3.2 Thermal responses to habitat restoration in the Benewah watershed

Temperature measurements collected from pool habitats and their associated downstream riffles on August 4 of 2009 revealed moderate thermal refugia in a 650 m reach of the upper mainstem of Benewah Creek that was restored in 2008 (Figure 33). Before channel reconstruction, there were numerous pools in this reach, but none that exceeded 1.0 m in residual depth. Although several of the pools of at least 0.8 m exhibited temperature differentials between 1.5 and 3.0ºC, approximately 62% of the pools surveyed were less than 0.6 m in residual depth, with most of these pools displaying temperature differences less than 0.5ºC. After reconstruction, pools were less numerous but all with residual depths greater than 1.0 m and bottom temperatures that were 1.5 - 3.0ºC cooler than those in downstream associated riffles.

Notably, these thermal differences were not as great as those recorded in previous post-construction surveys for more downstream restored reaches. For example, in an August 2008 survey of reaches that underwent construction in 2005-2007, it was common for pools with greater than 1.0 m of residual depth to display pool temperatures that were typically 3.0 – 6.5ºC cooler than downstream riffles (Firehammer et al. 2010). Cool ambient stream temperatures could not explain the lack of a detection of strong thermal differences in the 2009 survey, given that temperatures measured in riffles averaged 18.4ºC throughout monitoring, and furthermore, the fact that July and August temperatures were generally warmer in 2009 than in 2008 in the Benewah mainstem.

Thermal refugia monitoring was also conducted along a 2.6 km meadow reach of the upper Benewah mainstem (Gore Creek to Windfall Creek) that is undergoing treatment as part of Phase 2 restoration. The survey conducted in early August indicated a general lack of temperature differences between pool bottoms and associated riffles (Figure 34). Of the 84 pools surveyed, only 5 (6%) displayed temperature differentials between 1.0 and 2.5ºC; four of these five pools were the deepest ones surveyed with residual depths of 1.1-1.2 m. Seventy-five (89%) of the pools were less than 1.0 m of residual depth, with most of these pools exhibiting temperature differentials that were less than 0.5ºC.

3.3.3.3 Evaluation of habitat response to Benewah main channel restoration

Changes in habitat attributes at the mainstem reach restored in 2008

Both wood loadings and residual pool depths met performance objectives at the site surveyed in the reach that underwent channel re-construction in 2008. Large wood loading increased 803% from 2.76 m^3/100 m in 2008 to 24.9 m^3/ 100m in 2009, exceeding the performance standard of 9 m^3/ 100m. Number of wood pieces also substantially increased from 30 to 89 after restoration activities were completed in 2008. All pools that were identified at the site in 2009 met the residual depth performance standard of 1.0 m for mainstem reaches. Though the number of pools decreased from 11 in 2008 to 6 in 2009 after restoration was completed, mean residual depth increased from 0.67 m to 1.34 m and maximum pool depth increased from 0.98 m to 1.46 m. Pool volume in 2009 was 131.1 m^3/100 m.

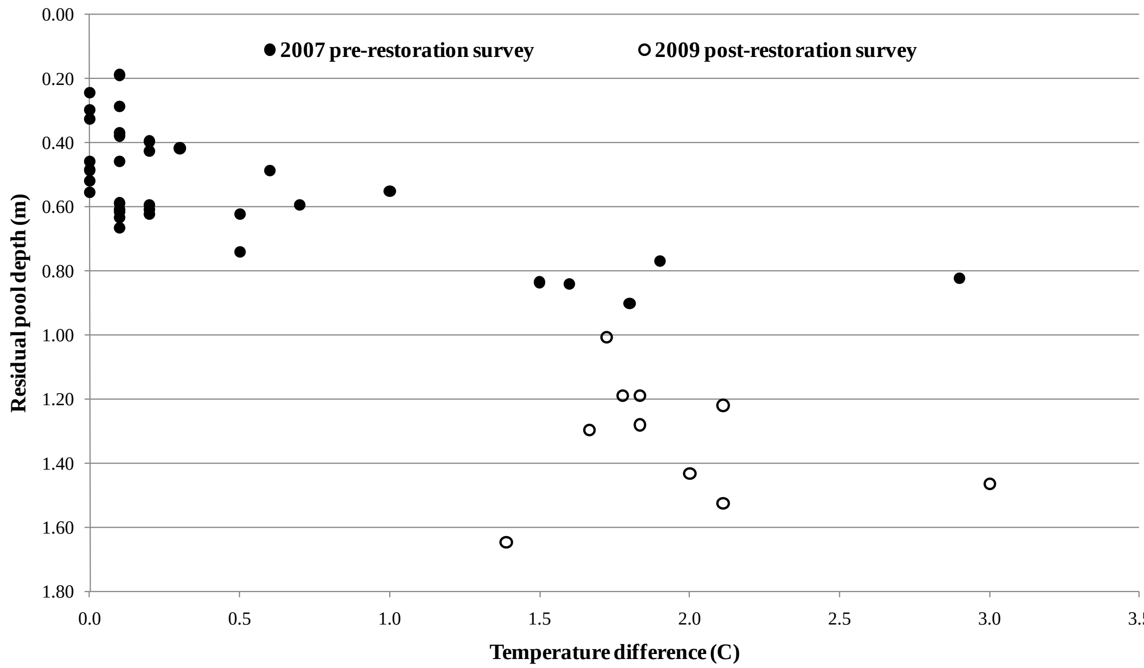

Figure 33. The relationship between temperature difference and residual pool depth for surveys conducted in 2007 (filled circles) and 2009 (open circles), periods before and after implemented restoration actions, along the upper mainstem Benewah reach that was restored in 2008. Temperature difference was calculated as the temperature measured along the pool bottom minus the temperature measured in the associated downstream riffle.

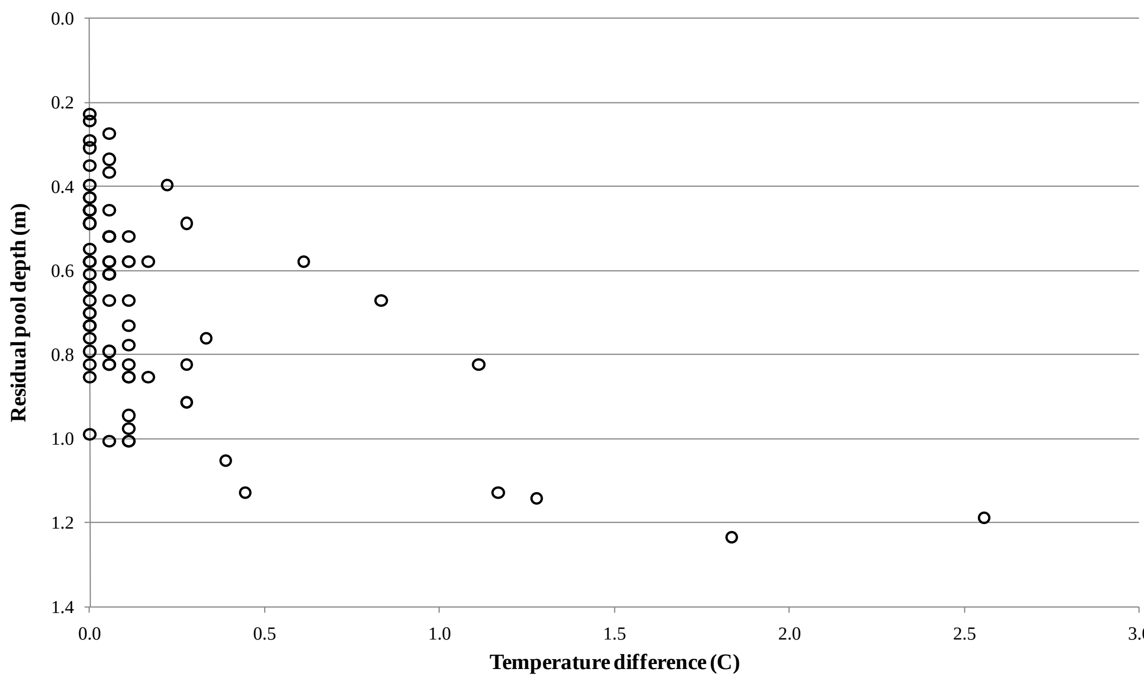

Figure 34. The relationship between temperature difference and residual pool depth for surveys conducted in 2009 along a 2.6 km reach in the upper Benewah mainstem. Temperature difference was calculated as the temperature measured along the pool bottom minus the temperature measured in the associated downstream riffle.

The percentage of fines at the site decreased from 51.68% in 2008 to 30.03% in 2009 (42% decrease). The differences seen in substrate sampling between the two years may be due to how much of the sampling focused on the areas between "active bed" flow and bankfull flow. Bankfull areas outside the wetted channel have more fines than in the active bed. For example, at one riffle site that was surveyed in 2009, there were no particles surveyed in the active channel bed that were less than 2 mm. At the same riffle, there were 34 particles collected outside of the active channel bed that were less than 2mm. The location of where the substrate sample was collected was recorded in 2009 but not in 2008. In the future, the sampling locations of the particles measured during substrate sampling will be recorded in order to remove the variability due to location out of the substrate analysis. The performance objective of less than 15% fines in riffle/run habitats was not met before or after restoration for the site.

Consistent with previously restored sites in the upper Benewah mainstem, canopy cover at the site decreased from 59% in 2008 to 32% in 2009. The lower canopy cover percentages estimated post-restoration was likely due to the removal of established vegetation during construction activities that modified and re-aligned the channel. Given the width of this restored mainstem reach, a period of time will be required before newly planted trees and shrubs become established and attain the height required to provide consistent shade across the channel.

Beaver dam monitoring in the Phase II restoration reach of the upper Benewah mainstem

Morphological attributes measured at monitored beaver dams in the upper reach of the Benewah mainstem changed considerably between the two survey periods in 2009. During the first survey, in late June through early July, 39 beaver dams were documented. At this time, 26 of the 39 dams (67%) lacked the presence of newly placed materials (e.g., green woody stems) and were considered inactive. Furthermore, seven of the 39 were observed to be breached and not backing up water upstream, and as a result assigned a dam height of 0. Median dam height during the early summer survey period was 0.6 ft, with only 10 of the 39 dams (26%) greater than 1.0 ft in height (Figure 35).

During the fall survey period in 2009, approximately three months later, 47 dams were documented; though 7 of those surveyed earlier were not located in the fall, 15 new dams were observed. Of the 47 dams identified in the fall survey, only 5 (11%) were considered to be inactive, indicating evidence of considerable building activity over late summer and early fall. As such, median dam height in the fall period was 1.34 ft, a value over twice that recorded in the spring survey (Figure 35). Further, all surveyed dams were considered structurally intact, with the lowest dam measured at 0.55 ft, and 32 (68%) of the dams greater than 1.0 ft in height. For those 32 dams that were documented during both survey periods, dam height significantly increased over the summer on average by 0.67 ft (Figure 36). In total over both survey periods, only 14 of the 54 dams (26%) documented were considered to be either built with or upon stable materials (e.g., large woody debris); nine of these 14 were located in two reaches that still maintained an adjacent relatively intact riparian forest community.

Seasonal increases in all four of the attributes that described backwatered habitat were observed in association with the change in dam height at monitored Benewah mainstem dams in 2009 (Figure 36). Inundated area, pool area, pool volume, and mean residual pool depth all displayed significant increases over time for the 32 dams surveyed in both time periods. Inundated and pool area increased by a mean value of 1068 and 951 ft^2, respectively, and pool volume increased by a mean value of 763 ft^3. The mean change in pool volume displayed the highest precision of all four backwater attributes (Figure 36). Residual pool depth, a metric that has been linked to the suitability of salmonid rearing habitat, increased by 0.6 ft, a value similar to that recorded for change in dam height. For all monitored dams, the median of the mean residual pool depth increased from 2.1 ft in early summer to 3.0 ft in the fall.

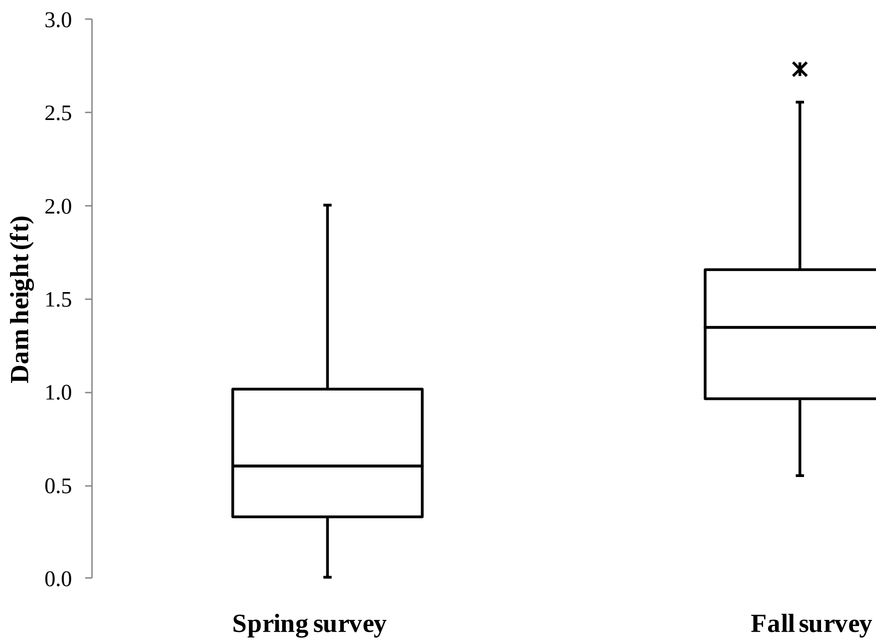

Figure 35. Box plots illustrating distribution of measured beaver dam heights in the upper Benewah mainstem during spring (n=39) and fall (n=47) surveys in 2009.

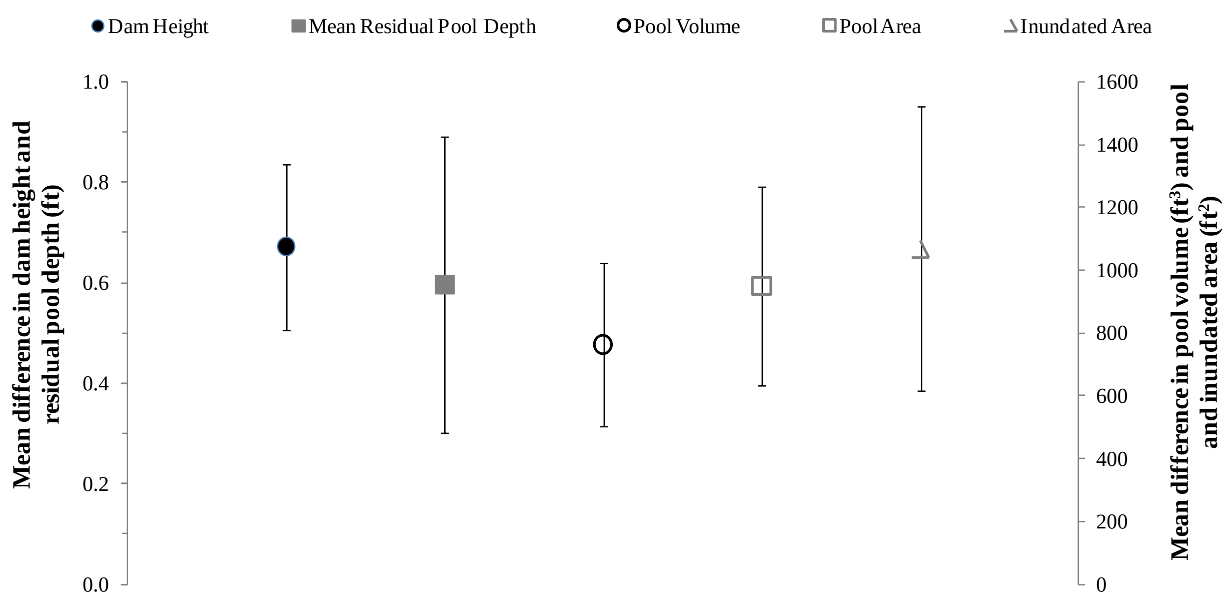

Figure 36. Mean changes and associated 95% confidence intervals for dam height and four attributes that described backwatered habitat for thirty-two dams monitored in both spring and fall survey periods in the upper Benewah mainstem, 2009.

3.3.4 Effectiveness monitoring – Response to brook trout removal in Benewah Creek

A total of 529 brook trout was removed from the upper Benewah Creek watershed during removal efforts in 2009 (Table 21). Of these 529, 501 were removed during shocking efforts conducted over the 2.0 km reach of contiguous mainstem habitat above the 12-mile bridge to the confluence of the two forks. Removal activities for this reach occurred over a four day period (average of 3.5 h per day) within the timeframe of August 31 – September 16. The other 28 were captured by shocking the small reach enclosed by the temporary trap that was installed on August 26 upriver of the 12-mile bridge. From September 11 to November 6, at which time the trap was removed, this 25 m reach was sampled on five separate occasions, approximately one to two weeks apart. Given the minimal time expended shocking the enclosed reach (5-10 min/sampling occasion), much less effort was spent in 2009 than in previous years. However, the number of ascending brook trout captured by the trap, 28, was substantially less than the numbers of brook trout removed annually from mainstem reaches below the 12-mile bridge, 514 to 1192, over the last three years (Table 21).

Total numbers of brook trout removed in 2009 were much less than in previous years of the suppression program because of the reduced effort. When comparing numbers removed from the 2.0 km reach above 12-mile bridge, a reach that has been regularly sampled over the last five years, calculated densities in 2009 (250 fish/km) were still much less than those in 2005 and 2006 (452 - 481 fish/km). However, the most recent density estimates indicate that over the last three years there may be a slight increasing trend in brook trout numbers in this reach. In addition, the percent of large fish over 150 mm and the estimated percent of adults in 2009 were the lowest values documented over the last four years for each of the two metrics. However, caution should be exercised when interpreting this result given that the mainstem reach below 12-mile bridge, which has also been shown to hold large adult brook trout, was not sampled in 2009.

Table 21. Summary of stream length sampled and brook trout removed from two mainstem reaches and tributary habitats in the Benewah watershed, 2004-2009. Probability of maturation models derived separately for each year and sex were used to assign maturation status to fish that were not assessed for removal years 2004-2008. Maturation status for fish removed in 2009 was estimated using the probability models derived from data collected in 2008.

	9-mile bridge to 12-mile bridge			12-mile bridge to confluence of south and west forks			Tributaries					Mature fish removed (%)	
Year	Survey length (km)	Fish removed	Fish/ km	Survey length (km)	Fish removed	Fish/ km	Survey length (km)	Fish removed	Fish/ km	Total fish removed	Percent fish > 150 mm	Females	Males
2004	.	.	.	0.5	61	122.0	3.7	605	164.1	666	12	81 (12)	95 (14)
2005	0.8	193	231.4	2.0	962	481.0	3.7	233	63.2	1388	18	319 (23)	207 (15)
2006	3.4	1192	351.9	2.0	904	452.0	3.7	421	114.2	2517	36	736 (29)	659 (26)
2007	6.0	514	85.7	2.0	311	155.5	3.7	260	70.5	1085	40	181 (17)	141 (13)
2008	5.2	829	159.4	2.0	384	192.0	1.5	138	92.0	1351	31	250 (19)	198 (15)
2009	.	.	.	2.0	501	250.5	.	.	.	529	23	70 (13)	58 (11)

Repeated measures analysis for examining brook trout trends

Trajectories of age 1+ brook trout differed between upper tributary reaches of the Benewah Creek watershed and upper reaches of the Alder Creek watershed over the years 2003-2009. When conducting the repeated measures analysis using all ten composite reaches from both watersheds and grouping by watershed, a significant interaction was detected between watersheds for the depletion estimate series ($p = 0.007$) and the first pass catch series ($p = 0.002$). Consequently, analyses were then conducted separately given that trends may be operating differently among watersheds. In the Alder Creek watershed, significant synchronous differences were detected among years for both series of depletion estimates ($p = 0.002$) and first pass catch ($p = 0.001$; Table 22). In addition, significant linear and higher order trends were apparent in both series, though the linear trends were the strongest in each, explaining 57 and 46% of the annual variation in the series of depletion estimates and first pass catch, respectively. Generally, as illustrated in the time series of depletion estimates, densities were relatively low in 2003 and 2004, increased but remained relatively stable over the period from 2006-2008, and then displayed a more recent increase in 2009 (Figure 37).

Conversely, neither concurrent differences nor overall trends were detected among years across the five composite tributary reaches in the upper Benewah watershed for both the depletion estimates ($p = 0.435$) and first pass catch data ($p = 0.560$; Table 22). The lack of a synchronous trend among tributaries was illustrated by the plotted series of depletion estimates (Figure 38). For Whitetail, South Fork, and West Fork tributaries, age 1+ brook trout densities were generally high or increasing from 2003 to 2006. However, over the past three years, mean densities have been lower in all three tributaries, and appreciably so in West Fork. On the other hand, brook trout densities have been generally increasing, though variable, in both Windfall and Schoolhouse Creeks.

Table 22. Summary of repeated measures analysis for series of standardized depletion estimates and first pass catch to detect trends in age 1+ brook trout over the years 2003-2009.

	Depletion-removal estimate (fish/100 m)			**1st pass catch (fish/100 m)**		
Statistical test	***F***	***p***	**Percent explained by trend**	***F***	***p***	**Percent explained by trend**
Alder Creek						
Difference among years	5.96	0.002	.	6.57	0.001	.
Linear trend	12.02	0.026	57	9.16	0.039	46
Cubic trend	7.30	0.054	19	9.65	0.036	22
4th order trend	11.78	0.026	23	15.48	0.017	25
Benewah creek - upriver of 9-mile bridge						
Difference among years	1.02	0.435 [a]	.	0.81	0.560 [a]	.

[a] Huynh-Feldt conditions not satisfied. No significant trends were detected.

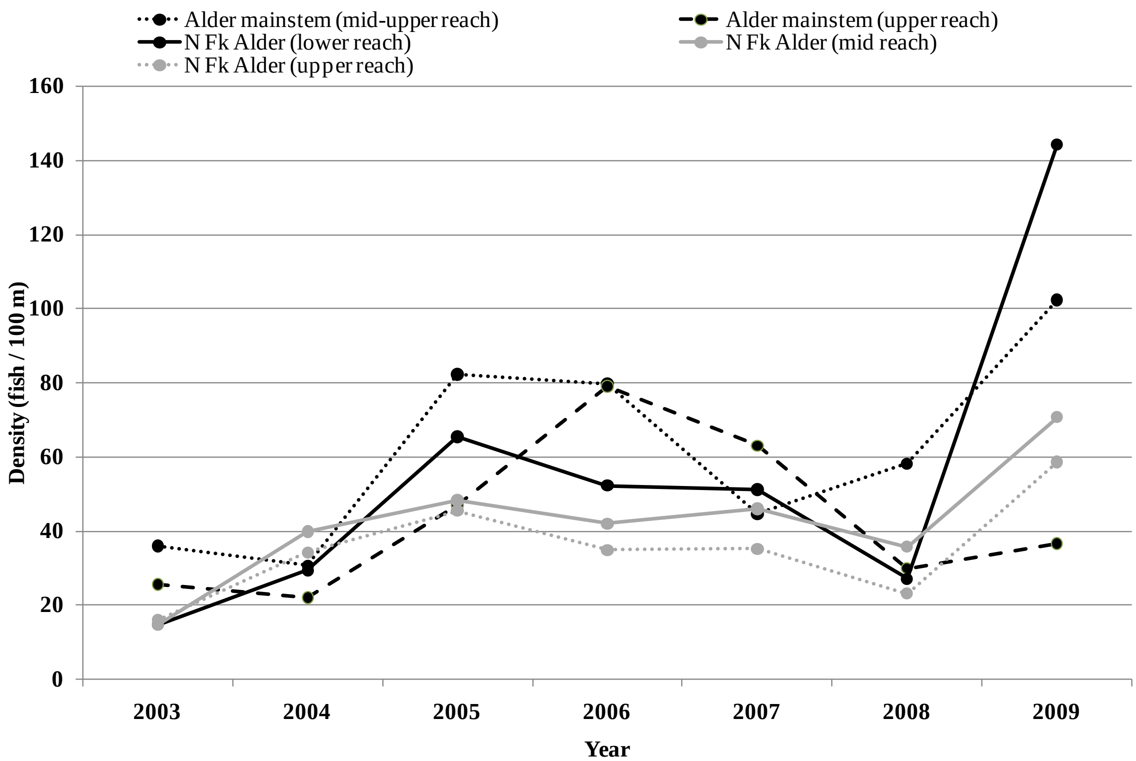

Figure 37. Depletion-removal estimates (fish/100 m) of age 1+ brook trout for five composite reaches in the upper Alder Creek watershed, 2003-2009.

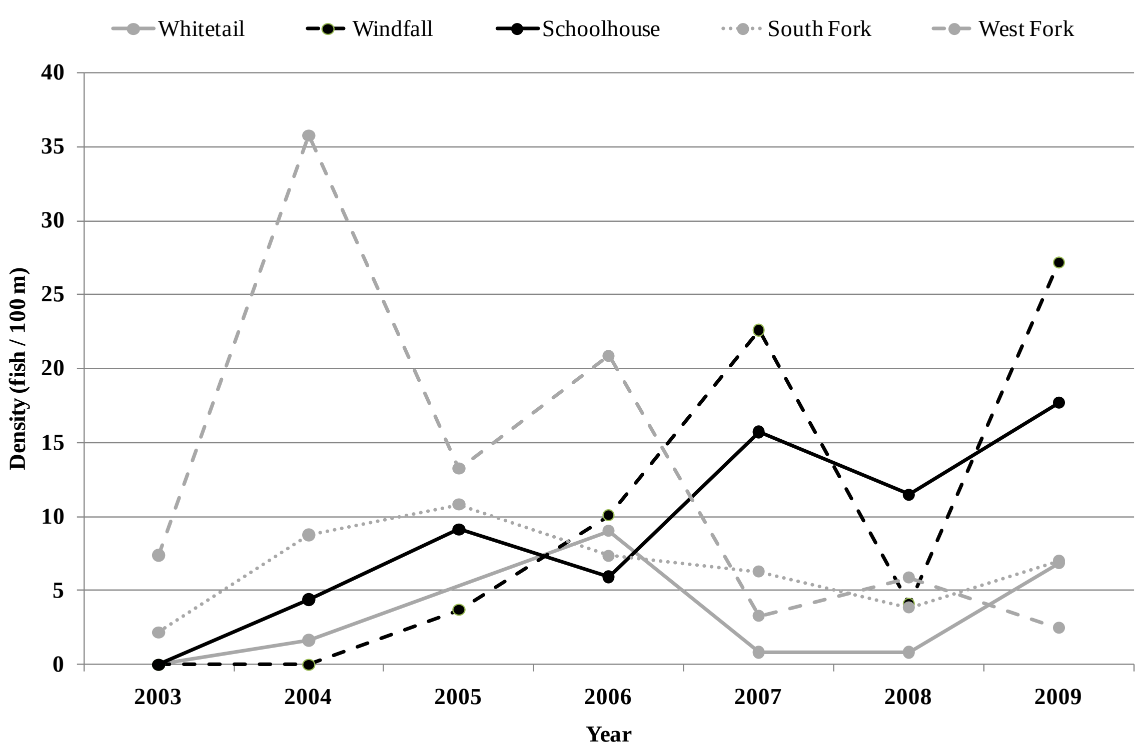

Figure 38. Depletion-removal estimates (fish/100 m) of age 1+ brook trout for five composite tributary reaches in the upper Benewah Creek watershed, 2003-2009.

3.4 Discussion

3.4.1 Status and trend monitoring

3.4.1.1 Adfluvial cutthroat trout migration

It is imperative that we reliably track temporal changes in adult spawners given that one of the primary objectives of our recovery efforts is to augment the number of returning adult cutthroat to our adfluvial watersheds. However, reliable unbiased spawner abundances cannot be obtained using adult counts at upriver traps because of the inconsistency in trapping efficiency that can occur due to flow regime variability across years. For example, over the years from 2005 to 2007, twenty-four to 124 spawners have been annually captured by the RBW trap in Lake Creek. Given the similarity in counts of post-spawn adults captured across these years (i.e., 233-258), the variability in upriver counts was most likely due to inconsistencies in annual trapping performance. In 2009, the effective use of a semi-permanent recognizable mark (i.e., opercle punch) allowed us to obtain our first abundance estimate with a rather precise interval of 5-6%. Such accuracy in annual estimates should permit the detection of true trends in adult spawners over time.

It should be duly noted, however, that modifications were made to the RBW trap in Lake Creek, which enabled the trap to effectively fish under a much wider range of conditions than in previous years. The ability to hoist the trap panels, adjusting their position relative to the water surface, permitted a large percentage of the upriver migrants to be intercepted in 2009. For example, approximately equivalent numbers of adults were captured in the RBW and DN traps in 2009, whereas in the past typically two to three times more adults were captured in the DN than in the RBW trap. The ability to capture and mark a large percentage of the available fish contributed greatly to the certainty in our spawner abundance estimate.

Because of the apparent success of this modification to the Lake Creek RBW trap, we intend to modify the Benewah Creek RBW trap accordingly in 2010. Over the past two years, high spring flows have been observed to repeatedly depress the panels of the Benewah RBW trap below the water surface during the spring migratory period, and as a likely result, only one adult upriver migrant has been captured. Being able to keep panels elevated during high spring flows in Benewah Creek should enable a substantial portion of the upriver migration to be captured and marked, and consequently, permit a spawner abundance to be estimated for the upper Benewah watershed. In addition, we have also noticed insufficient current velocities at the entranceway to the live box raceway at the Benewah Creek RBW, which likely have not been providing the necessary cues to attract fish, and could be contributing to our inability to capture upriver migrants. To address this deficiency, during the spring trapping period in 2010 we intend to redirect the flow upriver of the RBW to augment that delivered through the raceway to provide a more prominent velocity cue.

Our estimate of 175 spawning adults in Lake Creek in 2009 was much lower than the range of post-spawn fish, 233 to 257, that had been captured over the years 2005-2007, a range that is likely biased low given that it doesn't account for mortality on the spawning grounds (a reliable value was not available in 2008 given that traps were seriously compromised by high flows in that year). The decrease in estimated spawners in 2009, after a relatively consistent level of abundance, may reflect a true decline in the Lake Creek subpopulation of mature adfluvial adults present in Lake Coeur d'Alene. However, we should not exclude the possibility that our improved trap performance could have adversely influenced the number of upriver migrants captured. If there is a tendency for some fish to engage in trap avoidance behavior, then the improved ability to impede upriver movement may discourage some fish from entering the entranceway to the livebox raceway; in the past, these fish could have waited for an opportunity to pass when periodic freshets submerged trap panels. Whatever the reason for the low numbers of adults estimated to have ascended past the RBW trap in 2009, it is imperative that we continue to monitor spawners annually in Lake Creek to evaluate if this is an anomaly or a real declining trend.

Results from the PIT-tagging efforts that have been implemented since 2005 in Lake Creek indicate that a low percentage of outmigrating juveniles return to spawn as adults. Our estimate of 1.8% for survival to first spawn, in combination with the assumption, corroborated by our tag return data, that many of the juveniles first return to spawn after two years of lake residence, translates to an annual in-lake survival rate of approximately 14-15%. Although empirical estimates of in-lake survival rates for adfluvial cutthroat trout are scarce, several studies have provided values with which comparisons may be drawn. May et al. (1988) estimated mean annual survival rates of cutthroat trout in Hungry Horse Reservoir, Montana at 56%, though distinctions between adult and juvenile survival in the reservoir were not drawn. In Yellowstone Lake, Stapp and Hayward (2002) computed annual survival rates of 37% for juvenile cutthroat trout during lake residence. Annual survival rates of 49% were estimated in Libby Reservoir for cutthroat trout from reservoir entry as juveniles to first time spawning two years later (Huston et al. 1984). Compared with these studies, our annual estimates are substantially lower.

The low apparent survival rates may be an artifact of sampling procedures, including compromised detection probability, and either tag loss or tag-related mortality. With regards to detection probability, however, it is highly likely that even without capture a tagged adult returning to spawn will be detected by our monitoring systems. The fixed PIT-tag antennas span the entire channel width in Lake Creek and interrogate the wetted channel in Benewah creek under most flows, and are positioned immediately downriver of the RBW traps in both systems where the likelihood of detection would be great as upriver migrants linger in the vicinity of the detection field as they attempt to negotiate the trap. Further, tagged juveniles released as test batches upriver of the antenna array in Lake Creek demonstrate detection rates of 99% (Firehammer et al. 2010). High rates of immediate tag loss or unintended handling mortality also likely do not sufficiently explain the absence of detected fish. Over the past four years in which mortality/retention trials have been conducted, all fish have been alive upon release and found to retain their tags. Although we have captured adults with a clipped adipose fin that have not scanned, indicating that tags have been shed, tag loss may have occurred during a prior spawning event. Tag loss in cutthroat trout on the spawning grounds has been reported in other systems (Bateman et al. 2009). An evaluation of when tag loss occurs in our watersheds may be aided by analyzing images of collected scales to determine if adults that do not scan are first-time or repeat spawners.

Survival rates of juveniles during in-lake residence may also be speciously underestimated given that a percentage of tagged juveniles may not actually engage in an outmigration to the lake, or may not display strong fidelity as adults to their natal spawning grounds. As demonstrated in the Benewah system, a couple of juveniles that had been regarded as adfluvial and tagged in 2008 were recaptured in the trap in 2009 with markings resembling those of resident fish. At this time, there is a degree of uncertainty as to how many of the tagged juveniles, purported to be outmigrants, are residualizing in reaches of both Lake and Benewah creeks. Introducing antenna arrays in lower mainstem reaches near the mouths of both systems may shed light on the prevalence of this behavior. In addition, as for the likelihood of adult straying, we have yet to detect a fish in one watershed (e.g., Benewah Creek) that has been tagged in the other watershed (e.g., Lake Creek). However, more information on movement between watersheds, especially those with outlets to the lake that are in close proximity to one another (e.g., Lake and Fighting creeks), would permit a better assessment of the strength of homing behavior in the Coeur d'Alene basin.

Alternatively, the low juvenile-to-adult survival rates may be real and attributed to processes operating in Lake Coeur d'Alene. Further, though these seemingly limiting processes are not well understood, the juvenile attributes of those fish that have been detected as adults may yield insight into some of the mechanisms. Juveniles that have survived to return to spawn generally migrated earlier in the spring, but more importantly, were larger when tagged than those that have not returned. Size at outmigration may reflect the energetically-mediated capacity to survive, especially if size at tagging is positively related to the size or condition of the individual at onset of the overwintering period. In addition, large size at outmigration may confer benefits to the individual by decreasing its vulnerability to predation either through enhanced swimming performance or the capability to escape gape-limited predators. Whatever the reason, it is necessary to better understand whether predation is a predominant mechanism regulating survival rates in Lake Coeur d'Alene and potentially inhibiting recovery of cutthroat trout, particularly given the seeming increase in non-native predators that have been documented in recent surveys (Maiolie et al. 2010).

In-lake processes may not only be impacting juveniles but could also be influencing survival rates of post-spawn adults. Moreover, spatial variability in these processes may exist in the lake, and could be giving rise to some of the morphometric differences observed between Lake and Benewah creek adults. Post-spawn females in Benewah Creek were generally of lower condition than those sampled in Lake Creek in 2009, suggesting a potential disparity in somatic growth opportunities for adults between these two watersheds, and a consequent energetic disadvantage for post-spawn Benewah Creek females. In addition, males captured in 2009 were generally smaller in length in Benewah Creek than in Lake Creek, which may indicate that there are less repeat spawners present, which in turn could suggest that post-spawn survival rates are lower for fish in Benewah Creek. However, caution should be exercised when interpreting the age of an adult spawner from its size at capture given that our PIT-tag data suggest that, whereas growth rates are relatively high during early lake residence before maturation, somatic growth may considerably decrease after the initial spawn. Notwithstanding the similar discrepancy that was also apparent in last year's data, the addition of several more years of adult return data should aid in evaluating whether the differences between watersheds are genuine or just an artifact of the small sample sizes in Benewah Creek over the last two years.

Furthermore, given the heretofore difficulty in evaluating post-spawn survival because of low numbers of detected PIT-tagged fish, the supplemental tagging of adults, which was first conducted in Lake Creek in 2009, will increase the number of detectable fish and allow us to more accurately estimate post-spawn survival rates and return frequency. As performed in Lake Creek this year, adults will only be tagged at upriver RBW traps so that post-spawn survival rates can be adjusted upwards by short-term tag retention rates, adjustments that can only be estimated by the recapture of double-tagged fish (i.e., opercle-punched) at downriver traps. Additional information regarding the age, growth, and return rates of adfluvial fish in our watersheds should provide insight into potential mechanisms that may also be impacting adult cutthroat trout in Coeur d'Alene Lake and whether the strength of these mechanisms differs depending on where they are operating within the lake.

Adult spawner estimates, in combination with juvenile outmigration estimates and associated age structure information, will also permit the derivation of outmigrant per spawner ratios, indices that would allow tracking of watershed-wide trajectories in juvenile production in addition to aiding in the assessment of in-stream population response to our restoration actions (Bradford et al. 2005). Though results from Lake Creek in 2009 indicate the potential for attaining accurate spawner abundances, we do not yet have the capability of obtaining accurate juvenile outmigrant abundance estimates in either watershed. In Benewah Creek in 2009, DN trap efficiencies were variable and relatively low during most of the release trial periods resulting in an imprecise outmigration estimate. Furthermore, notwithstanding the potential for high trap efficiencies and precise estimates as were calculated during release trial periods in Lake Creek in 2009, total abundance estimates were undoubtedly biased low in both watersheds. As supported by the large number of juveniles captured in both systems immediately upon trap installation, a considerable portion of the outmigration may have been missed given our inability to capture fish before DN traps could be effectively deployed. The later date of DN trap deployment may have explained in part the considerably lower outmigrant abundance estimate in Benewah Creek than in Lake Creek.

PIT-tag detections in Benewah Creek also corroborate the probable omission of an early component in our outmigration estimates. Several fish that were tagged as juveniles in 2008 were detected briefly in mid-March through mid-April in 2009 before trap installation. Although these fish may have been residents, they may also have been 'holdovers' that waited a year before outmigrating, which lends credence to the fact that other juveniles may have also been moving downriver at this time. Aside from problems arising from the timing of trap deployment, periods of trap inoperability during structurally damaging high discharge events, as has happened in previous years (Firehammer et al. 2010), also precludes the ability to capture juveniles and generate unbiased abundance estimates. Both biases, however, may have the potential to be redressed by using PIT-tagged juveniles in mark-recapture models to estimate outmigration abundances. Juveniles that had been tagged during late summer and early fall electrofishing surveys in tributary habitats and passively detected by fixed antennas the following spring would serve as marked fish in models. The recapture of a percentage of these 'marked' individuals, along with other unmarked fish, in DN traps during operable periods would then enable the calculation of the total number of outmigrating juveniles, and thus obviate the need to effectively capture fish throughout the spring outmigration period. Such a change in protocol is contingent upon the restructuring of sampling procedures in tributary habitats and the ability to reformulate PIT-tag methodology, which will be given further consideration in the near future.

Alternatively, there may be a need to re-evaluate the techniques we employ to capture juveniles to ensure that the full range of traits expressed in the outmigrating cohort is reflected in those individuals that are tagged. Though juveniles in both watersheds were tagged representatively throughout *capture* periods in 2009, it may be necessary to capture and tag those early outmigrants to further our understanding of the apparent observed relationship between timing at outmigration and the probability of return to first spawn. Furthermore, a relationship may exist between the time and size at which juveniles initiate their downstream movement to the lake, which cannot be accurately assessed without handling the early component of the outmigration.

Trapping modifications will require those that permit structures to be installed under a wide variety of flow conditions, especially at high discharge during early spring when juveniles may be first cued to outmigrate.

In addition to achieving a better understanding of the characteristics of early migrants, there is also a need to better understand that which was exhibited by juveniles outmigrating toward the end of the trapping season in 2009. For example, though the size of captured juveniles was similar between the two systems throughout May, the average size decreased in June in Benewah Creek and was much lower than that recorded in Lake Creek. Moreover, several small-sized juveniles tagged in Benewah Creek in late May and early June of last year were briefly detected during outmigration periods in 2009, implying that these fish may have not been motivated to outmigrate in 2008 but resided in the stream for another year. At this time, it is unclear as to whether smaller fish captured late in the season in Benewah Creek are actively moving out of the system or are just inadvertently intercepted by the trap during localized early-summer foraging movements.

3.4.1.2 Index site cutthroat trout abundance

Population surveys conducted at index sites during the summer and fall of 2009 permitted an assessment of cutthroat trout trends at a much finer spatial scale than that attainable using our migrant trap data. Consistent with surveys conducted in previous years, cutthroat trout in our adfluvial watersheds were primarily found in tributaries, though their distribution within tributaries varied between the two watersheds. In Lake Creek, relatively high densities were observed in the three major tributaries that comprise the upper watershed, but only at the uppermost sample sites in each tributary. Habitat data collected in previous years indicate much lower large woody debris loadings and higher percent fines in riffles in lower than in upper tributary reaches (Firehammer et al. 2010). Sub-optimal rearing conditions could be contributing to the absence of fish in these lower tributary reaches. Prioritizing these reaches for prospective habitat improvements should increase connectivity and promote a more robust meta-population structure in upper Lake Creek. Relative to upper tributaries, the finding of moderate densities in lower mainstem reaches downriver of the trap site in Lake Creek may either suggest that reproduction is also occurring in the lower watershed, or may be indicative of stepwise migratory behavior in which fish gradually move downstream to larger-sized habitats (Zydlewski et al. 2009).

In contrast to Lake Creek, cutthroat trout in the Benewah watershed were observed across most of the sites in upper and lower reaches of all sampled tributaries other than Coon Creek, but at comparably modest densities. The lower densities estimated across tributary reaches may reflect the generally lower number of adfluvial adults that have been captured over the past couple of years in Benewah Creek than in Lake Creek. Compared with tributary habitats, age 1+ cutthroat trout were rarely captured in most of the mainstem sites. On the other hand, age-0 cutthroat trout were observed in relatively large numbers in a couple of the upper mainstem sites near tributary sources, suggesting that young-of-the-year cutthroat trout may be expanding downstream and utilizing these reaches as rearing habitat. In addition to age-0 cutthroat trout, we also observed relatively large densities of both age-0 and older non-native brook trout in upper mainstem habitats. Because of the observed overlap in habitat use between species, competitive interactions may be adversely impacting cutthroat trout demographics in this reach, especially during these early life stages as has been demonstrated in other systems (Peterson et al. 2004a).

Tracking age 1+ cutthroat trout densities in these mainstem habitats over time should reveal if such competitive mechanisms are prevalent in the upper Benewah watershed.

In Evans and Alder creek watersheds, which support prevailing resident cutthroat trout populations, spatial distributions were vastly different between systems, but were similar to those documented during previous surveys within each system. Consistent with past years, cutthroat trout in Alder Creek were only found in lower reaches, and at low densities, and have been seemingly displaced from upper reaches of the watershed, where they are virtually absent but brook trout are numerous. In comparison, cutthroat trout in Evans Creek were observed at moderate densities in mainstem reaches across the entire watershed, a pattern that has been repeatedly observed in our annual population surveys.

Population survey data collected across watersheds in 2009 validated the exclusion of age-0 fish when comparing density data across watersheds or over years. Age-0 cutthroat trout were often prevalent at sites sampled in upper reaches of most tributaries in Benewah Creek, though were relatively scarce in surveys conducted in Evans Creek and even in tributaries of Lake Creek. Given that Evans and Lake creeks were sampled earlier than Benewah Creek, young-of-the-year may not have yet recruited to the sampling gear in those two systems. Alternatively, sample sites in Evans and Lake creeks may not have been located in heavily utilized spawning areas in 2009. Whatever the reason for the observed discrepancy among watersheds, changes in the timing of spawning or preference of spawning reaches among years could confound the interpretation of temporal and spatial trends. Furthermore, age-0 fish are typically more difficult to capture in deeper or more complex (e.g., large wood loadings) reaches. Lastly, the presence of age-0 fish in surveyed reaches may merely inform the level of reproductive success in any given year, but may not yield insight into changes in processes that regulate other demographics, such as survival, which in our case may be of primary interest given our stated objective of restoring suitable rearing habitats.

Index site data collected over the last seven years revealed the presence of temporal trends in age 1+ cutthroat trout in some of our monitored watersheds, though the abundance trajectories varied among the systems surveyed. Synchronous trends in cutthroat abundance among reaches were apparent in both the Evans Creek watershed and the upper Benewah Creek watershed. In Evans Creek, though there was evidence of a linear increase in abundance over time, a greater portion of the annual variability in abundance was explained by a cyclical trend. Generally, densities were found to decrease from 2003 to 2005, exhibit an increase from 2005 to 2207, and then decrease slightly over the next two years, so that in half of the composite reaches densities in 2009 were not appreciably different from those in 2003. In comparison, cutthroat trout in upper Benewah Creek (i.e., upriver of the 9-mile bridge) displayed a more prominent linear increase in tributary-wide densities over time. Similar concurrent trends, however, were not apparent in tributary and mainstem reaches downriver of 9-mile bridge. These results suggest that processes that influenced cutthroat trout demographics in tributaries in the upper Benewah watershed were operating similarly and contributing to an overall increase in juvenile abundance, whereas those that influenced abundance in the lower reaches were likely operating independently from one another.

The positive trends in cutthroat trout abundance observed in both Evans Creek and tributaries of the upper Benewah watershed may have been due to a combination of a regionally favorable environment and population responses to recovery actions. Given that Benewah and Evans creeks are spatially-distinct watersheds within the Coeur d'Alene system, basin-wide stream conditions that were conducive to spawning success and to increased survival rates of early life stages, could in part explain the trajectories observed. Concordant population abundances, indicative of regional climatic influence, have commonly been reported in regional networks of small salmonid streams (Platts and Nelson 1988; Gowan and Fausch 1996). However, given that the abundance trajectory exhibited a more linear profile in Benewah Creek than in Evans Creek, observed increases in cutthroat trout abundance in upper Benewah may have also been a collective response to the large-scale habitat restoration and the aggressive brook trout suppression program that have proceeded in upper Benewah reaches since 2004. In comparison, Evans Creek has received minimal management intervention in recent years. As additional years of data are collected, further comparison between these two watersheds will allow us to better evaluate whether population responses in upper Benewah are the result of our remedial actions.

In contrast to Evans Creek and the upper Benewah watershed, results from the trend analysis in Lake Creek indicated the absence of a watershed-scale trend in cutthroat trout abundance since 2003, and the likelihood that processes regulating cutthroat abundance are operating independently from one another in sampled reaches. The lack of a consistent, detectable trend, especially across those upper tributary reaches where cutthroat trout have been found to be prevalent, may indicate that tributary-specific carrying capacities have been reached and that annual changes in estimated abundances reflect natural variability around those capacities. As mentioned previously, improving rearing conditions in lower reaches of tributary habitats through restorative treatments should permit expansion from spawning habitats and improve production potential.

Results from our trend analyses also indicated that first pass catch data provided similar interpretations of watershed-wide abundance trends in cutthroat trout as did our removal-depletion estimates. Additionally, first pass catch data and depletion estimates displayed remarkably similar profiles in some of the examined composite reaches, as demonstrated by those trends in upper Lake Creek tributaries. These results lend support to using first-pass catch data as an index of abundance rather than multi-pass depletion estimates to examine long-term trends in our watersheds. The multipass-depletion technique can be time-consuming, especially in our watersheds where the relatively large amount of fine sediment leads to much time expended between passes waiting for water clarity to improve. In addition, the probability of unintended injury may increase with each subsequent pass, as previously stunned fish that were unable to be initially captured are continuously submitted to additional shocking events. Furthermore, as has been previously reported (Firehammer et al. 2009), the large degree of variability observed among index site depletion estimates in our systems do not permit a reliable examination of absolute abundance trends when expanded to either the reach or the watershed scale, and consequently, are only useful for examining site-specific temporal changes. Because of these concerns and the desire to increase sampling efficiency, an index of abundance is considered preferable to an absolute estimate, providing that it tracks true abundance over time.

The mark-recapture study that was conducted in our watersheds in 2009 provided evidence that a single-pass estimator of abundance would have the capability of tracking true abundance. Even at high densities of marked fish (e.g., over 60 trout marked at two Alder Creek sites), a high percentage of these marked fish were recaptured the following day during the recapture event. Others have also found single-pass indices to perform well in predicting abundances for salmonid populations in small-streams (Strange et al. 1989; Jones and Stockwell 1995; Kruse et al. 1998; Mitro and Zale 2000; Bateman et al. 2005). More importantly, we found that depletion estimates, particularly at high-density sites, underestimated the true abundance, primarily as a result of an overestimation of capture probability during subsequent passes. Although this conclusion could be confounded by variable sampling efficiencies between marking and recapture events, the similarity in first pass catch for both events at most sites indicated a consistency in initial capture probability between days. Additionally, our findings were consistent with other studies that documented similar biases associated with depletion-removal estimates for salmonids in small stream systems (Riley and Fausch 1992; Rodgers et al. 1992; Peterson et al. 2004b; Rosenberger and Dunham 2005).

Based on the results from the marking study, depletion estimates were also found to be either unreliable or to provide spurious estimates of precision. Unreliable estimates (e.g., wide confidence intervals) were generated at several of the sites and were most often the result of the inability to substantially deplete numbers of captured fish over passes. This, in turn, was frequently the result of highly variable capture probabilities among the depletion passes, which could have been attributed to unique habitat features at these sites (e.g., deep pools, large woody debris accumulations). On the other hand, intervals generated around depletion estimates at most of the other sites were much more precise than those generated by mark-recapture estimates. However, given the evident bias associated with depletion estimates, this can misleadingly provide confidence in their ability to measure true abundance. As a result of this study, we intend to change our sampling protocol and replace depletion estimates with single pass indices to track abundance trajectories in our watersheds. Moreover, because of the reduced effort associated with single-pass efforts, we should also be able to incorporate additional reaches into our annual sampling work plans to enable us to expand our efforts across a greater percentage of our watersheds to better understand salmonid demographics.

3.4.1.3 Longitudinal water temperatures

The ambient stream temperatures recorded in Lake and Benewah watersheds in 2009 still support the suitability of tributaries over mainstem reaches as cutthroat trout rearing habitats during mid-summer periods. Temperatures remained below 17^{o}C, a value above which is considered sub-optimal for cutthroat trout growth (Bear et al. 2007), more than 95% of the time in upper tributaries of Lake Creek and in all monitored tributaries of Benewah Creek during the months of July and August. In contrast, temperatures exceeded this threshold more than 50% of the time in the mainstem reach of Lake Creek near our trap site and in upper mainstem reaches of Benewah Creek that were restored from 2005-2008. Given the consistently higher densities of cutthroat trout observed in tributary than in mainstem habitats, the mid-summer differences in rearing temperatures between tributary and mainstem reaches likely explain in part the distributional patterns of cutthroat trout observed in both watersheds (Dunham et al. 1999; Paul and Post 2001; Sloat et al. 2001; de la Hoz Franco and Budy 2005).

However, in the Benewah watershed, the mainstem meadow reach that is currently receiving Phase 2 restoration treatments (i.e., 3.2-6.0 km upriver of 9-mile bridge) afforded more suitable ambient stream temperatures than reaches downriver that had been restored during Phase 1. Temperatures were relatively consistent throughout the Phase 2 reach, and remained below the 17^{o}C benchmark at least 75% of the time during the summer. Observed differences in temperature signatures between these two mainstem reaches may in part be explained by differences in available canopy cover. An enclosed canopy of hawthorne and alder is regularly present along the Phase 2 reach, whereas much of the Phase 1 reach is still relatively exposed as a result of the channel re-construction that removed much of the vegetation. Years will be required before the post-construction streamside and riparian plantings will ameliorate the conditions introduced by the channel disturbances.

Alternatively, the observed differences in stream temperatures may also be explained by the greater influence of groundwater inputs in the upper than in the lower reach. Monitored springbrooks in the upper watershed have consistently displayed temperature signatures during summer months that were much cooler than those recorded in adjacent mainstem habitats. In addition, data from the peizometers that were installed within floodplain habitats of the unconstrained alluvial Phase 2 reach indicated that transmission of groundwater from off-channel sources to the main channel generally occurs along the interface between the gravel/cobble and silt/clay layers located 4-6 feet below the surface. Apparently, this reach of the mainstem is closer to these off-channel groundwater sources and/or receives substantially more cool groundwater inputs than downstream reaches that have already been restored.

Similar to the results obtained in 2008, ambient stream temperatures recorded in2009 in both Benewah and Lake creek watersheds were overall cooler than those in 2007. These results indicate that a proper evaluation of whether our habitat enhancement activities are moderating thermal regimes will require accounting for all those drivers that may influence the thermal regime in any given year. The large snowpacks that accumulated in our watersheds over the previous two winters likely moderated stream temperatures in both 2008 and 2009 relative to 2007. Temperature models that examine the influence of channel restoration actions on water retention in floodplain habitats and resulting groundwater input will thus require other covariates, such as descriptive indices of the annual flow regime, to clarify linkages. In addition, cooler summer temperatures over the last two years could have provided more favorable growing environments for cutthroat trout than in 2007. An ageing analysis that examines growth rates of cutthroat trout captured during our sampling efforts over the last 4-5 years is scheduled to be conducted to attempt to address this question.

3.4.2 Effectiveness monitoring – Response of indicators to habitat restoration

3.4.2.1 Habitat and fish response to restoration in the Evans watershed

The increase in westslope cutthroat trout density at Evans 3 in the years after construction was likely due to the increase in cover provided by the ELWd^{TM} structures and not because of pool habitat afforded by the structure. Pool habitat characteristics did not change substantially at the site post-restoration yet fish populations dramatically increased and were greater than those in proximate reaches. In comparison, pool depth metrics increased from 2005 to 2009 at site 4, a control site upriver, yet estimated abundance did not change; a similar lack of change in abundance was also demonstrated at an additional un-restored site downriver. Other studies have also found salmonids to exhibit localized, rapid increases in abundance in response to placement of habitat-forming in-stream structures (Roni et al 2002, 2008). Cover from the ELWd^{TM} is the key difference in habitat characteristics between Evans 3 and its neighboring habitat sites. The cover created by these structures is likely attracting fish to reside in the pools even though a majority of the pools have less than 1 foot residual depth. Some of the pools created by the ELWd^{TM} structures are located both upstream and downstream of the structure. The ELWd^{TM} structures are larger in diameter than natural wood present in lower reaches of Evans Creek. The pools that were formed underneath the structures are covered by the ELWd^{TM} structure and any accumulated wood. The addition of the ELWd™ structures increased overall habitat diversity at the site.

Apparently, pool depth, as intended to be created with the addition of the ELWd™ structures, may not be as important in creating suitable rearing habitat in Evans Creek as in our other systems. Water temperatures in the Evans Creek watershed are not as limiting as temperatures found in Benewah Creek. For example, water temperatures at Evans site 3 exceeded 17 C less than 2% of the time compared to approximately 50% of the time in Benewah mainstem sites near 9-mile bridge in 2006 (Vitale et al. 2008). Thus, the thermal refugia that have been observed in deep restored habitats in the upper Benewah watershed may not be as advantageous for cutthroat trout in Evans Creek.

Measured large woody debris differences between restored and un-restored habitats is the direct result of our reconstruction activities. LWD loadings were substantially higher in the restored reach compared to untreated reaches upstream. All of the ELWd™ structures present in the restored reach in 2006 were still present at the site in 2009. Two of the structures that were originally spanning the channel have moved since 2006 so that they are located on the left channel margins, parallel to the creek. During initial construction, the structures were installed on top of the existing streambed and were not buried. The ELWd™ structures are anchored into the channel by cables that are attached to nearby alder trees. As a result, the structures are not anchored to a fixed place in the channel. The structures have flexibility to move up and down during high flows. During high stream flow, water moves both under and over the structures. This may decrease the amount of pool scour that is associated with the structures. Visual observation in 2009 revealed that besides scour beneath the structures, sediment has been deposited downstream of many of the structures. This deposition and scour is causing micro-scale complexity to the channel bed though this is not currently detected by pebble counts at the site. More pebble counts will need to be taken at the site in future years in order to help quantify the impacts that the wood structures have on material sorting.

The nature of how the ELWd™ structures are placed in the channel likely will cause variation in pool characteristics in future years. Evans site 3 is located in an alluvial valley and has gravelly banks that are susceptible to lateral erosion and scour. There is also a side channel that becomes active during higher flows. This side channel is diverting water from the main channel that could otherwise increase pool scour. This may contribute to why there has not been more scour around the wood structures placed in the channel at site 3. Residual pool depth decreased at the restored site post-construction compared to 2003-2004. This change could be due to how "high" the landowner built the in-stream rock structures that caused the pools during this period. The landowner did not build pools in 2005 so the pool depths for that year occurred naturally. There may have been an event in 2006 that increased bed scour at the restored site. After 2006 the pools may not have been subjected to higher scouring flows so these pools may have filled in with sediment as spring flows dropped and bedload transport decreased. Mean and maximum depth increased at the un-restored site between 2005 and 2009. It was expected that this same trend would also have occurred at the restored site. No data was collected in 2006 at the Evans 4 so it is not known if there had been more pool scour in 2006 like there was at Evans site 3. It is expected that the pools created by the ELWd™ structures may deepen as more wood is entrained on the structures leading to increased habitat complexity. Periodic monitoring of both treated and control reaches in the Evans Creek watershed will need to be completed to detect changes in pool characteristics through time.

3.4.2.2 Habitat response to restoration in the Benewah watershed

From 2005-2008, stream restoration activities involved major channel alterations by building new meander bends and filling in existing sections of incised channel, elevating the streambed in other incised reaches to create new riffles with the addition of imported rock, and adding a sizeable amount of large woody debris to stabilize banks and provide in-stream cover. This direct modification of the channel resulted in immediate changes to the amount of large wood, residual pool depth, and canopy cover. Residual pool depths increased by raising adjacent riffle elevations. The new pools that were created are, in general, longer and deeper than pools that existed at the site pre-restoration. Riffle habitats are longer, in some cases over 31 meters. Channel entrenchment at riffles has decreased such that the bankfull flood can access the floodplain. Sinuosity increased at the site because of the addition of new meanders. There are large amounts of wood on the banks, in association with meander bend pools, and also on the floodplain. In many of the restored areas, riparian vegetation was disturbed during construction. New plants are growing well in these areas but will take years to shade the stream channel significantly.

The restoration approach for the upper Benewah mainstem will change beginning in 2009. The new approach to the Benewah mainstem restoration effort (i.e., Phase 2) involves minimal in-channel work and a reliance on beavers to aggrade the incised stream channel over time. A series of in-stream structures will be constructed that serve as a base for beavers to construct their dams. Minimal riparian vegetation will be removed as a result. One historic channel segment will be reactivated to increase channel length (the channel will be filled in that area). Rock will only be added to the area adjacent to the beaver structures. Because this new restoration approach relies on beavers, channel change will occur more gradually over time. We expect that canopy cover pre and post-restoration will be similar. The amount of wood added to the channel will be significantly less than the previous approach. Over time, wood will accumulate behind the structures but we will not likely see a large increase in wood loading immediately after treatment as was apparent during Phase 1 restoration. Because no rock was added to create higher riffle elevations, the channel will remained entrenched until enough material becomes entrained behind the in-stream structures to caused sediment to accumulate upstream. Residual pool depth should increase as the beaver dams stabilize and increase in size but this will occur over time and not one-year post construction. Long-term monitoring will need to be conducted in the Phase 2 reach to better understand the gradual changes associated with the new restoration approach and to use the acquired knowledge to adaptively manage the beaver colonies (e.g., providing food and materials for dam construction).

Our documentation of dam occurrence during the 2009 field season represents a significant influence of beaver in the upper mainstem of Benewah Creek. The frequency of documented dams ranged from 11.1 – 13.4 per km over the two sample periods. If considering only the active dams identified in the fall, the frequency is 12 per km. The spacing for 80% of dams observed during our surveys ranged between about 15-91 m apart, and the median spacing was 52 m. At the height of dam building in the fall, as much as 84 percent of available habitat in the reach existed in a backwatered condition. Other studies of undisturbed beaver populations indicate that frequencies of around 10 dams per km are typical in low-gradient streams similar to Benewah Creek (Naiman et al. 1986; Woo and Waddington 1990; Scheffer 1938). Two studies examining dam occurrence across entire, multiple watersheds found frequencies of 2.5 per km for the 750 km^2 Kabetogama Penninsula in Minnesota and 9.6 dams per km for an 85 km^2 area encompassing two watersheds in Wyoming (Skinner et al. 1984; Johnston and Naiman 1990). Suitable habitats can reportedly accommodate up to 1.2 colonies/km of stream (Allen 1983). Collen and Gibson (2001) estimated overall mean of 5.2 individuals per colony of North American beaver. Recognizing both the high spatial variation and uncertainty of estimates of both colony density and individuals per colony, the population of beaver within the 3.5 km of upper Benewah Creek may consist of 22 or more individuals.

There has been widespread recognition that beaver dams play a vital role in maintaining and diversifying stream and riparian habitat (Naiman et al. 1988; Pollock et al. 1994, 2003; Gurnell 1998; Collen and Gibson 2001). Because beaver dams slow stream velocity, they should also attenuate flood peaks. Research on the effects of wood dams in small (third order) streams suggests that they can retain water at least 50% longer than streams where such dams are absent (Ehrman and Lamberti 1992). Given the much lower permeability of beaver dams compared to large wood jams, it is reasonable to expect them to retain water for much longer periods of time. Using simulated peak-flow routing, Beedle (1991) estimated that a single full beaver pond reduced peak flows by more than 5%, but that five large ponds in series could reduce peak flows of a 2-year event by 14% and peak flows of a 50-year event by 4%. The slow velocity of water behind beaver dams creates extensive depositional areas for sediment and organic material transported from upstream reaches. Together, the onsite deposition of sediment and organics is linked to processes of streambed aggradation, which promotes connectivity between channel and floodplain in degraded stream systems. Sediment storage behind beaver dams can be substantial. Measured sediment accumulation rates behind dams range from 0.25 to 6.5 cm/year over decadal time scales (Scheffer 1938; Devito and Dillon 1993; Butler and Malanson 1995). We cite evidence from the upper mainstem of Benewah Creek which suggests that historical engagement of flood flows on the valley floor was most likely in response to both (i) blockage effects of large wood pieces falling into the channel and aggregating smaller wood, and (ii) beaver dams (DeVries and Fetherston 2008). Loss or reduction of these structural elements in the active channel over time has contributed to channel incision and enlargement.

Increasingly, beaver are being viewed as valuable partners in restoration initiatives in the Pacific Northwest and elsewhere (Pollack et al. 2007; Bondi 2009; Walker et al. 2010; Finnigan and Marshall 1997). The significant presence of beaver in upper Benewah Creek and the expected long-term benefits of dam building certainly justify that role in our current efforts. Much of the expected benefits, as well as the degree and spatial and temporal scales, at which restoration efforts can move habitats toward a re-expression of natural habitat capacity and quality, are predicated on the stability of dams and their ability to function during flows that are generally greater than the 5-10% exceedance flows (~84cfs). It is not until the depths associated with these higher flows are reached that the Shields relation (Leopold et al. 1964) predicts initial entrainment of the bed surface in this reach. The channel blockages and flow constrictions associated with stable, persistent wood aggregations and beaver dams then begin to more effectively sort the mobilized sediments, storing finer particles and progressively enhancing floodplain connectivity through backwater effects. As indicated by our monitoring efforts, 67% of dams in Benewah Creek are inactive for much of the year. Consequently, the role of natural dams in flood attenuation, sediment storage and streambed aggradation, and promotion of floodplain connectivity are much more uncertain. There is at least some evidence from our initial surveys in Benewah Creek that suggest that dams comprised of stable materials are generally more persistent and we have documented evidence of overbank flows initiated at the 1.5 year return interval flood associated with these features (Picture 3). In total over both survey periods, 14 of the 54 dams (26%) documented were considered to be either built with or upon stable materials (e.g., large woody debris). There is also clear association of these stable, persistent dams with intact riparian forest and a historical continuity of recruitment of coarse wood to the channel; for example 64% of dams with stable materials were adjacent to source areas for coarse wood.

Our long-term restoration strategy is to recover riparian forest communities throughout the upper Benewah valley to address deficiencies in riparian-stream interactions and degraded processes. Coincident with this work, the various approaches we are employing of adding large wood to the channel (see section 4.1.1 Project B_9.7: Instream/Channel Construction for the *'Ełtumish* Project) are intended to support a short-term goal of lending stability to natural dams and improve the trajectory for natural process recovery. The ongoing monitoring effort should be of value in describing the effectiveness of this approach. Where large wood was added to the channel this past year, these treatments had the effect of providing habitat conditions consistent with stable, persistent natural beaver dams. Three of seven structures were constructed at cross-sections previously occupied by less stable natural dams. The intended effect of these structures was to increase pool metrics similar to the mean changes measured at other dams. The remaining structures were built in a relict channel that will be reactivated in several years and the effects will become measurable at that time. Because these structures remain stable at a range of stream flows, they will provide similar benefits for trout that over-winter in deeper mainstem pool habitats, in addition to increasing the frequency and extent of overbank flows. Implementation planned for the next two years will replace and/or reinforce an additional approximately 14 natural dams spaced relatively evenly throughout the larger 3.5 km reach; resulting in five channel segments with 10-11 treatments per km, and four 250-490 m channel segments serving as untreated controls. The distribution of these treatments may further facilitate redistribution of native fishes by better connecting improved mainstem habitats with source populations in tributaries.

Tracking the interactions of natural and constructed dams and making additional observations regarding the temporal stability of these dam complexes may provide some valuable insights for restoration approaches that can be applied to other similarly degraded systems. Some refinement of the survey protocols may make future monitoring more efficient in achieving these ends. Making detailed measurements within the backwatered channel identified important relationships between dam characteristics (i.e., height) and the dependent variables of inundated and pool area, pool volume and residual depth. Describing the changes in these metrics following restoration is useful for purposes of implementation and effectiveness monitoring, however, collecting this data is time intensive. These relationships are only likely to change if natural dams are constructed differently in the future or if significant accumulation of sediment over time results in measureable changes in channel dimensions. While these types of changes are anticipated, the frequency of measuring these variables could be reduced without losing much information. On the other hand, observations that better describe the timing of dam construction and failure have been overlooked. Devising a rapid reach scale assessment of dam condition that could be conducted multiple times during the year at critical timeframes could yield important information to further document restoration effectiveness.

Picture 3. Over bank flows in discrete channel segments of upper Benewah Creek are initiated at the 1.5 year return interval flood (168 cfs) in areas that are associated with stable, persistent beaver dams, large wood aggregations and intact riparian forest.

3.4.2.3 Thermal response to restoration in the Benewah watershed

Thermal refugia were documented in 2009 in the reach that underwent large-scale channel restoration in 2008, though temperature heterogeneity in post-restored pools was not as great as that observed in previous years in restored reaches downriver. Though residual pool depths exceeded 1.0 m in restored pools in the 2008 reach, temperature differences of less than 2.5^{o}C were typically found. In comparison, temperature differences between 3 and 6^{o}C were commonly observed in pools of similar depths in surveys conducted downriver in 2008. Though data collected in previous years indicate that detection of refugia may only be apparent during periods of elevated ambient stream temperatures (Firehammer et al. 2010), we conducted our survey in 2009 during one of the warmer periods of the summer. Rather, our results may be due to inherent variability in groundwater pathways and dynamics that influenced stream temperatures differently across mainstem reaches that have been restored from 2005 to 2008. More importantly, given that cold-water patch frequency and area have been considered important indices that explain salmonid occurrence and abundance in small stream systems (Torgersen et al. 1999; Ebersole et al. 2001, 2003), our data illustrate the potential for erroneous conclusions to be drawn regarding the positive impacts from stream restoration if only select reaches are surveyed for the presence of thermal refugia.

Thermal heterogeneity was also not appreciably evident in the upper meadow reach that is dominated by beaver dam pools and is part of Phase 2 restoration. However, approximately 90% of the monitored pools during early August were less than 1.0 m in depth, and consequently may not display the temperature differences that are commonly observed in deeper pools. Pool depths evidently increased after our temperature survey, given that 32% of residual depths recorded during the fall beaver dam survey along the same reach were greater than 1.0 m. However, most of the increase in pool depth associated with dam building likely occurred after critical summer rearing temperatures declined. Additional years of monitoring should indicate whether our restoration strategies in this reach create more stability in beaver dam complexes that maintain deep pool habitat and concomitant thermal refugia throughout the summer.

Stream temperature data collected by our loggers also lend support to the intent of our restoration strategies to increase floodplain connectivity and water retention in upper mainstem reaches of the Benewah watershed. Though summer mainstem stream temperatures in 2009 were generally cooler than those recorded in 2007, a greater difference between years was found in the upper meadow Phase 2 reach. Likewise, though loggers indicated that stream temperatures were mostly warmer in 2009 than in 2008, less of a difference was detected in the same reach. Given the documented evidence of overbank flows occurring during January of 2009 in this reach (Picture 3), our temperature data suggest that channel features that promoted the engagement of stream flows with the floodplain likely regulated stream temperatures in 2009 relative to past years. Progressive channel restoration along contiguous reaches within the upper mainstem valley that improves water retention capability and restores floodplain connectivity should augment groundwater recharge and promote hyporheic dynamics that moderate main channel summer temperatures. In turn, this should increase the availability of suitable rearing habitats for cutthroat trout and provide favorable corridors that promote tributary connectivity.

3.4.2.4 Cutthroat trout response to restoration in the Benewah watershed

Despite the mosaic of thermal refugia and the complex habitat (e.g., deep pools and LWD additions) that has been created in restored reaches of the upper Benewah mainstem, we have yet to see evidence of a significant response by cutthroat trout. Various explanations have been proffered for the apparent lack of utilization of these restored habitats, which have been described in detail in previous annual reports (Firehammer et al. 2009, 2010). Briefly, these include, but are not limited to, the following: (1) a sufficient degree of isolation between core rearing tributaries and restored habitats, mediated by distance or other barriers (e.g., temperature), that inhibit dispersal (Bond and Lake 2003; Pretty et al. 2003); (2) insufficient tributary densities to induce density-dependent emigration responses (Johnson et al. 2005; Shrank and Rahel 2006); (3) a lag in positive fish response because of the repeated, acute artificial disturbances imposed by channel reconstruction on ecological and hydrological stream properties over the previous four years; and (4) the persistence of limiting factors in reaches adjacent to those restored (Moerke and Lamberti 2003; Cowx and Van Zyll de Jong 2004). We realize that because we are not only amending local deficiencies in habitat complexity but also addressing impaired processes that operate at larger spatial scales, the re-establishment of natural processes will occur gradually, and as such, detection of positive responses by cutthroat trout may require a longer timeframe. As we progressively address contiguous reaches in the upper Benewah mainstem with Phase 2 implementation, we expect to continue to increase the extent of favorable rearing habitats that are conducive for cutthroat trout colonization and growth.

Another explanation for the absence of cutthroat trout in restored habitats, which has not been adequately tested, is our inability to capture fish using our current sampling techniques. Given the thermal refugia that have been observed at the bottom of deep pools in restored reaches, cutthroat trout, if present, would most likely be using these micro-habitats. However, restored pools are frequently over 4 ft deep, and not only is visibility poor but both wading and netting prove challenging at these depths. Furthermore, because of the low conductivities in our watersheds, the electrical fields generated by our backpack electrofishing equipment are exceptionally small and consequently may not elicit electrotaxis in fish lying along the bottom. Data collected in 2009 also corroborated the ineffectiveness of electrofishing in deep habitats. Site 16 consisted of two equally-sized long pools separated by a short constructed riffle. Depths typically ranged between 2.5 and 3.5 ft in the downstream pool but were often greater than 4.5 ft in the upstream pool. Whereas 18 brook trout were captured during the first pass in the downstream pool, none were subsequently captured in the pool immediately upstream. In 2010, we plan to forego electrofishing in restored reaches because of these shortcomings, and instead experiment with the deployment of fyke nets in select restored pools to evaluate their effectiveness.

Though a direct numerical response to restoration has not been observed in mainstem reaches, the significant increase in cutthroat trout densities in tributary habitats demonstrated by our trend analysis may suggest an indirect response to restoration. Deepened mainstem reaches may have provided suitable overwintering habitat that was available only in a limited capacity before restoration. Both juvenile and adult cutthroat trout have been found to prefer deep pools as winter refuge habitat in small stream systems (Jakober et al. 1998; Brown and Mackay 1995; Harper and Farag 2004; Lindstrom and Hubert 2004). In addition, cutthroat trout have been found to respond positively to improvements to winter refuge habitat. Solazzi et al. (2000) found cutthroat trout abundance to increase, presumably owing to higher overwinter survival rates, following the creation of winter habitat for salmonids in coastal Oregon streams. In addition, Roni and Quinn (2001) found higher densities of cutthroat trout at sites with experimental large woody debris additions than at control sites, but only during winter and not summer sampling. Evaluating the winter distribution of cutthroat trout in upper Benewah mainstem habitats may reveal benefits of our channel construction activities that were not realized from summer surveys. In order to perform such an evaluation, cutthroat trout captured in tributaries during summer and fall electrofishing surveys will need to be PIT-tagged and their movements monitored throughout the fall and winter using strategic placement of antenna arrays in mainstem habitats. However, given the exorbitant cost of introducing additional full duplex structures into the Benewah watershed, we intend to experiment with more manageable, less expensive half-duplex interrogating antennas during the field season of 2010 to evaluate their feasibility in our systems.

3.4.3 Effectiveness monitoring – Nonnative brook trout control

The brook trout suppression program that has been implemented in the upper Benewah watershed since 2004 has been effective at regulating numbers of brook trout at an apparently manageable level. Overall trends in the upper Benewah watershed have yet to display trajectories that would project densities similar to those observed in Alder Creek. In most reaches, present densities are more than five times lower in the upper Benewah than in upper Alder. However, even though over 7000 brook trout have been removed over the years 2004-2008, a significant overall reduction in densities was unable to be detected in the upper Benewah watershed. The lack of a measurable reduction across tributaries was likely explained by the differences in trends observed among the monitored tributaries. Whereas densities generally remained at low levels in Whitetail Creek and the South Fork, they declined substantially in the West Fork, but displayed increasing trends in Schoolhouse and Windfall creeks.

The differences in trends observed across tributaries may be attributed to one or more of several factors including the proximity to colonizing sources, changes in reach accessibility, and varying degrees of effort applied in previous removal activities. First, the location of Schoolhouse and Windfall creeks in the upper part of the watershed may in part explain the positive trends observed in both tributaries. The mouths of both creeks are located along the mainstem reach where densities estimated during removal efforts have consistently been found to be the highest, thus increasing the probability for mobile individuals to colonize these tributary reaches. Others have noted the importance of both proximity and connectivity to source localities in determining probabilities of brook trout establishment (Benjamin et al. 2007). Brook trout expansion into Windfall Creek, however, was likely inhibited until 2004 when culvert replacement and channel reconstruction virtually eliminated this barrier. Thus, local sub-populations, colonized by the more mobile individuals, may not have yet had the opportunity to become firmly established in Windfall Creek (Peterson and Fausch 2003), which may partly explain the variable densities observed in this tributary over the last four years. As a result of the recent re-connectedness of Windfall Creek with the mainstem, this tributary should continue to be monitored in the future to assess rates of brook trout expansion into this newly accessible habitat. Additionally, the differences observed among tributaries may have been due to the focus of removal efforts during the first couple of years. Initially, before it was discovered that many of the larger adults were residing in upper mainstem habitats, efforts were concentrated in tributaries, most notably the South and West Forks. Given that the most marked decrease in abundance was demonstrated in the lower West Fork, the unequal distribution of past sampling efforts may partly explain the results from our survey data.

The comparison of brook trout trends in Benewah Creek with those in the neighboring Alder Creek watershed over the same time period also suggested that, though a significant decline was not appreciably detected in Benewah, our control program was effective in suppressing abundance. Brook trout densities in composite reaches in the upper Alder Creek watershed exhibited significant synchronous linear increases since 2003. Abundances in highly populated reaches, where we would expect density-dependent compensatory mechanisms to predominate, even displayed substantial numerical increases. These findings suggest that regional conditions were likely favorable for brook trout growth and survival. Because these two watersheds presumably share common environmental drivers that govern recruitment rates, we should have expected similar responses in Benewah Creek.

Watershed comparisons may also provide predictive insight into the productive potential for brook trout in the Benewah watershed. Even before commencement of the suppression program, densities of brook trout in Alder Creek have been consistently higher than those documented in Benewah Creek. In addition, whereas distributions of cutthroat and brook trout are almost entirely disjunct in Alder Creek, suggesting probable displacement by the latter (Dunham et al. 2002), distributions of both species overlap in Benewah Creek. Differences between these two watersheds could be explained by an invasion process that is still in its incipient stage in Benewah, though given the proximity of these watersheds to each other, expansions should have proceeded at similar rates if colonizing migrants arrived from common downriver sources (Peterson and Fausch 2003). As another possible explanation, the productive adfluvial life-history strategy that is prevalent in the Benewah but not the Alder watershed may confer an advantage to cutthroat trout in the former that permits a greater biotic resistance to invasion (Griffith 1988). Differences in apparent vulnerabilities of proximate systems have also been reported by others that have examined brook trout invasions in the west (Adams et al. 2002; Dunham et al. 2002; Shepard 2004; Benjamin et al. 2007).

Alternatively, habitat conditions that are more conducive to brook trout establishment may be more prevalent in Alder than in Benewah. For example, the spatial distribution of brook trout and their habitat preferences have commonly been associated with low gradient reaches with deep, low velocity habitats (e.g., beaver ponds) that serve both as summer rearing and overwintering habitat (Chisholm et al. 1987; Cunjak 1996; Lindstrom and Hubert 2004; Benjamin et al 2007). Recent habitat surveys conducted across our watersheds have indicated that pool habitat is approximately three times as great in Alder Creek than in Benewah Creek (Miller et al. 2008). Additionally, the surveys found that 33% of the pool habitat documented in Alder Creek was formed by dams, whereas only 3% of the pool habitat in Benewah Creek was dammed. Given our current restoration approach to encourage the stability of beaver dam complexes and augment associated pool habitat in the upper Benewah watershed, we may also be increasing suitable habitat for brook trout. The elevated densities of brook trout observed at upper Benewah mainstem index sites, and the increase in the numbers of brook trout removed above 12-mile bridge over the last three years of our suppression program may allude to the recent occurrence of such processes.

Given the potential for our restoration actions to improve brook trout rearing habitats in upper mainstem reaches of the Benewah watershed, it is imperative that we offset these unintended benefits and create recruitment bottlenecks at other vital life stages. Our current suppression approach, curtailed in effort from previous years, aims to re-focus our tactics toward curbing reproductive success in the upper watershed. In the past, an inordinate amount of time was being annually allocated to shocking the deep, pool habitats from 9-mile bridge to 12-mile bridge. As our mark-recapture study in 2009 indicated, single pass capture probability can be less than 30% in deep habitats, and as a result we may have been only capturing a minority of the brook trout residing in these mainstem reaches. Further, these habitats are dominated by low-gradient depositional beaver dam pools, which, though likely serving as suitable rearing habitats, may not provide suitable spawning substrates. As a result, we are currently concentrating our shocking efforts in that reach of the mainstem above 12-mile bridge that has been considered most suitable for spawning (e.g., preferable substrate size) and where adult densities have been the greatest over the suppression program. In addition, we are also inhibiting further access to this reach by erecting a temporary barrier upstream of 12-mile bridge. Though the barrier was configured to also serve as an enclosure that could intercept brook trout spawners ascending from holding habitats downriver, hardly any fish were captured in the enclosed habitat in 2009. However, trapping fish was only a secondary objective, with the primary objective being to prevent fish from accessing upriver reaches. Given the recent increases in densities observed in Windfall Creek, we intend to deploy an additional temporary barrier in 2010 at the mouth of Windfall to prevent ascension into that tributary. Examining the length distribution of brook trout removed from upper reaches of the Benewah watershed in subsequent years should allow us to evaluate if we are successfully inhibiting reproduction using this new tactical approach to our suppression strategy. Over time, if these methods prove successful, than we may be able to reduce the frequency at which we conduct our suppression measures. Several years of consecutive removals followed by a couple years of suspended implementation may minimize the costs of the program but still provide benefits to our cutthroat trout population (Peterson et al. 2008b). In addition, refraining from removing fish over a year or two will allow us to examine the compensatory resilience of brook trout in the Benewah watershed (Meyer et al. 2006).

4.0 RESTORATION AND ENHANCEMENT ACTIVITIES

4.1 Introduction to Project Summaries

Implementation of restoration and enhancement activities occurred in Benewah and Lake creeks during 2009, with most of the projects related to large scale channel restoration efforts in both watersheds. All activities completed during the contract period June 1, 2009 through May 31, 2010 are summarized in *Table 23* followed by a more detailed site characterization and summary of activities for individual treatments. In several locations, multiple treatments have been implemented to meet the objectives for larger sites. These treatments are grouped under the same project ID heading so that the interrelationship of activities is more apparent.

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, E=Evans Creek, etc.). The series of numbers that follow correspond to the river-mile location (in miles and 10^{ths}) at the downstream end of treatment sites. River mile is tabulated in an upstream direction from mouth to headwaters and treatments that are located in tributary systems have river mile 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 miles up on a tributary that has its confluence with the mainstem 8.2 miles 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.

Table 23. Summary of restoration/enhancement activities and associated metrics completed for BPA Project #199004400.

Project Description			Project Chronology		
Project ID	**Activity**	**Treatments (Metrics)**	**Pre-2007**	**2008**	**2009**
B_9.7 (page 95)	Stream Channel Construction	Channel construction (810 m)		Developed restoration design for 2.4 km of mainstem habitats (Reach D-2)	Constructed/enhanced 810 m of stream channel; installed 7 instream wood structures
B_9.7 (page 99)	Plant Vegetation	Streambank stabilization (0.78 ha, 969 m of streambank			Planted 14,904 herbaceous plugs and 6,950 deciduous trees (0.78 ha of floodplain, 969 m of streambank)
B_9.7 (page 101)	Plant Vegetation	Riparian enhancement (51.47 ha; 4,431 m of streambank)	Planted 49,068 conifers (46.3 ha of floodplain, 3689 meters of stream bank)	Planted 2,100 conifers (1.86 ha of floodplain)	Planted 10,058 herbaceous plugs, 4,634 deciduous trees, 3,800 conifers (3.31 ha of floodplain, 742 m of streambank)
L_8.2/0.7 (page 104)	Stream Channel Construction	Channel construction (106 m, 3.2 ha of floodplain wetlands)		Developed restoration design for 1.2 km of tributary habitats in WF Lake Creek.	Signed landowner contract. Constructed 106 m of new channel, created 3.2 ha of new floodplain, constructed 8 instream structures
L_8.2/0.7 (page 108)	Plant Vegetation	Riparian enhancement (1.01 ha; 212 m of streambank)			Planted 800 conifers, 300 herbaceous plugs and 450 deciduous trees (1.01 hectares of floodplain, 212 m of streambank)

4.1.1 Project B_9.7: Instream/Channel Construction for the *'Ełtumish* Project

Project Location:

Watershed: Benewah	Legal: T45N, R4W, S13 NE ¼ SE ¼
Sub Basin (River Kilometer): 15.6 rkm	Lat: 47.241292N Long: 116.771454W

Site Characteristics:

Slope/Valley gradient: 0.7%	Aspect: N	Elevations: 830 m
Valley/Channel type: B2/C4	Proximity to water: In channel	

Other: *Project implements first year actions identified in the Reach D2 restoration design, including: construction of 439 m of new channel (element D2-1);re-grading 371 m of an existing swale to create a high flow swale with native vegetation (element D2-2); and construction of seven in-channel wood structures (element D2-4).*

Problem Description: Historically, the Benewah Creek valley was a mosaic of open stands of conifers, wet meadows and stream corridor riparian forest (Mikkelesen and Vitale 2006). Forest composition and structure was maintained by frequent fires. A compositionally diverse, coniferous dominated forest was likely distributed along complex gradients of elevation, aspect and site water balance. Historically, frequent engagement of flood flows on the valley floor was most likely in response to both (i) blockage effects of large wood pieces falling into the channel and aggregating smaller wood, and (ii) beaver dams, with local gravel and fine sediment accumulations upstream. Whenever the channel did avulse in response to blockages, it likely did so through rapid down-cutting through the easily eroded loess layer, reaching a base gravel layer in the valley relatively quickly and then remaining at the grade defined by that layer. Following a more recent history of intensive logging, forest clearing, beaver trapping, and grazing, the hydraulic influence of local beaver dam/sediment accumulation was reduced or removed. The stream banks were more susceptible to unraveling and channel widening, leading to the state seen at some locations where a new, lower elevation alluvial floodplain appears to have established between the upper bank surfaces defined by the valley floor. Hydraulic analysis of representative channel cross-sections show the overall level of channel incision/containment is approximately equivalent to the capacity of a 5-year return interval peak flow event with some areas exhibiting a capacity that approaches the 10-year peak flow.

The significantly reduced access of flood flows to the former floodplain and broader valley bottom has affected wetland habitats on a large scale and accelerated streambank erosion. Several avulsion channels and to a lesser extent, remnant historical channels have left portions of the valley bottom with some wetland habitat, however, it appears that shallow groundwater tables have been lowered and recharge of wetlands by overbank flows has been greatly reduced. Many of the remaining wetland areas are only marginal in size and a band of xeric vegetation of variable width is located along the channel margin throughout the project reach. The most recent estimates of stream bank erosion indicate that erosion rates approach 476±208 metric tons/yr/km. When extrapolated to the larger reach located between river kilometer 14.3 and 19.1, total annual sediment yield from streambanks ranges from 1286-3283 metric tons/yr.

This stream reach is located in a portion of the watershed that historically provided important summer and winter rearing habitats for westslope cutthroat trout. Existing conditions currently support low densities of cutthroat trout (<2 fish/100 sq. m). Lack of habitat diversity, localized loss of low gradient channel segments, reduced infiltration of water from adjacent wetlands, and elevated water temperatures are all factors that limit the productivity of these reaches.

Description of Treatment: Several new design elements for the D2 reach were implemented during this first year of construction to address the findings and specific needs identified in the problem assessment:

Element D2-1. Construction involved excavation of 439 m of an existing relict channel down to the valley-wide gravel sub-layer. The long profile of the channel generally followed the top of the gravel layer, although small pools and riffles were constructed on a directed work basis. Cut material designated to fill the existing channel was stockpiled on site, and excess fill was moved to form topography along the base of the valley slopes. The average bankfull channel width conformed to a 6 m design criteria. The cross-section side slopes were excavated to approximate a 1.5H:1V ratio. The design slope reflects a balance between achieving a more natural, vegetated near-vertical bank appearance occurring in the project reach, and minimizing the potential for collapse of newly formed banks before they are strengthened by rooted vegetation. Where the relict channel topography was wider, vegetated benches were constructed at intermediate elevations, with a gentler side-slope between around 30H:1V to 20H:1V. The narrow aspect ratio of the newly excavated channel is comparable to that observed in more heavily vegetated segments where the banks do not appear to have been significantly eroded.

High flows will be prevented in the newly excavated channel for the first two years by maintaining the existing channel as-is. This will allow root masses to develop without scouring flows. Following this period of establishment, the existing channel segment will then be filled and vegetated. The upstream end of the bypassed channel will function as a high flow swale, passing water during flows that approach bank-full discharge, while the downstream end will be left unfilled and function as a connected backwater channel. Completion of this element will result in 197 m of added channel length and will lead to a locally reduced stream gradient, from 0.45% to 0.24%.

Element D2-2. Work was done to re-grade 371 m of an existing swale to create a high flow swale with native vegetation. A HEC-RAS model was used to guide the design by predicting water surface elevations in the main channel for target flow rates. The upstream end was re-contoured to an armored inlet grade control that begins to flow at the 1.5 year flood, or approximately 4.7 cms. The location of the inlet coincides with logs placed in a previous restoration project while the downstream end ties in with recently completed wetland enhancement work in the larger project reach. The inlet and transition to the swale channel was armored with river cobbles as a scour countermeasure, but no additional logs were added to supplement those installed previously. The control elevation at the head of the channel was constructed to maintain flow-connectivity in the side channel on a nearly annual basis. The wetland swale will be used as a nursery area for propagation of black cottonwood and willow whips and live stakes for riparian zone restoration throughout the Benewah Creek valley and is more thoroughly described in the project summary below (*See 4.1.3 Project B_9.7: Riparian/Planting*).

Element D2-4. A total of seven in-channel wood structures were constructed, which emulate flow obstruction effects of natural wood jams and beaver dams. Three of these structures were loose aggregations of large wood with key pieces anchored in the bed and banks of the channel to approximate historical, natural wood recruitment processes. The remaining four structures were engineered "flow choke structures" in which the concept was to create increased backwater effects during floods such that the valley floor would become connected annually. The concept involves two types of flow and thus upstream water surface elevation controls (Figure 39):

1. Weir flow over a horizontal cross-log, with sufficient depth to permit passage of floating debris at the bankfull level (2 structures built with this configuration); and
2. A combination of weir flow over a horizontal cross-log as well as orifice flow under the log, with both lateral and vertical constriction throttling down the flow past the structure (2 structures built with this configuration).

Figure 39. Engineered "flow choke structures" constructed in Benewah Creek illustrating two variations of flow type and surface elevation controls, including 1) weir flow over a horizontal cross-log (left), and 2) a combination of weir flow and orifice flow under the horizontal log (right). These structures were built in a newly excavated relict channel that will be reconnected to the mainstem of Benewah Creek.

To implement the design concept, construction involved:

1. Placement of a horizontal cross-log that acts as a control weir at flood flows. The bottom elevation of the orifice was designed to emulate general low flow control elevations formed by numerous beaver dams present in the reach, where median depths were 0.36 m at the riffle crest and 0.97 m below the floodplain; these served as natural process-based design criteria for situating the orifice control elevation and the depth of impounded gravel upstream. An additional horizontal log was buried beneath the weir at a depth that exceeded the estimated scour depth for each site.
2. A series of horizontal cross-logs protruding from each stream bank that project a blocked area in the downstream direction leaving a central orifice area for lower flows to pass through.
3. A pad of rock placed at the downstream end of the structure as a scour countermeasure, to protect the integrity of the structure.

4. A deposit of finer gravel, sized to be comparable to stones occurring naturally in the river banks and bed, placed on the bed of the upstream side of the structure to facilitate smoother streamlines and potentially provided trout spawning habitat.
5. Laid back stream banks within the upstream and downstream footprints of the structure to prevent saturated bank collapse, avulsion, and loss of structure integrity. A maximum graded slope of 1.5H:1V was specified here as an initial approximation to reduce the amount of excavation on either side of the structure while maintaining a saturated slope stability safety factor above 3. The laid back banks were re-vegetated with herbaceous plants.

Additionally, as part of this design element approximately 24 cubic meters of wood (40 20-33 ft. long logs), primarily aspen, was added to the stream channel and near bank region within a 200 meter reach to aid beavers in dam construction and increase wood loading to approximate a target volume of 6-9 m^3/100 m for mainstem and tributary habitats in the watershed.

The three approaches to channel wood additions that were implemented as part of this design element allows for more frequent and extensive floodplain connection during annual floods, and is a natural analog alternative to large scale riffle construction that maintains connectivity with cooler groundwater during summer months.

Project Timeline: Coordination with the landowners in the area began in May 2008. A field survey of the site, including wetland delineation, was completed in October 2008. Two design alternatives were developed initially and the preferred site design was finalized in May 2009. The initial restoration work was completed from June through August 2009.

Project Goals & Objectives: Goals for this project include 1) create wetland habitats and increase the hydraulic connections with the valley bottom; 2) reduce bank erosion 3) provide a long-term source of large woody debris for natural recruitment; and 4) provide measurable increase in abundance and distribution of westslope cutthroat trout.

Relationship to Scope of Work: This project fulfills the Program commitments for WE D in the 2009 Scope of Work and Budget Request (Contract #42560) for the contract period June 1, 2009 through May 31, 2010.

4.1.2 Project B_9.7: Riparian/Planting

Project Location:

Watershed: Benewah	Legal: T45N, R4W, S13 NE ¼ SE ¼
Sub Basin (River Kilometer): 15.6 rkm	Lat: 47.241292N Long: 116.771454W

Site Characteristics:

Slope/Valley gradient: 0.7%	Aspect: N	Elevations: 830 m
Valley/Channel type: B2/C4	Proximity to water: Floodplain	

Other: *Project specifically treats the 969 meters of streambanks and 0.78 hectares of associated floodplain disturbed during stream channel construction in 2009 (See 4.1.1 Project B_9.7: Instream/Channel Construction).*

Problem Description: Historically, the Benewah Creek valley was a mosaic of open stands of conifers, wet meadows and stream corridor riparian forest (Mikkelesen and Vitale 2006). Forest composition and structure was maintained by frequent fires. A compositionally diverse, coniferous dominated forest was likely distributed along complex gradients of elevation, aspect and site water balance. Tree species likely included: ponderosa pine, western white pine, western larch, Douglas fir, lodgepole pine, grand fir, western red cedar, Engelmann spruce, aspen and black cottonwood. Historic land use since European contact, including valley-wide forest removal, beaver trapping, in-channel large wood removal, construction of splash dams, timber mill operations, pasture grass management and 70+ years of extensive cattle grazing, has resulted in a radically altered valley ecosystem with eroding stream banks and a plant community dominated by invasive forbs, grasses and woody species unpalatable to cattle. Given the extreme perturbation of stream channel and forest structure and processes, the goal of the ecological restoration of the riparian forest and wetland ecosystem is to steer the system toward recovery using both ecological engineering and restoration forestry.

Description of Treatment: Although riparian forests throughout the Benewah Creek drainage are all degraded to a significant degree relative to historic conditions, current riparian forests may be used as a reference system upon which to base the vegetation composition of the restoration design. Currently, the Benewah Creek riparian corridor supports forest fragments of western red cedar, Engelmann spruce, western white pine, black cottonwood, grey alder, Douglas fir, western larch, black hawthorn, lodgepole pine, ponderosa pine, Aspen and grand fir. Shrub species include snowberry, ninebark, mountain maple, ocean spray, spirea, red osier dogwood, mountain alder and willows. Wetland herbaceous species include slender sedge, lenticular sedge, small-winged sedge, nebraska sedge, beaked sedge, Baltic Rush, common rush, daggerleaf rush, slender rush, and small-fruited bulrush.

The life history strategies of these plants (i.e., hydrologic requirements, reproductive strategies, shade tolerance, growth rates, life forms, phenologies, etc.), are used strategically in the riparian and wetland restoration design to lay the foundation for a compositionally and structurally diverse forest ecosystem to develop over the next 25-50 years. The great challenge in restoring the Benewah Creek riparian ecosystem is to assemble a suite of plants that will survive initial site conditions, rapidly change the local and landscape scale micro-climatic and hydrologic conditions, and develop into a self-sustaining plant community. To this end, the planting plan aims to extensively utilize the unique life history characteristics of black cottonwood to rapidly change the current degraded scrub-shrub riparian plant community into a structurally complex and compositionally diverse riparian and floodplain forest.

A total of 14,904 herbaceous plugs and 3,622 woody trees and shrubs were planted in fall 2009 along 969 meters of streambanks and 0.78 hectares of associated floodplain that was disturbed during construction. In addition, all floodplain surfaces and the temporary roads used to access the site were hand seeded and mulched with herbaceous grasses applied at a rate of 48 kg/ha. In the spring of 2010, an additional 3,328 live willow poles were planted to complete the vegetation treatments on these sites. Plant species included eleven species of woody trees and shrubs, ten species of herbaceous sedges (*Carex sp. and Scirpus sp.*) and rushes (*Juncus sp*.), and six species of herbaceous grasses.

Project Timeline: Two design alternatives were developed initially and the preferred site design and vegetation plan was finalized in May 2009. The initial restoration work was completed from June through August 2009, with additional construction activities planned through 2011. Annual plantings will be completed in the fall and the spring immediately following stream channel construction. Annual and periodic inspections will be completed to evaluate survival and growth and determine if restocking of planting sites is warranted.

Project Goals & Objectives: Goals for this project include 1) increase stream shading; 2) provide a long-term source of large woody debris for natural recruitment; 3) promote streambank and floodplain stabilization; 4) increase riparian species diversity and cover; and 5) enhance stream buffer capacity. Success criteria include: establish at least 80% herbaceous cover by native species at the end of 2 years following site disturbance; and, establish woody vegetation types on floodplain surfaces at a minimum stocking density of 197 stems/hectare and provide for significant increases in canopy density and overhanging vegetation over a ten year timeframe.

Relationship to Scope of Work: This project fulfills the Program commitments for WE E in the 2009 Scope of Work and Budget Request (Contract #42560) for the contract period June 1, 2009 through May 31, 2010.

4.1.3 Project B_9.7: Riparian/Planting

Project Location:

Watershed: Benewah	Legal: T45N, R4W, S13 NE ¼ SE ¼
Sub Basin (River Kilometer): 15.6 rkm	Lat: 47.241292N Long: 116.771454W

Site Characteristics:

Slope/Valley gradient: 0.7%	Aspect: N	Elevations: 830 m

Other: *Project treats 3.31 hectares of floodplain and off-channel wetlands and 371 m of channel serving as a high-flow swale/native plant nursery.*

Problem Description: Historically, the Benewah Creek valley was a mosaic of open stands of conifers, wet meadows and stream corridor riparian forest (Mikkelesen and Vitale 2006). Forest composition and structure was maintained by frequent fires. A compositionally diverse, coniferous dominated forest was likely distributed along complex gradients of elevation, aspect and site water balance. Tree species likely included: ponderosa pine, western white pine, western larch, Douglas fir, lodgepole pine, grand fir, western red cedar, Engelmann spruce, aspen and black cottonwood. Historic land use since European contact, including valley-wide forest removal, beaver trapping, in-channel large wood removal, construction of splash dams, timber mill operations, pasture grass management and 70+ years of extensive cattle grazing, has resulted in a radically altered valley ecosystem with eroding stream banks and a plant community dominated by invasive forbs, grasses and woody species unpalatable to cattle. Given the extreme perturbation of stream channel and forest structure and processes, the goal of the ecological restoration of the riparian forest and wetland ecosystem is to steer the system toward recovery using both ecological engineering and restoration forestry.

Description of Treatment: A primary strategy being utilized for the Benewah Creek restoration is the utilization of black cottonwood's unique life history characteristics to rapidly "flip" or change the current degraded riparian ecosystem into a diverse self-sustaining riparian forest. Although black cottonwood's regenerative strategy (seedling establishment on bare alluvial substrates and branch fragment vegetative propagules) likely resulted in it historically playing a non-dominant role in the riparian forest, its life history characteristics make it ideal for rapidly establishing a complex riparian forest. Establishment of a cottonwood forest along the Benewah Creek floodplain and stream banks will provide exceptional hydrologic, biogeochemical and plant and animal habitat functional lift within 5-10 years as well as control the trajectory of ecosystem development over next 100+ years.

Hydrologically, dense plantings of cottonwood will supply local beaver populations with ample dam building materials resulting in local backwater flooding of adjacent wetlands. These hydrologically restored areas will support a diverse emergent, scrub-shrub and forested wetland plant community. Additionally, other hydrologic functions will be enhanced (per Jankovsky-Jones 1999) including: dynamic water storage; energy dissipation; and long-term surface water storage. Enhanced biogeochemical functions (also per Jankovsky-Jones 1999) will include the ability of the wetland to contribute to local or regional water quality by the removal of imported nutrients, contaminants, another elements or compounds. Given the active use of private lands for cattle and horse pasture, enhanced beaver dam construction will significantly support wetland sediment and nutrient retention and removal functioning.

An established cottonwood forest will rapidly enhance plant community functions through the maintenance of a characteristic native plant community in terms of species composition and physical characteristics of living plant biomass, and of detrital biomass in terms of the production, accumulation and dispersal of dead plant biomass of all sizes (Jankovsky-Jones 1999). The planting restoration design calls for establishing a matrix of floodplain cottonwood interplanted with understory cedar and Engelmann spruce. Cottonwood will establish a closed canopy within about 5 years and act as nursery cover for establishing understory conifers. Cottonwood break-up will occur at about 60-90 years, relinquishing understory conifers to a dominant canopy position. This technique has been used successfully with cottonwood and western red cedar in trials in British Columbia (Peterson et al. 1996). The establishment of an interior forest micro-climate following canopy closure will support the development of native understory riparian plant community.

The cottonwood forest will provide significant enhancement of fish and wildlife habitat throughout the Benewah Creek valley as well as the riparian ecosystem. Specifically, the new riparian forest will provide for maintenance of habitat interspersion and connectivity, reflecting the capacity of a wetland to permit aquatic organisms to enter and leave the wetland via permanent or ephemeral surface channels, overbank flow, or unconfined hyporheic grave aquifers, and access of terrestrial or aerial organisms to contiguous areas of food and cover (Jankovsky-Jones 1999). The forest will support enhanced fish habitat through stream shading, allochthonous input of fine, coarse and organic carbon to the aquatic ecosystem, and input of large wood structures in the stream. Vertical and horizontal forest structural elements will maintain bird and mammal habitat throughout the riparian corridor. Cottonwood will also provide dead snags for cavity nesting birds and mammals within about 50 years.

A total of 10,058 herbaceous plugs and 2,415 woody trees and shrubs were planted in fall 2009 along 1.09 hectares of riparian floodplain and the 371 m of channel that was re-graded to form a high flow swale (*See 4.1.1 Project B_9.7: Instream/Channel Construction; Element D2-2).* In much of these areas, invasive reed canarygrass (*Phalaris arundiacea*) that had become established was mechanically scraped from planting areas prior to treatment. All floodplain surfaces and the temporary roads used to access the site were hand seeded and mulched with herbaceous grasses applied at a rate of 48 kg/ha. In the spring of 2010, an additional 2,219 live willow poles were planted to complete the vegetation treatments on these sites. Plant species included eleven species of woody trees and shrubs, ten species of herbaceous sedges (*Carex sp. and Scirpus sp.*) and rushes (*Juncus sp*.), and six species of herbaceous grasses.

A total of 3,800 conifer seedlings were also planted in the spring 2010, treating an area of approximately 2.22 hectares of stream adjacent uplands, where the proximity of these habitats to Benewah Creek offered the greatest potential for future large wood recruitment to the channel. Conifer plantings consisted of Engelmann spruce (*Picea engelmannii*), lodgepole pine (*Pinus contorta*) and ponderosa pine (*P. ponderosa*).

Project Timeline: Two design alternatives were developed initially and the preferred site design and vegetation plan was finalized in May 2009. Annual plantings will be completed in the fall and the spring of each year between 2009-2011. Annual and periodic inspections will be completed to evaluate survival and growth and determine if restocking of planting sites is warranted.

Project Goals & Objectives: Reestablish a patchwork of native vegetation communities on approximately 25 acres of the valley floor to lay the foundation for a compositionally and structurally diverse forest ecosystem to develop over the next 25-50 years. Achieve minimum stocking densities of 197 trees/hectare and provide for significant increases in canopy density and overhanging vegetation over a 20 year timeframe.

Relationship to Scope of Work: This project fulfills the Program commitments for WE F in the 2009 Scope of Work and Budget Request (Contract #42560) for the contract period June 1, 2009 through May 31, 2010.

4.1.4 Project L_8.2/0.7: Instream/Channel Construction for the *Hnmulshench* Project

Project Location:

Watershed: Lake Creek	Legal: T24N, R45E, S36, E½ of SE¼
Sub Basin (River Kilomter): 13.1/1.1 rkm	Lat: 47.526627N Long: 117.048639W

Site Characteristics:

Slope/gradient: 0.6%	Aspect: N	Elevations: 792 m
Valley/Channel type: C4/C5	Proximity to water: Instream and adjacent floodplain	

Other: *Project implements first year actions identified in the Hnmulshench restoration design, including: construction of 106 m of new channel to final grade (an additional 365 m excavated to subgrade);construction of eight in-channel wood structures within the new channel; and re-grading of a field and adjacent hillside to create 3.2 ha of new floodplain.*

Problem Description: The lower reaches of the West Fork contain an important stream corridor linking the headwaters to the mainstem of Lake Creek. Currently, there is limited production potential for cutthroat trout within the reach due to channel incision, fine sediment, increased stream temperatures, lack of cover, and lack of large woody debris. Fish population data has been collected for the watershed since 1996. This section of the West Fork of Lake Creek had an average westslope cutthroat trout density from 2002-2008 of 1.1 fish/100 square m while fish densities further upstream were greater than 20 fish/100 square m.

This stream rehabilitation project includes about 805 m of WF Lake Creek and 305 m of an unnamed tributary. Both streams exhibit many of the classic signs of impairment caused by channel ditching and straightening. WF Lake Creek (WFLC) is deeply entrenched as a result of incision of the streambed as a series of head-cuts migrated upstream through the reach. Historic head-cuts have already moved upstream through the project, and three additional head-cuts were identified within the reach. These existing headcuts imply that the incision trend is expected to continue as the head-cuts progress upstream. There is exposed bedrock 91 m upstream of the site preventing further incision above that point. The unnamed seasonal tributary intersects WFLC at approximately mid way up the project reach. This tributary channel is also deeply incised and two head-cuts were observed. Bank erosion and bankslope failures have been ongoing since initial incision occurred in both WFLC and the tributary. Several bank erosion sites were observed and streambanks will likely continue to fail. Bank erosion rates on WFLC were estimated to be 8.07 metric tons/year upstream of a stream crossing and 28.24 metric tons/year downstream of a stream crossing. Streambank vegetation is generally reed canary grass and Mountain Alder. The historic floodplain, where hay is produced, is perched and rarely accessed by flooding. There are 1.1 hectares of wetlands on the property.

Although these erosion processes negatively influence short-term sediment loading, vegetation establishment, and aesthetic, they are the natural processes by which an incised stream can eventually recover over the long term. Through erosion and sediment transport processes (of the streambed initially, and then streambanks and terraces) over several decades the channel will gradually create a new inset floodplain and riparian habitat at the lower level, terraced several feet below the existing valley bottom. Currently, the channel at the project reach is underway in this recovery process, but at different stages of development through the reach. In some channel segments the new inset floodplain width approaches 12 m while in other segments, width is less than 4.5 m. It is expected to continue to erode downward and laterally until a new floodplain forms that has enough width to allow floods to spread out and when vegetation can become established, to resist the rapid erosion processes that are currently underway.

Description of Treatment: The design developed for this project calls for filling 610 m of the existing incised West Fork Lake Creek channel and diverting flows into a newly constructed, 922 m long channel that is well connected with the valley bottom to allow dissipation of flood flows over a broad floodplain (Figure 41). Upstream of the newly constructed channel, imported wood will be placed in the existing channel to create habitat. A seasonal stream will be partially filled to repair the degradation that has occurred and will be extended to the newly built WF Lake Creek stream channel. Native plants will be planted in riparian and adjacent upland areas. Large wood material will be used throughout the project to increase lateral roughness where needed, create banks and maintain planform until hydric plant communities become fully established. Construction will increase the stream length by more than 50 percent and nine acres of wetlands will be created through this project (0.33 hectares will be filled).

The following construction phases were the focus of restoration work in summer-fall 2009:

Phase 1A- Floodplain Grading: New floodplain was created along the southwest side of the valley. Sections of existing hillside were cut to extend the floodplain. In some areas, bedrock was encountered which caused a change in channel design. Grading was completed for 2 hectares of the project. Temporary stockpiles of topsoil and general fill were created in areas that were west of the proposed berm. These areas were seeded and mulched in November 2009.

Phase 1B- New Channel Grading (Figure 40): New channel grading involved creating a new channel excavated into the new floodplain surface to channel subgrade depth. The subgrade was 5.5 m wide downstream of the new confluence with the seasonal tributary and 5.2 m wide upstream of the new confluence. Bankfull width for riffles was 3.7 m downstream and 3.4 m feet upstream of the confluence. New channel habitat was constructed over the channel subgrade by using imported gravels and logs to create streambed and streambanks. Rock was placed in the channel combined with logs to form riffles and pools. Logs were placed on the new floodplain to provide erosion protection and will be anchored or buried. Fill was placed in temporary stockpile areas. A total of 457 m of channel was excavated to the subgrade (1840 cubic meters of soil) and 107 m of channel was constructed to final grade. Sections of floodplain in this area were re-graded after the channel work was complete.

Project Timeline: The site design was finalized in May 2009. All NEPA work was completed by August 2009. Construction began in August 2009. Restoration work is to be completed over three years ending in October 2011.

Project Goals & Objectives: Goals for this project include 1) create wetland habitats and hydraulic connections with the valley bottom; 2) reduce bank erosion 3) provide a long-term source of large woody debris for natural recruitment; and 4) provide measurable increase in abundance and distribution of westslope cutthroat trout.

Relationship to Scope of Work: This project fulfills the Program commitments for WE H in the 2009 Scope of Work and Budget Request (Contract #42560) for the contract period June 1, 2009 through May 31, 2010.

Figure 40. Channel construction for the WF Lake Creek Hnmulshench project proceeded in two stages: excavation to subgrade (left), then refilling the channel with rock and wood to achieve the final design dimensions (right). The bedrock outcroppings seen in the foreground (left) were incorporated into the new channel.

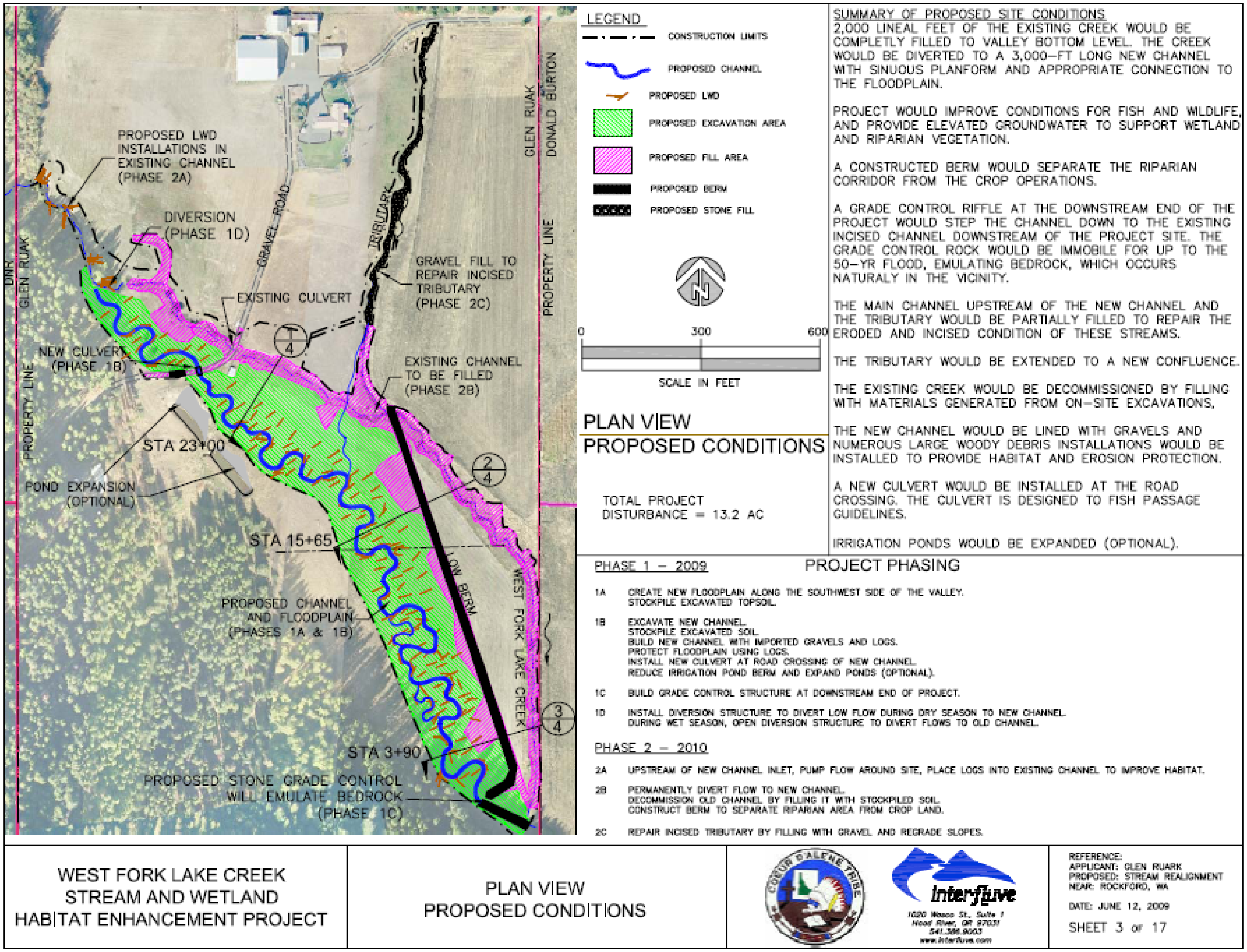

Figure 41. Design approach for the West Fork of Lake Creek Hnmulshench project.

4.1.5 Project L_8.2/0.7: Riparian/Planting

Project Location:

Watershed: Lake Creek	Legal: T24N, R45E, S36, E½ of SE¼
Sub Basin (River Kilomter): 13.1/1.1 rkm	Lat: 47.526627N Long: 117.048639W

Site Characteristics:

Slope/gradient: 0.6%	Aspect: N	Elevations: 792 m
Valley/Channel type: C4/C5	Proximity to water: Instream and adjacent floodplain	

Other: *Project specifically treats the 1.01 ha of hillside and 3.2 ha of associated floodplain disturbed during stream channel construction in 2009.*

Problem Description: Restoration of the West Fork of Lake Creek is underway to restore stable channel pattern and geometry by creating 994 m of new stream channel in the historic valley. In 2009, 3.2 ha of ground were disturbed through construction activities. This area will require rapid establishment of woody and herbaceous species to support the short- and long-term stability of the site.

Current wetland function is degraded in the entrenched West Fork of Lake Creek channel as a result of the processes of channel incision that has occurred since before the 1930's. Based on local site conditions and conditions in reference wetlands in other nearby watersheds, it is evident that both groundwater and periodic overbank flooding once provided much of the hydrology to maintain wetlands in the project area. A band of xeric vegetation of variable width is located along the channel margin throughout the incised reach. A series of springs that historically connected to the historic channel are now feeding an irrigation pond.

Description of Treatment: A vegetation plan was developed for the site based on inventories of native wetland plant species conducted during wetland delineations and functional assessments on the project site at and at a control site in the watershed. Planting activities are described in the WF Lake Creek Restoration Planting Plan and in the Stormwater Pollution Prevention Plan (SWPPP) for construction activities. The plan identifies a mix of 27 native species to be planted on the site, delineates planting areas based on key environmental gradients, and provides material specifications and planting densities. Plant species include seven species of woody trees and shrubs, 10 species of herbaceous sedges (*Carex sp. and Scirpus sp.*) and rushes (*Juncus sp.*), and 10 species of herbaceous grasses.

A total of 300 herbaceous plugs were planted along 100 meters of newly built stream bank. 800 conifer seedlings and 450 shrubs were planted in spring 2009 along 1.01 ha of adjacent hillside to reestablish native vegetation in an area that was formerly a hay field. In addition, newly graded floodplain surfaces and stockpile areas were hand seeded and mulched with herbaceous grasses applied at a rate of 48 kg/ha.

Project Timeline: The site design was finalized in May 2009. All NEPA work was completed by August 2009. Construction began in August 2009. Seeding and mulching occurred in October-November 2009. Conifer planting occurred in March 2010. Woody plants and herbaceous plugs were planted in April 2010. Restoration work is to be completed over three years ending in October 2011. Annual and periodic inspections will be completed to evaluate survival and growth and determine if restocking of planting sites is warranted.

Project Goals & Objectives: Goals for this project include 1) create wetland habitats and hydraulic connections with the valley bottom; 2) reduce bank erosion 3) provide a long-term source of large woody debris for natural recruitment; and 4) provide measurable increase in abundance and distribution of westslope cutthroat trout. Success criteria include: establish at least 80% herbaceous cover by native species at the end of 2 years following site disturbance.

Relationship to Scope of Work: This project fulfills the Program commitments for WE I in the 2009 Scope of Work and Budget Request (Contract #42560) for the contract period June 1, 2009 through May 31, 2010.

4.2 Project Prioritization

A fundamental goal of the Coeur d'Alene Tribe Fisheries Program is to identify restoration and enhancement needs and opportunities in areas that have the greatest potential to improve habitat and translate into positive biological responses to recover depressed native cutthroat trout populations. Within this context we are interested in answering the question, "What are the highest priority restoration actions at the watershed scale and at finer spatial scales?" To help structure the process of identifying and prioritizing restoration actions we utilized a four-step process that connects watershed analyses and status and trend monitoring to prioritization through 1) setting clear goals and objectives for restoration activities, 2) selecting a prioritization scheme that is consistent with the goal, 3) using watershed assessments to identify restoration actions, and 4) prioritizing the list of actions (Beechie et al. 2008). These steps fit within the broader restoration process that we have used in developing other programmatic plans, such as the Fisheries Program Management Plan (Lillengreen et al. 1999) and Research Monitoring and Evaluation Plan (Vitale et al. 2002), which includes restoration planning, implementation, and evaluating the success of restoration actions (Figure 42).

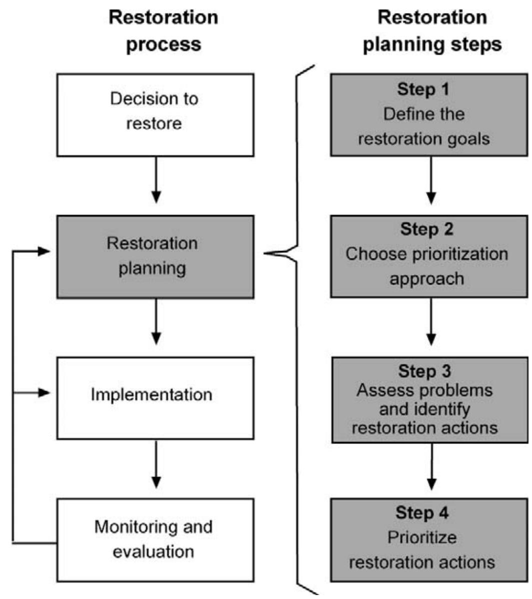

Figure 42. Diagram of the restoration process and the steps used for identifying and prioritizing restoration actions that are nested within this broader process.

4.2.1 Restoration Goals and Objectives

Ranked aquatic resource goals for the Coeur d'Alene Subbasin were developed as part of the NPPC Subbasin Planning process. The highest priority goal included protection and restoration of harvestable surpluses of naturally reproducing adfluvial adult fish from Lake, Benewah, Evans and Alder creeks and other populations well-distributed in tributaries throughout the basin (Intermountain Province Subbasin Plan 2004). The restoration goal that is corollary to the subbasin goal is to "support recovery of resident and migratory westslope cutthroat trout through restoration of landscape processes that form and sustain riverine habitat diversity, while managing the riparian/aquatic interface for both wildlife and limited domestic uses that do not conflict with protection of water quality, public health and the fisheries resource". This goal is stated in the context of landscape and aquatic processes that drive habitat degradation and species declines, as well as human constraints on recovery, so as to be both realistic and explainable.

We developed specific process-based objectives and criteria for describing impairment to watershed process functions that would be useful in identifying the restoration actions needed to achieve the above goal and in prioritizing those actions (Table 24). The watershed processes that were considered included sediment, flood hydrology, riparian and channel processes, water quality and biological productivity. For each of these processes, criteria were developed that described the degree of impairment relative to the watershed or sub-watershed scale. It was difficult to find suitable criteria in the peer-reviewed literature for all of these functions. Where existing criteria were not available, we developed definitions based on results from our long-term status and trend monitoring (e.g., for biological productivity) and based on the range of measured values identified during watershed assessments (e.g., for sediment, flood hydrology, riparian and channel). Ratings of high and moderate indicated a degree of process impairment warranting restoration action.

Table 24. Restoration objectives for watershed process functions and definitions for process impairment criteria; ratings of high (H); moderate (M), and low (L) indicate the degree to which each impaired process alters riverine habitat conditions.

Watershed process-function	Criteria
Sediment *Objective 1: Reduce sediment delivery from hydrologically connected road segments by 75%*	High: >15 tons/yr/sq.mi. of direct/indirect sediment delivery Moderate: 5-15 tons/yr/sq.mi. Low: <5 tons/yr/sq.mi.
Objective 2: Treat 100% of culverts with high risk of failure	High:>4 culverts w/ attention priority codes of 1 or 2 Moderate:2-4 culverts w/ attention priority codes of 1 or 2 Low:<2 culvert w/ attention priority codes of 1 or 2
Flood hydrology *Objective: Reduce length of hydrologically connected road segments wherever opportunities exist*	High: >0.4mi/sq.mi. of hyrologically connected road Moderate: 0.2-0.4 mi/sq.mi. Low: <0.2 mi/sq.mi.
Riparian function *Objective 1: 70% of stream reaches with ability to meet instream wood loading criteria over 150 years*	High:>60% of reaches with high sensitivity to management Moderate:30-60% of reaches with high sensitivity Low:<30% of reaches with high sensitivity to management
Objective 2: 75% canopy cover in 2nd order tributaries	High:>50% of riparian habitats in non-forested condition Moderate:25-50% non-forested Low:<25% non-forested
Channel *Objective 1: 70% of available habitat to meet LWD loading criteria of $6m^3$/100m over 150 years*	High: >50% of channel not meeting LWD criteria Moderate: 30-50% of channel not meeting LWD criteria Low: <30% of channel not meeting LWD criteria
Objective 2: Treat all culverts blocking passage for adult cutthroat trout. Evaluate treatments for other high/moderate priority culverts on a case by case basis	High: >25% of available habitat blocked to adult passage for more than 50% of flows Moderate:10-25% of available habitat blocked Low:<10% of available habitat blocked
Water quality *Objective 1: <17˚C during the warmest period of the year*	High: >25% exceedance Moderate: 5-25% exceedance Low: <5% exceedance
Biological productivity *Objective: Achieve at least 80% of the mean maximum density at index sites distributed throughout the subbasin.*	Identify the mean maximum cutthroat trout density (current productivity potential) for each subbasin as well as the difference between mean max/min density (current productivity distance). Index to be used as a modifier to weight restoration priority.

4.2.2 Prioritization Approach

There are a variety of available prioritization approaches, and selecting an approach that matches restoration goals and assessment capabilities is helpful in linking restoration goals, watershed assessments, and prioritization into a coherent strategy for river restoration (Beechie et al. 2008). We selected a prioritization approach consistent with the logic approach (decision support system) described by Lewis et al. (1996), SRSRC (2004) and Cipollini et al (2005). This approach utilizes an array of semi-quantitative tools for prioritizing restoration actions, including, information developed from watershed assessments that describe causes of impairment, biological benefits associated with classes of restoration actions, as well as estimated costs. The fundamental objective is to assemble and weigh information considered important to setting priorities (Cipollini et al. 2005). The approach is considerably more flexible than others that were reviewed and allowed for incorporating values important to the Coeur d'Alene Tribe and local landowners.

A decision support system score sheet was developed to obtain a relative "score" for each planned project. Criteria were drafted to reflect the values embodied in the goal statement as well as the constraints of implementing projects within the target watersheds. The criteria include consideration of species that benefit from restoration, the degree to which restoration actions address causal processes, uncertainty associated with project actions and habitat/biological responses, and how the project accommodates local socioeconomic goals. The criteria are scored on either a discrete or continuous scale, as well as being weighted, then summed to a total score. Total scores are useful in differentiating projects (Table 25).

In the initial use of this approach, we selected just two of the focal watersheds, Benewah and Lake creeks, to develop a list of projects and conduct the preliminary prioritization of restoration efforts. These watersheds were chosen because they both have resident and adfluvial westslope cutthroat trout and relatively more restoration actions have been implemented compared with Alder and Evans creeks. In proceeding with this approach we recognize the importance of watershed scale restoration as well as the value in maintaining a treatment/control approach to monitoring action effectiveness. Within these two watersheds, 12 subbasins were delineated so that priorities could be viewed and implemented at multiple scales. These subbasins encompass the distribution of cutthroat within the watersheds and contain the critical habitats for spawning and early life stage rearing. The Lake Creek watershed includes three subbasins: Bozard, Upper Lake, and WF Lake; while the Benewah Creek watershed includes nine subbasins: Bull, Coon, Hodgson, Schoolhouse, SF Benewah, WF Benewah, Whitetail, Whittrock, and Windfall.

4.2.3 Identifying Restoration Actions

Watershed assessments and long-term monitoring data collected as part of this BPA funded project (Table 26), provided most of the information needed to identify and prioritize restoration actions. The most recent assessments included 1) inventory and analysis of road conditions and fish passage associated with 540 km of forest roads and more than 400 stream crossings (Duck Creek Associates 2009); and 2) large wood recruitment inventory and analysis which examined existing in-stream wood loads, stream conditions and the wood recruitment capacity of riparian forests associated with more than 74 km of streams (Miller et al 2008). These assessments provided the critical understanding of natural potentials as they relate to sediment, flood hydrology and riparian and channel function, and the degree to which restoration efforts can move habitats toward a re-expression of natural habitat capacity and quality (Poff and Ward 1990; Ebersole and Liss 1997; Frissell et al. 1997; Pess et al. 2003).

Table 25. Example of a project score sheet to facilitate prioritization of a list of restoration actions.

Project number: 05-01
Project title: SF Benewah Creek LWD addition
Description: Add LWD, rkm 0-0.5, to address 340m of channel w/ 150 yr wood loading deficits

Evaluation Criteria	**Weight**	**Score**	**Total**
Does the project directly address a cause of habitat impairment identified in the watershed assessment? (discrete)	3	3	9
Directly address causal process – 5			
Indirectly addresses causal process – 3			
Does not address any process – 1			
What is the project's contribution to meeting the objective for the impaired process/function? (continuous)	3	3	9
Contributes substantially to meeting the objective – 5			
Contributes minimally to meeting the objective - 1			
What is the scope of the project? (discrete)	3	3	9
Project affects multiple processes operating at large scale – 5			
Project affects multiple processes operating at small scale – 3			
Project affects single process operating at small scale – 1			
Does the project have local landowner support? (discrete)	3	3	9
Strong support, willingness to cost-share – 5			
Strong support, limited financial support - 3			
Strong resistance, generally provides short-term benefits – 1			
What is the proximity to source populations and existing or planned enhancement projects? (continuous)	2	4	8
Project less than 100m – 4			
Project >500m – 1			
What are the logistical challenges of the project? (continuous)	2	4	8
Project will result in little indirect disturbance to non-target resources, easy access – 5			
Project will result in direct and indirect disturbance to non-target resources, difficult access – 1			
What is the education and cultural value of the project? (continuous)	1	3	3
High visibility, identifiable educational and cultural value – 5			
Low visibility, little educational and cultural value – 1			
What is the certainty of project success? (continuous)	1	4	4
Proven technique that rarely fails – 4			
Experimental technique with high degree of uncertainty – 1			
What is the project cost? (discrete)	1	3	3
Low (<$50K) – 3			
Mod ($50-100K) – 2			
High (>$100K) – 1			
What is the likelihood of obtaining funding? (continuous)	1	5	5
Currently funded, within scope of project – 5			
Likely difficult to fund, not within project scope – 1			
What is the difficulty of project design and permitting? (continuous)	1	4	4
Completed designs and permits – 5			
Requires multiple permits and extensive coordination – 1			
Total Project Score			**71**

Table 26. Summary of assessments and inventories used to identify the condition of watershed processes and function.

Watershed process or function	Assessment technique	Inventory procedure
Sediment	Sediment budget, surface erosion models, road condition assessment	Forest road inventory (ODFW), WARSEM
Flood hydrology	Empirical methods	Water routing by roads
Riparian function	Growth and recruitment models, remote sensing of riparian vegetation	Inventory of riparian/stream wood conditions
Channel	Wood loading, mapping of culverts, fish passage models	Inventory of stream wood conditions Inventory of migration blockages/available habitat/fish distribution
Biological productivity	Annual abundance surveys	Inventory fish distribution and abundance

In order to translate the watershed assessment results into a list of necessary restoration actions, we first prepared a summary to clearly identify which processes or functions were most impaired and most responsible for habitat degradation (Table 27). The summary identifies the degree of impairment for each of the subbasins in the Lake and Benewah creek watersheds consistent with the definitions for process impairment that were developed and described above. The summary of impairments was then translated into a list of restoration needs, which includes types of restoration actions, their locations, and approximate levels of effort needed to address each of the impaired processes (Table 28).

4.2.4 Prioritizing Restoration Actions

Prioritization of restoration actions is an important part of the overall exercise to ensure that limited restoration funds can be focused on actions that will have the greatest impact and locations that will receive the greatest benefit. To this end, the delineated subbasins were further ranked by relative restoration priority according to the overall level of impairment, proximity to restored habitats and the potential for increasing fish production (Table 28). A weighted impairment value was calculated for each subbasin, wherein a moderate impairment rating was scored as 1 point and a high rating was scored as 2 points and the scores were summed. Subbasins with the highest impairment values were considered higher priorities for restoration. Where impairment values for subbasins within the same watershed were equal, the rankings were modified to favor priority for subbasins in closer proximity (connectivity) to restored habitats or with greater potential for increasing fish production. This potential was indicated by the “current productivity distance”, defined as the difference in mean maximum/minimum cutthroat trout densities within the subbasin.

Table 27. Summary of process impairments identified by watershed assessment in subbasins within the Lake Creek and Benewah Creek watersheds. Subbasins lacking assessment data are indicated by ND.

		Subbasin[1]											
Process-		**Lake Creek**			**Benewah Creek**								
function	**Specific cause of problem**	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Hydrology	Drainage systems increase peak flow	M	L	M	L	M	L	M	H	H	M	L	H
Sediment	Road surface erosion	L	L	M	L	L	L	L	H	H	L	L	M
	Culvert/road crossing failure	M	L	M	L	L	M	L	H	H	M	L	H
Riparian	Reduced wood delivery to channel	H	H	H	L	L	H	H	H	L	M	M	H
	Lack of shade	M	H	M	L	M	L	L	L	L	L	L	L
Channel	Simplified habitat (lack of LWD)[3]	H	H	H	H	H	H	H	H	H	H	H	H
	Impassable culverts	M	H	L	L	L	L	L	H	H	M	H	M
	Reduced floodplain connectivity												
Water quality	Temperature/nutrient loading	H	H	H	M[2]	ND	ND	M	M[2]	M[2]	L	ND	M
Productivity	Current productivity potential	55.7	16.6	25.1	42.2	10.1	ND	7.2	17.8	14.4	9.5	ND	27.5
	Current productivity distance	52.0	16.6	24.0	27.3	5.0	ND	1.7	12.1	0.2	4.8	ND	18.7

[1]Lake Creek - 1=Bozard, 2=Upper Lake, 3=WF Lake; Benewah Creek – 1=Bull, 2=Coon, 3=Hodgson, 4=School, 5=SF Benewah, 6=WF Benewah, 7=Whitetail, 8=Whittrock, 9=Windfall.

[2]Impairment value inferred from professional judgment because continuous data were not available

[3]Lake Creek – 17492 m (85%) <$6m^3$/100m; Benewah Creek – 25990m (63%) <$6m^3$/100m

Table 28. Summary of restoration needs and relative restoration priority by subbasin within the Lake Creek and Benewah Creek watersheds. Proximity to restored mainstem habitat is indicated as near (N) or far (F), where applicable.

		Subbasin[1]											
		Lake Creek			**Benewah Creek**								
Process-function	**Restoration action**	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Hydrology	Disconnect roads and drainage systems from stream network, remove roads	M		M		M		M	H	H	M		H
Sediment	Reduce surface erosion, remove roads			M					H	H			M
	Reduce culvert/road failure risk	M		M			M		H	H	M		H
Riparian	Conserve functional riparian areas, manage for increased growth recruitment	H	H	H			H	H	H		M	M	H
	Plant riparian buffer	M	H	M		M							
Channel	Increase complexity (add wood)	H	H	H	H	H	H	H	H	H	H	H	H
	Remove or fix migration barriers	M	H						H	H	M	H	M
	Increase floodplain connectivity												
Water quality	Increase shade and connectivity	H	H	H	M			M	M	M			M
Weighted impairment value		10	10	10	3	4	5	6	13	11	6	5	11
Proximity to restored habitat		F	N	N	F	F	N	N	N	N	N	F	N
Relative restoration priority		1	3	2	9	8	6	5	1	3	4	7	2

[1]Subbasin Key: Lake Creek - 1=Bozard, 2=Upper Lake, 3=WF Lake; Benewah Creek – 1=Bull, 2=Coon, 3=Hodgson, 4=School, 5=SF Benewah, 6=WF Benewah, 7=Whitetail, 8=Whittrock, 9=Windfall.

A list of spatially explicit projects was developed to meet the stated process objectives for each of the highest priority subbasins (6 in Benewah Creek and 3 in Lake Creek). A total of 105 projects were identified and prioritized in these subbasins (Appendix B). Figure 43 shows the distribution of projects based on watershed process-function. Only 2 percent of the ownership in these project areas is Tribal, while 49 percent is owned by 4 private companies and an additional 39 percent is owned by 18 individual landowners. Cumulatively, these projects affect 41.1 km of stream and riparian habitat (29.7 km in Benewah Creek, 11.4 km in Lake Creek), with passage projects expected to have the greatest impact. The list of projects will be used over the next several years to negotiate landowner agreements for implementation, and to develop project proposals and scopes of work.

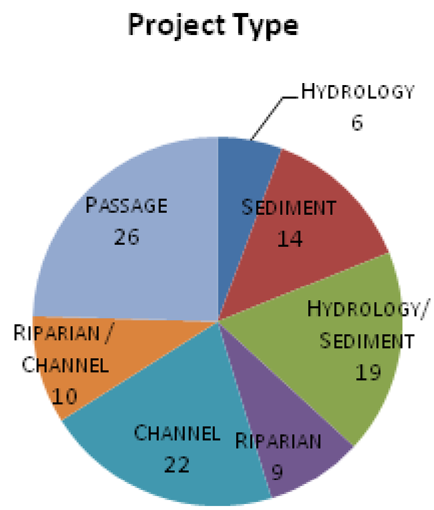

Figure 43. Number and distribution of restoration projects by project type.

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Appendix A

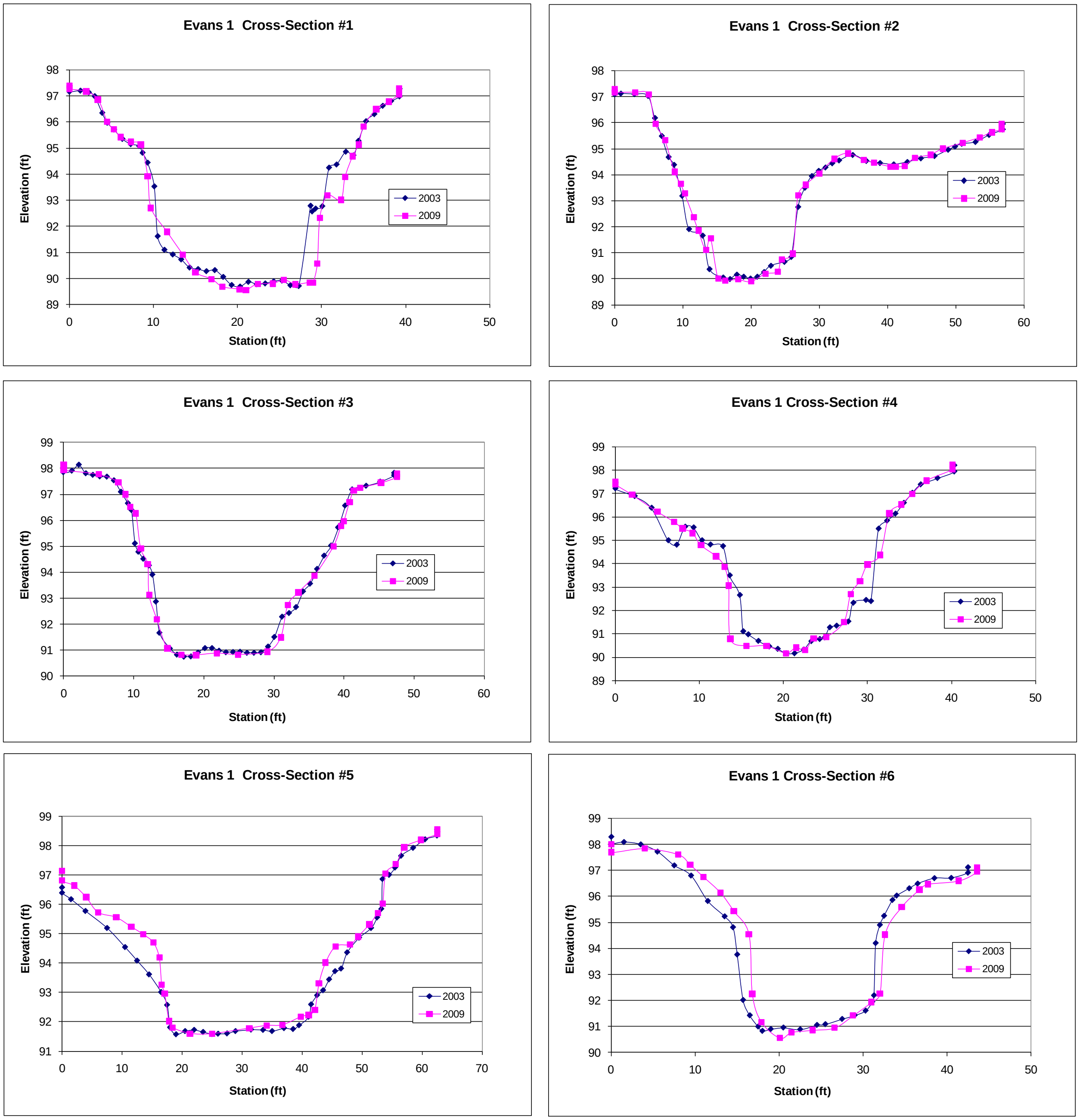

Figure A-1. Cross-section comparison for site Evans 1 for 2003 and 2009.

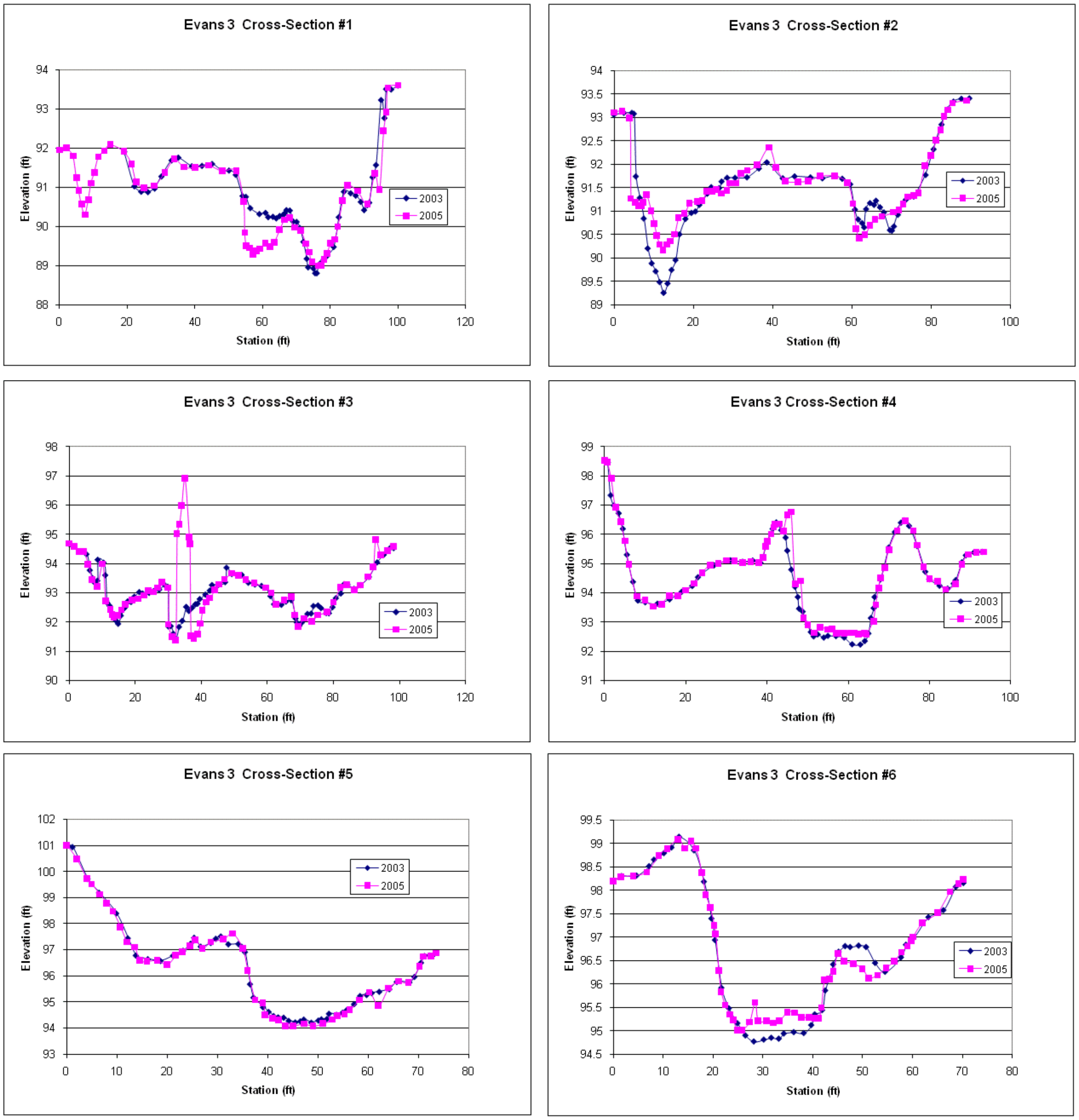

Figure A-2. Cross-section comparison for site Evans 3 for 2003 and 2005. These years were before in-stream wood additions were placed in the channel.

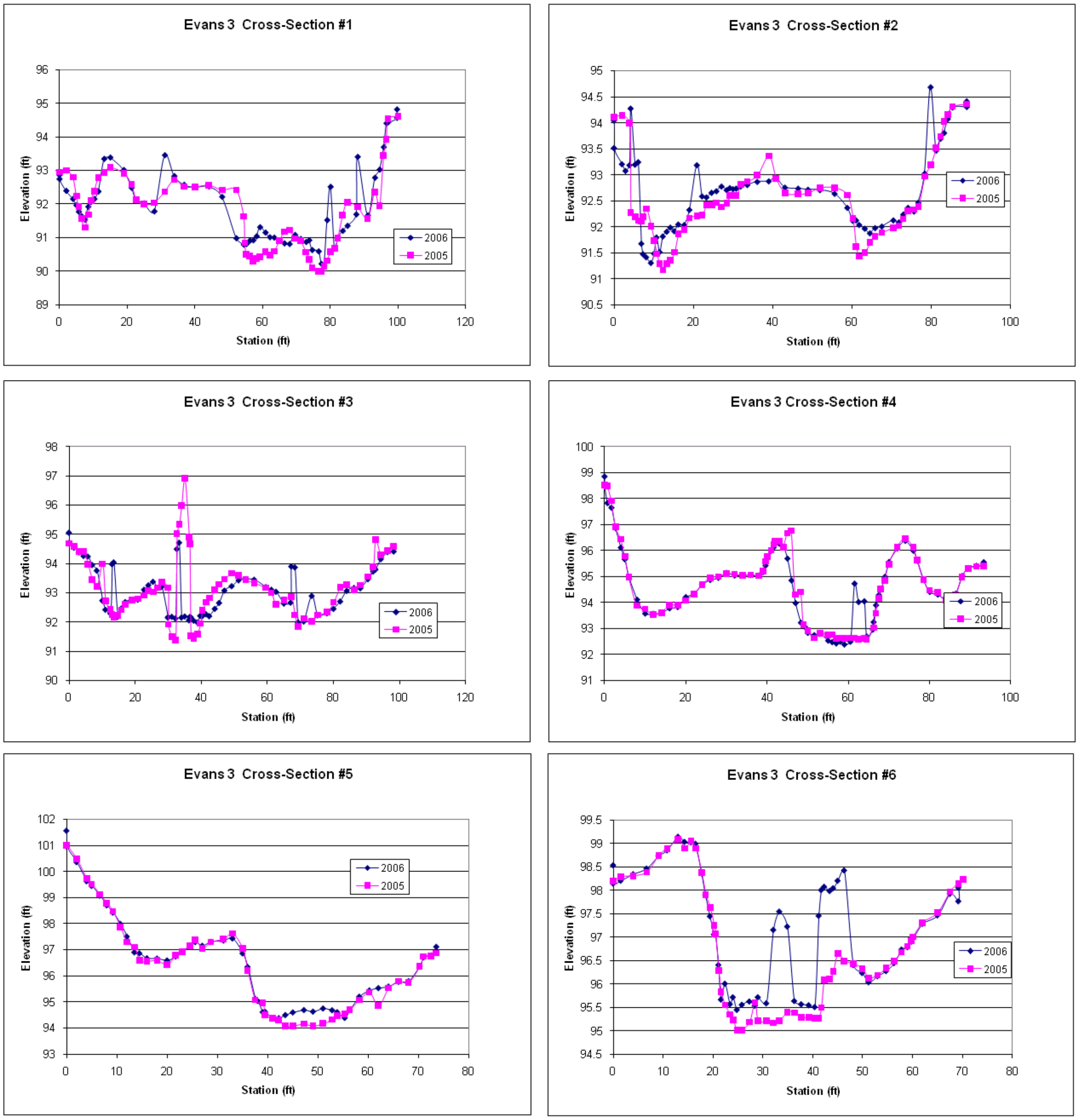

Figure A-3. Cross-section comparison for site Evans 3 for 2005 and 2006. In-stream wood additions were placed in the channel in fall 2005.

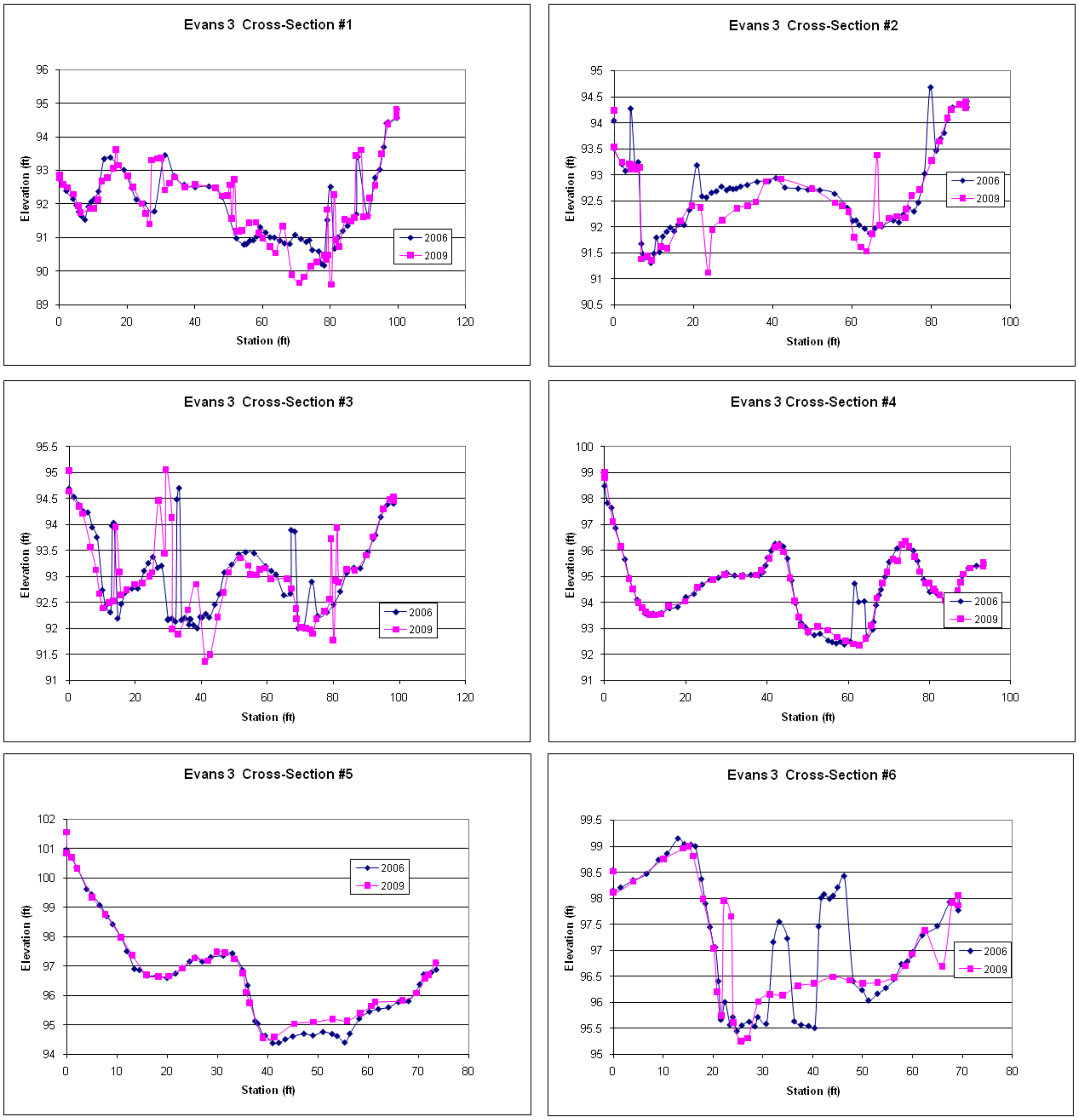

Figure A-4. Cross-section comparison for site Evans 3 for 2006 and 2009 for years following construction. In-stream wood additions were placed in the channel in fall 2005.

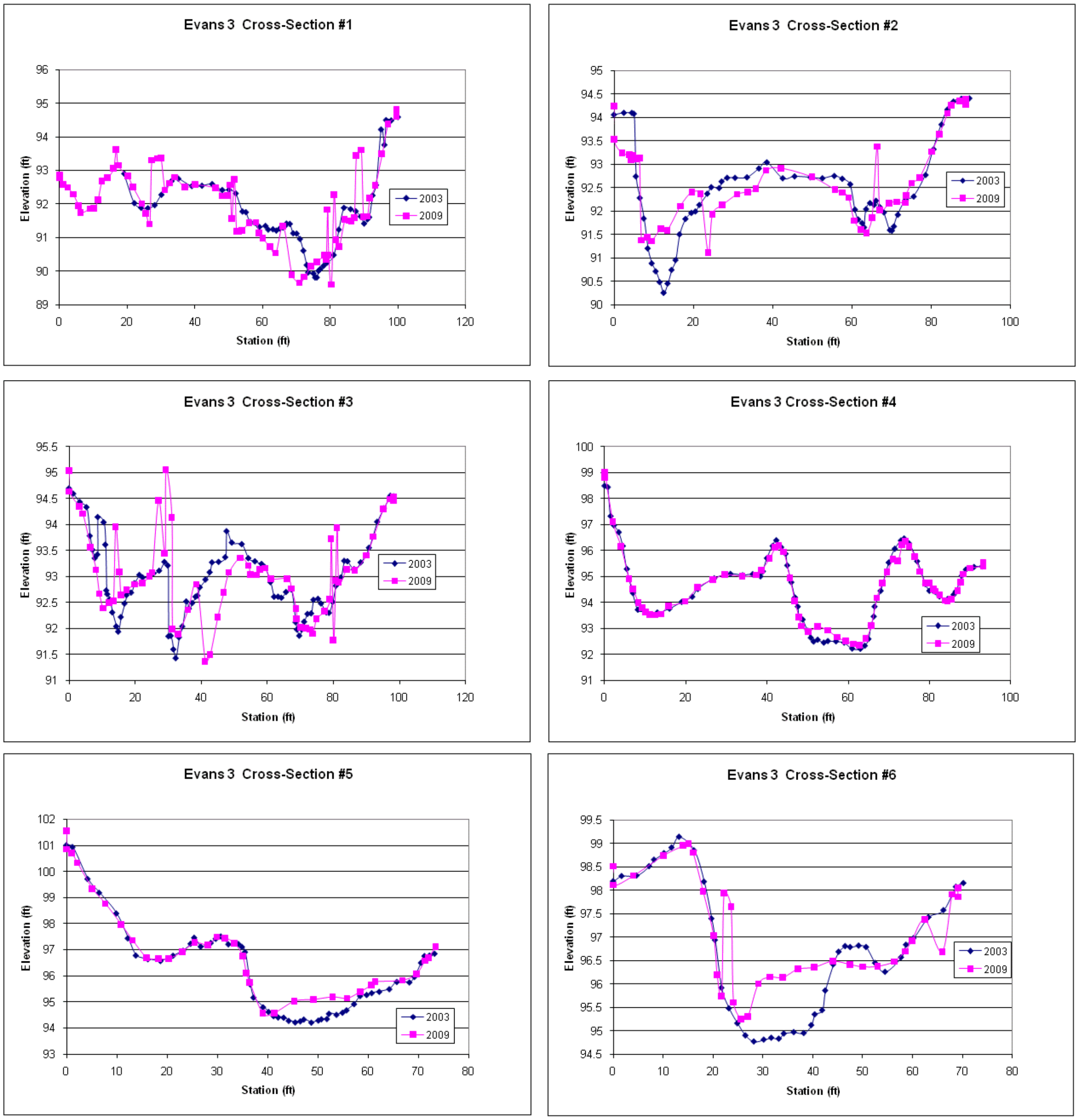

Figure A-5. Cross-section comparison for site Evans 3 for 2003 and 2009. In-stream wood additions were placed in the channel in fall 2005.

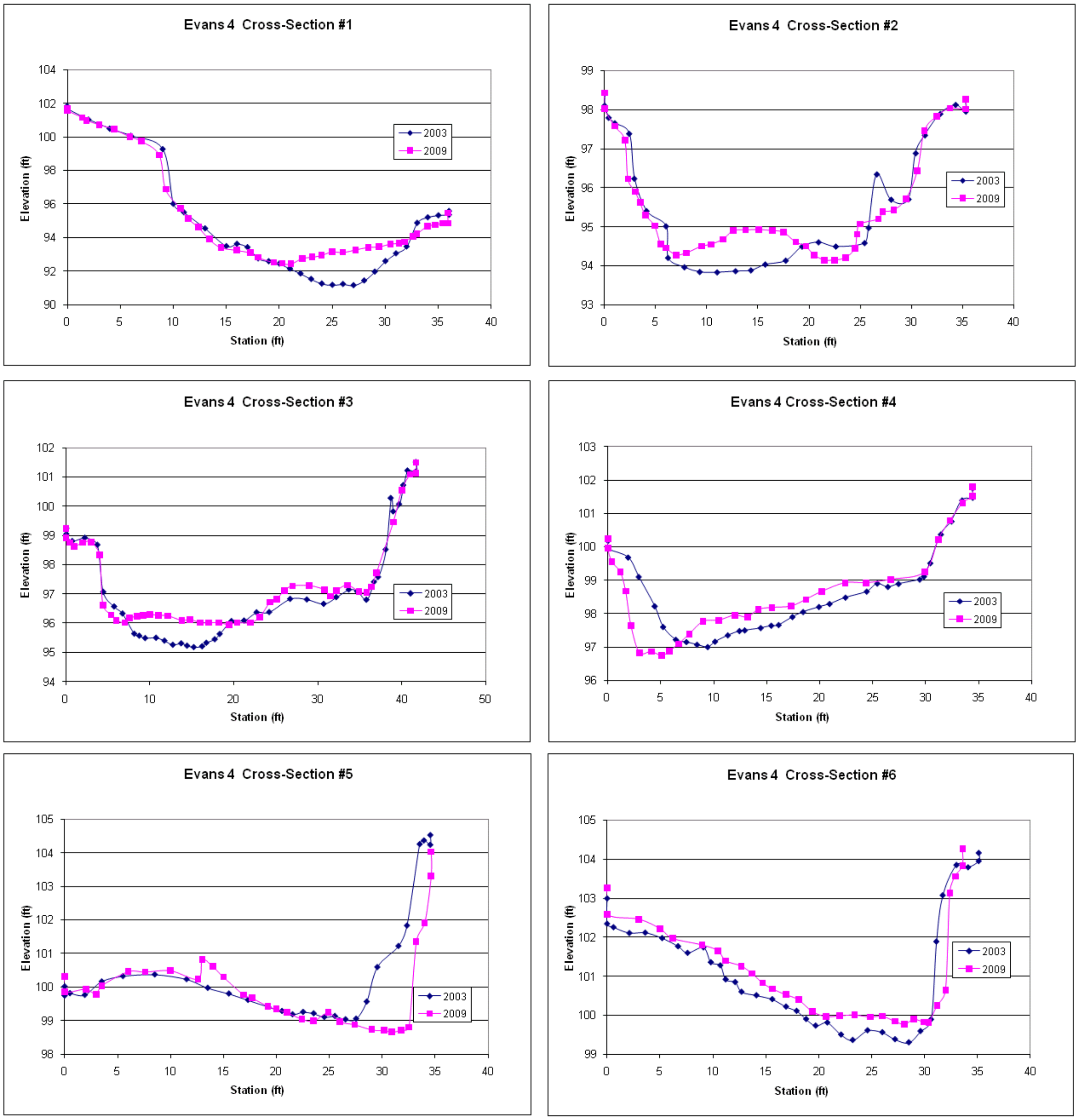

Figure A-6. Cross-section comparison for site Evans 4 for 2003 and 2009.

Figure A-7. Cross-section comparison for site Evans 5 for 2003 and 2009.

Appendix B

Preliminary list of prioritized projects based on assessment results for sub-basin within the Benewah and Lake Creek watersheds.

Project number	Project Title	Project description	Subbasin priority	Importance	Priority Score[1]	Project type	Owner type	Project metrics	x coordinate	y coordinate
B03-01	EF Hodgson Creek LWD addition	Add LWD, rkm 0.0-0.8, to address 580m of channel w/ 50 yr wood loading deficits	6	High	81	C	P	580	-116.7560	47.2510
B03-02	Hodgson Creek Culvert Replacement	Improve fish passage on Hodgson Creek at adult fish barrier, road 3724_945.	6	Low	79	P	I	930	-116.7317	47.2433
B03-03	Improve road drainage and reduce sediment delivery	Install cross drains on road 3700.	6	Low	78	H	C	104	-116.7550	47.2530
B03-04	Hodgson Creek LWD addition	Add LWD, rkm 0.2-1.2, to address 350m of channel w/ 50 yr wood loading deficits	6	High	74	C	P	350	-116.7510	47.2470
B03-05	Reduce sediment delivery	Replace stream crossing at 3701_3090.	6	Moderate	72	S	P	20	-116.7524	47.2456
B03-06	Hodgson Creek LWD addition	Add LWD, rkm 1.2-2.1, to address 256m of channel w/ 50 yr wood loading deficits	6	High	71	C	P	256	-116.7460	47.2420
B03-07	Hodgson Creek LWD addition	Add LWD, rkm 2.1-2.7, to address 100m of channel w/ 50 yr wood loading deficits	6	High	68	C	P	100	-116.7430	47.2370
B03-08	Reduce sediment delivery	Resurface 274m of road 3702	6	Low	67	S	P	274	-116.7550	47.2511
B03-09	Reduce sediment delivery	Resurface 152m of road 3711	6	Low	65	S	I	152	-116.7260	47.2391
B04-01	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	5	High	84	C	P	300	-116.7820	47.2240

Project number	Project Title	Project description	Subbasin priority	Importance	Priority Score[1]	Project type	Owner type	Project metrics	x coordinate	y coordinate
B04-02	School House Creek riparian management prescriptions	Develop silvicultural prescription, rkm 0.7-2.2, for increasing growth and recruitment	5	High	82	R	I	1500	-116.7790	47.2160
B04-03	School House Creek LWD addition	Add LWD, rkm 0.0-0.3, to address 225m of channel w/ 150 yr wood loading deficits	5	High	76	C	I	225	-116.7860	47.2270
B04-04	IDL Creek LWD addition	Add LWD, rkm 1.0-1.9, to address 400m of channel w/ 150 yr wood loading deficits	5	High	68	C	I	400	-116.7770	47.2150
B04-05	Improve road drainage and reduce sediment delivery	Replace stream crossing at 3003_7480	5	Low	67	S	S	20	-116.7843	47.2070
B04-06	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	5	Moderate	67	HS	I	324	-116.7722	47.2173
B04-07	Improve road drainage and reduce sediment delivery	Resurface 182m of roads 3511, 3512 and 3543, install cross-drains on road 3530	5	Moderate	64	HS	I	285	-116.7640	47.2118
B04-08	Improve road drainage and reduce sediment delivery	Install cross drains on road 3521	5	Moderate	61	H	I	205	-116.7560	47.2230
B05-01	SF Benewah Creek culvert replacement	Improve fish passage on SF Beneawh Creek at adult fish barrier, 3100_5662	1	High	84	P	C	6118	-116.7983	47.2027
B05-02	SF Benewah Creek riparian planting	Riparian planting, rkm 0.8-1.5	1	Moderate	79	R	P	700	-116.8000	47.2070

Project number	Project Title	Project description	Subbasin priority	Importance	Priority Score[1]	Project type	Owner type	Project metrics	x coordinate	y coordinate
B05-03	SF Benewah Creek LWD addition	Add LWD, rkm 0.5-1.4, to address 670m of channel w/ 150 yr wood loading deficits	1	High	76	C	P	670	-116.8000	47.2070
B05-04	SF Benewah Creek riparian management prescriptions	Develop silvicultural prescription, rkm 1.5-3.2, for increasing growth and recruitment	1	High	76	R	P	1700	-116.7980	47.2020
B05-05	WF of SF Benewah Creek culvert replacement	Improve fish passage on WF of SF Benewah Creek at adult fish barrier, 3119_1730	1	High	75	P	I	0	-116.8053	47.1973
B05-06	Reduce road surface erosion	Replace undersized culverts at roads 3108_3510 and 3108_3835, and regrade/resurface 175m of road, 3100_13756-14331	1	High	73	S	P	236	-116.7945	47.1842
B05-07	Improve road drainage and reduce sediment delivery	Install cross drains and resurface 833m of roads 3100, 3101, 3102	1	High	73	HS	I	1320	-116.7920	47.1900
B05-08	WF of SF Benewah Creek culvert replacement	Improve fish passage on WF of SF Benewah Creek at adult fish barrier, 3115_2330	1	High	72	P	I	0	-116.8086	47.1949
B05-09	SF Benewah Creek culvert replacement and road surface erosion reduction	Improve fish passage on SF Benewah Creek at adult fish barrier, 3105_80 and resurface 80m of road 3105_0-265	1	High	72	P	I	0	-116.7920	47.1851
B05-10	SF Benewah Creek LWD addition	Add LWD, rkm 0-0.5, to address 340m of channel w/ 150 yr wood loading deficits	1	High	71	C	P	340	-116.7980	47.2160

Project number	Project Title	Project description	Subbasin priority	Importance	Priority Score[1]	Project type	Owner type	Project metrics	x coordinate	y coordinate
B05-11	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	1	High	71	HS	P	1659	-116.7893	47.1875
B05-12	Improve road drainage on Fletcher Rd.	Install cross drains on 304m of road, 3100_1950-2950	1	High	68	H	C	304	-116.7980	47.2027
B05-13	Improve road drainage and reduce sediment delivery	Install cross drains and resurface 481m of road 3105	1	High	67	HS	I	366	-116.7960	47.1875
B05-14	SF Benewah Creek LWD addition	Add LWD, rkm 1.4-3.2, to address 850m of channel w/ 50 yr wood loading deficits	1	High	65	C	P	850	-116.7980	47.2020
B05-15	Improve road drainage and reduce sediment delivery	Install cross drains and resurface 231m of road 3126 and 3127	1	High	64	HS	M	474	-116.8060	47.1892
B05-16	Reduce road sediment delivery	Replace ford crossing with a culvert on unnamed tributary, 3150_2800	1	High	61	S	I	60	-116.8059	47.2027
B06-01	WF Benewah Creek LWD/Riparian Assessment	Inventory and assess stream and riparian condition related to wood recruitment potential, rkm 1.6-3.2	3	High	97	R	I	1600	-116.8200	47.2160
B06-02	WF Benewah Creek culvert replacement	Improve fish passage on WF Benewah Creek at adult fish barrier, 3799_110	3	High	87	P	I	3390	-116.8138	47.2144
B06-03	WF Hart Creek culvert replacement	Improve fish passage on WF Hart Creek at adult fish barrier, 3143_6535	3	High	82	P	I	781	-116.8096	47.2105
B06-04	WF Hart Creek culvert replacement	Improve fish passage on WF Hart Creek at adult fish barrier, 3143_3560	3	High	77	P	I	48	-116.8172	47.2080

Project number	Project Title	Project description	Subbasin priority	Importance	Priority Score[1]	Project type	Owner type	Project metrics	x coordinate	y coordinate
B06-05	Hart Creek culvert replacement	Improve fish passage on Hart Creek at juvenile fish barrier, 3143_6080	3	High	75	P	I	327	-116.8105	47.2091
B06-06	WF Benewah Creek LWD addition	Add LWD, rkm 1.0-1.6, to address 300m of channel w/ 50 yr wood loading deficits	3	High	72	C	I	300	-116.8120	47.2140
B06-07	Improve road drainage and reduce sediment delivery	Replace stream crossing at 3142_460, install cross drains and resurface 798m of roads 3140, 3142 and 3143	3	High	72	HS	I	1219	-116.8222	47.2135
B06-08	Hart Creek culvert replacement	Improve fish passage on Hart Creek at adult fish barrier, 3143_5260	3	High	71	P	I	643	-116.8114	47.2072
B06-09	WF Benewah Creek LWD addition	Add LWD, rkm 0.0-0.5, to address 100m of channel w/ 150 yr wood loading deficits	3	High	67	C	P	100	-116.8010	47.2170
B06-10	WF Benewah Creek LWD addition	Add LWD, rkm 0.5-1.0, to address 320m of channel w/ 150 yr wood loading deficits	3	High	65	C	P	320	-116.8040	47.2150
B06-11	Improve road drainage and reduce sediment delivery	Install cross drain and resurface 307m of roads 3131 and 3130	3	High	63	HS	I	476	-116.8370	47.2087
B07-01	Whitetail Creek culvert replacement	Improve fish passage on Whitetail Creek at adult fish barriers, 3200_9184 and 3200_9205	4	Moderate	87	P	I	4740	-116.7829	47.2625
B07-02	Whitetail Creek riparian management prescriptions	Develop silvicultural prescription, rkm 1.7-2.6, for increasing growth and recruitment	4	Moderate	82	R	I	900	-116.7790	47.2620

Project number	Project Title	Project description	Subbasin priority	Importance	Priority Score[1]	Project type	Owner type	Project metrics	x coordinate	y coordinate
B07-03	Whitetail Creek LWD addition	Add LWD, rkm 1.7-2.6, to address 342m of channel w/ 50 yr wood loading deficits	4	High	78	C	I	342	-116.7790	47.2620
B07-04	Reduce sediment delivery	Resurface 367m of roads 3205, 3204, and 3203	4	Low	73	S	I	367	-116.7830	47.2626
B07-05	Whitetail Creek LWD addition	Add LWD, rkm 2.6-3.0, to address 226m of channel w/ 50 yr wood loading deficits	4	High	72	C	I	226	-116.7860	47.2620
B07-06	Whitetail Creek riparian planting	Riparian planting, rkm 0.5-1.1	4	Moderate	72	R	P	600	-116.7710	47.2520
B07-07	Whitetail Creek LWD addition	Add LWD, rkm 0.5-1.1, to address 270m of channel w/ 50 yr wood loading deficits	4	High	71	C	P	270	-116.7710	47.2520
B07-08	Whitetail Creek riparian management prescriptions	Develop silvicultural prescription, rkm 2.6-3.0, for increasing growth and recruitment	4	Moderate	71	R	I	400	-116.7860	47.2620
B07-09	Whitetail Creek culvert replacement	Improve fish passage on Whitetail Creek at adult fish barrier, 3203_2865	4	Moderate	71	P	I	1619	-116.7923	47.2628
B07-10	Improve road drainage and reduce sediment delivery	Install cross drains and resurface 246m of roads 3203 and 3205	4	Moderate	67	HS	I	367	-116.7980	47.2609
B07-11	Reduce sediment delivery	Replace undersize culvert, install cross-drains and resurface 59m of road 3203_990	4	Moderate	63	HS	I	118	-116.7867	47.2631
B07-12	Reduce sediment delivery	Resurface 102m of road 3200	4	Low	58	S	I	102	-116.7770	47.2642

Project number	Project Title	Project description	Subbasin priority	Importance	Priority Score[1]	Project type	Owner type	Project metrics	x coordinate	y coordinate
B09-01	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	2	High	83	C	T	1400	-116.7890	47.2360
B09-02	Windfall Creek riparian planting	Riparian planting, rkm 0.0-0.9	2	Moderate	83	R	T	900	-116.7870	47.2350
B09-03	SF Windfall Creek culvert replacement	Improve fish passage on SF Windfall Creek at fish barrier, 3158_235	2	Moderate	80	P	I	853	-116.8026	47.2352
B09-04	SF Windfall Creek culvert replacement	Improve fish passage on SF Windfall Creek at fish barrier, 3155_3045	2	Moderate	79	P	I	1352	-116.8066	47.2307
B09-05	Windfall Creek riparian management prescriptions	Develop silvicultural prescription, rkm 1.2-2.6, for increasing growth and recruitment	2	High	76	R	P	1400	-116.8030	47.2360
B09-06	Windfall Creek culvert replacement	Improve fish passage on Windfall Creek at fish barrier, road 3169_110	2	Moderate	76	P	P	391	-116.8163	47.2446
B09-07	NF Windfall Creek culvert replacement	Improve fish passage on NF Windfall Creek at adult fish barrier, 3178_258000	2	Moderate	76	P	P	0	-116.8258	47.2393
B09-08	Windfall Creek culvert replacement	Improve fish passage on Windfall Creek at adult fish barrier, 3164_2660	2	Moderate	76	P	P	1057	-116.8090	47.2312
B09-09	Improve road drainage and reduce sediment delivery	Install cross drain and resurface up to 390m of road 3155	2	High	70	HS	I	450	-116.8159	47.2267
B09-10	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	2	Moderate	69	S	I	741	-116.8173	47.2514

Project number	Project Title	Project description	Subbasin priority	Importance	Priority Score[1]	Project type	Owner type	Project metrics	x coordinate	y coordinate
B09-11	Improve road drainage and reduce sediment delivery	Replace stream crossing 3178_23156, install cross drains and resurface 905m of roads 3178 and 3185	2	High	68	HS	P	1111	-116.8030	47.2360
B09-12	Windfall Creek LWD addition	Add LWD, rkm 1.2-2.6, to address 460m of channel w/ 50 yr wood loading deficits	2	High	66	C	P	460	-116.8101	47.2399
B09-13	Improve road drainage and reduce sediment delivery	Replace stream crossing 3175_300 and resurface 180m of road 3175	2	Moderate	65	S	I	240	-116.8380	47.2401
B09-14	Improve road drainage and reduce sediment delivery	Install cross drains and resurface 807m of road 3160	2	High	64	HS	S	1614	-116.8169	47.2416
B09-15	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	2	High	63	HS	P	1427	-116.8201	47.2383
L01-01	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	1	High	87	RC	P	732	-117.0240	47.5460
L01-02	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	1	High	87	RC	I	896	-117.0240	47.5610
L01-03	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	1	High	86	RC	P	497	-117.0270	47.5260

Project number	Project Title	Project description	Subbasin priority	Importance	Priority Score[1]	Project type	Owner type	Project metrics	x coordinate	y coordinate
L01-04	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	1	High	84	RC	P	466	-117.0170	47.5540
L01-05	Bozard Creek culvert replacement	Improve fish passage on Bozard Creek at adult fish barrier, 4510_7430	1	Moderate	83	P	I	3855	-117.0252	47.5556
L01-06	EF Bozard Creek LWD addition	Add LWD, rkm 1.0-2.1, to address 532m of channel w/ 50 yr wood loading deficits	1	High	75	C	I	532	-117.0049	47.5584
L01-07	EF Bozard Creek culvert replacement	Improve fish passage on EF Bozard Creek at fish barrier, road 4505_5105	1	Moderate	75	P	I	515	-117.0044	47.5587
L01-08	Improve drainage and reduce sediment delivery	Install cross drains on road 4514	1	Moderate	72	H	C	132	-117.0240	47.2580
L01-09	EF Bozard Creek culvert replacement	Improve fish passage on EF Bozard Creek at adult fish barrier, road 4500_19660	1	Moderate	70	P	I	593	-117.0002	47.5612
L01-10	Bozard Creek culvert replacement	Improve fish passage on Bozard Creek at adult fish barrier, road 4500_9590	1	Moderate	68	P	I	616	-117.0165	47.5718
L01-11	Improve road drainage and reduce sediment delivery	Replace stream crossing at 4500_13590, and resurface 365m of roads 4925, 4920, 4505 and 4500	1	Moderate	63	S	I	425	-117.0111	47.5681
L01-12	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	1	Moderate	63	HS	I	487	-116.9913	47.5627

Project number	Project Title	Project description	Subbasin priority	Importance	Priority Score[1]	Project type	Owner type	Project metrics	x coordinate	y coordinate
L01-13	Improve road drainage and reduce sediment delivery	Install cross drains and resurface 365m of roads 4500 and 4510	1	Moderate	61	H	I	512	-117.0280	47.5678
L01-14	Reduce sediment delivery	Replace stream crossing at 4506_1255	1	Moderate	57	S	I	20	-117.0065	47.5474
L02-01	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	3	High	87	RC	P	732	-117.0380	47.4590
L02-02	Lake Creek culvert replacement	Improve fish passage on Lake Creek at adult fish barrier, MSL_235	3	High	83	P	P	3381	-117.0378	47.5442
L02-03	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	3	High	76	RC	P	107	-117.0350	47.5290
L02-04	Lake Creek culvert replacement	Improve fish passage on Lake Creek at adult fish barrier, road 4515_14800	3	High	75	P	P	1482	-117.0420	47.5610
L02-05	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	3	High	73	RC	P	91	-117.0350	47.5310
L02-06	Improve road drainage and reduce sediment delivery	Install cross drains on road 4514	3	Low	72	H	C	157	-117.0360	47.5280
L02-07	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	3	Low	67	HS	I	533	-117.0509	47.5781
L02-08	WF of Upper Lake Creek culvert replacement	Improve fish passage on WF of Upper Lake Creek at fish barrier, road	3	High	66	P	P	1529	-117.0410	47.5492

Project number	Project Title	Project description	Subbasin priority	Importance	Priority Score[1]	Project type	Owner type	Project metrics	x coordinate	y coordinate
		4515_10360								
L02-09	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	3	High	66	RC	P	210	-117.0350	47.5330
L02-10	Upper Lake Creek LWD addition	Add LWD, rkm 1.4-1.8, to address 441m of channel w/ 150 yr wood loading deficits	3	High	63	C	P	441	-117.0350	47.5370
L02-11	Improve road drainage and reduce sediment delivery	Install cross drains on road 4023 and resurface up to 213m of roads 4023 and 4022	3	Low	60	HS	I	278	-117.0550	47.5612
L03-01	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	2	High	86	RC	S	334	-117.0850	47.5330
L03-02	WF Lake Creek LWD addition	Add LWD, rkm 0.0-0.5, to address 345m of channel w/ 150 yr wood loading deficits	2	High	75	C	P	345	-117.0370	47.5220
L03-03	Olsen Creek culvert replacement	Improve fish passage on Olsen Creek at fish barrier, 4600_2090	2	Low	69	P	C	390	-117.0654	47.5305
L03-04	Improve road drainage and reduce sediment delivery	Add cross-drains and resurface 609m of road 4600	2	Moderate	68	HS	P	850	-117.0610	47.5365
L03-05	WF Lake Creek riparian planting and LWD addition	Riparian planting and LWD addition, rkm 0.5-0.9, to address 315m of channel w/ 150 yr wood loading deficits	2	High	67	RC	P	158	-117.0440	47.5230

Project number	Project Title	Project description	Subbasin priority	Importance	Priority Score[1]	Project type	Owner type	Project metrics	x coordinate	y coordinate
L03-06	WF Lake Creek LWD addition	Add LWD, rkm 2.3-3.9, to address 1136m of channel w/ 50 yr wood loading deficits	2	High	67	C	P	1136	-117.0600	42.5420
L03-07	Olsen Creek culvert replacement	Improve fish passage on Olsen Creek at adult fish barrier, 4303_5630	2	Low	66	P	P	1480	-117.0682	47.5317
L03-08	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	2	Moderate	63	HS	I	974	-117.0739	47.5562
L03-09	Reduce sediment delivery	Resurface 457m of road 4301	2	Moderate	58	S	P	457	-117.0640	47.5495
L03-10	Reduce sediment delivery	Resurface 304m of roads 4303, 4302 and 4017	2	Moderate	54	S	I	304	-117.0770	47.5455