Silver Creek 2016 Summary Report

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State of California

Department of Fish and Wildlife

Heritage and Wild Trout Program

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Introduction

Federally Threatened Lahontan Cutthroat Trout (*Oncorhynchus clarkii henshawi*; LCT) are native to the Lahontan Basin which, in California, includes the Truckee, Carson, and Walker river drainages. They have been extirpated from most of their range due to overfishing, dam construction, habitat fragmentation, and the introduction of nonnative species (Behnke 1992).

Silver Creek, a tributary to the West Walker River (Mono County), contains a refuge population of LCT upstream of a fish barrier. Silver Creek is a snow-fed tributary on the east side of the Sierra Nevada Mountains, in the Humbolt-Toiyabe National Forest, and is located about 20 miles northwest of Bridgeport, CA (Figure 1). Non-native Brook Trout (*Salvelinus fontinalis*) were, at some unknown point, introduced into Silver Creek to provide a sport fishery.

Brook Trout negatively affect stream-resident populations of LCT due to their comparatively high population density, aggressive feeding behavior, rapid growth rate, and high fecundity (Dunham et al. 2003). Walker River basin LCT have been heavily impacted by nonnative Brook Trout. LCT exist in only a few small isolated tributaries of the Walker River. Silver Creek was chemically treated with rotenone from 1994 through 1996 to remove Brook Trout and establish Silver Creek as an LCT refuge. In 1995, Silver Creek was closed to fishing to help support the recovery of the population. In 2004, Brook Trout were again detected in the lower reaches of the creek, which may have been the result of a failed treatment or illegal reintroduction. Since then, manual removal efforts have been conducted with the goal of eradicating Brook Trout; however, the level and intensity of manual removal was not consistent over time.

Silver Creek currently supports populations of both LCT and Brook Trout. In 2013, eradication efforts increased with a cooperative project between the California Department of Fish and Wildlife (CDFW), California Trout, Trout Unlimited (TU), the Federation of Fly Fishers, and several local fishing clubs. Brook Trout removal, using backpack electrofishers, was focused in the upper reaches of Silver Creek. Two modified Alaskan weirs were constructed to segment the creek and improve the odds of project success by creating discrete stream segments and preventing upstream fish movement.

This report summarizes the results of the 2016 field season. In addition to manual removal of Brook Trout, other elements of the project included:

- Stream mapping to delineate wetted habitat in various flow conditions and document fish presence/absence in all tributaries
- Installation of temperature loggers

- Amphibian surveys
- Depletion electrofishing surveys to establish baseline population metrics
- Implantation of Passive Integrated Transponder (PIT) tags into LCT to monitor instream movement and barrier efficacy

The results from these surveys will aid in evaluating project success, identifying areas for improvement or modified approaches that may enhance Brook Trout removal, and in developing comprehensive long-term eradication strategies.

Methods

Stream mapping

From May 31 to June 3, 2016, the Heritage and Wild Trout Program (HWTP) mapped Silver Creek from the barrier falls upstream to the headwaters (Figure 2). The project area was divided into five roughly equal sections in order to compare outcomes across different portions of the drainage. Each section was approximately one mile long, except for Sections 4 and 5. These section boundaries were developed based on the presence of temporary weirs that provided a presumed break in habitat and population connectivity (Figure 3). During stream mapping, the following features were identified and geo-referenced using handheld Global Positioning System (GPS) equipment (North American Datum 1983):

- wetted features and stream characteristics that may affect electrofishing efficacy
- tributaries were mapped from the Silver Creek confluence upstream to either fish migration barriers or the upper extent of wetted habitat
- notable features such as upstream fish distribution, changes in gradient and habitat types, and potential barriers to upstream fish migration were documented

Air and water temperatures (Cº) were measured and average wetted widths (ft) and water depths (ft) were estimated for each wetted tributary. Streamflow (cubic feet per second; cfs) was measured on June 1 near the access road's end in Section 3. Representative photographs were taken throughout the project area.

On September 7, stream mapping was again performed in Sections 3, 4, and 5 to document conditions during the fall flow regime. Stream flow was measured at benchmark locations established during the depletion electrofishing surveys.

Depletion electrofishing

Depletion electrofishing surveys were conducted from July 8th to 10th to establish baseline data on fish abundance and condition, proportion of Brook Trout to LCT, and size class distribution for each species. One depletion electrofishing location was randomly selected in each of the established sections (1-5). Silver Creek was delineated into100-meter points using Geographic Information System software and each point was sequentially numbered. Using a random numbers table, one point was chosen from each of the project sections.

Using GPS equipment, surveyors navigated to each randomly selected point and determined survey feasibility. Where possible, the downstream block net was installed at the randomly selected point; if this location was not conducive to net placement, surveyors moved upstream to the nearest suitable location. HWTP staff approximated 500 ft upstream from the downstream block net and installed an upstream net at the nearest feasible location.

At each boundary, nylon mesh block nets were installed across the wetted width, effectively enclosing the population within the section. Both sides of the nets were secured above bankful width and heavy rocks were placed side by side along the net bottom, taking care to ensure no gaps existed through which fish could escape. The top of the net was secured out of the water with either sticks or rebar. Block nets were anchored with additional rebar to provide support in problematic areas, such as deep water or fast currents. Nets were routinely monitored throughout the surveys to ensure their integrity and prevent fish from moving in or out of the survey section.

Prior to electrofishing, a Visual Encounter Survey (VES) was conducted along both stream banks to detect the presence of amphibians; in particular, Sierra Nevada Yellow-Legged Frogs (*Rana sierrae*; SNYLF), a federally-listed species previously documented in and near Silver Creek.

Air and water temperature (ºC) and specific and ambient conductivity (microsiemens; µS) were measured. These measurements were used to determine appropriate electrofisher settings. If conductivity was less than 50 µS, four-pound salt blocks were placed in the water directly upstream of the section to increase conductivity and improve capture efficiency. The number of salt blocks used was determined by the conductivity, size of the stream, and the current flow conditions. Specific conductivity was re-measured at the downstream block net until the effects of the salt were noted by an increase in conductivity. This new value was recorded. Geographic coordinates were recorded for the upstream and downstream survey boundaries (North American Datum 1983).

Personnel needs were determined based on stream width, habitat complexity, and water visibility. For each of the surveys, individuals were assigned to electroshock, net, and tend live cars for the duration of the effort. Three shockers, three primary netters, two back-up netters, and one live-car tender were used in each section. Surveys began at the downstream block net and proceeded in an upstream direction, with netters capturing fish and placing them in live cars for holding until they could be processed. Live cars were plastic trash bins perforated with holes to allow water circulation. Fish were stored separately by pass number. A minimum of three passes were conducted in each section, unless zero fish were captured in any one pass. More than three passes were conducted when depletion rates were less than 50% between passes.

Fish were handled carefully to minimize injury and stress and were processed separately by pass number. Each fish was identified to species, measured (total length in mm), weighed (g), and inspected for injury. Additionally, LCT six inches or larger were tagged with 12 mm PIT tags placed in the body cavity between the pyloric caeca and pelvic girdle. The insertion point was posterior to the pelvic fins on the left side of the body. An injection needle was inserted with the bevel up and then rotated 180° before the tag was injected. The tagged LCT were marked with an adipose fin clip. LCT were recovered in live cars with fresh flowing water and released live back into the section. All Brook Trout were euthanized using a sharp knife quickly inserted in the top of the head, directly into the brain. This method was determined to be the most humane means of euthanasia. A sodium bicarbonate bath was also temporarily evaluated, but project staff stopped using this method due to the large amount of sodium bicarbonate and extended time required for the bath to be lethal. All Brook Trout were dispatched and buried.

A habitat assessment was conducted in each section to collect baseline data on resource condition, habitat types and quality, water condition, substrate, discharge, bank condition, and other attributes. The HWTP habitat assessment is a pared-down synthesis of Rosgen (1994) and the California Salmonid Stream Habitat Restoration Manual (CSSHRM; Flosi et al. 1988). Section length (ft) was measured along the thalweg. The length of the section was then divided into five cells of equal length. Wetted widths (ft) were measured at the center of each of the five cells. Across each width transect, five depths (ft) were taken (also at the center of five evenly divided cells), and both widths and depths were averaged for each section. Streamflow (cfs) was measured in each section and this location was benchmarked to compare measurements over time.

Stream characteristics, including active erosion (erosion occurring in the present), erosion at bankful, and canopy closure were measured as percentages of either the total stream area (canopy cover) or bank area (erosion). Section percentages were defined for each habitat type (riffle, flatwater, and pool) following Level 2 protocols as defined by the CSSHRM. Using visual estimates, substrate size classes and the percentage of each class relative to the total bottom material within the wetted width were quantified. A rating (between poor and excellent) was given to the instream fish cover and cover types were identified and defined as percentages of total instream cover. The change in water surface elevation (section gradient; %) was measured. Representative photographs of the section were taken.

Population density and capture probability were calculated by species and section using MicroFish Fisheries Software (Van Deventer). Mean Fulton's condition factors (K) were calculated by species and section using the formula $K = \frac{100000W}{L^3}$ where W is the weight (g) and L is total length (mm). An analysis of variance (ANOVA) and two sample t-tests were used to compare condition factors between sections. Young of the year (YOY) and deformed trout with perch-shaped bodies were removed from the analysis since their weight to length ratio reflects their life stage and deformities and not necessarily their condition.

Mechanical removal

From July 11 to October 20, the HWTP and TU conducted mechanical removal of Brook Trout throughout the project area, with a focus on Sections 3- 5. Single passes were conducted in Silver Creek using Smith Root backpack electrofishers to capture trout. Following the same protocols as depletion electrofishing surveys, water quality was measured and a VES was conducted prior to electrofishing. On August 23rd, a SNYLF was observed in the water during the electrofishing survey in Section 5. This frog was not detected during the VES and, as a result, modified and enhanced protocols were implemented to increase detection probability. In all subsequent VES, both banks were surveyed along the water's edge and long-handled dip nets were used to move aside vegetation and increase visibility, as well as to potentially disturb basking adults which are known to have a strong flight response.

The number of shockers and netters varied depending on wetted width, habitat complexity, and the number of personnel available. One to three electrofishers were used with an equal or greater number of netters and one live car tender. Prior to electrofishing, one to four blocks of salt were used to increase conductivity and improve capture efficiency. The number of salt blocks used was determined by the ambient conductivity, size of the stream, and the current flow conditions. Salt was not always used in tributaries 1 and 3 since the small width and low flows did not require a large electrical field. All electrofishing was conducted in an upstream direction. Survey start and end points were geo-referenced each day and electrofishing proceeded from the previous day's end point.

Captured fish were placed in a five-gallon bucket with water and held for processing. All captured fish were identified to species and measured to the nearest inch (total length) with a calibrated landing net. Brook Trout were euthanized using the same methods as the depletion electrofishing surveys and dispatched (buried or consumed). LCT six inches or larger were PIT-tagged and the adipose fin was removed to identify future recaptures. If a captured LCT did not have an adipose fin, a PIT tag reader was used to identify the tag number. Tag numbers and total length of the fish were recorded. If the reader did not detect a tag on an adipose-clipped fish, the tag was considered shed or not working. The insertion area was closely examined and if no overt signs of injury were observed, a new PIT tag was inserted.

All LCT were released live back into Silver Creek. Fin clips were collected for genetic analysis on a subsample of the tagged fish. Tissue collection was distributed evenly throughout the sections, with a goal of collecting 40 samples both upstream and downstream of the lower weir (downstream boundary of Section 4).

In previous years, LCT were relocated into areas in Sections 4 and 5 where Brook Trout had been removed to prevent repeated exposure to electricity. Temporary holding areas were created as refuges for captured LCT. In 2016, rather than create and maintain holding areas in these upper sections, LCT captured in Sections 4 and 5 were relocated into Section 3 (downstream of the lower weir), where the Brook Trout population had been reduced earlier in the season. Due to time constraints and a focus on the upper sections, no Brook Trout removal was conducted in Section 1. Woody debris and overhanging vegetation that impeded electrofishing were removed throughout the project area to improve capture efficiency. Woody debris removal was primarily focused in Sections 2 and 3, since crews in previous years had performed extensive removals in Sections 4 and 5.

In late September and October, redds were trampled during the electrofishing surveys in Sections 4 and 5. Although no redds were positively identified in Sections 4 and 5, any depression in the gravel was trampled as a precautionary measure. On October 20, redds were trampled throughout the upper mile of Section 3, where the highest Brook Trout densities had been previously observed.

Temperature loggers

Four Onset HOBO temperature loggers were installed in December, 2015 throughout Silver Creek to profile seasonal fluctuations in water temperature. Loggers were distributed across project sections 1 through 5, in habitats assumed to be preferred by LCT (e.g., areas with lower velocity and sufficient depth and complexity to provide holding and foraging opportunities). Locations were selected in both pools and flatwater, where water depth was conducive to capturing temperatures year-round.

At each selected site, a three-foot piece of rebar was hammered into the substrate as an anchor point for the logger. The loggers were encased in PVC piping with holes to ensure constant water flow to the logger. The PVC piping was attached to the rebar as close to the substrate as possible, without inhibiting the free flow of the logger in the water column (Figure 4). Each logger was programed to begin sampling after install and to measure water temperature (C°) at 30 minute intervals.

At each installation site the water depth (ft), wetted width (ft), and distance from substrate to logger (ft) were measured. The habitat type, substrate, and canopy cover were recorded. Install locations were georeferenced, described in detail, and sketched. Temperature data were downloaded from the loggers in July and August, 2016 and the final download occurred in July, 2017.

Temperature data will be compared to the findings of Coleman and Fausch (2007) to determine the suitability of Silver Creek for LCT growth and reproductive success based on the annual temperature profile (pending analysis).

Results

Stream mapping

Surveyors observed a large amount of rapidly melting snow while stream mapping in May and June. This snowmelt created an extensive and complex network of temporary springs, seeps, tributaries, and off-channel pools (Figure 4). Project staff identified six perennial tributaries: two in Section 2, one in Section 3, and three in Section 5. It was confirmed that all perennial tributaries, except one in Section 5, held fish. Six ephemeral tributaries were also mapped; however, these were no longer flowing when mechanical removal began in July. In September, project staff noted considerably less wetted area and a decrease in hydrological complexity compared to May and June (Figure 5).

Both weirs were compromised during the high flows in May and June. The accumulation of debris on the weir between Sections 3 and 4 caused a large pool to form and the water to overflow around the sides. The failure of the Section 4 and 5 boundary weir was less severe and was no longer compromised by the time mechanical removal began in July.

Stream flow measurements from June to October ranged from 1.8 to 44.9 cfs and the highest flows were in June and July (Table 1 and Figure 6).

Pacific Chorus Frogs (*Pseudacris regilla*) and Mountain Garter Snakes (*Thamnophis elegans elegans*) were observed in the low-gradient meadow areas where off channel pools were common. No SNYLFs were observed during stream mapping.

Depletion electrofishing

Sections 1 and 2 were not surveyed due to high flows and turbid water; however, multiple-pass depletion electrofishing sections were established in Sections 3, 4 and 5.

Section 38 was established in Section 3 of the project area and was surveyed on July 8^{th}. Three passes were conducted, with a total of seven LCT captured and an estimated abundance of 69 LCT per mile (Table 2). LCT ranged in size from 85 to 209 mm and mean condition factor was 1.0. A total of 265 Brook Trout were captured with an estimated abundance of 3399 Brook Trout per mile. Brook Trout ranged in size from 31 to 214 mm, with the majority between 90 and 180 mm. Mean condition factor was 1.0 (Figure 7). Substrate was dominated by gravel, sand, boulder, and cobble. Undercut banks, boulders, water turbulence, and water depth comprised the majority of the instream cover. Section 38 contained 75% flatwater, 25% pool, and no riffle habitat. Section length was 539 feet, with an average wetted width of 12.78 feet, average water depth of 0.87 feet, and gradient of 2.3%. Streamflow was 13.0 cfs.

Section 50 was established in Section 4 of the project area and was surveyed on July 9^{th}. Rebar was used to help stabilize the lower block net but, after Pass 2, a slight failure occurred. The block net was compromised near both stream banks, due to high flows and debris loads. However, the failure was considered not substantial enough to end the survey. Four passes were conducted in Section 50, with a total of three LCT and 15 Brook Trout captured with an estimated abundance of 21 LCT per mile. The three LCT were 96 mm, 114 mm, and 230 mm and the mean condition factor was 1.08 (Figure 7). The Brook Trout ranged in size from 40 mm to 204 mm and mean condition factor was 1.21. Substrate was dominated by boulder, cobble, and sand. Water turbulence, boulders, and water depth comprised the majority of instream cover. Section 50 contained 73 % riffle, 25 % flatwater, and 2 % pool. Section length was 515 feet, with an average wetted width of 15.8 feet, average water depth of 0.7 feet, and gradient of 1.4%. Streamflow was 13.35 cfs.

Section 66 was established in Section 5 of the project area and was surveyed on July 10th. Four passes were conducted in Section 66, with a total of four LCT and five Brook Trout captured. The LCT ranged in size from 40 mm to 234 mm and mean condition factor was 1.06. Captured Brook Trout ranged in size from 147 mm to 229 mm and mean condition factor was 1.13 (Figure 7). Two of the captured LCT had unusual black spotting on the underside of their bodies. This could suggest an infection with a digenetic trematode, although careful examination of fresh specimens will be required to confirm this (Figure 8; Dr. Mark Adkison, CDFW, pers. comm. 2016). The block net failed following pass 1 due to high velocity flows and debris. The depletion electrofishing survey was not completed and, therefore, no fish data were collected. Substrate was dominated by sand, gravel, boulder, and cobble. Undercut banks, water turbulence, and boulders comprised the majority of instream cover. Section 66 contained 50% riffle, 40% flatwater, and 10% pool habitat. Section length was 512 feet, with an average wetted width of 10.8 feet, average water depth of 0.9 feet, and gradient of 2%. Streamflow was 10.17cfs.

Mechanical removal

Section 2 was surveyed from July 22nd through September 14th. Two complete and one partial pass were completed (Table 3). A total of 2423 Brook Trout were captured, ranging in total length from less than one to ten inches (Figure 9). Eighty-nine percent were between three and seven inches. A total of 154 LCT were captured, four of which were recaptures (3%). Captured LCT ranged in total length from two to ten inches. Most were between four and six inches (77%) (Figure 10). Tissue samples were collected from 24 LCT in Section 2 for future genetic analyses. The higher-gradient reaches were difficult to electrofish, particularly in late July, due to dense willows, high velocity streamflow and turbulence. Dense willows, in particular, obstructed shocking efforts; some were removed or cut back to improve electrofishing efficacy. Surveyors noted it was easier to shock this section following willow removal. Electrofishing success also improved later in the season, with reduced streamflow and improved visibility. Between two and three shockers and four and five netters conducted the removal efforts in Section 2; surveyors noted they were limited by the number of staff. Fewer trout were captured in the higher-gradient areas than in lower-gradient reaches.

Section 3 was surveyed four times from July 11th through August 20th (Table 4). A total of 4569 Brook Trout were captured, ranging in total length from less than one to ten inches. Most were between four and seven inches (61%). A few trout had injuries on their caudal fin, which appeared to be bite marks (Figure 11). A total of 668 LCT were captured, 147 of which were recaptures (22%). Captured LCT ranged in size from less than one to twelve inches; most were between four and seven inches (68%). Tissue samples were collected from 42 LCT in Section 3. The first LCT YOY was captured in Section 3 on August 8th; it was approximately ½ inch in length. Thereafter, more YOY were observed and, by August 19th, surveyors noted they were growing in size. One eight-inch LCT had unusual spotting suggesting possible black spot disease. The majority of this section was lower-gradient meadow, although some higher-gradient cascade habitat existed. These higher-gradient areas were difficult to electrofish, as were deeper pools in the meadows. Project staff removed large woody debris from the stream to reduce habitat complexity. Sodium bicarbonate was used to euthanize Brook Trout on July 21 to compare this method with the standard procedure. The sodium bicarbonate worked effectively but required a relatively large amount and took 12 minutes to induce mortality. The standard procedure (inserting a knife into the brain) was therefore adopted for the remainder of the project period.

Section 4 was surveyed from August 9th to October 19th and seven passes were completed. A total of 406 Brook Trout were captured, ranging in total length from less than one to ten inches (Table 5). More than half of the captured Brook Trout were between two and five inches (62%). Numerous Brook Trout had deformed spines including perch-like body forms (Figure 11), indicating injury from prior electrofishing surveys. A total of 253 LCT were captured in Section 4 and ranged from less than one to 13 inches in total length. More than half were between two and five inches (60%). Section 4 had the highest proportion of less than one-inch trout (11%) and the largest individual LCT captured during the 2016 surveys (13 inches). Tissue samples were collected from 23 LCT in Section 4. Possible black spot disease was observed on four LCT, all of which were greater than six inches in length. As noted, further laboratory analyses are required to verify this assumption. Given the prominence of dark, circular spotting LCT exhibit as part of their natural phenotype, pathogenic screening should be performed on suspect fish to validate this observation. All LCT were released in Section 3, downstream of the lower weir. On September 15th, two LCT that were relocated to Section 3 were recaptured in Section 4 directly upstream of the weir. Thereafter, surveyors relocated LCT farther downstream in Section 3. During this time frame, crews noted better capture efficiency, including increased numbers of YOY, due to lower streamflow. On September 19th, in the lower reach of Section 4, mature brook trout were captured and may have been staging to spawn. Gradient in Section 4 increased farther upstream and appeared correlated with lower trout densities. This section was cleared of woody debris and willows in previous years, improving capture efficacy. By October 19th, ice had formed on the water surface, especially in slower-moving pools, which impeded electrofishing efforts.

Section 5 was surveyed between July 10th and October 5th; four complete passes and a partial fifth pass were conducted. A total of 192 Brook Trout were captured between one and eleven inches in total length. Most Brook Trout were one to two inches in length (56%). A total of 475 LCT were captured, which ranged in size from less than one to twelve inches. Eighty percent were between two and five inches. Tissue samples were collected from 32 LCT in Section 5. Section 5 also contained both meadow and higher-gradient habitat, the latter comprised of cascades and numerous braids. Trout abundance appeared to decrease in the upstream portion of Section 5. Tributary 6 was very steep with many step pools and an extensive network of braided channels, making electroshocking difficult and time-consuming. The upper extent of this tributary ends in a boulder field with subterranean flow. Dense willows in the riparian zone impeded electrofishing efforts. On September 19th, Brook Trout were caught in possible breeding pairs. As with Section 4, ice was forming on the water surface by early October.

In total, 7590 Brook Trout and 1550 LCT were captured during the single-pass mechanical removal effort. There were substantial decreases in the number of Brook Trout captured in each pass (Tables 3-5). The total number of LCT includes recaptures and YOY. Each species varied in the numbers of fish captured in each size class between sections (Figures 9 and 10). A higher proportion of smaller-size class LCT was captured in Sections 4 and 5 than in Section 2 and 3. The largest Brook Trout captured was 11 inches, whereas several 11 inches or larger LCT were captured, including a 13-inch fish (Figure 10).

317 LCT were implanted with PIT tags and 191 recaptures were recorded. Of the recaptured LCT, identified with a missing adipose fin, 35 lost their PIT tags (18%).

Several LCT were observed with unusual black pigmentation on the undersides of their bodies, which is typically uniform white (Figure 8). This pigmentation was only seen in LCT six inches and larger, and was most prevalent in Sections 4 and 5, with only one observation recorded in Section 3 and none in Section 2. These spots appeared slightly raised above the scales, as opposed to normal body spots that appear as flat pigmentation on the body surface. Many of these LCT also showed signs of fin erosion. No Brook Trout were observed with black spots.

At least three adult SNYLFs were observed in the upper portion of Section 5 (Figure 12). Two adult SNYLFs were observed multiple times in the same location on September 3rd, 6th, 16th, and 19th. They were presumably the same individuals and were consistently observed under a log on the left bank of the creek adjacent to a rusty barrel. These frogs were not relocated and shocking teams avoided them successfully. Sightings of an adult SNYLF occurred on August 23rd and September 15th within approximately 0.1 miles of one another. It is unknown whether they were different frogs or the same individual. A SNYLF tadpole was also observed near the headwaters of Silver Creek on September 6th (Figure 3) in a pool approximately seven-feet-wide, one foot deep, and 10 feet long. Neither the tadpole or single adult were relocated.

Pacific Chorus Frogs were also observed throughout the project area of Silver Creek over the course of the season.

Discussion

Stream mapping

Streamflow and associated areas of wetted habitat were highest in the early summer, during peak snow melt, and decreased as the season progressed. During stream mapping in June, field crews observed an increase in flow and turbidity during the day due to melting snow. These daily fluctuations impaired visual detection and effective netting during electrofishing surveys. High flows also restricted access to the higher gradient sections of Silver Creek; in particular, Section 1 and the downstream extent of Section 2. Surveys in the lower portion of Section 2 in July were time consuming and likely ineffective. Efficacy increased greatly in August and September. Consequently, future project initiation, depending on the water year, should generally occur in late July or early August. Increased project staff is also recommended, with a minimum of three electrofishers, five netters, and one live car tender for the lower sections.

Overall, the Silver Creek project in 2016 was limited by high flows in the early- to mid-summer and the formation of ice in late fall. Depending on winter snowpack, surveys may not be feasible in early July and flow conditions should be monitored each year before surveys are initiated to maximize the efficiency of mechanical removal. Starting later in July or focusing early efforts in the upper sections, where Silver Creek is smaller, may improve project outcomes. Snow and ice in October made electrofishing difficult in Section 5 but did not affect Sections 3 and 4.

Stream temperatures varied throughout the year and differed between the five sections. In December, the lowest average temperature was measured at 0.5 ºC, with the lowest temperatures observed in the upper portions of the drainage. In June, Sections 2 and 3 were both 8 ºC and Sections 4 and 5 averaged 3 ºC. This pattern of lower water temperatures in the upper portions of the drainage continued throughout the field season. An analysis of temperature logger data will aid in better evaluating trends across seasons and sections.

Project staff noted that both weirs were compromised during the stream mapping surveys in May and June. High flows caused an accumulation of debris on the weir between Sections 3 and 4, forming a large pool which allowed water to overflow around the sides. Although the level of overflow decreased throughout the season, PIT tagging revealed that this weir was not a complete barrier to fish migration during the project period. The failure of the Section 4 and 5 weir was less severe and was no longer compromised by the time mechanical removal began in July.

Depletion electrofishing

The depletion electrofishing surveys were conducted soon after the peak in the seasonal hydrograph began to recede. Block net failure, due to high flows and debris, occurred in Sections 50 and 66. As a consequence, the required assumption of a closed population was not met in these two sections. This resulted in unreliable estimates of fish abundance with high confidence intervals. Low densities and difficult shocking conditions also led to poor depletions, which likely further contributed to unreliable abundance estimates.

The mechanical removal component of the project revealed variability in fish densities throughout the upper sections. Due to this variability, it is assumed that the Section 50 and 66 depletion survey results did not provide fish abundance estimates that were representative of the upper project area as a whole. This was most notable in the Section 66 (established within Section 5 of the project area) survey, which estimated ten LCT per mile; however, a total of 475 LCT were captured in Section 5.

The depletion electrofishing survey in Section 38 was representative of the predominant habitat type and Brook Trout abundance in Section 3. Section 3 is primarily low gradient meadow habitat with slow flatwater, deep pools, and high Brook Trout densities. The low Brook Trout densities in Sections 4 and 5 may be the result of intensive mechanical removal in these sections in previous years. 2016 was the first year Section 3 was consistently electrofished and Brook Trout densities were substantially higher in this section. The total Brook Trout captured in Section 3 during the mechanical removal efforts was slightly greater than the population estimate generated from the Section 38 depletion electrofishing survey. This was likely due to low capture rates of YOY during the depletion electrofishing survey. Brook Trout YOY were very small at the time of the survey, less susceptible to the electric field, and difficult to see. As the season progressed capture rates increased, most notably in the fourth single pass of Section 3 in which 395 of the 759 captured Brook Trout were YOY.

In spite of the noted challenges and unreliability of some of the abundance estimates, these surveys provided baseline data to evaluate the condition and relative abundance of trout in Silver Creek. LCT condition factors were relatively low, although this may be due to the survey timing, with considerable overlap early in the growing season. This is not necessarily an indication of the effects of interspecific competition, given the similarly low densities of Brook Trout in the upper sections. It may be helpful to collect additional baseline data in the fall months of 2017 to better understand growing conditions throughout Silver Creek. Recapturing LCT with PIT tags will provide information on growth rates, mortality and potentially movement patterns.

Comparison of LCT condition factor across sections showed they were not significantly different (ANOVA, P=0.82), although the sample sizes were likely too small for an accurate statistical analysis. Brook Trout condition factor was significantly lower in Section 3 than Section 4 (one tailed t-test, P=3.26E-7) or Section 5 (one tailed t-test, P=0.011). The high population density and significantly lower condition factor suggest more intense competition in Section 3. Brook Trout are adapted to live in higher densities, although this often leads to a population comprised of small fish in poor condition (Donald and Alger 1989; Figure 7). Previous removal efforts in the upper sections may have improved the condition factor of the surviving Brook Trout by reducing competition. Condition factors between Section 4 and 5 were not significantly different (two tailed t-test, P=0.29).

Mechanical removal

Streamflow was high and turbid when manual Brook Trout removal began in July; the field crew was also inexperienced early in the season. Both factors likely led to poor capture rates. Section 3 was targeted first because the depletion electrofishing surveys indicated this area had the highest density of Brook Trout. As flows dropped and the crew became more proficient at electrofishing, with presumably less fish injury, efforts were focused on Sections 4 and 5 where LCT densities were thought to be higher. Conditions in Section 2 were not suitable for electrofishing until August.

The mechanical removal data suggest that Sections 3 and 5 had the highest LCT densities, with total catches of 668 and 475 respectively. However, the higher number captured in Section 3 included 147 recaptures. Potential recapture of unmarked LCT smaller than 6 inches may have also increased the total count in Section 3. The total number of LCT captured in Section 5 was not inflated by recaptures, since LCT were not relocated into this section.

During the course of the season, variability in the size class distribution of LCT was observed across the project sections. This was most notable in Sections 4 and 5, where a higher proportion of smaller-size classes were captured than in Sections 2 and 3 (Figure 9). This may reflect increased recruitment and higher survival rates of younger LCT in the upper sections, where Brook Trout densities had been reduced in previous years. This pattern is consistent with previous studies which have demonstrated that Brook Trout negatively impact the survival rates of younger Cutthroat Trout through competition, predation, and behavioral changes (Peterson et al. 2004, Scoppettone et al. 2012). Although Section 5 had high numbers of smaller LCT, there were very few large individuals. Later snowmelt, truncation of the growing season, colder water temperatures or other higher-elevations habitat variables may be contributing factors. Future surveys, with the continued application of PIT tags, will provide more information on recruitment, growth rates and survivability of LCT across the project area.

Several LCT were observed with dark pigmentation that could indicate an infection from a digenetic trematode, commonly known as black spot disease. Most of these LCT were located in the upper sections, where water temperatures are colder and fish densities are lower. This pattern is inconsistent with other studies, which have found disease prevalence to be positively correlated with increased temperatures and fish density (Cairns et al. 2005). It is also unusual that no Brook Trout appeared to be infected since they are also susceptible to black spot disease (Steedman 1991). Fresh specimens will need to be examined in a laboratory to determine if this unusual spotting pattern is black spot disease. Genetic analyses of suspected fish should also be performed, since this unique pigmentation (and/or infection) may indicate that they were transplanted from another population.

In previous years, mechanical removal began in the headwaters of Silver Creek and project staff worked downstream over the course of the field season. Sections were cleared of Brook Trout and isolated with two temporary Alaskan weirs. The stream mapping exercise in early June, 2016 revealed that both Alaskan weirs were compromised at high flows. Accumulation of debris resulted in overflow around the weirs, creating passage for fish. The lower weir was compromised again in October due to the accumulation of ice, which diverted water around the sides. Project staff, using electrofishers, confirmed that Brook Trout were present in these overflow channels and could regain access to the cleared sections upstream of the weirs. In addition, PIT-tagged LCT released into Section 3 were recaptured in Section 4, substantiating the compromised nature of the barriers. The culvert that defines the break between Sections 1 and 2 may serve as an additional barrier. Modification to this culvert could prevent year-round upstream movement of Brook Trout from below the project area.

Brook Trout are known to exhibit compensatory responses to population reductions by increasing reproductive rates and juvenile survival (Cooper et al. 1962). These compensatory responses allow Brook Trout abundance to fully rebound from manual removal projects in as little as two years if complete eradication is not achieved (Meyer et al. 2006, Cooper et al. 1962). In order to overcome these compensatory responses, eradication efforts must focus on eliminating reproduction by removing all Brook Trout that will be sexually mature during the next spawn (Pacas and Taylor 2015). This goal may have been achieved in Section 5, since only four Brook Trout large enough to spawn were caught in the last two passes.

Several restoration projects have successfully eradicated Brook Trout using intense manual removal efforts and a variety of supporting tools and techniques. Shepard et al. (2002) constructed barriers to isolate cleared sections and used pumps to drain deep pools. Buktenica et al. (2013) utilized fyke nets to improve capture rates while electrofishing, by corralling fish into traps that might otherwise be missed. Silver Creek is a large and complex stream system that requires a large crew; at times three shockers with six netters were used. Shepard et al. (2002) and Buktenica et al. (2013) both removed woody debris prior to electrofishing to decrease habitat complexity. This technique was used throughout Silver Creek and appeared to substantially increased capture rates. Intensive electrofishing (repeated passes throughout the course of a five month period), combined with the use of other tools to increase capture efficiency, will be needed in order to achieve complete eradication in Silver Creek.

Conclusion

The 2016 manual removal project in Silver Creek provided insights that will be useful in refining and developing future restoration actions. The HWTP proposes several recommendations for 2017:

- Continue mechanical removal at the same level, intensity, and frequency to further mitigate the compensatory responses of Brook Trout.
- Build additional barriers and modify existing temporary weirs to create more effective year-round fish migration barriers.
- Continue the use of PIT tags to further evaluate weir efficacy. Use 8 mm tags instead of 12 mm tags to acquire information on smaller size classes of fish. Data from multiple years and more size classes will provide a better understanding of the movement patterns, survival rates, and growth rates of LCT in Silver Creek. Switch to a bevel down technique with the insertion point posterior to the pectoral fins to improve tag retention rates.
- Use additional tools such as gill nets, fyke nets, and water pumps to help remove fish from areas with complex habitat that reduces capture efficiency.
- Experiment with different electrofisher setups, such as larger electrodes and different waveforms to increase the electrical field area, improve fish response, and increase capture rates.
- Continue monitoring flows to determine the best timing for electrofishing surveys and maximize the time and effort spent on mechanical removal.
- Continue removal of woody debris and overhanging vegetation to reduce habitat complexity and increase capture rates.
- Collect fresh LCT specimens with black pigmentation to evaluate the potential presence of black spot disease. Collect tissues from LCT with and without the suspected black spot pigmentation in order to compare their genetic makeup and determine if they belong to the same source population.

This project has demonstrated the challenges involved with mechanical removal of Brook Trout in a larger, high elevation stream. The size and complexity of Silver Creek necessitates a considerable effort, with extensive planning and a substantial time commitment. This project has also demonstrated the ecological importance and unique restoration and recovery potential in the Silver Creek drainage. The reappearance of endangered Sierra Nevada Yellow Legged Frogs in Silver Creek may indicate the potential for future coexistence with LCT, both of which presumably coevolved in higher elevation portions of the broader Walker River basin. Silver Creek also supports a sizable LCT population, with larger individuals than those found in other Walker River tributaries. If the Brook Trout population is fully eradicated, these larger LCT may have even greater growth potential and Silver Creek would offer a rare and unique heritage trout fishery for stream-resident LCT.

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Figure 1. Vicinity map of 2016 Silver Creek survey location. Silver Creek is a tributary to the West Walker River located approximately 20 miles northwest of Bridgeport.

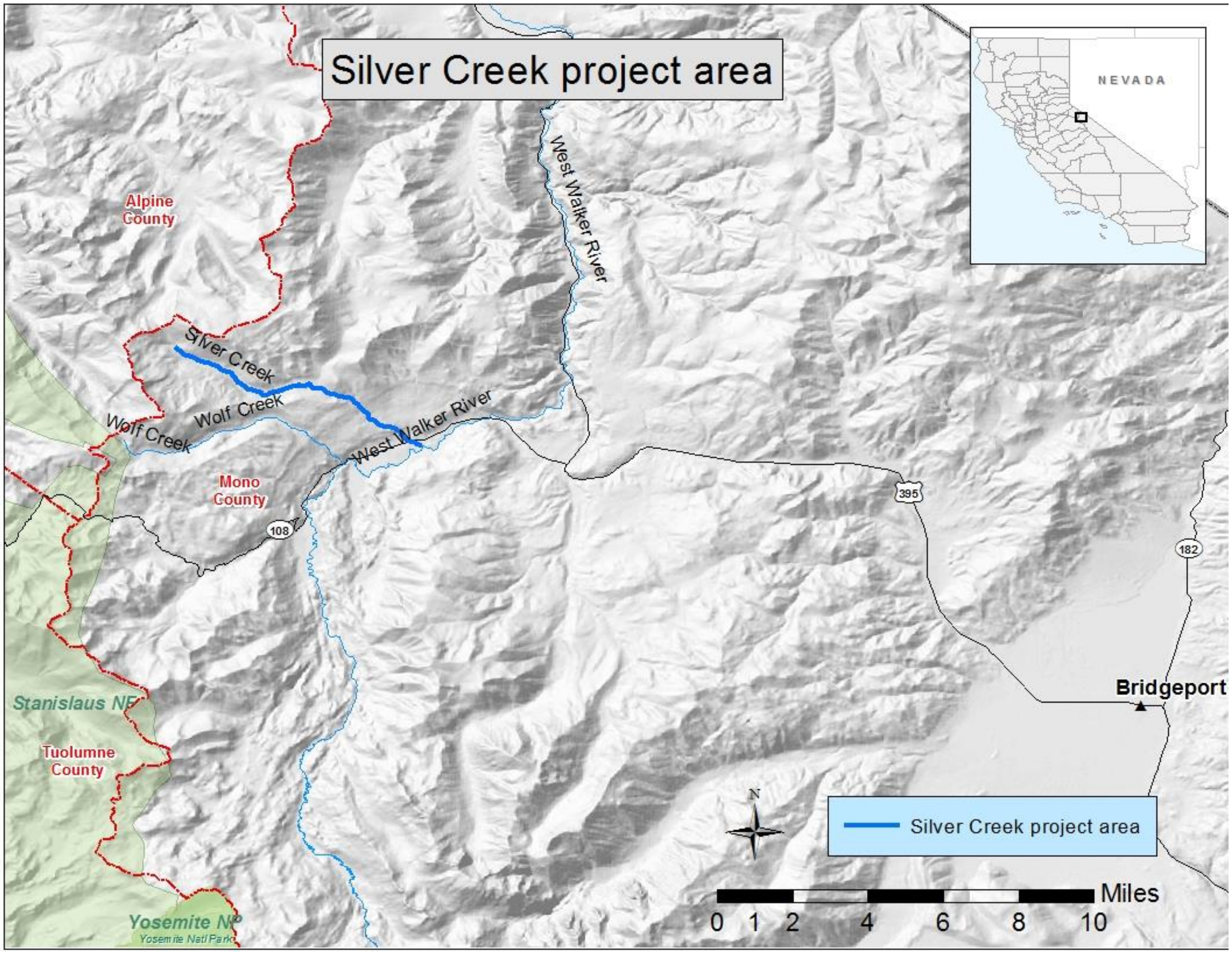

Figure 2. Ten foot waterfall at the beginning of Section 1 with crew member for scale. This is the downstream barrier of the project area.

Figure 3. Map of 2016 Silver Creek project area showing Sections 1 through 5, weir locations, depletion electrofishing survey locations, and SNYLF sightings.

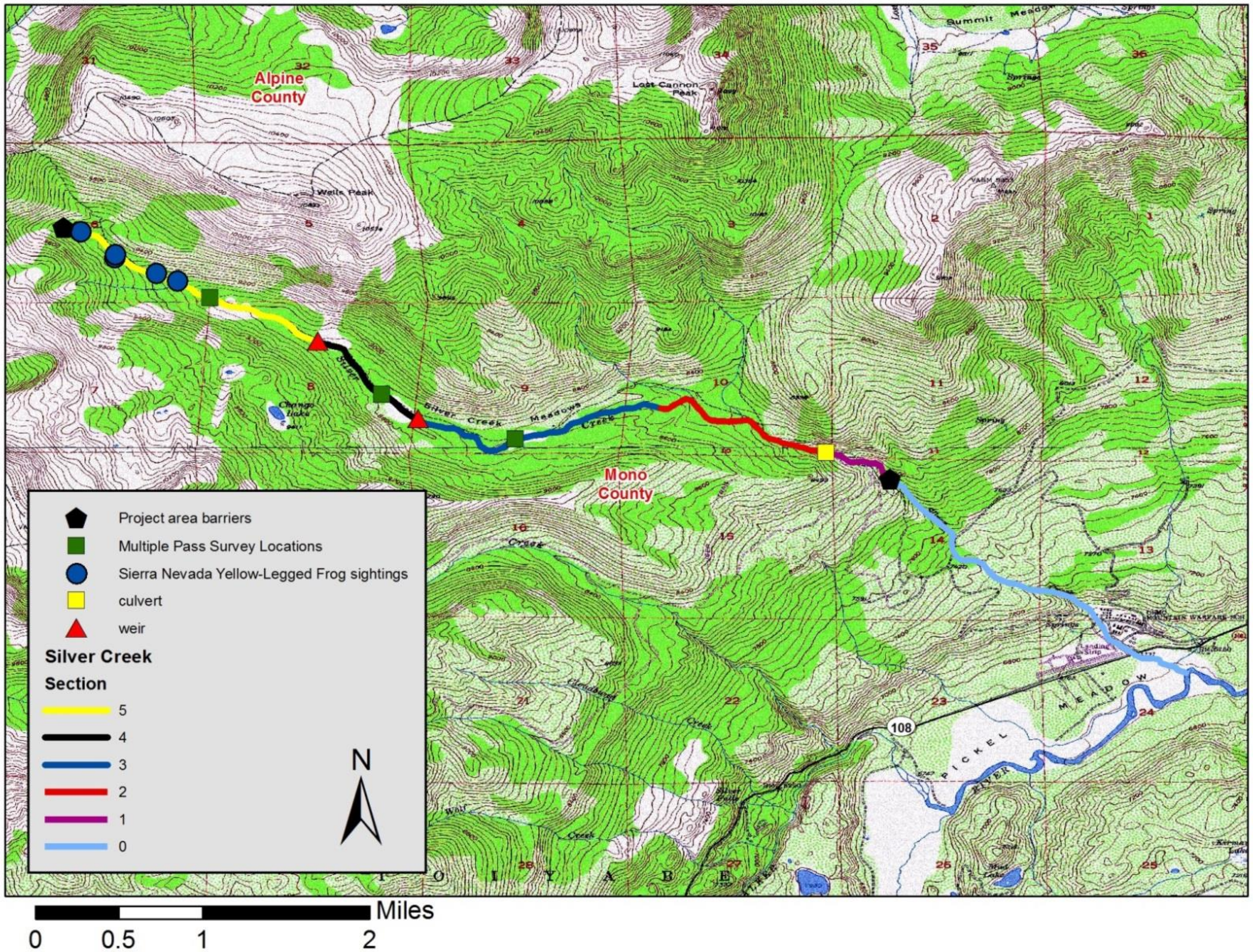

Figure 4. Photos of the Onset Hobo temperature logger install in Silver Creek in December, 2015.

Figure 5. Stream mapping results from June, 2016 showing the wetted areas of Silver Creek.

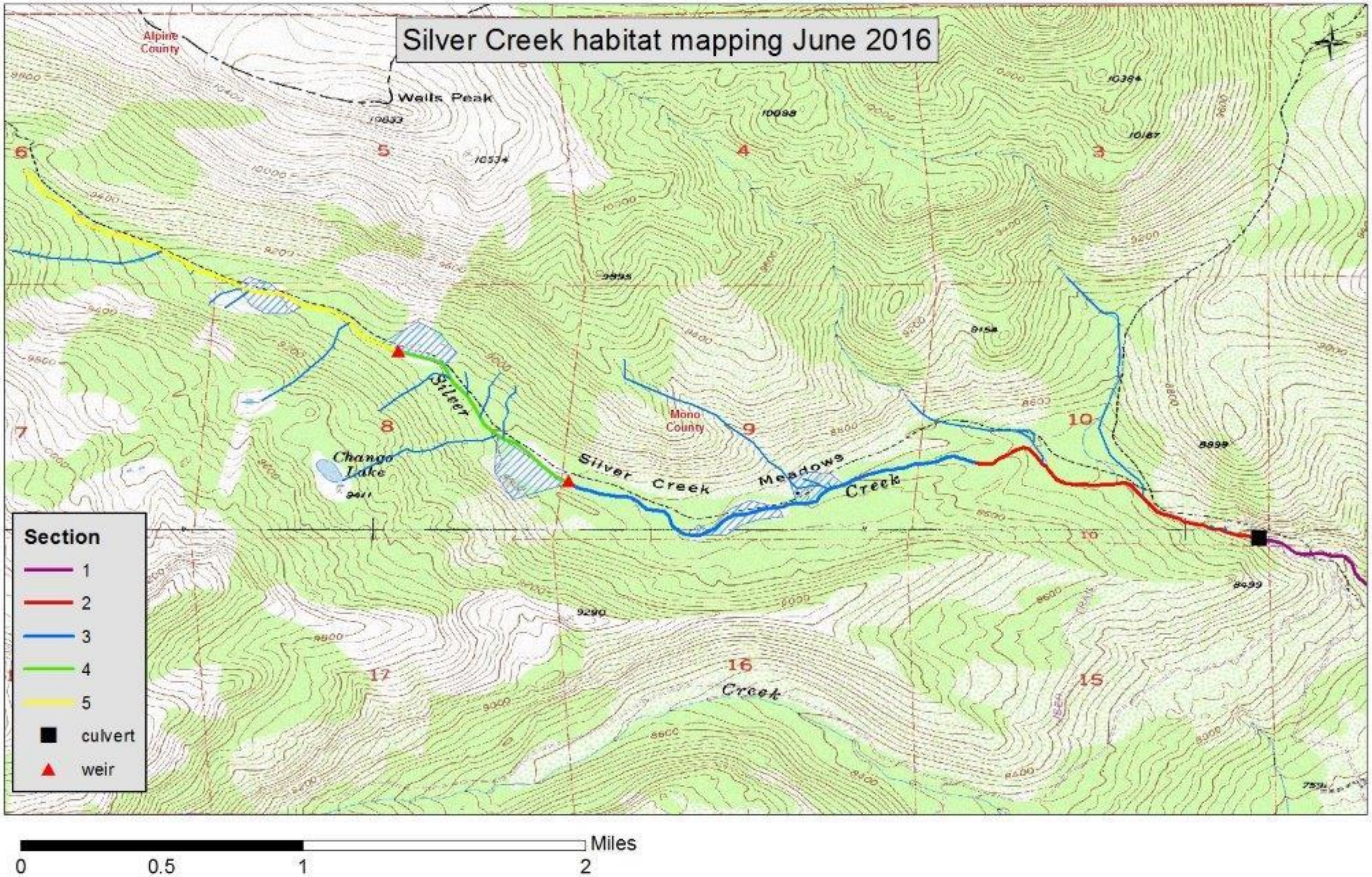

Figure 6. Representative photos of Silver Creek demonstrating the variability in habitat type and flows throughout the season and across sections.

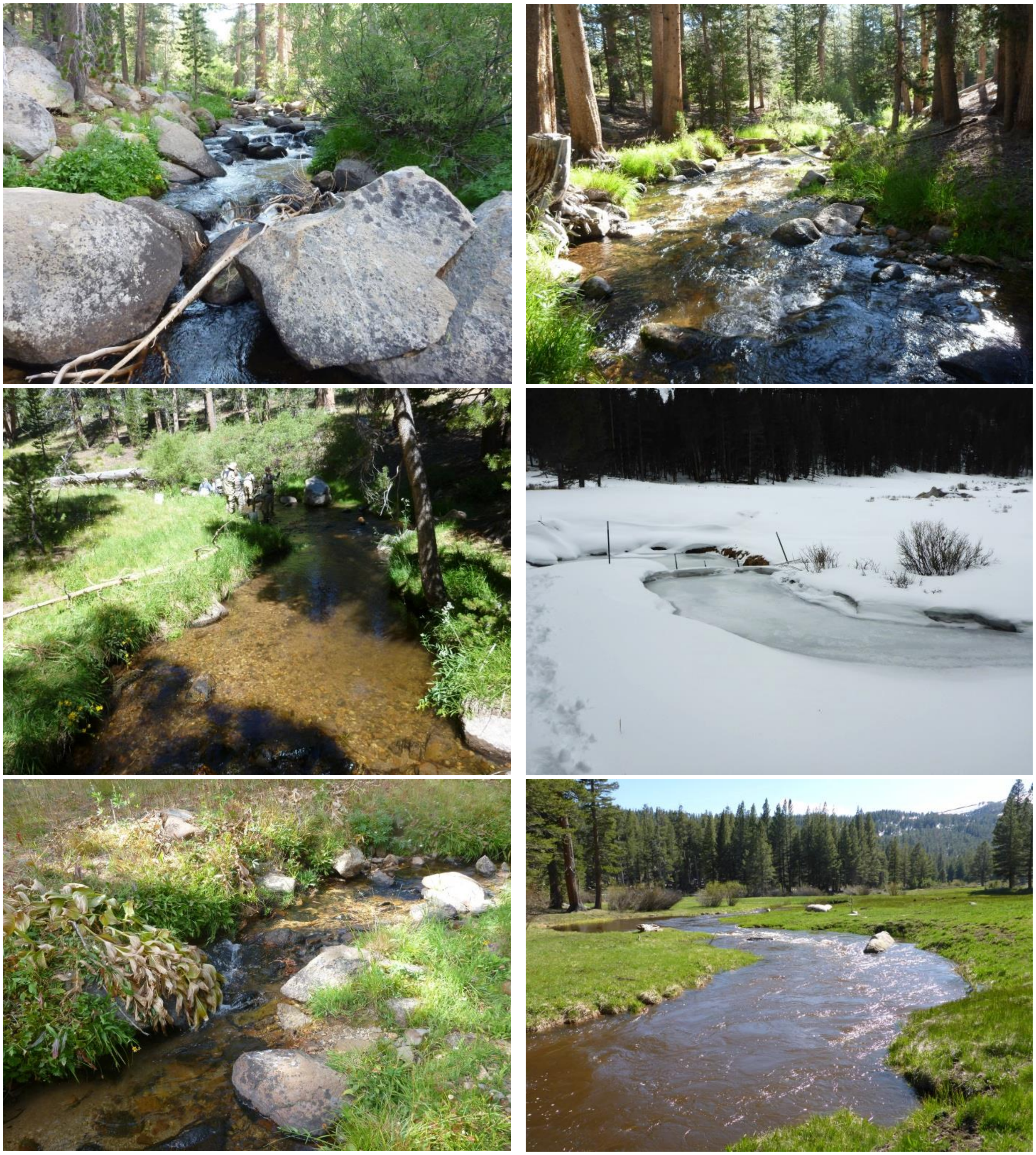

Figure 7. Representative photographs of LCT and Brook Trout captured in Silver Creek, from upper left clockwise. Photo 1: Adult Brook Trout (from Section 3) showing typical body characteristics including: small size, disproportionately large head, and skinny body. Photo 2: Close up of an LCT showing the eyespots and orange cutthroat marks. Photo 3: A large 12 inch LCT captured in section 4.

Figure 8. Representative photos of potential black spot disease observed on a limited number of LCT in Silver Creek.

Figure 9. Brook Trout captured by size class shown as a percentage of the total catch in each section of Silver Creek.

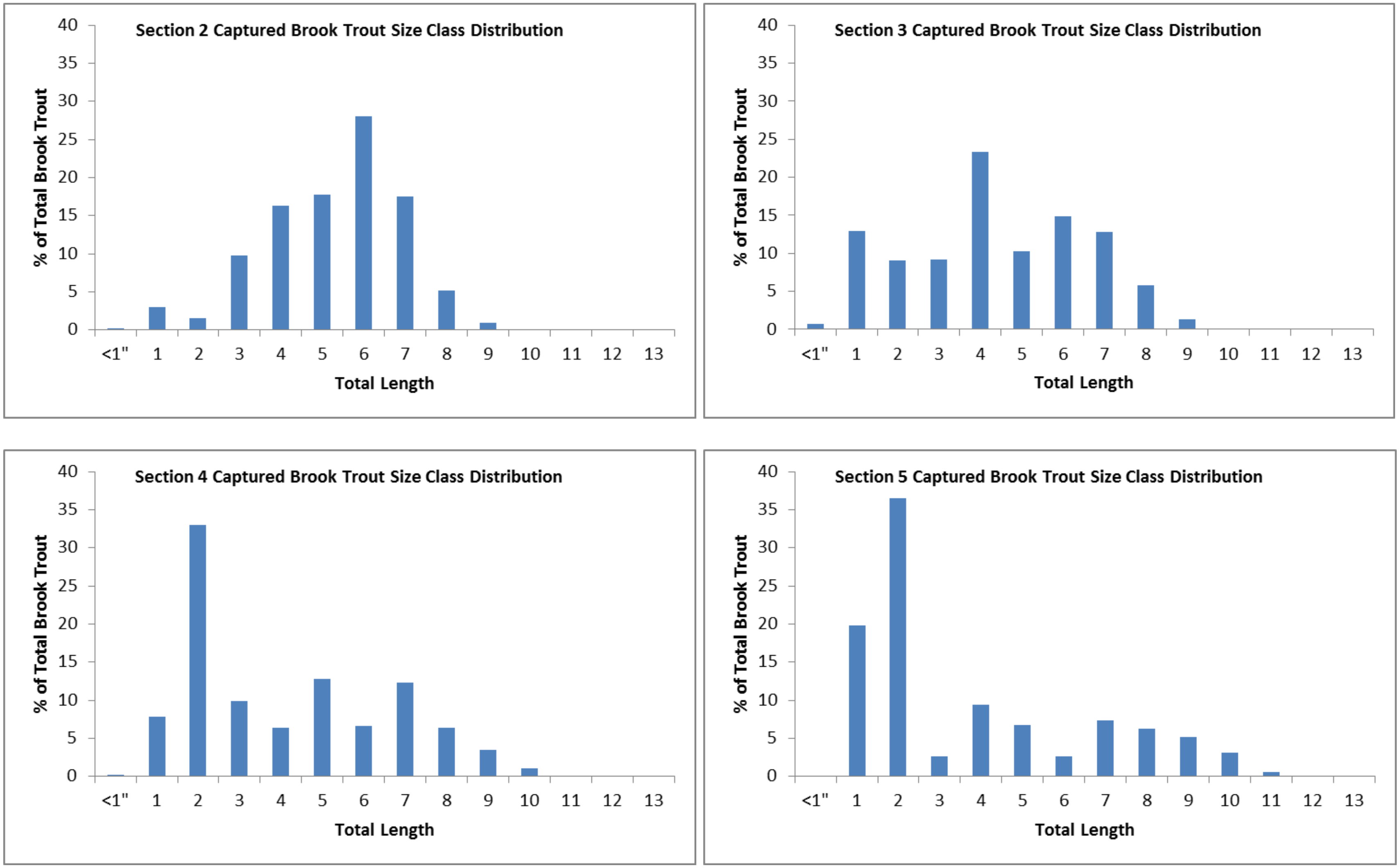

Figure 10. LCT captured by size class shown as a percentage of the total catch in each section of Silver Creek.

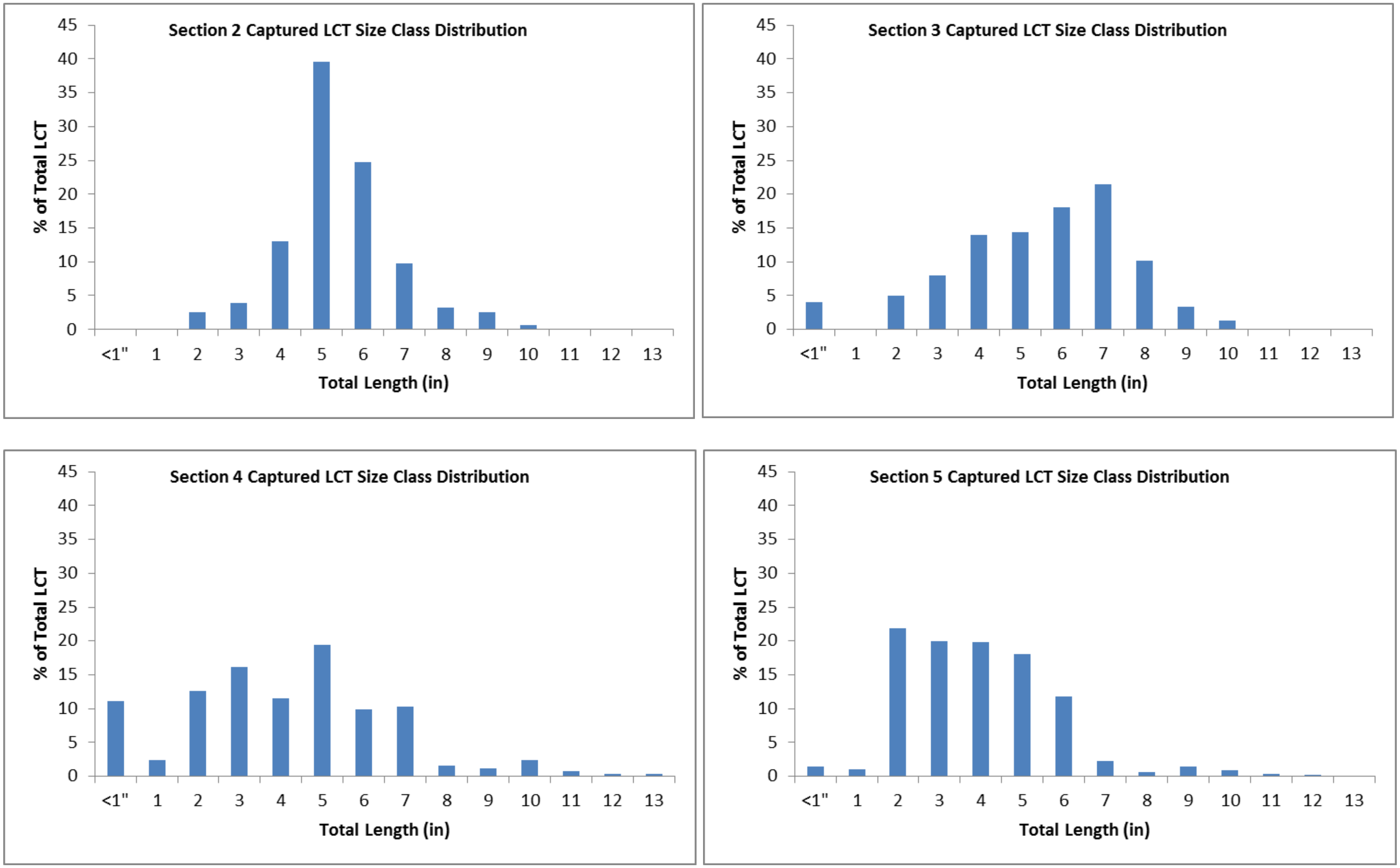

Figure 11. Representative photos of trout with perch-like body shapes (upper photos) in Silver Creek and photos of injuries observed throughout Silver Creek (lower photos).

Figure 12. Sierra Nevada Yellow-Legged frog observed in the upper portion of Section 5.

Table 1. Streamflow measurements in Silver Creek at benchmark locations from June to October, 2016.

Date	Section	Streamflow (cfs)
7/25/2016	2	9.8
6/1/2016	3	44.9
7/8/2016	3	13.0
7/20/2016	3	7.9
9/7/2016	3	3.4
10/20/2016	3	3.0
7/9/2016	4	13.4
9/7/2016	4	1.8
7/10/2016	5	10.2
9/7/2016	5	1.8

Table 2. Results from multiple-pass electrofishing surveys in Silver Creek Sections 38, 50, and 66.

Species	Section	Number of fish captured in pass 1	Number of fish captured in pass 2	Number of fish captured in pass 3	Number of fish captured in pass 4	Total captured	Estimated section population	Estimated abundance (fish/mi)	Capture probability
Lahontan Cutthroat Trout	38	3	3	1	-	7	7	69	58%
Brook Trout	38	140	65	60	-	265	347	3399	38%
Lahontan Cutthroat Trout	50	1	1	0	1	3	2	21	-
Brook Trout	50	2	8	4	1	15	21	215	7%
Lahontan Cutthroat Trout	66	1	3	4	3	11	16	10	5%
Brook Trout	66	5	4	4	0	13	14	144	45%

Table 3. Effort and number of trout captured by species and pass in Section 2.

Section	Pass	Effort (days)	Number of Brook Trout captured	Number of LCT captured
2	1	3	1375	65
2	2	3	958	77
2	3-partial	3	90	12
2	**Total**	**9**	**2423**	**154**

Table 4. Effort and number of trout captured by species and pass in Section 3.

Section	Pass	Effort (days)	Number of Brook Trout captured	Number of LCT captured
3	1	4	1654	132
3	2	4	1031	170
3	3	3	1125	171
3	4	3	759	195
3	**Total**	**14**	**4569**	**668**

Table 5. Effort and number of trout captured by species and pass in Section 4.

Section	Pass	Effort (days)	Number of Brook Trout captured	Number of LCT captured
4	1	3	161	52
4	2	1	80	48
4	3	1	46	22
4	4	2	41	36
4	5	2	50	63
4	6	2	10	17
4	7	2	18	15
4	**Total**	**13**	**406**	**253**

Table 6. Effort and number of trout captured by species and pass in Section 5.

Section	Pass	Effort (days)	Number of Brook Trout captured	Number of LCT captured
5	1	6	95	276
5	2	4	37	109
5	3	4	27	44
5	4	3	25	31
5	5-partial	3	8	15
5	**Total**	**20**	**192**	**475**