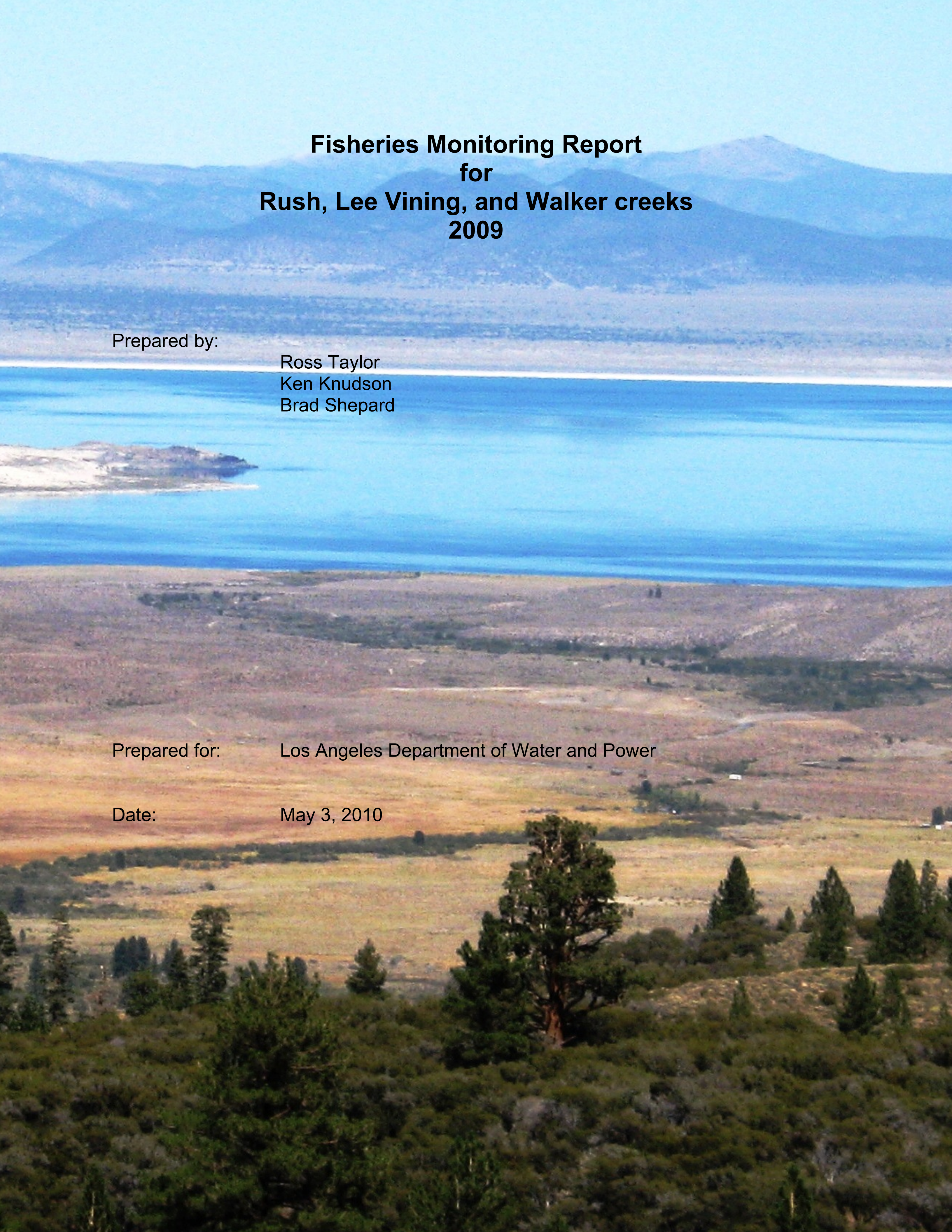
Section 3

Fisheries Monitoring Report for
Rush, Lee Vining, Parker, and Walker Creeks
2009-10



Fisheries Monitoring Report for Rush, Lee Vining, and Walker creeks 2009

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Executive Summary

This report presents the results of the thirteenth year of fish population monitoring for Rush, Lee Vining, and Walker creeks pursuant to State Water Resources Control Board (SWRCB) Decision #1631 and the eleventh year following SWRCB Orders #98-05 and #98-07. Pilot studies were conducted in 1997 and 1998 to determine appropriate methods for generating statistically valid population estimates with 1999 being the first year estimates were generated for all study sections.

Starting in 2008, the annual sampling sections were modified as follows. In Rush Creek the MGORD (Mono Gate One Return Ditch) and Upper sections were maintained, the Lower section was discontinued, a new Bottomlands section was added and the County Road section was shortened. The Parker Creek section was also discontinued. In Lee Vining Creek the Upper main channel and side channel sections were dropped, the Lower main channel section was extended by approximately 100 meters and the Lower side channel section was maintained.

The 2009 electro-fishing sampling occurred between September 10th and 20th. Mark-recapture electro-fishing techniques were utilized to estimate trout populations in three sections of Rush Creek and one section of Lee Vining Creek. The lower boundary of County Road section of Rush Creek was moved back downstream to the original boundary location, which added 92 m from the 2008 section boundaries. Fish population estimates for the Lower Lee Vining Creek side channel and Walker Creek were made using electro-fishing depletion methods. In 2009, the MGORD section of Rush Creek was sampled for the purpose of generating RSD-values, condition factors and implanting PIT tags. The MGORD section is sampled for a population estimate in even-years only.

Density Estimates of Age-1 and older Brown Trout

In 2009,the estimated density (number per hectare) of age-1 and older brown trout in the County Road section of Rush Creek was the highest ever recorded at any section on Rush Creek during the eleven-year sampling period. Between 2008 and 2009, the Bottomlands and Upper sections of Rush Creek both experienced slight decreases in the estimated densities of age-1 and older brown trout. The Bottomlands section of Rush Creek had an estimated density of 1,489 age-1 and older brown trout/ha. The Upper section of Rush Creek had an estimated density of 1,318 age-1 and older brown trout/ha.

In Walker Creek the 2009 density estimate was 14% less than the 2008 estimate; however the 2009 density estimate of 6,348 age-1 and older brown trout/ha was the second highest estimate for the eleven-year sampling period. Since 2002 Walker Creek has annually had the highest density estimates of age-1 and older brown trout for all sample sections.

The six age-1 and older brown trout captured in the side channel section of Lee Vining Creek produced an estimated density of 123.1 fish/ha in 2009. This side channel has had very low baseflows since RY2006 and therefore has supported relatively few fish the past four years. Between 2008 and 2009, the estimated density of age-1 and older brown trout (1,083.4 kg/ha) in the main channel of Lee Vining Creek decreased by 16%; however the 2009 estimate was the 5th highest in the 11 sample seasons.

Density Estimates of Age-0 Brown Trout

Between 2008 and 2009, estimated densities of age-0 brown trout declined slightly at all three Rush Creek sections. The Upper section's 2009 density estimate (2,509 age-0 brown trout/ha) declined by 5% from the 2008 estimate to the lowest estimate ever recorded for this section. The relatively new Rush Creek Bottomlands section had an estimated density of 2,357 age-0 brown trout/ha in 2009, which was an 11% drop from the 2008 estimate.

In Walker Creek age-0 densities of brown trout decreased by 54% in 2009 from 2008; however the 2009 density estimate of 8,478 age-0 brown trout/ha was still greater than any section of Rush Creek during the past eight years.

In 2009, the age-0 brown trout density estimate in the main channel section of Lee Vining Creek dropped by 93% from densities estimated in 2008. Five age-0 brown trout were captured in 2009 within the Lee Vining Creek side channel which generated a density estimate of 102.6 age-0 brown trout/ha.

Density Estimates of Age-1 and older Rainbow Trout

Because rainbow trout have comprised a minor component of Rush Creek's trout population a decision was made in 2008 to cease attempting to generate population, density and biomass estimates of rainbow trout. In most years too few rainbow were captured to generate valid estimates.

Estimated densities of age-1 and older rainbow trout during 2009 in the Lee Vining Creek main channel section were the second highest recorded for the 11 years of annual sampling. For Lee Vining Creek, the 2009 main channel density estimate was the second rainbow trout density estimate derived from a population estimate since the 2002 sampling season.

Density Estimates of Age-0 Rainbow Trout

In 2008, the age-0 rainbow trout density estimate in the main channel section of Lee Vining Creek dropped by 86% from densities estimated in 2008. This was the second straight year in which a large decrease in age-0 rainbow trout densities decreased (a decrease of 65% occurred between 2007 and 2008). In 2009, no age-0 rainbow trout were sampled in the side channel section of Lee Vining Creek.

Standing Crop Estimates of Brown Trout

In Rush Creek, brown trout standing crop estimates increased from 2008 to 2009 in all sample sections. In the County Road section, the 2008 estimated standing crop of 143.9 kg/ha was the highest value ever recorded in this section and was a 68% increase from the 2008 estimate. In the Bottomlands section, the 2009 estimated standing crop of 129.1 kg/ha was a 32% increase from the 2008 estimate. In the Upper Rush section, the 2009 estimated standing crop of 131.2 kg/ha was a 22% increase from the 2008 estimate. For the first time in eleven years of sampling, the standing crop estimate at the Upper Rush section in 2009 was lower than the County Road section's estimate.

Between 2008 and 2009, Walker Creek experienced a decrease of 16% in estimated standing crop; however both of these years had estimates greater than 400 kg/ha.

In Lee Vining Creek total standing crop (brown and rainbow trout combined) increased by 114% between 2008 and 2009 in the side channel area, but in the main channel total standing crop decreased by 25% between 2008 and 2009.

Condition Factor of Brown Trout between 150 mm and 250 mm in Length

In 2009 condition factor in the County Road section improved to 1.00. For 2009, the Upper Rush Creek section experienced an increase in condition factor from the previous year and was greater than 1.00 for the first time since 2006. The 2009 season was the second year that the Bottomlands section of Rush Creek was sampled and the condition factor was 1.00, up from 0.92 computed for 2008.

The mean condition factor for 150 to 250 mm brown trout in Lee Vining Creek during 2009 was over 1.00 in both the main and side channel sections, indicating that brown trout condition was good. The mean condition factors in 2009 were improvements from the 2008 values which were the lowest condition factors documented in Lee Vining Creek since annual sampling started in 1999.

Relative Stock Densities (RSD's)

RSD-225 values for brown trout in two of three Rush Creek sample sections decreased between 2008 and 2009, including a 22% drop in the County Road section and a 24% decrease in the Upper section. The RSD-225 values for the County Road and Upper sample sections were the lowest values recorded for these sections during the past 10 sampling seasons and 2009 was the third consecutive year that values decreased in these two sections. Between 2008 and 2009, the Bottomlands section of Rush Creek experienced a 20% increase in RSD-225 (Table 16).

RSD-300 values remained low in the Upper Rush Creek section, with a drop from 3 to 2 between 2008 and 2009; however two brown trout greater than 375 mm in length were sampled. The Rush Creek County Road section has had an RSD-300 value of 0 since 2002. The Bottomlands section had an RSD-300 value of 1 in 2009, which included one fish greater than 375 mm in length.

The RSD-225, RSD-300, and RSD-375 values in the MGORD section of Rush Creek all increased between 2008 and 2009. The RSD-225 value increased by 32% between 2008 and 2009, and the 338 brown trout between the lengths of 225-299 mm was the most fish ever sampled within this size class. The RSD-300 value experienced a 30% increase between 2008 and 2009. The RSD-375 value for 2009 was 4 and has been 4 or less for three consecutive sampling years.

In the Lee Vining Creek main channel sample section, the RSD-225 value for all trout (brown and rainbow trout combined) increased by 70% between 2008 and 2009, after a 75% drop occurred between 2007 and 2008. In 2009, the Lee Vining Creek main channel section had a RSD-300 value of 1 after two consecutive years where no fish greater than 300 mm were sampled.

Termination Criteria

In Rush Creek, neither of the annually sampled sections met the target of meeting four out of five termination criteria for the average of the three-year period of 2006-2008. The County Road and Upper sections met only one of the five the termination criteria, with estimated densities greater than 3,000 fish per kilometer.

Because the Lee Vining Creek main channel section was not sampled in 2006, two of the three, three-year running averages were comprised of data collected in 2004, 2005 and 2007. In Lee Vining Creek, the current sampling section failed to achieve the target of meeting three out of four termination criteria. The current sampling section has met the same two of the four termination criteria (biomass and condition factor) for the past three sets of three-year running averages.

The MGORD section of Rush Creek met only one of three RSD termination criteria (RSD-225) for the average of years 2007-2009. The RSD-375 average for 2007-2009 failed to meet termination criteria due to three consecutive years where low (less than 5) values were recorded.

Introduction

This report presents the results of the thirteenth year of fish population monitoring for Rush, Lee Vining, Parker and Walker creeks pursuant to State Water Resources Control Board (SWRCB) Decision #1631 and the eleventh year following SWRCB Orders #98-05 and #98-07. As required, fish population monitoring will continue until the streams have met termination criteria included in the Settlement Agreement. These termination criteria describe the presumed pre-project conditions for fish population structure:

1. Rush Creek fairly consistently produced brown trout weighing ¾ to two pounds. Trout averaging 13 to 14 inches were also regularly observed.

2. Lee Vining Creek sustained catchable brown trout averaging eight to 10 inches in length. Some trout reached 13 to 15 inches.

In addition to these criteria, Order 98-07 states the monitoring team will develop and implement a means for counting or evaluating the number, weights, lengths and ages of fish present in various reaches of Rush Creek, Lee Vining Creek, Parker Creek and Walker Creek. No specific termination criteria were set forth for Parker and Walker creeks, tributaries to Rush Creek.

The Settlement Agreement states that the monitoring team will consider young-of-year (age-0) production, survival rates between age classes, growth rates, total fish per mile and any other quantified forms as possible termination criteria, although the Settlement Agreement does not compel the choice of any one form. In 2006, a new suite of termination criteria were proposed by the Fisheries Stream Scientist in an attempt to make the calculation and interpretation of the fisheries termination criteria more quantifiable. The proposed metrics were well received; however, the proposed values assigned to signify “recovery” of the fishery were contentious. Along with population estimates; the annual fishery monitoring report will include the metrics of biomass, density, condition factor and relative stock density (RSD) because these are generally accepted by fishery professionals as repeatable and quantifiable measurements of stream-dwelling trout populations.

This report provides fish population data mandated by the Orders and the Settlement Agreement. Fish length data are reported in millimeters (mm) in this report. For those not used to working in the metric system, an easy numerical reference point is 200 mm which is approximately eight inches. An eight-inch trout is often referred to as the minimum size of a “catchable” trout.

Study Area

Starting in 2008, the annual sampling sections were modified as follows. In Rush Creek the MGORD and Upper sections were maintained, the Lower section was discontinued, a new Bottomlands section was added and the County Road section was shortened from 813 meters to 237 meters. In 2009 92 m were added to bottom end of the County Road section of Rush Creek making this section 329 m long The Parker Creek section was also discontinued, while the Walker Creek section was maintained. In Lee Vining Creek the Upper main channel and side channel sections were dropped, the Lower main channel section was extended by approximately 100 meters and the Lower side channel section was maintained.

In Rush Creek the Lower section was located immediately downstream of where the channel split into two channels. The east channel (aka the 10-channel) had been mechanically re-opened prior to 1999. In 1999, this section was originally selected as a sampling area, but we were never able to effectively sample the 10-channel because it was not yet an established channel. Instead, much of the 10-channel flowed through some old pond areas and across the floodplain in many extremely small rivulets. However, during the past ten years water flows down the 10-channel have both incised the channel and annually increased, so that less and less flow has been moving through the original Lower Rush sample section. Consequently, after the 2007 annual sampling we decided to discontinue sampling the Lower Rush section.

To aid in the transition to a “new” sample section in the lower reach of Rush Creek, annual sampling within the County Road section was conducted in 2008 and will be continued into the foreseeable future. The rationale for sampling an abbreviated reach within the County Road section was to maintain a long-term time-series of trout population data in Rush Creek downstream of the Narrows. In 2009, 92 m was added to the abbreviated County Road section because in 2008 we had trouble getting a high-quality mark-recapture estimate in the shorter 237 m section. Maintaining a long-term monitoring reach in lower Rush Creek is important because over the past eleven years these data have tracked fish population responses to a wide range of run-off types, summer thermal regimes, and evolving pool habitats. The continuation of sampling within the County Road section also prevents an interruption in the termination criteria analysis of a sample section located downstream of the Narrows based on examining three-year running averages.

Comparisons of estimated standing crops were relatively consistent between the County Road and Lower sections over time from 2000 to 2007; indicating data from either section will provide the information needed to evaluate how management decisions affect fish populations within this reach (Figure 1). The Bottomlands sampling section established in 2008 is located between the County Road and Lower Rush Creek sections.

The decision to select a new sample section within lower Rush Creek was made after the 2008 pool survey of the entire stream (Knudson et al. 2009). The approximately

1,200 meter section of Rush Creek located downstream of the 10-channel return and upstream of the County Road ford had characteristics we believe are most representative of the dynamic equilibrium that the stream is moving toward through time and where the stream was contained within a single channel. Within the 1,200-meter reach a 437-meter section was selected for annual sampling, starting in 2008. This new sample section was named the “Bottomlands” section and will eventually replace both the Lower Rush and County Road sections. In 2008 the length of the County Road section was reduced by 576 meters and in 2009 this section was increased by 92 m and now terminates at the location of the long-term lower boundary.

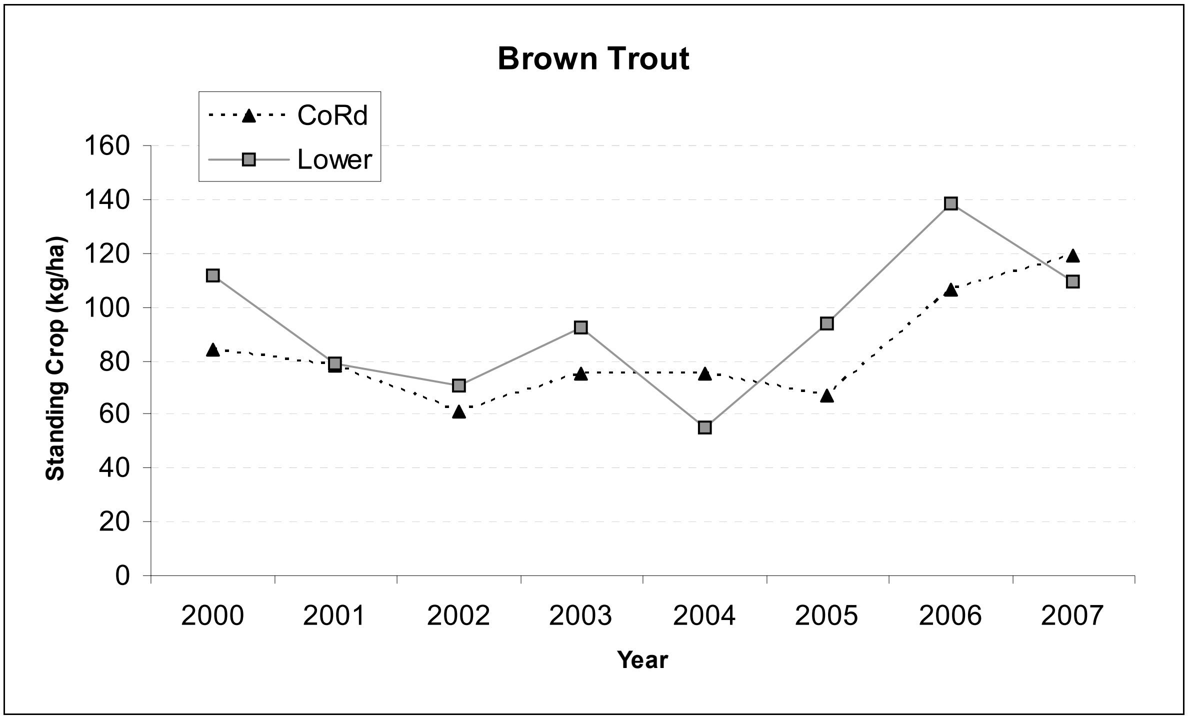


Figure 1. Standing crop estimates of age-0 and older brown trout in two sections of Rush Creek from 2000 to 2007.

In Lee Vining Creek both the main channel and associated side channel of the Upper section were discontinued in 2008. The Upper and Lower main channel sections of Lee Vining Creek are physically very similar, so data collected for these sections have shown similar trends of fish abundance through time (Figure 2). Flows in the side channel associated with the Upper section have declined annually until now this channel is either dry or nearly dry during September, so it cannot be sampled. The Lower Lee Vining Creek main channel section was lengthened by 100 meters, but the side channel associated with the Lower section was the same length as in previous years.

Aerial photographs of the currently-sampled long-term monitoring sections are provided in Appendix A.

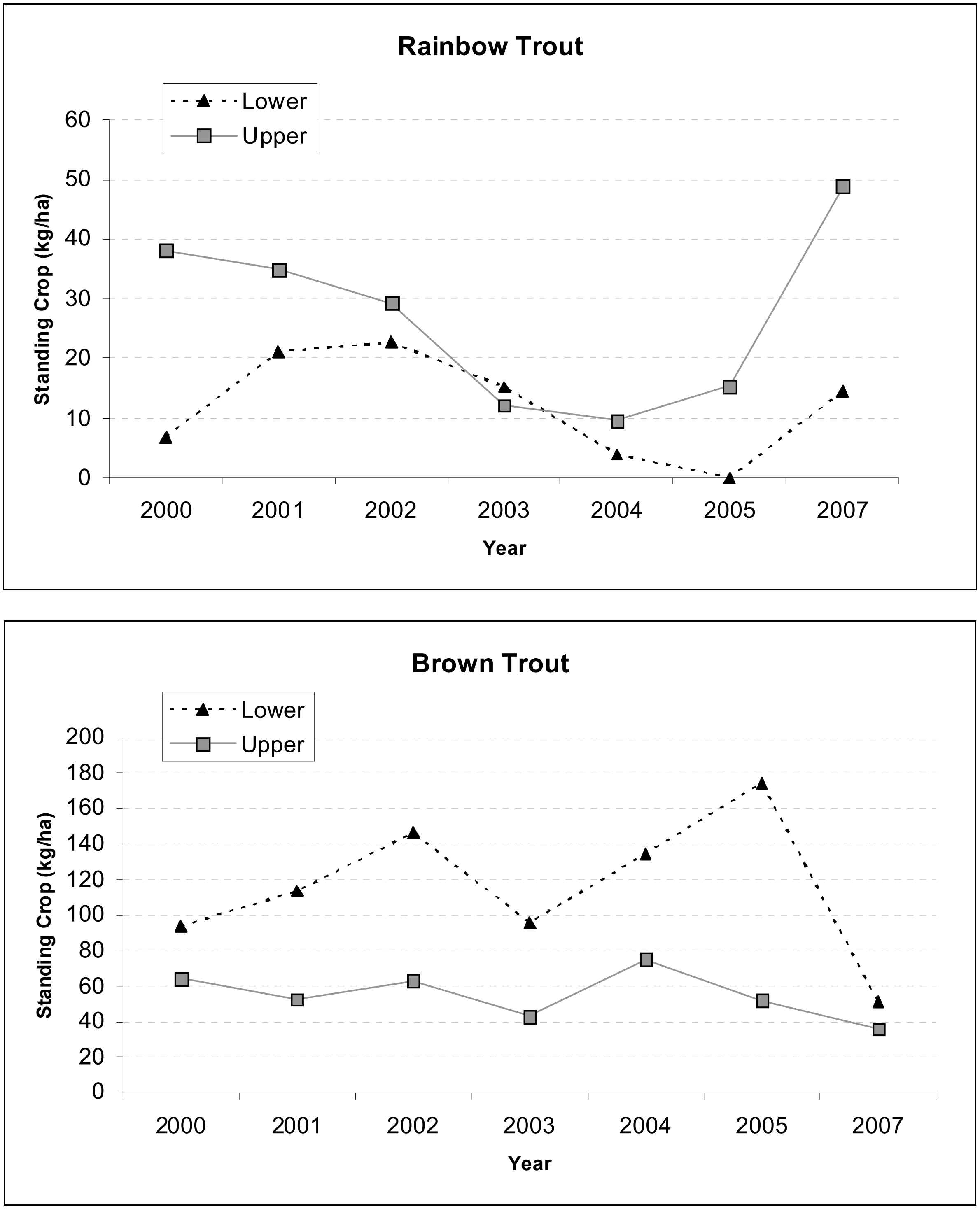


Figure 2. Standing crop estimates of age-0 and older rainbow trout (top) and brown trout (bottom) in two sections of Lee Vining Creek from 2000 to 2007.

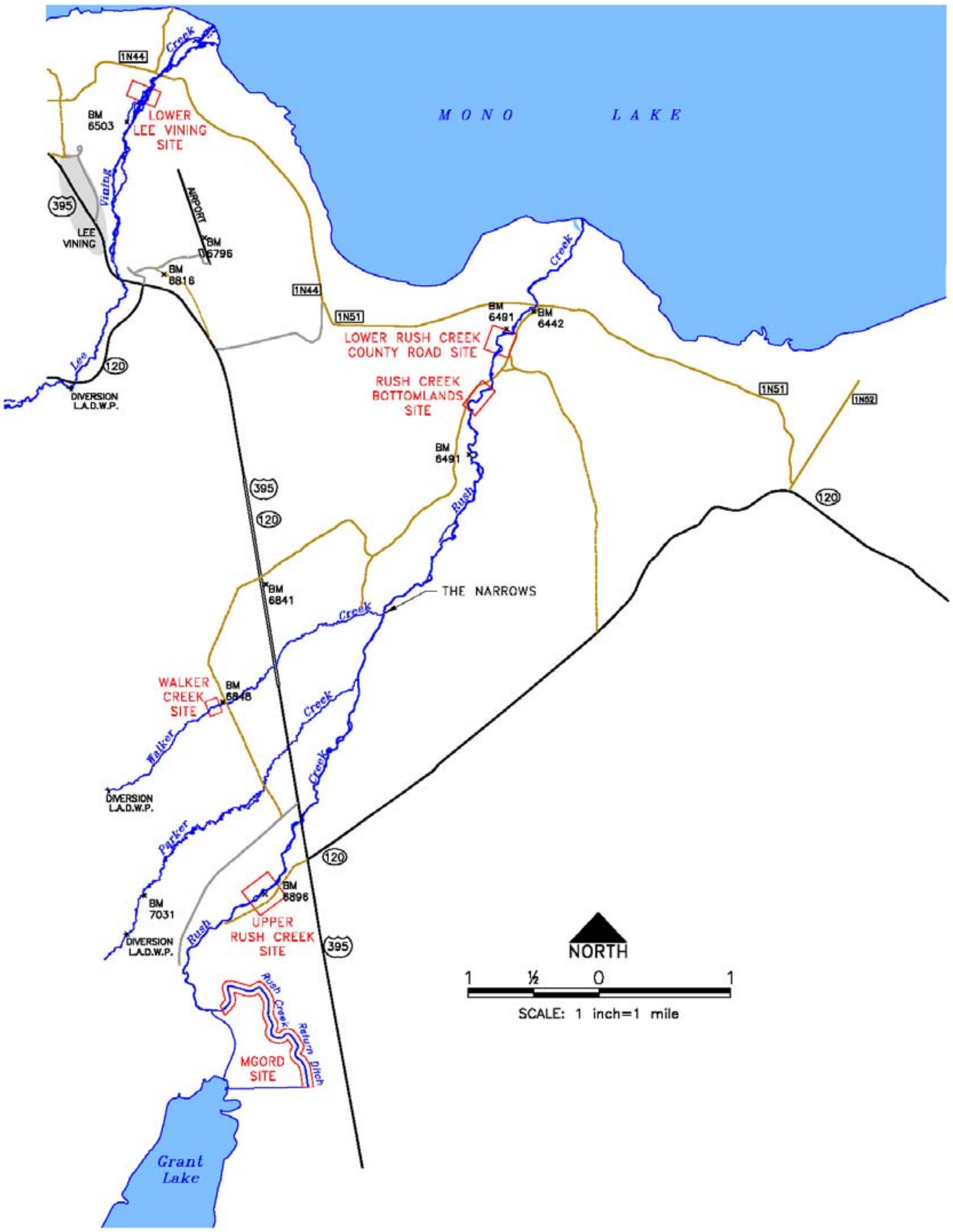


Figure 3. Map of Mono Basin study area with 2009 fish sampling sites displayed (created by McBain and Trush 2009).

The 2009 Runoff Year Forecast for the Mono Basin made in April of 2009 was 88% and was designated a "Normal" Runoff Year, the second “Normal” runoff year since 2000. According to Order WR98-05, the prescribed SRF peak flow release into Rush Creek from Grant Lake Reservoir (GLR) in a “Normal” runoff year is 380 c.f.s. for five days and 300 c.f.s. for seven days. However, the extremely low storage level in GLR in January of 2009 was a concern to the Stream Scientists who expressed these concerns to LADWP in two letters in early 2009 (Appendix B). The two primary issues were the potential for elevated turbidity levels in water released from an extremely low GLR and a poor summer thermal regime that would affect brown trout growth, condition factor, and survival. The low storage level of GLR dictated that no SRF release occurred (solid line on Figure 4). After several conference calls between LADWP, State Water Resources Control Board, the Stream Scientists and key stakeholders a unanimous decision was made to get a low flow variance extended to May 15 and delay exports to prioritize filling GLR. The result of this management decision increased GLR storage from a low of 6,100 ac-ft on February 12, 2009 to approximately 37,000 ac-ft by July of 2009.

Flows released into the MGORD from GLR were approximately 23 c.f.s. for most of April and May, followed by releases of approximately 47 c.f.s. for the remainder of the summer months (Figure 4). Flows in Rush Creek downstream of the Narrows were augmented by the snowmelt peaks of Parker and Walker creeks (Figure 4). The peak flow below the Narrows was 111 c.f.s. which occurred on June 1, 2009 (Figure 4).

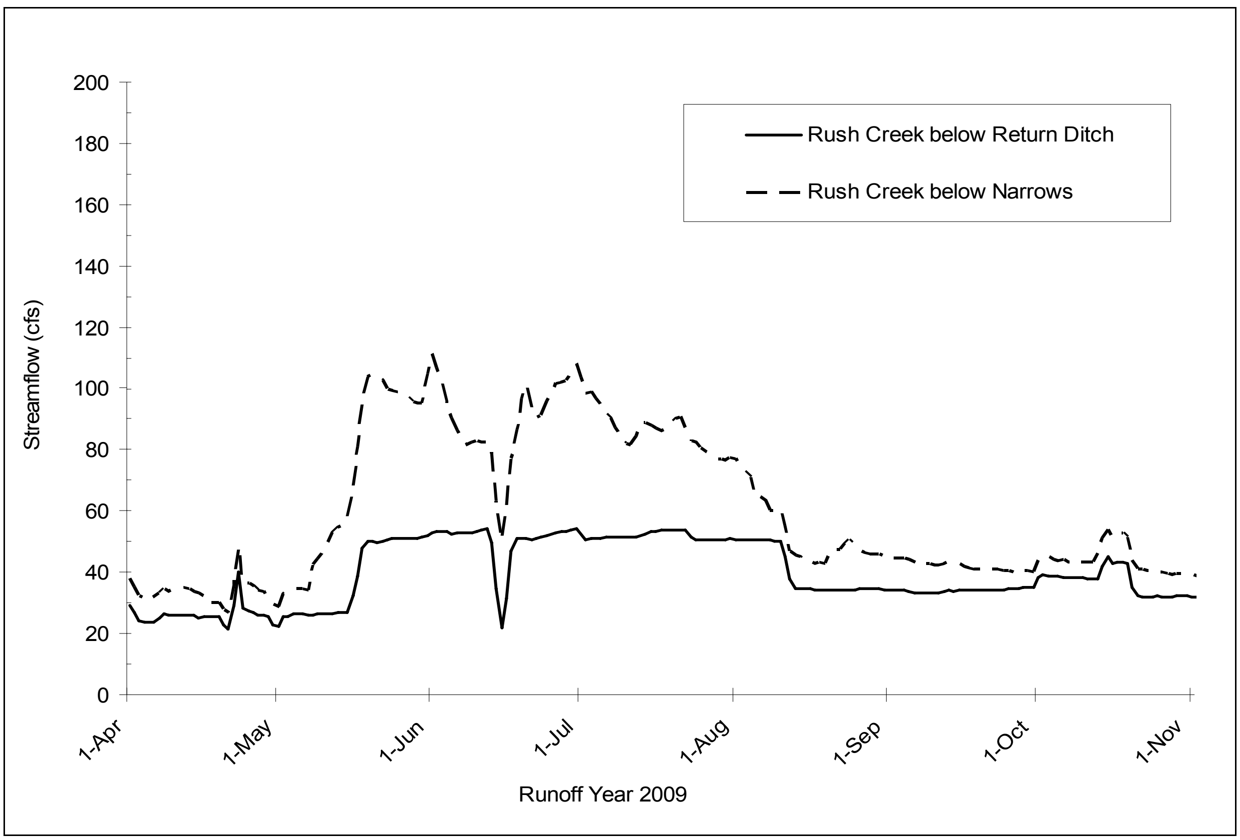


Figure 4. Daily stream flows (c.f.s.) in Rush Creek below the MGORD (aka Return Ditch) between March and September 2009. Data were provided by LADWP.

The peak flow in Lee Vining Creek below the LADWP diversion in 2009 was 232 c.f.s. and occurred on May 18th (Figure 5). As during most years, Lee Vining Creek experienced several distinct peaks in run-off due to snowmelt occurring at distinct breaks in elevation and/or the effects of cooling and warming air temperatures. A secondary peak of 176 c.f.s. occurred on June 3rd (Figure 5).

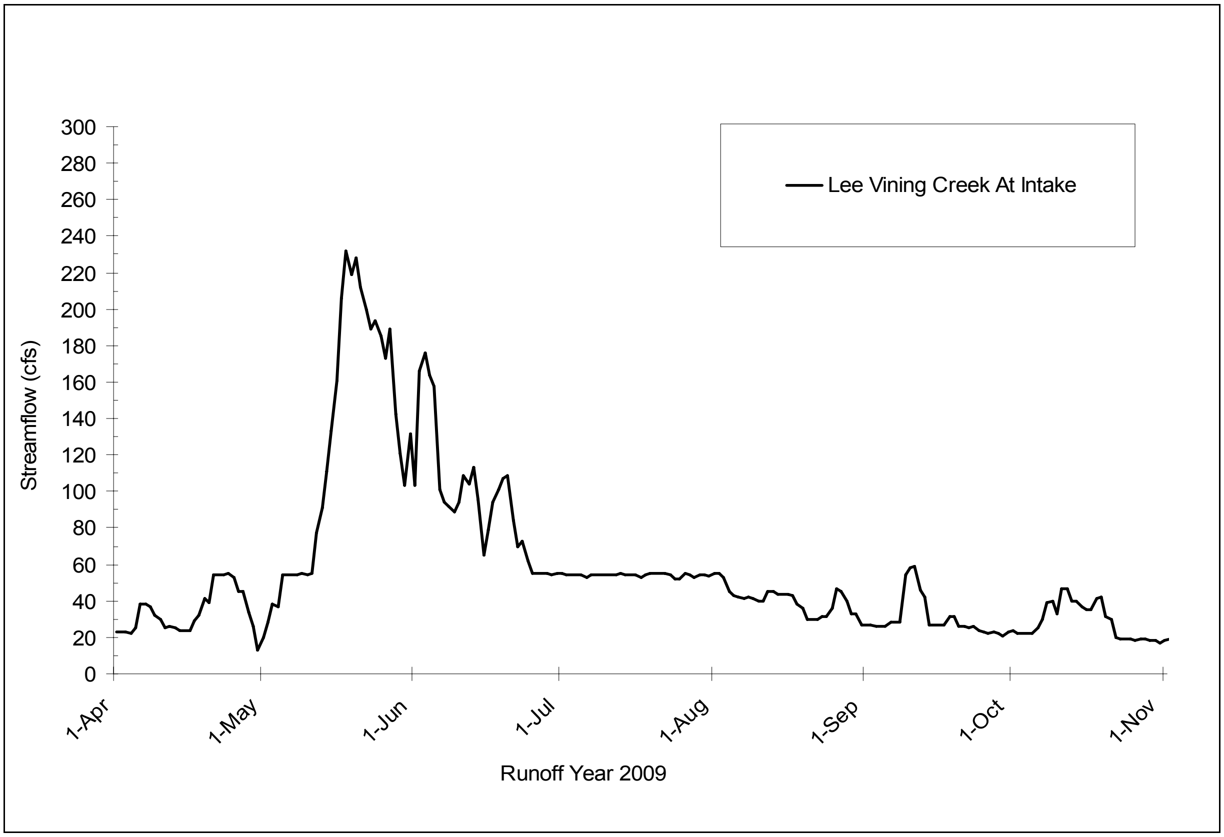


Figure 5. Daily stream flows (c.f.s.) in Lee Vining at the LADWP diversion between March and September 2009. Data were provided by LADWP.

Methods

Field sampling for generating fish population estimates occurred during the late summer between September 10th and 20th, 2009. Mark-recapture estimates were made in the shortened County Road section, the new Bottomlands section, and the Upper section of Rush Creek and in the Lower main channel section of Lee Vining Creek.

For all mark-recapture sampling efforts in Rush Creek, fish were captured using a Smith-Root® 2.5 GPP electro-fishing system that consisted of a Honda® generator powering a variable voltage pulsator (VVP) that had a rated maximum output of 2,500 watts. This unit was contained in a six-foot long fiberglass barge that was walked down the Rush Creek channel. A sampling run consisted of a single downstream pass starting at the upper block fence and terminating at the lower block fence. During mark-recapture electro-fishing an insulated cooler with several battery-powered aerators was also carried in the barge to transport captured fish. A pair of two-person teams consisting of an anode operator and a dip netter fished each half of the channel as the barge moved in a downstream direction (Figure 6). The fifth crewmember skillfully maneuvered the barge downstream, monitored the condition of the captured fish in the fish cooler, and acted as the crew's safety officer (Figure 7). All netted fish were placed in the insulated cooler shortly after capture. In all sections of Rush Creek, frequent stops were made to process fish as the cooler became full.

A drift boat was utilized to capture fish in the MGORD and required a five-person crew to operate. The electro-fishing barge was tied-off to the starboard side of the drift boat and two persons walked the drift boat downstream with the boat perpendicular to the channel with the port side facing downstream. An anode was thrown back and forth across the width of the MGORD by a crewmember in the drift boat. Another crewmember netted stunned fish from the drift boat and placed them in the insulated cooler. A third person sat in the stern of the drift boat, monitored the electro-fishing equipment and was responsible for the safety of other crewmembers. Usually no more than several hundred meters of the MGORD could be sampled before the cooler was full of fish. At these sub-stops, all captured fish were transferred to net-pens. A separate team of three people was required to process captured fish and record data.

Mark-recapture sampling on the Lower Lee Vining Creek main-channel section was accomplished with two Smith-Root® backpack electro-fishers (models12-B and SR-20). A sampling run consisted of two passes through the study section, first an upstream pass from the lower block fence to the upper block fence, immediately followed by a downstream pass back to the lower block fence. This technique also required five persons: two electro-fisher operators, two dip netters, and a bucket carrier to transfer captured fish to net pens.

Depletion estimates were made in the Walker Creek sample section and in the side-channel associated with the Lower Lee Vining Creek section (aka B-1 channel). For all depletion estimates the Smith-Root® backpack electro-fishers were used to capture fish. Two backpack electro-fishers were used to sample the Lee Vining Creek side-channel and a single electro-fisher was used to sample Walker Creek. One dip-netter accompanied each electro-fisher and netted fish stunned by that electro-fisher. Another crew member served as a backup dip-netter and carried a five-gallon live bucket equipped with an aerator in which captured fish were placed immediately after capture.

To meet the assumption of a closed population for sampling purposes, all sample sections were blocked at both ends (upper and lower boundaries) prior to sampling, including both boundaries of the County Road sub-section. For all sections sampled for mark-recapture estimates 12 mm mesh hardware cloth fences were installed at the upper and lower boundaries of the sections. These hardware cloth fences were installed by driving metal t-posts at approximately two-meter intervals through the bottom portion of the hardware cloth approximately 15 cm from its bottom edge. Rocks were hand-placed along the bottom edge of the hardware cloth to prevent fish from passing underneath the block fence. Rope was then strung across the top of each t-post and anchored to either t-posts or trees on each stream bank. The wire fence was held vertically by wiring the top of the cloth to this rope with baling wire. These fences were installed prior to the marking run and maintained in place until after the recapture effort was completed. Fences were cleaned and checked at least twice daily to ensure they remained in place and for enumerating any dead fish caught on the fences between the mark and recapture sampling period (duration of seven days).

For the two sections (Lower Lee Vining Creek side-channel and Walker Creek) where depletion estimates were made, the upper and lower boundaries were temporarily blocked with 12 mm mesh seine nets. These nets were in place only for the duration of the multiple passes required to generate estimates, usually no more than several hours.

All captured fish were anesthetized, measured to the nearest mm (total length) and most were weighed to the nearest gram on a digital scale. Data were entered onto data sheets (hard copies) and into a hand-held personal computer (Compaq iPAC®).

All fish captured in study sections where mark-recapture estimates were made were fin-clipped during the marking electro-fishing run for later identification during the recapture electro-fishing run. The lower caudal fin was clipped to mark fish in the County Road section of Rush Creek and in Lee Vining Creek. The upper caudal fin was clipped to mark fish in the Bottomlands section of Rush Creek. Finally, in Upper Rush Creek the anal fin was clipped to mark fish. When clipping a fin, scissors were used to make a straight vertical cut from the top, or bottom, of the fin approximately 1-3 mm deep at a location about 1-3 mm from the posterior edge of the fin.

For calculating biomass and density estimates, channel lengths and widths were re-measured. Wetted widths were measured with a tape along the entire length of each study reach at approximately 10-meter intervals. The annual re-measurement also provided insight into potential changes in channel geometry within the study reaches.

Population and biomass estimates were made for all mark-recapture and depletion estimates using Montana Fish, Wildlife and Parks’ Fisheries Analysis Plus computer package (version 1.2.7; Montana Fish, Wildlife and Parks 2004). All mark-recapture estimates employed the modified Peterson estimator within the Fisheries Analysis Plus software package (Chapman 1951, as cited in Ricker 1975).

Figure 6. Anode operators and netters sampling Rush Creek's Upper section, 2009.

Figure 7. Electro-fishing barge with generator and cooler on Upper Rush Creek, 2009.

Length-Weight Relationships

Length-weight regressions (Cone 1989) were calculated for brown trout in each section of Rush Creek by year to assess differences in length-weight relationships between sections and years. Log_{10} transformations were made on both length and weight prior to running regressions. Only brown trout 100 mm and longer were analyzed. Fulton-type relative condition factors were also computed according to methods initially developed by LeCren (1951) and expanded by Swingle (1965) and Swingle and Shell (1971) for all brown trout 150 to 250 mm.

Due to the difficulty of accurately sexing most brown trout captured during our annual sampling, no attempt was made to determine separate condition factors for male and female fish. However our sampling occurs at the same time every year (early to mid-September), thus any changes in condition factor would not be due to seasonal differences.

Fin Clips, PIT Tags and Growth Estimates

Starting in 2009, PIT tags were implanted in age-0 brown trout to estimate future growth. All PIT-tagged fish were also given permanent adipose fin clips so that during future sampling events all adipose fin-clipped fish will be scanned with a tag reader. In 2009, PIT tags were implanted in any recaptured age-1 trout that had received an adipose fin clip as an age-0 fish in 2008. Finally, PIT tags were implanted in nearly all of the trout captured in the single electrofishing pass conducted in the MGORD section of Rush Creek.

Age-0 and age-1 fish were implanted with 12 mm tags and 20 mm tags were implanted into all trout larger than 200 mm

During the 2009 sampling, captured fish were carefully examined to see if they had been fin-clipped in the previous four years, as follows:

- Year 2003 = Adipose fin clip – identifying them as age-0 fish in 2003 and age-6 fish in 2009.
- Year 2004 = Left pelvic clip – identifying them as age-0 fish in 2004 and age-5 fish in 2009.
- Year 2005 = Right pelvic clip – identifying them as age-0 fish in 2005 and age-4 fish in 2009.
- Year 2006 = Adipose clip – identifying them as age-0 fish in 2006 and age-3 fish in 2009.

All recaptured brown trout that were clipped as age-0 fish were noted on the data sheets and their lengths and weights were averaged by stream and sample section to derive empirical growth rates.

Relative Stock Density (RSD) Calculations

Relative stock density (RSD) was introduced as a new parameter in 2006 as a quantitative termination criterion. RSD's are numerical descriptors of length-frequency data and given representative samples of a population, RSD's are easily calculated and can provide insight or predictive ability about population dynamics. Please refer to the 2006 Mono Basin Fisheries Report for a more detailed literature review regarding RSD concepts and relevance as a quantifiable form of termination criteria (Hunter 2007).

RSD values are simply reported as the proportions (percentage x 100) of the total number of brown trout ≥150 mm (~6") in length that are also ≥225 mm or ~9" (RSD-225), ≥300 mm or ~12" (RSD-300) and ≥375 mm or ~15" (RSD-375). These three RSD values are calculated by the following equations:

RSD-225 = [(# of brown trout ≥225 mm) ÷ (# of brown trout ≥150 mm)] x 100
RSD-300 = [(# of brown trout ≥300 mm) ÷ (# of brown trout ≥150 mm)] x 100
RSD-375 = [(# of brown trout ≥375 mm) ÷ (# of brown trout ≥150 mm)] x 100

Termination Criteria Calculations and Analyses

In Decision-1631, the agreed upon termination criteria for Lee Vining Creek is to sustain a fishery for naturally-produced brown trout that average eight to 10 inches in length (200 to 250 mm) with some fish reaching 13 to 15 inches (330 to 375 mm). The agreed upon termination criteria for Rush Creek states that Rush Creek fairly consistently produced brown trout weighing from 0.75 to two pounds. Trout averaging 13 to 14 inches (330 to 350 mm) were also allegedly observed on a regular basis prior to the 1941 diversion of this stream.

The termination criteria provided in this report are based on the suite of termination criteria proposed by the Fisheries Stream Scientist in an attempt to make the calculation and interpretation of the fisheries termination criteria a more quantifiable exercise. The rationale for replacing the original termination criteria was to evaluate brown trout populations with metrics derived from quantifiable methodologies that are generally accepted as standards by fisheries professionals. As stated in our ten previous annual reports no data were available that provided a scientifically quantitative picture of trout populations that these streams supported on a self-sustaining basis prior to 1941 (Hunter et al. 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008).

Four repeatable and quantifiable metrics will be employed as termination criteria to evaluate the brown trout populations in the Upper, Bottomlands, and County sections of Rush Creek – biomass, density, condition and relative stock density (RSD) of catchable trout (≥225 mm or ≥9") in the populations. The same four criteria will be applied to all trout (brown and rainbow combined) in the Lee Vining Creek sample section. A fifth metric for Rush Creek sections only will be RSD-300 of brown trout (proportion of brown trout ≥300 mm or ≥12"). The values for these fisheries metrics, as discussed below, represent realistic recovery goals for the streams.

Finally, three termination criteria metrics of RSD will be applied to the Rush Creek MGORD only – the RSD of brown trout ≥225 mm (RSD-225), ≥300 mm (RSD-300) and ≥375 mm (RSD-375).

Rush Creek TC for Upper, Bottomlands and County Road Sections

Termination Criterion #1 – Biomass: Total brown trout standing crop estimates based on kilograms per hectare of biomass. Total standing crop estimates will also be reported to reflect contribution by two age-classes (age-0 and ≥age-1). The termination criterion for biomass estimate is **≥ 175 kg/ha**. Trends in brown trout standing crop data are assessed with three-year moving averages by computing the average of the three most-current years of data and that average should meet the termination criteria of at least **175 kg/ha**.

Termination Criterion #2 – Density: Total number of brown trout per unit length (km) of stream channel. The termination criterion for total number of trout per kilometer is **≥3,000 trout/km**. Trends in total number of trout per kilometer are assessed with three-year moving averages by computing the average of the three most-current years of data and that average should meet the termination criteria of at least **3,000 trout/km**.

Termination Criterion #3 – Condition: Condition factor of brown trout ≥age-1+ is computed and should not drop below **1.00**. Values below 1.0 should be of concern to managers. When standing crop values drop, fishery would be considered in "good condition" if condition factors remain stable or increase. It is possible that higher densities (# of fish/ha) will result in lower condition factors for individual groups of trout due to density dependent competition. Trends in condition factor are assessed with three-year moving averages by computing the average of three most-current years of data. That average should meet the termination criteria of condition factor **≥1.00**.

Termination Criterion #4 – RSD-225: RSD-225 values of brown trout are computed for all sections of Rush Creek and should not drop below **35**. Trends in RSD-225 are assessed with three-year moving averages by computing the average of the three most-current years of data. That average should meet the termination criteria RSD-225 value of at least **35**.

Termination Criterion #5 – RSD-300: RSD-300 values of brown trout are computed for all sections of Rush Creek and should not drop below **5**. Trends in RSD-300 are assessed with three-year moving averages by computing the average of the three most-current years of data. That average should meet the termination criteria RSD-300 value of at least **5**.

Lee Vining Creek TC

Termination Criterion #1 – Biomass: Total trout (brown and wild rainbow combined) standing crop estimates based on kilograms per hectare of biomass. Total standing crop estimates will also be reported to reflect contribution by two age-classes (age-0 and ≥age-1). The termination criterion for biomass estimate is **≥ 150 kg/ha**. Trends in total trout standing crop data are assessed with three-year moving averages by computing the average of the three most-current years of data and that average should meet the termination criteria of at least **150 kg/ha**.

Termination Criterion #2 – Density: Total number of trout per unit length (km) of stream channel. The termination criterion for total number of trout per kilometer is **≥1,400 trout/km**. Trends in total number of trout per kilometer are assessed with three-year moving averages by computing the average of the three most-current years of data and that average should meet the termination criteria of at least **1,400 trout/km**.

Termination Criterion #3 – Condition: Condition factor of trout ≥age-1+ is computed and should not drop below **1.00**. Trends in condition factor are assessed with three-year moving averages by computing the average of three most-current years of data. That average should meet the termination criteria of condition factor **≥1.00**.

Termination Criterion #4 – RSD-225: RSD-225 values of all trout (brown and wild rainbow) are computed for both Lee Vining Creek study sections and should not drop below **30**. Trends in RSD-225 are assessed with three-year moving averages by computing the average of the three most-current years of data. That average should meet the termination criteria RSD-225 value of at least **30**.

Rush Creek TC for the MGORD Section

For the Rush Creek MGORD study section three termination criteria metrics of RSD are utilized – the RSD of brown trout ≥225 mm (≥9”), ≥300 mm (≥12”) and ≥375 mm (≥15”).

RSD-225 value in the MGORD is computed and should not drop below **60**.

RSD-300 value in the MGORD is computed and should not drop below **30**.

RSD-375 value in the MGORD is computed and should not drop below **5**.

Trends in RSD-225, RSD-300 and RSD-375 were assessed with three-year moving averages by computing the average of the three most-current years of data. The averages should meet the termination criteria of **60**, **30** and **5**, respectively.

The rationale for assessing these “large trout” metrics specifically for the MGORD is that this human-constructed section below Grant Reservoir has unique spring creek-like characteristics that support the growth of large brown similar to the pre-1941 productivity of the human-influenced springs below the Rush Creek Narrows. Two years of movement study data have demonstrated that approximately 40 to 50% of the large (>300 mm) radio-tagged brown trout migrated between the MGORD and lower reaches of Rush Creek, especially during autumn and winter. To most accurately evaluate the status of large brown trout in the Rush Creek system immediately downstream of Grant Lake Reservoir, data for computing RSD values of MGORD brown trout should be collected in September, prior to the onset of the fall spawning season when migrations occur.

How to use the Quantifiable Termination Criteria

1. With the most-current data set, calculate the biomass, density, condition factor and RSD-225 values for each section of Rush Creek and Lee Vining Creek. Calculate the RSD-300 values for Rush Creek sections only.

2. For Lee Vining Creek, the biomass estimates from the main and side (if watered) channels were combined for a total value. For densities and condition factors, the values from the main and side (if watered) channels were averaged.

3. For the current year and the two previous years, calculate the three-year running averages of biomass, density, condition factor and RSD-225 for each section of Rush Creek and Lee Vining Creek. Calculate the three-year running averages of RSD-300 for Rush Creek sections only. *Five years of data are necessary to compute a complete set of three, three-year running averages.*

4. For the Upper, Bottomlands and County Road sections of Rush Creek, a section would be considered “recovered” if it met four of the five termination criteria for three consecutive years that the three-year running averages were calculated. The rationale is that in years of high young-of-year (age-0) recruitment, densities will be high with fairly low biomass estimates. Conversely, in years of low age-0 recruitment densities will probably drop, but biomass of older trout should increase. Years of high densities may also exhibit lower condition factors due to density-dependent competition for available food and/or habitat.

5. For Lee Vining Creek, the sample section would be considered “recovered” if it met three of the four termination criteria for three consecutive years that the three-year running averages were calculated.

Results

Channel Lengths and Widths

Due to differences in the September streamflow between 2008 and 2009, channel widths could not be reliably compared between years; however, previous channel measurements are presented to illustrate the lengthening of the County Road section of Rush Creek (Table 1). Slight differences in channel widths between sample years may also be attributable to the varying locations where each width measurement was taken to generate a sample reach's average width.

Table 1. Total length (m), average wetted width (m), and total surface area (m^2) of sample sections in Rush, Lee Vining, and Walker creeks sampled between September 10 -20, 2009. Values for 2008 provided for comparisons.

Section	Length (m) 2008	Width (m) 2008	Area (m^2) 2008	Length (m) 2009	Width (m) 2009	Area (m^2) 2009
Rush – Co. Road	237	8.2	1,943.4	329	7.4	2,434.6
Rush - Bottomlands	437	8.0	3,496.0	437	7.7	3,364.9
Rush – Upper	430	8.9	3,827.0	430	8.8	3,784.0
Rush - MGORD	2,230	12.0	26,760.0	*N/S	*N/S	*N/S
Lee Vining – Main	255	5.4	1,377.0	255	5.9	1,504.5
Lee Vining - Side	195	2.5	488.0	195	2.5	488.0
Walker Creek	100	1.8	180.0	100	2.3	230.0

*N/S = not sampled for population estimate in 2009

Fish Population Abundance

Rush Creek – County Road Section

In 2009 approximately 34% of the 643 brown trout captured in the County Road section of Rush Creek were young-of-the-year (age-0) fish between 58 and 125 mm in length; and the longest brown trout captured was 293 mm (Figure 7). This section supported an estimated 472 age-0 and 526 age-1 and older brown trout (Table 2); about 77% of the latter were brown trout ranging from 126-199 mm, which (based on the recapture of adipose fin-clipped cohorts in 2009) were primarily age-1 fish. Estimates of brown trout densities were more precise than previous years with standard errors ranging from 4% to 13% of the estimates.

Ten rainbow trout were sampled in 2009 and these ranged in length from 145 to 241 mm (Figure 10). No population estimates were generated for rainbow trout due to insufficient numbers of recaptures.

Rush Creek – Bottomlands Section

In 2009 approximately 48% of the 761 brown trout captured in the Bottomlands section of Rush Creek were young-of-the-year (age-0) fish between 66 and 124 mm and the longest brown trout captured was 425 mm (Figure 9). A second brown trout greater than 300 mm was also captured in the Bottomlands section of Rush Creek (Figure 9). This section supported an estimated 791 age-0 and 501 age-1 and older brown trout (Table 2). Estimates of brown trout were more precise than previous years with standard errors ranging from 4% to 12% of the estimates.

Five rainbow trout from 143 to 221 mm were sampled in 2009 (Figure 10). No population estimates were generated for rainbow trout due to insufficient numbers of recaptures.

Rush Creek – Upper Section

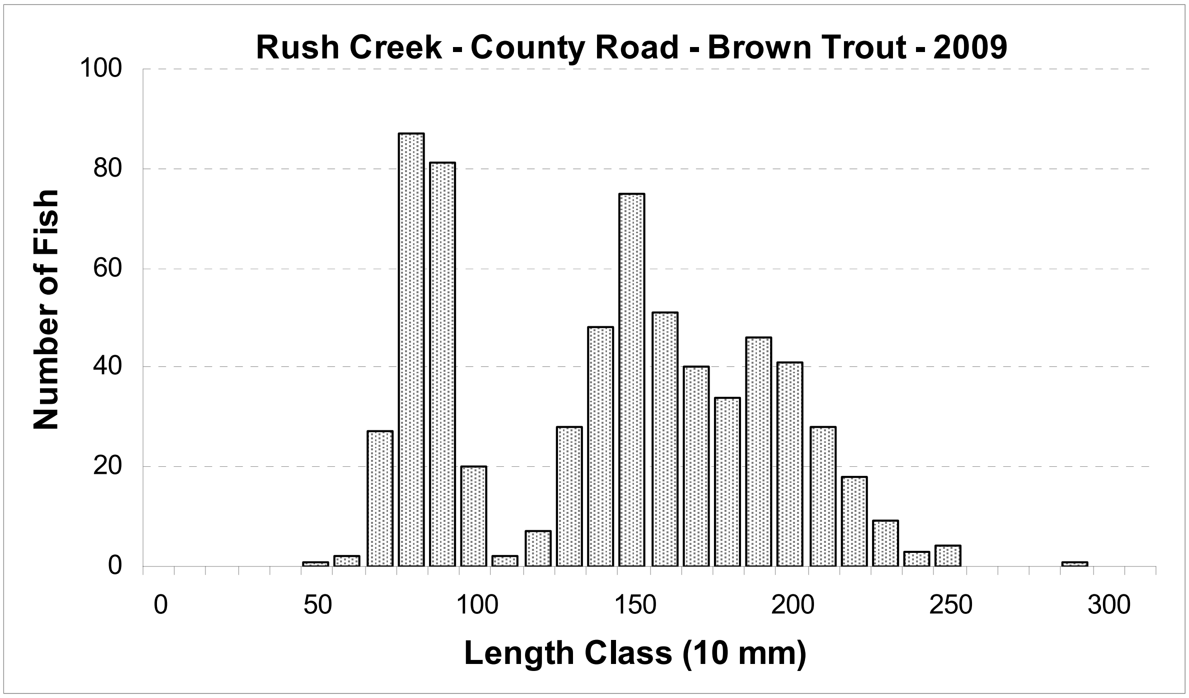
In 2009 approximately 55% of the 806 brown trout captured in the Upper section of Rush Creek were young-of-the-year (age-0) fish between 68 and 124 mm and the longest brown trout captured was 406 mm (Figure 9). Seven brown trout greater than 300 mm were sampled in 2009, including three fish greater than 350 mm. This section supported an estimated 946 age-0 and 504 age-1 and older brown trout (Table 2). Estimates of brown trout in Upper Rush Creek Estimates of brown trout were more precise than previous years with standard errors ranging from 6% to 9% of the estimates.

Forty-eight rainbow trout (38 age-0 fish) were sampled in 2009 that ranged in length from 67 to 253 mm (Figure 11). An estimated 112 age-0 rainbow trout (<125 mm in length) inhabited this section during 2009, but this estimate was unreliable due to the relatively small number of recaptures (only two fish). No population estimates were generated for other size groups due to insufficient numbers of recaptures.

Rush Creek – MGORD Section

In 2009 only a single electrofishing pass was made on the MGORD section of Rush Creek, thus no population estimate was generated. A total of 691 brown trout were captured during this single electrofishing pass and 54 of these were age-0 fish (Figure 9). Twenty-six of these brown trout were at least 375 mm in length, and 13 of these fish were greater than 400 mm in length (Figure 9).

Only five rainbow trout were captured during the single electrofishing pass, thus rainbow trout comprised less than one percent of the 696 trout sampled within the MGORD in 2009. These five rainbow trout ranged from 211 mm to 303 mm in length.



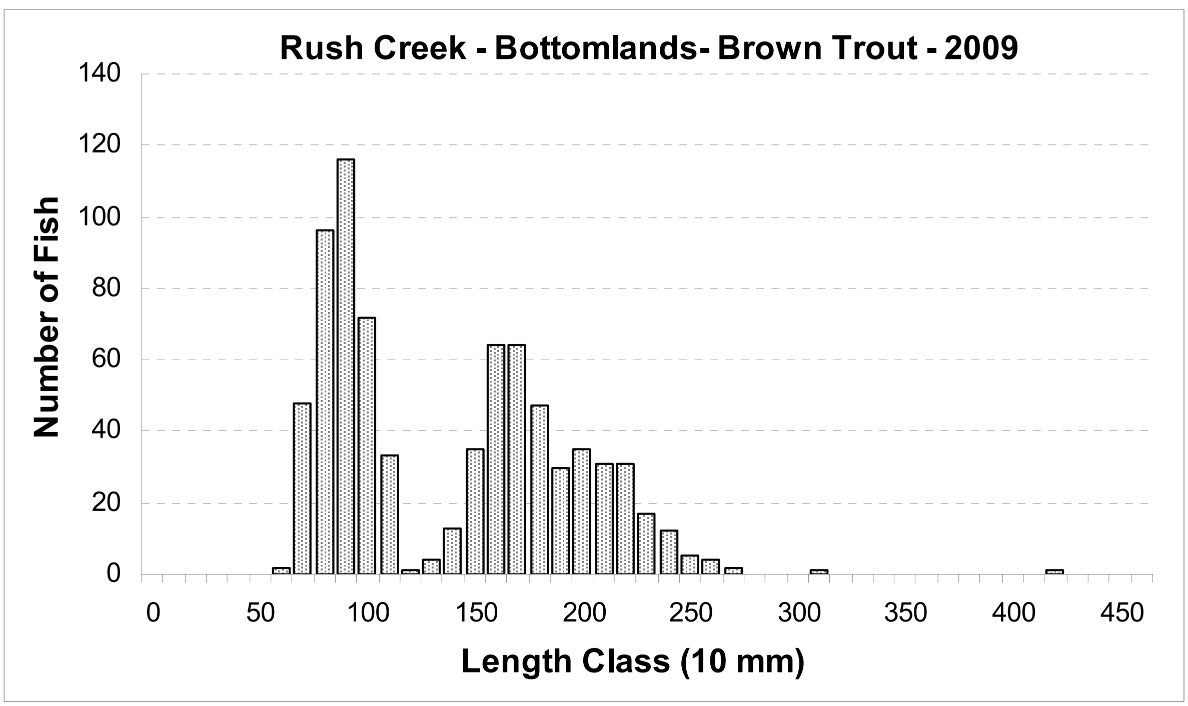
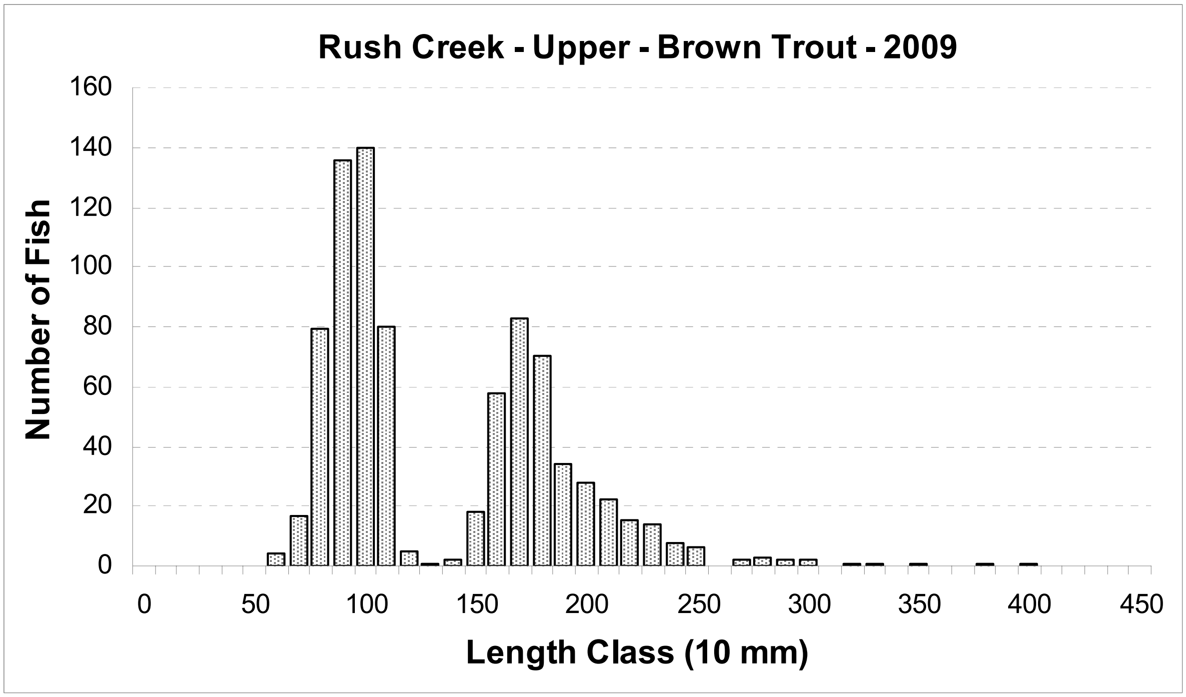


Figure 8. Length-frequency histograms of brown trout captured in the County Road (top) and Bottomlands (bottom) sections of Rush Creek between September 10th and 20th, 2009. Note different scales on the y-axes.



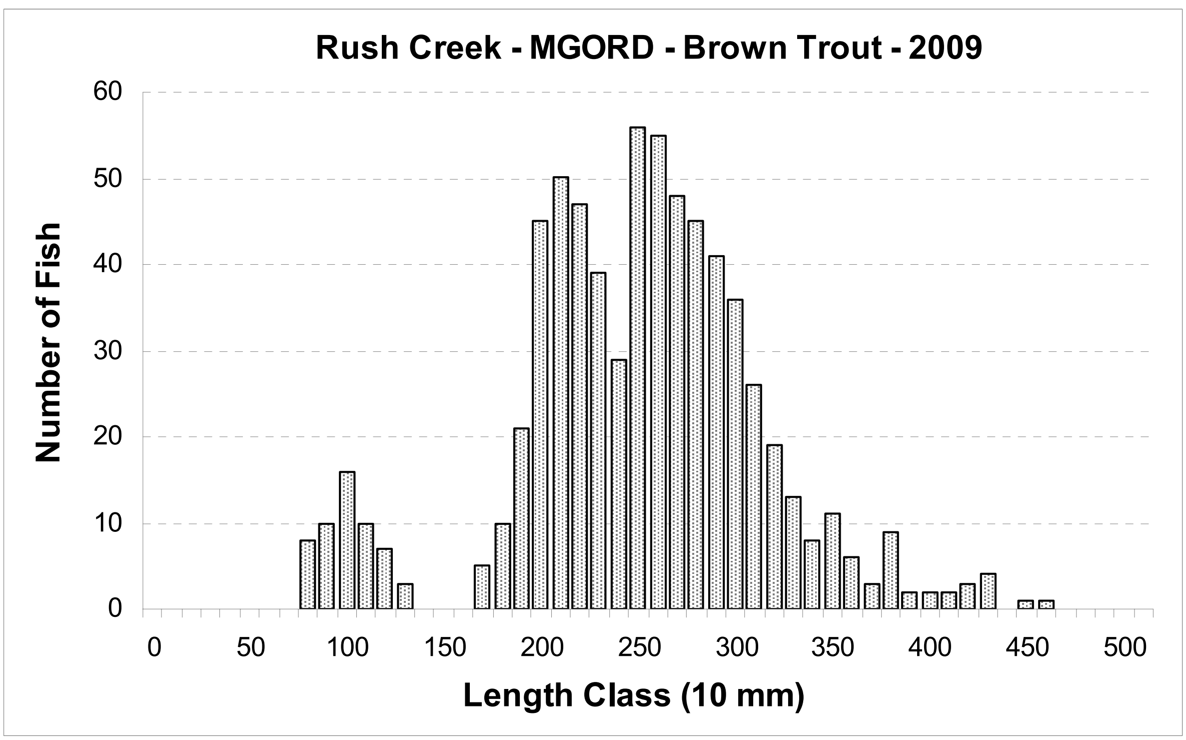
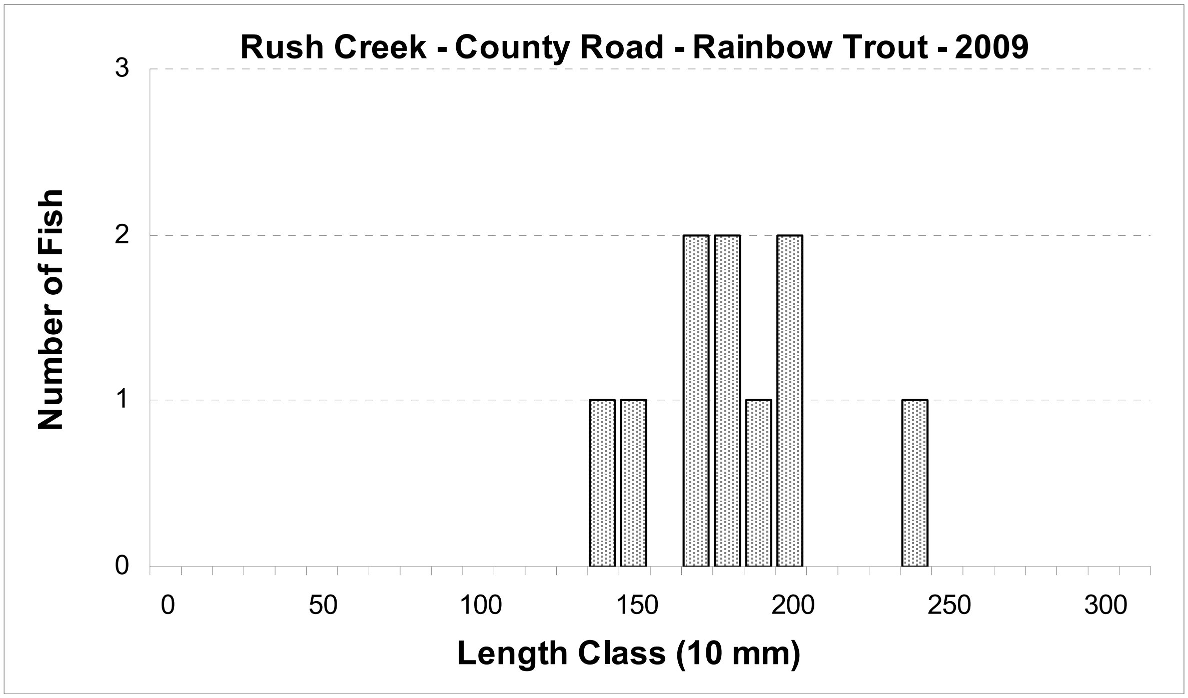


Figure 9. Length-frequency histograms of brown trout captured in the Upper (top) and MGORD (bottom) sections of Rush Creek between September 10th and 20th, 2009. Note different scales on both x-axes and y-axes.



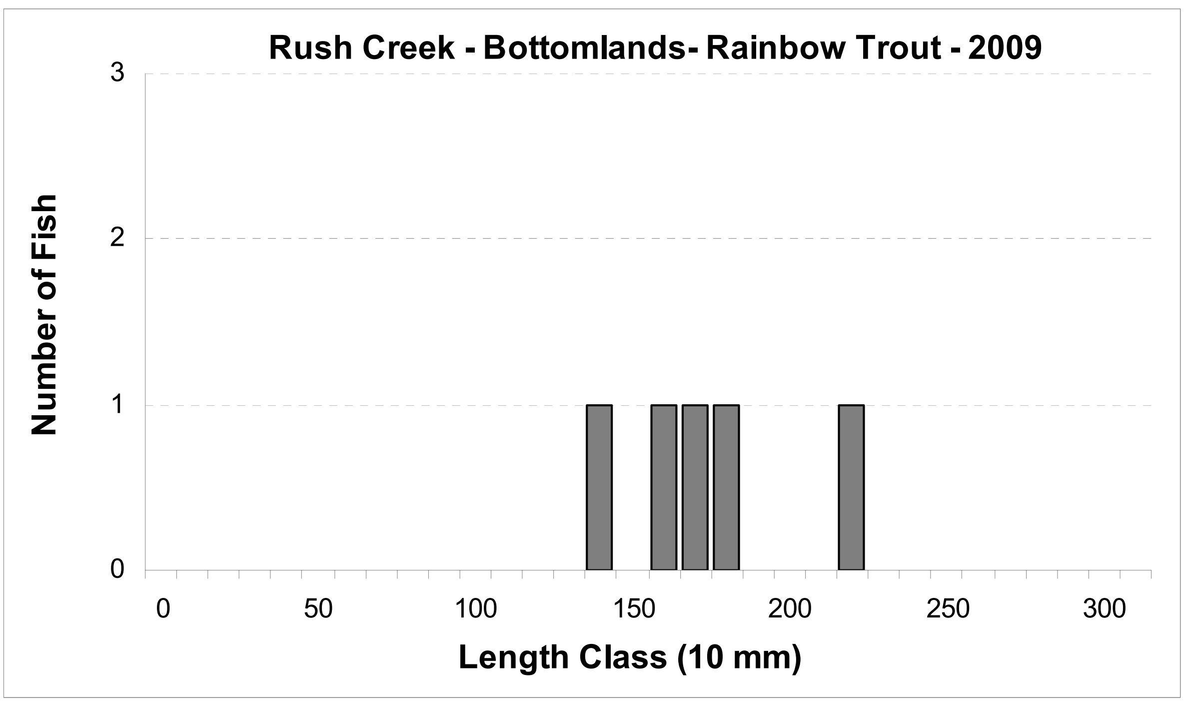


Figure 10. Length-frequency histograms of rainbow trout captured in the County Road (top) and Bottomlands (bottom) sections of Rush Creek between September 10th and 20th, 2009.

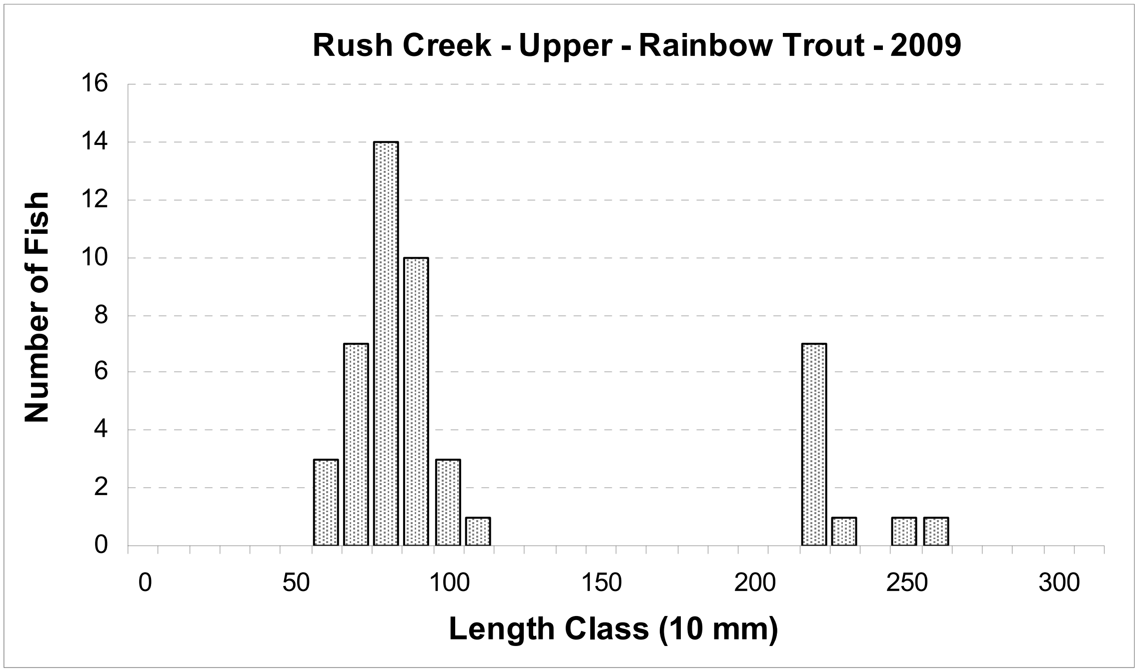


Figure 11. Length-frequency histogram of rainbow trout captured in the Upper section of Rush Creek between September 10th and 20th, 2009.

Table 2. Rush Creek and Lee Vining Creek mark-recapture estimates for 2009 showing total number of fish marked (M), total number captured on the recapture run (C), total number recaptured on the recapture run (R), and total estimated number and its associated standard error (S.E.) by stream, section, date, species and size class. Mortalities (Morts) were those fish that were captured during the mark run, but died prior to the recapture run. Mortalities were not included in mark-recapture estimates and should be added to estimates for accurate total estimates. NP = estimate not possible.

Stream / Section / Date / **Species**	Size Class (mm)	Mark - recapture estimate parameter values: M	C	R	Morts	**Estimate**	S.E.
Rush Creek							
County Road							
9/12+19/09							
Brown Trout							
	0 - 124 mm	123	125	32	6	**472**	59.8
	125 - 199 mm	216	229	122	3	**405**	16.4
	>200 mm	69	81	46	1	**121**	6.6
Bottomlands							
9/11+17 /09							
Brown Trout							
	0 - 124 mm	230	191	55	2	**791**	76.8
	125 - 199 mm	195	139	79	0	**342**	19.2
	>200 mm	116	88	64	0	**159**	6.8
Upper Rush							
09/10+17/09							
Brown Trout							
	0 - 124 mm	223	278	65	25	**946**	84.9
	125 - 199 mm	173	169	79	4	**369**	22.0
	>200 mm	66	80	39	2	**135**	9.6
Lee Vining Creek							
Main Channel							
9/13+20/09							
Brown Trout							
	0 - 124 mm	6	7	2	0	**18**[b]	5.6
	125 - 199 mm	54	71	29	0	**131**	12.2
	>200 mm	18	18	10	0	**32**	4.0
Rainbow Trout							
	0 - 124 mm	4	4	0	1	**NP**[a]	NP
	125 - 199 mm	24	16	6	0	**60**[b]	14.0
	>200 mm	15	16	6	0	**38**[b]	7.9

a/ "NP" indicates an estimate was not possible due to too few recaptures.
b/ These estimates have fewer than 7 recaptures.

Lee Vining Creek – Main Channel Section

In 2009 only 8% of the 133 brown trout captured in the main channel section of Lee Vining Creek were young-of-the-year (age-0) fish between 78 and 96 mm and the longest brown trout captured was 290 mm (Figure 12). The estimate of 18 age-0 brown trout at this section was unreliable, since only two fish in this size range were recaptured (Table 2). Estimates of brown trout in the 125-199 mm length class (131 fish) and the >200 mm length class (32 fish) yielded standard errors ranging from 9% to 12%% of the estimates.

A total of 68 rainbow trout were captured in 2009 with only nine (13%) of these fish being age-0 fish that ranged from 62 to 81 mm in length (Figure 13). This section supported an estimated 98 age-1 and older rainbow trout (Table 2). No estimate of age-0 rainbow was possible because no recaptures were made during the capture electrofishing pass. Estimates of rainbow trout yielded standard errors ranging from 21% to 23% of the estimates; however the age-1 and older estimates were generated with less than seven recaptures (Table 2).

Lee Vining Creek – Side Channel Section

In 2009, a total of 11 brown trout were captured in the side channel section of Lee Vining Creek; five fish were age-0 and six fish were age-1 and older (Figure 12).The longest brown trout captured was 257 mm (Figure 12). All fish were captured on the first of two electro-fishing depletion passes made. This section supported an estimated five age-0 brown trout and six age-1 and older brown trout (Table 3).

For rainbow trout, only 15 fish were sampled in 2009 and none were age-0 fish (Figure 13). The longest rainbow trout captured in this side-channel was 343 mm (Figure 13). As for brown trout, all fish were captured on the first of two electro-fishing depletion passes made. This section supported an estimated 15 age-1 and older rainbow trout (Table 3).

Walker Creek

In 2009, 330 brown trout were captured in two electro-fishing passes and 113 of these brown trout were age-0 fish between 62 and 101 mm in length (Figure 14). For the past six years, age-0 brown trout numbers have fluctuated widely in Walker Creek with very high numbers (>300) captured in 2007 and 2008, 80 captured in 2006, four captured in 2005, and 203 captured in 2004. In 2009, Walker Creek supported an estimated 195 age-0 and 146 age-1 and older brown trout (Table 3).

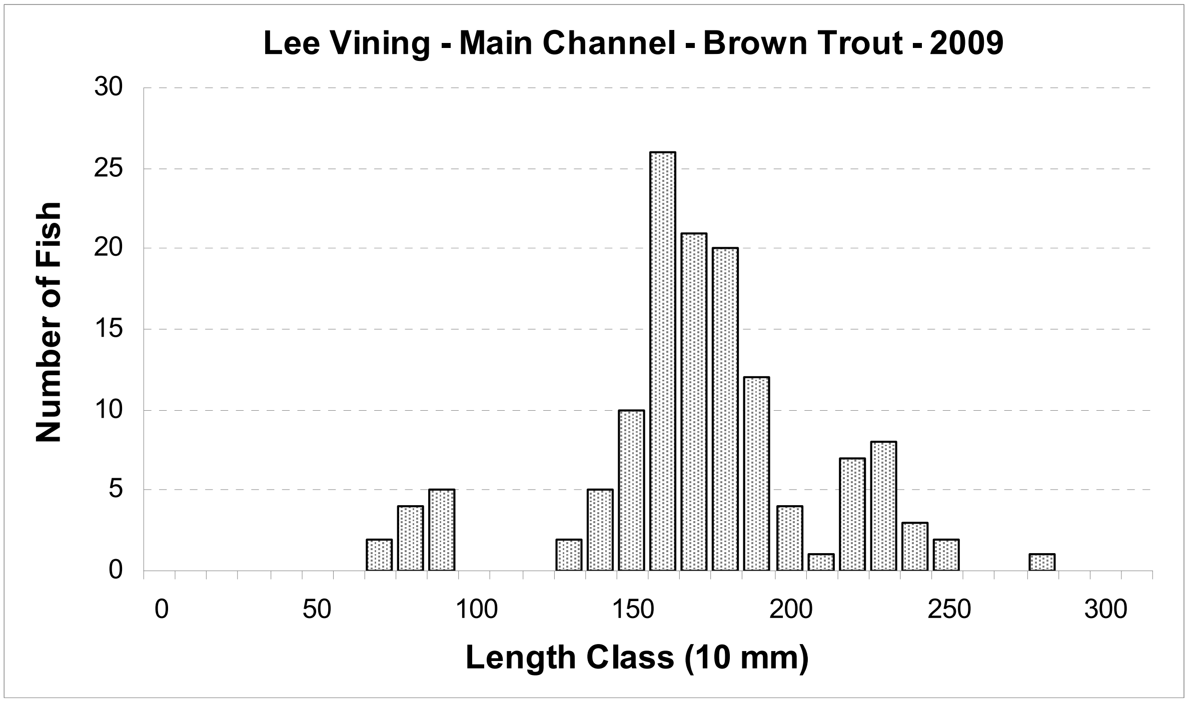


Figure 12. Length-frequency histograms of brown trout captured in the Main channel (top) and Side channel (bottom) sections of Lee Vining Creek between September 10th and 20th, 2009. Note different scales on both x-axes and y-axes.

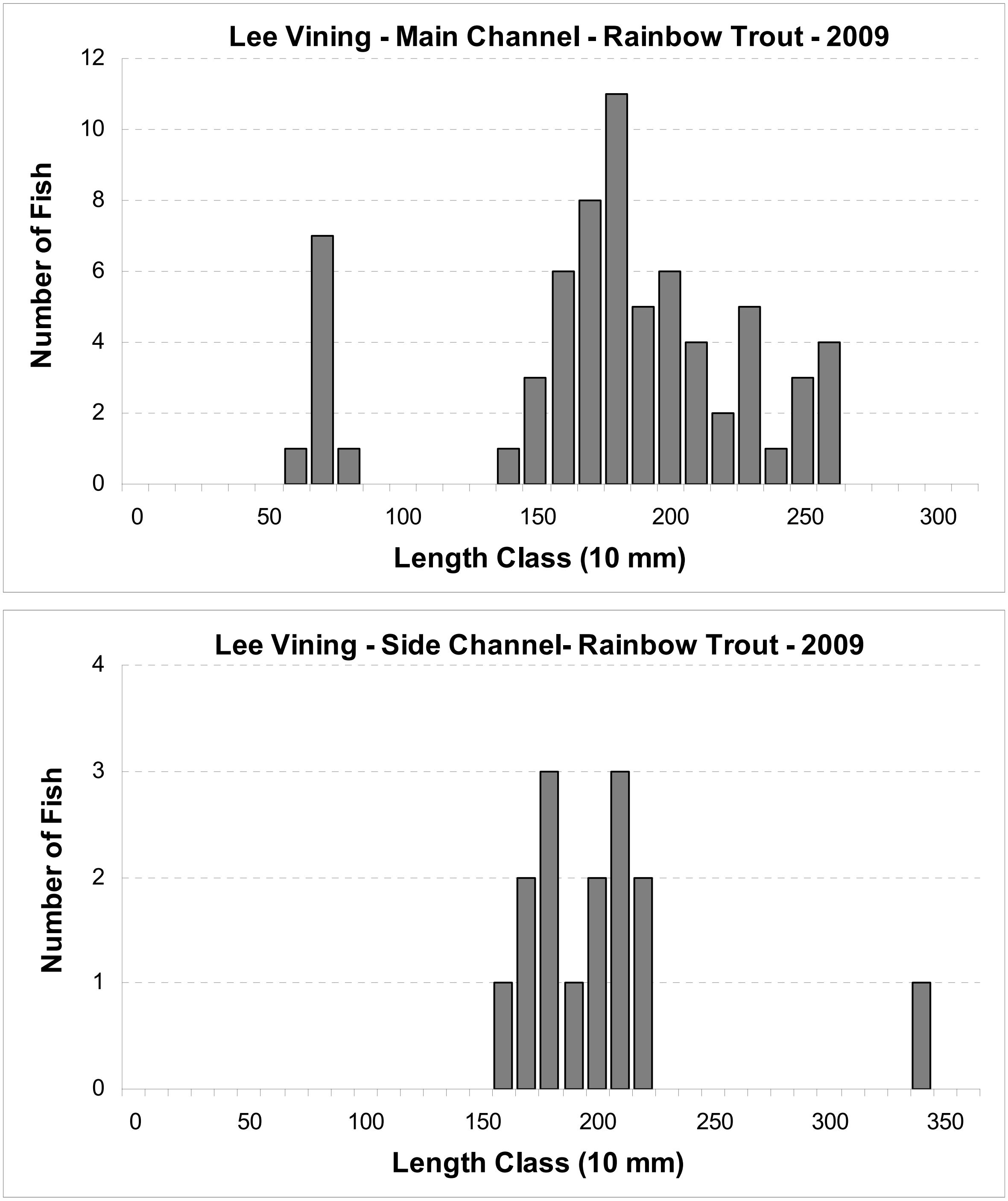


Figure 13. Length-frequency histograms of rainbow trout captured in the Main channel (top) and Side channel (bottom) sections of Lee Vining Creek between September 10th and 20th, 2009. Note different scales on both x-axes and y-axes.

Table 3. Depletion estimates made in the Lower side channel section of Lee Vining Creek and Walker Creek during September 2009 showing number of fish captured in each pass, estimated number and standard error (S.E.) by species and length group.

Stream - Section Date / **Species**	Size Class (mm)	Removals	Removal Pattern	**Estimate**	S.E.
Lee Vining Creek - Lower - B1 Channel 9/15/2009					
Brown Trout					
	0 - 124 mm	3	5 0	**5**	0.0
	125 - 199 mm	3	4 0	**4**	0.0
	200 + mm	3	2 0	**2**	0.0
Rainbow Trout					
	0 - 124 mm	3	0 0	**0**	0.0
	125 - 199 mm	3	7 0	**7**	0.0
	200 + mm	3	8 0	**8**	0.0
Walker Creek - Walker above road near Cane 9/15/2009					
Brown Trout					
	0 - 124 mm	2	119 50 16	**195**	4.98
	125 - 199 mm	2	99 14 8	**122**	1.28
	200 + mm	2	22 1 1	**24**	0.19

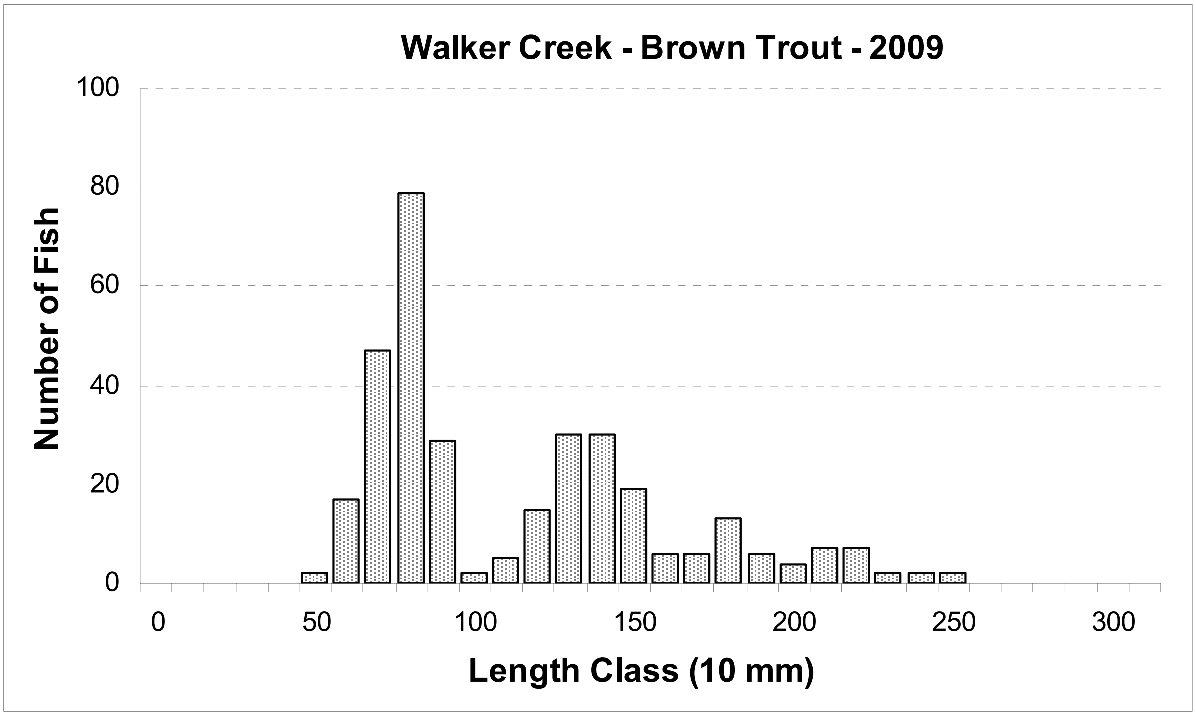


Figure 14. Length-frequency histogram of brown trout captured in Walker Creek on September 15, 2009.

Catch of Rainbow Trout in Rush and Lee Vining Creeks

For the past ten years of annual sampling, rainbow trout have been a minor component of the Rush Creek fishery, typically accounting for less than five percent of the total catch of trout. Starting with the 2008 annual report we proposed that the catch of rainbow trout in Rush Creek will simply be reported. Thus, no effort was made to extrapolate rainbow trout catch numbers into density estimates or utilized in the computation of total biomass estimates for Termination Criteria purposes.

Rainbow trout numbers in Lee Vining Creek have been variable over the past ten years, with enough fish sampled to generate estimates of age-0 fish or age-1 and older fish in some years (Tables 4 - 7). In the main channel section, sufficient numbers of age-0 rainbow trout were sampled to generate population estimates in four out of ten years (Table 4). In the main channel section, sufficient numbers of age-1 and older rainbow trout were sampled to generate population estimates in only three out of ten years (Table 5). Using depletion electrofishing, sufficient numbers of age-0 rainbow trout were captured in the side channel section to generate population estimates in eight of ten years (Table 6). In the side channel, population estimates of age-1 and older rainbow were generated in four of ten years (Table 7).

Because rainbow trout constitute a significant component of the Lee Vining trout fishery, an effort has been made to utilize whatever data were available in all years to generate density and biomass values. In years when sufficient numbers of rainbow trout were sampled to generate population estimates, these statistically valid estimates were used to compute density and biomass estimates. In years when insufficient numbers of rainbow trout were sampled to generate population estimates, catch numbers were used to compute density and biomass values. Although catch numbers are not statistically valid, density estimates generated by catch numbers are consistently lower than mark-recapture estimates in seasons when comparisons can be made (Tables 4 and 5).

Table 4. Numbers of age-0 rainbow trout caught in Lee Vining Creek main channel section, 2000-2009.

Sample Year	Area of Sample Section (Ha)	Number of Fish on Marking Run	Number of Fish on Capture Run	Number of Recap Fish	Pop Estimate	Estimated Number of Fish per Hectare	Number of Fish Caught (Catch)	Catch per Hectare
2009	0.1377	4	4	0	NP	NP	8	58
2008	0.1377	17	31	9	57	414	39	283
2007	0.0884	42	56	22	106	1,199	76	860
2006	NS*	--	--	--	--	--	--	--
2005	0.0744	0	0	0	0	0	0	0
2004	0.0744	1	0	0	NP	NP	1	13
2003	0.0744	0	0	0	0	0	0	0
2002	0.0744	0	1	0	NP	NP	1	13
2001	0.0898	3	5	1	NP	NP	7	78
2000	0.0898	0	1	0	NP	NP	1	22

*NS stands for not sampled due to high flows

Table 5. Numbers of age-1 and older rainbow trout caught in Lee Vining Creek main channel section, 2000-2009.

Sample Year	Area of Sample Section (Ha)	Number of Fish on Marking Run	Number of Fish on Capture Run	Number of Recap Fish	Pop Estimate	Estimated Number of Fish per Hectare	Number of Fish Caught (Catch)	Catch per Hectare
2009	0.1377	39	32	12	98	712	68	494
2008	0.1377	71	64	37	129	936	98	712
2007	0.0884	3	5	1	NP	NP	7	79
2006	NS*	--	--	--	--	--	--	--
2005	0.0744	3	3	0	NP	NP	6	81
2004	0.0744	2	2	2	NP	NP	2	27
2003	0.0744	5	6	5	NP	NP	6	81
2002	0.0744	10	10	7	14	188	13	175
2001	0.0898	9	8	4	NP	NP	13	145
2000	0.0898	1	3	0	NP	NP	4	45

*NS stands for not sampled due to high flows

Table 6. Numbers of age-0 rainbow trout caught in Lee Vining Creek side channel section, 2000-2009.

Sample Year	Area of Sample Section (Ha)	Number of Fish Caught on Pass #1	Number of Fish Caught on Pass #2	Number of Fish Caught on Pass #3	Pop Estimate	Estimated Number of Fish per Hectare	Number of Fish Caught (Catch)	Catch per Hectare
2009	0.0488	0	0	--	0	0	0	0
2008	0.0488	5	2	--	7	143	7	143
2007	0.0488	4	0	--	NP	NP	4	82
2006	0.0761	46	26	--	100	1,314	72	946
2005	0.0936	0	0	--	0	0	0	0
2004	0.0936	82	30	--	127	1,357	112	1,197
2003	0.0936	0	0	--	0	0	0	0
2002	0.0936	28	17	--	64	684	45	481
2001	0.1310	69	23	--	102	779	92	702
2000	0.0945	32	15	--	57	603	47	497

Table 7. Numbers of age-1 and older rainbow trout caught in Lee Vining Creek side channel section, 2000-2009.

Sample Year	Area of Sample Section (Ha)	Number of Fish Caught on Pass #1	Number of Fish Caught on Pass #2	Number of Fish Caught on Pass #3	Pop Estimate	Estimated Number of Fish per Hectare	Number of Fish Caught (Catch)	Catch per Hectare
2009	0.0488	15	0	--	15	307	15	307
2008	0.0488	3	1	--	4	82	4	82
2007	0.0488	6	0	--	NP	NP	6	123
2006	0.0761	5	0	--	NP	NP	5	66
2005	0.0936	7	2	--	9	96	9	96
2004	0.0936	5	0	--	NP	NP	5	53
2003	0.0936	13	0	--	NP	NP	13	139
2002	0.0936	29	4	--	33	353	33	353
2001	0.1310	38	3	--	41	313	41	313
2000	0.0945	9	0	--	NP	NP	9	95

Relative Condition of Brown Trout

Log_{10} transformed length-weight regressions for captured brown trout ≥100 mm had R^2-values over 0.98 for almost all sample events, indicating that weight was strongly correlated to length (Table 8). The length-weight relationships observed during 2009 indicated condition of brown trout 100 mm and longer in Rush Creek improved from the poorer conditions that occurred in 2007 and 2008 (Table 8). Brown trout in Lee Vining Creek appeared to be in good condition in 2009 and improved from the previous year (Table 4 and Figure 15).

A fish condition factor of 1.00 is considered average and mean condition factors for brown trout 150 to 250 mm were ≥1.00 for all sections in Rush Creek and in Walker Creek, indicating that brown trout condition was average-to-good in these sections during 2009 (Figure 16). Generally, condition factors in all sections declined between 2005 and 2008, with poor condition factors in 2007 and 2008 (Figure 16). Specifically, in 2008 the County Road section had a condition factor of less than 0.9 and this was the lowest value documented in 10 years of annual sampling (Figure 16). However, in 2009 condition factor in the County Road section improved to 1.00 (Figure 16). For 2009, the Upper Rush Creek section experienced an increase in condition factor from the previous year and was greater than 1.00 for the first time since 2006 (Figure 16). The 2009 season was the second year that the Bottomlands section of Rush Creek was sampled and the condition factor was 1.00, up from 0.92 computed for 2008 (Figure 16).

The mean condition factor for 150 to 250 mm brown trout in Lee Vining Creek during 2009 was over 1.00 in both the main and side channel sections, indicating that brown trout condition was good. The mean condition factors in 2009 were improvements from the 2008 values which were the lowest condition factors documented in Lee Vining Creek since annual sampling started in 1999 (Figure 16).

Table 8. Regression statistics for $\log_{10}$ transformed length (L) to weight (WT) for brown trout 100 mm and longer captured in Rush Creek by sample section and year. The 2009 regression equations are in **bold** type.

Section	Year	N	Equation	R^2	P
County Road	2000	412	$\log_{10}(WT) = 2.94*\log_{10}(L) - 4.83$	0.99	< 0.01
	2001	552	$\log_{10}(WT) = 2.91*\log_{10}(L) - 4.81$	0.98	< 0.01
	2002	476	$\log_{10}(WT) = 2.95*\log_{10}(L) - 4.88$	0.99	< 0.01
	2003	933	$\log_{10}(WT) = 3.00*\log_{10}(L) - 5.01$	0.99	<0.01
	2004	655	$\log_{10}(WT) = 2.97*\log_{10}(L) - 4.94$	0.99	<0.01
	2005	257	$\log_{10}(WT) = 2.97*\log_{10}(L) - 4.90$	0.98	<0.01
	2006	373	$\log_{10}(WT) = 3.00*\log_{10}(L) - 5.00$	0.99	<0.01
	2007	912	$\log_{10}(WT) = 2.789*\log_{10}(L) - 4.565$	0.98	<0.01
	2008	398	$\log_{10}(WT) = 2.794*\log_{10}(L) - 4.585$	0.99	<0.01
	2009	**456**	$\mathbf{\log_{10}(WT) = 2.994*\log_{10}(L) - 4.898}$	**0.99**	**<0.01**
Bottomlands	2008	611	$\log_{10}(WT) = 2.773*\log_{10}(L) - 4.524$	0.99	<0.01
	2009	**511**	$\mathbf{\log_{10}(WT) = 2.920*\log_{10}(L) - 4.821}$	**0.99**	**<0.01**
Upper	1999	317	$\log_{10}(WT) = 2.93*\log_{10}(L) - 4.84$	0.98	< 0.01
	2000	309	$\log_{10}(WT) = 3.00*\log_{10}(L) - 4.96$	0.98	< 0.01
	2001	335	$\log_{10}(WT) = 2.99*\log_{10}(L) - 4.96$	0.99	< 0.01
	2002	373	$\log_{10}(WT) = 2.94*\log_{10}(L) - 4.86$	0.99	< 0.01
	2003	569	$\log_{10}(WT) = 2.96*\log_{10}(L) - 4.89$	0.99	<0.01
	2004	400	$\log_{10}(WT) = 2.97*\log_{10}(L) - 4.94$	0.99	<0.01
	2005	261	$\log_{10}(WT) = 3.02*\log_{10}(L) - 5.02$	0.99	<0.01
	2006	485	$\log_{10}(WT) = 2.99*\log_{10}(L) - 4.98$	0.99	<0.01
	2007	436	$\log_{10}(WT) = 2.867*\log_{10}(L) - 4.715$	0.99	<0.01
	2008	594	$\log_{10}(WT) = 2.967*\log_{10}(L) - 4.937$	0.99	<0.01
	2009	**612**	$\mathbf{\log_{10}(WT) = 2.941*\log_{10}(L) - 4.855}$	**0.99**	**<0.01**
MGORD	2000	82	$\log_{10}(WT) = 2.909*\log_{10}(L) - 4.733$	0.98	<0.01
	2001	769	$\log_{10}(WT) = 2.873*\log_{10}(L) - 4.719$	0.99	<0.01
	2004	449	$\log_{10}(WT) = 2.984*\log_{10}(L) - 4.973$	0.99	<0.01
	2006	593	$\log_{10}(WT) = 2.956*\log_{10}(L) - 4.872$	0.98	<0.01
	2007	643	$\log_{10}(WT) = 2.914*\log_{10}(L) - 4.825$	0.98	<0.01
	2008	862	$\log_{10}(WT) = 2.827*\log_{10}(L) - 4.602$	0.98	<0.01
	2009	**689**	$\mathbf{\log_{10}(WT) = 2.974*\log_{10}(L) - 4.933}$	**0.99**	**<0.01**

Figure 15. Relative length-weight relationships for brown trout 100 mm and longer in four sections of Rush Creek (County Road: Co Rd, Bottomlands: Bottom, Upper, and the MGORD), the Lower section of Lee Vining Creek (LV-Low Main), and Walker Creek during 2009.

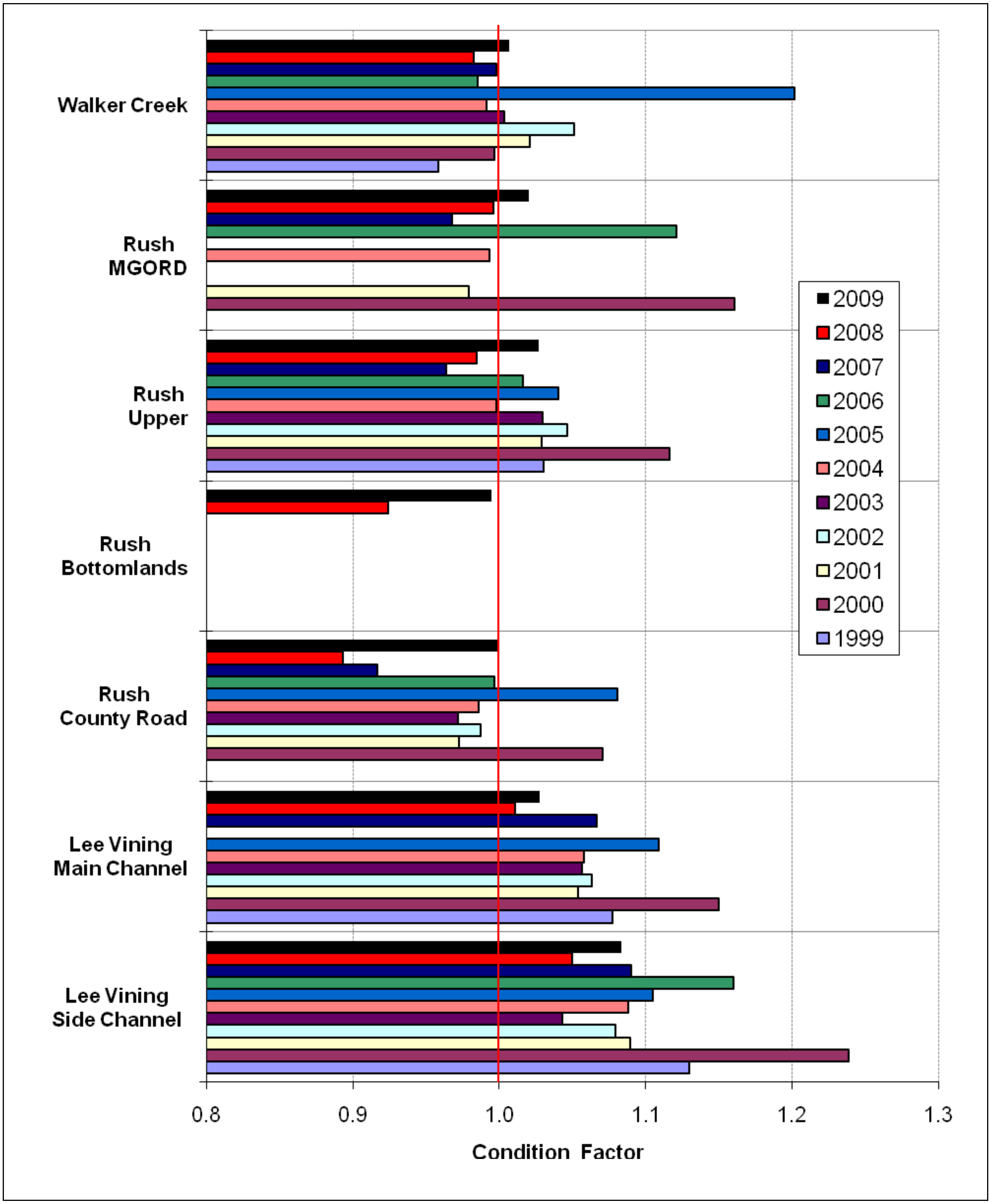


Figure 16. Condition factors for brown trout 150 to 250 mm long in sample sections of Rush, Lee Vining, and Walker creeks from 1999 to 2009. Note the x-scale starts at 0.8 and red vertical line indicates condition factor of 1.0.

Fin Clips and Growth Estimates of Brown Trout

During the 2008 sampling season 1,201 age-0 brown trout and 39 age-0 rainbow trout had their adipose fin removed so that growth of this cohort of fish could be tracked in subsequent years (Table 9). In 2009, 234 adipose fin-clipped fish (229 brown trout and 5 rainbow trout) were re-captured as age-1 fish: 136 in Rush Creek, 48 in Walker Creek, and 50 in Lee Vining Creek (Table 10). Average growth for the one year between 2008 and 2009, based on these recaptures, was 78.4 mm in length and 40.7 g in weight for brown trout in the County Road section of Rush Creek, 84.1 mm and 42.8 g for brown trout in the Bottomlands section of Rush Creek, 89.3 mm and 51.2 g for brown trout in the Upper Rush Creek section, and 67.9 mm and 26.9 g for brown trout in Walker Creek (Table 10). In Lee Vining Creek, the 45 brown trout re-captured as age-1 fish grew an average of 82.0 mm in length and gained an average weight of 45.4 g (Table 10).

In Lee Vining Creek, five age-1 rainbow trout were captured in 2009 that had received adipose fin clips as age-0 fish in 2008, and these five fish exhibited an average growth of 113.4 mm and 77.4 g (Table 11).

Apparent one-year survivals (2008 to 2009), based on the number originally clipped and assuming that any fish that left the sampling area died (“apparent mortality”), were approximately 28% for the County Road section, 25% for the Bottomlands section, 11% for the Upper section of Rush Creek and 15% for Walker Creek (Table 9). In Lee Vining Creek, the apparent one-year survival of age-0 to age-1 brown trout between September 2008 and 2009 was approximately 30% (Table 9).

PIT Tagging of Trout in Rush and Lee Vining Creeks

In 2009, a total of 1,596 age-0 trout received adipose fin clips and PIT tags, 1,572 were brown trout and 24 were rainbow trout (Table 12). In Rush Creek, 597 age-0 trout were clipped and tagged, in Walker Creek 114 age-0 fish were clipped and tagged, and in Lee Vining Creek 19 age-0 fish were clipped and tagged (Table 13).

In Rush Creek, 765 age-1 and older trout received adipose fin clips and PIT tags (642 were MGORD fish), in Walker Creek 51 age-1 trout were clipped and tagged, and in Lee Vining Creek 47 age-1 trout were clipped and tagged (Table 12).

Table 9. Average length (mm), minimum length, maximum length, average weight (g), and number (1,240 total fish) of age-0 trout that received adipose fin clips during the 2008 sampling season, by stream, sample section, and species.

Stream	Sample Section	Species	Number of Fish Clipped	Mean Length (mm)	Mean Weight (g)	Minimum Length (mm)	Maximum Length (mm)
Lee Vining Creek	Main Channel	Rainbow Trout	38	79.1	5.9	59.0	100.0
Lee Vining Creek	Main Channel	Brown Trout	150	91.6	8.0	70.0	107.0
Rush Creek	County Road	Brown Trout	109	88.0	7.2	60.0	120.0
Rush Creek	Bottom-lands	Brown Trout	274	86.8	6.7	58.0	119.0
Rush Creek	Upper	Rainbow Trout	1	82.0	--	82.0	82.0
Rush Creek	Upper	Brown Trout	349	90.7	7.8	61.0	120.0
Walker Creek	Above old 395	Brown Trout	319	77.1	4.7	56.0	119.0

Table 10. Age-1 brown trout captured in 2009 with adipose fin clips administered during the 2008 sampling season, by stream reach.

Collection Location	Number of Fish Recap.	Ave. Total Length (mm)	Min. Total Length (mm)	Max. Total Length (mm)	Ave. Weight (g)	Percent Recap.	Growth Ave. Length (mm)	Growth Ave. Weight (g)
Lee Vining Ck - Main	45	173.6	145	202	53.4	30%	82.0	45.4
Rush - Co. Road	30	166.0	134	206	48.0	28%	78.0	40.8
Rush - Bottomlands	68	170.9	146	203	49.5	25%	84.1	42.8
Rush - Upper	38	180.0	163	210	59.0	11%	89.3	51.2
Walker Creek	48	145.0	107	175	31.6	15%	67.9	26.9

Table 11. Age-1 rainbow trout captured in 2009 with adipose fin clips administered during the 2008 sampling season, by stream reach.

Collection Location	Number of Fish Recap.	Ave. Total Length (mm)	Min. Total Length (mm)	Max. Total Length (mm)	Ave. Weight (g)	Percent Recap.	Growth Ave. Length (mm)	Growth Ave. Weight (g)
Lee Vining Ck - Main	4	192.5	*167	212	83.3	11%	113.4	77.4
Rush - Upper	1	224	224	224	119	100%	142.0	**N/A

* This individual was captured in the side channel sampling section.
** Fish was not weighed in 2008 – see Table 9.

Table 12. Total numbers of trout implanted with PIT tags during the 2009 sampling season, by stream, sample section, age-class and species.

Stream	Sample Section	Number of Age-0 Browns	Number of Age-1 Browns	Number of Age-0 Rainbows	Number of Age-1 Rainbows	Reach Totals
Lee Vining Creek	Main Channel	10	45	4	3	62 fish
Lee Vining Creek	Side Channel	5	0	0	1	6 fish
Rush Creek	County Road	108	29	0	0	137 fish
Rush Creek	Bottom-lands	164	68	0	0	232 fish
Rush Creek	Upper	256	26	15	1	298 fish
Rush Creek	MGORD	54	642*	0	0	696 fish
Walker Creek	Above old 395	114	51	0	0	165 fish
Species and Age-class Totals:		**711**	**861**	**19**	**5**	**Grand Total: 1,596 fish**

*Many of these MGORD fish were >age-1.

Table 13. Average length (mm), minimum length, maximum length, average weight (g), and number (730 total fish) of age-0 trout implanted with PIT tags during the 2009 sampling season, by stream, sample section, and species.

Stream	Sample Section	Species	Number of Fish Clipped	Mean Length (mm)	Mean Weight (g)	Minimum Length (mm)	Maximum Length (mm)
Lee Vining Creek	Main+Side Channel	Rainbow Trout	4	76.0	4.8	73.0	81.0
Lee Vining Creek	Main+Side Channel	Brown Trout	15	93.4	8.9	80.0	105.0
Rush Creek	County Road	Brown Trout	108	93.3	9.3	80.0	123.0
Rush Creek	Bottom-lands	Brown Trout	164	97.4	9.9	80.0	119.0
Rush Creek	Upper	Rainbow Trout	15	89.2	7.9	80.0	114.0
Rush Creek	Upper	Brown Trout	256	102.0	11.6	80.0	125.0
Walker Creek	Above old 395	Brown Trout	114	87.5	6.8	80.0	101.0

Table 14. Average length (mm), minimum length, maximum length, average weight (g), and number (225 total fish) of known age-1 trout (ad-clip recaps) implanted with PIT tags during the 2009 sampling season, by stream, sample section, and species.

Stream	Sample Section	Species	Number of Fish Clipped	Mean Length (mm)	Mean Weight (g)	Minimum Length (mm)	Maximum Length (mm)
Lee Vining Creek	Main+Side Channel	Rainbow Trout	4	192.5	83.3	167.0	212.0
Lee Vining Creek	Main+Side Channel	Brown Trout	45	173.6	53.4	145.0	202.0
Rush Creek	County Road	Brown Trout	29	166.4	47.9	134.0	206.0
Rush Creek	Bottom-lands	Brown Trout	68	170.9	50.2	146.0	203.0
Rush Creek	Upper	Rainbow Trout	1	224.0	119.0	224.0	224.0
Rush Creek	Upper	Brown Trout	26	181.1	59.5	163.0	210.0
Rush Creek	MGORD	Brown Trout	1	213.0	87.0	213.0	213.0
Walker Creek	Above old 395	Brown Trout	48	145.0	31.6	107.0	175.0

Estimated Trout Density Comparisons

In 2009, the estimated densities (number per hectare) of age-1 and older brown trout in the County Road section of Rush Creek was the highest ever recorded at any section on Rush Creek during the eleven-year sampling period (Figure 17). This record density is a continuation of a recent trend at this section, where numbers of age-1+ brown trout per hectare roughly doubled to an average of about 2,000 fish/ha during 2007 through 2009, compared to an average density of around 1,000 fish/ha for the 2000 through 2006 time period (Figure 17).

Between 2008 and 2009, the Bottomlands and Upper sections of Rush Creek both experienced slight decreases in the estimated densities of age-1 and older brown trout (Figure 17). The Bottomlands section of Rush Creek had an estimated density of 1,489 age-1 and older brown trout/ha (Figure 17). The Upper section of Rush Creek had an estimated density of 1,318 age-1 and older brown trout/ha. The 2009 density value at the Upper section represents a continuation of a recent trend, where numbers of age-1+ brown trout per hectare have gradually declined from 2007 through 2009 (Figure 17).

In Walker Creek the 2009 density estimate was 14% less than the 2008 estimate; however the 2009 density estimate of 6,348 age-1 and older brown trout/ha was the second highest estimate for the eleven-year sampling period (Figure 17). Since 2002 Walker Creek has annually had the highest density estimates of age-1 and older brown trout for all sample sections (Figure 17).

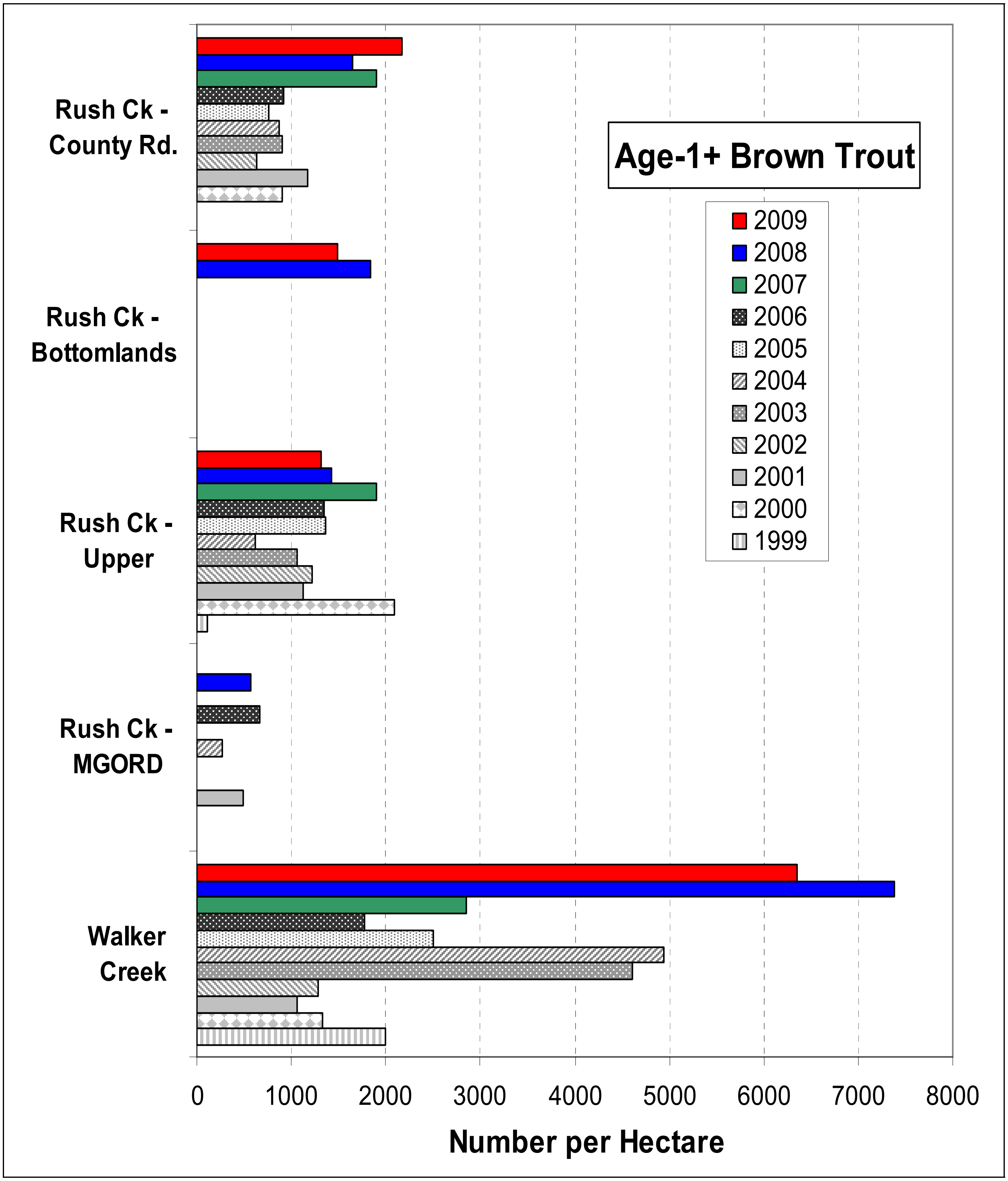


Figure 17. Estimated number of age-1 and older brown trout per hectare in sections of Rush and Walker creeks from 1999 to 2009.

The six age-1 and older brown trout captured in the side channel section of Lee Vining Creek produced an estimated density of 123.1 fish/ha in 2009 (Figure 18). This side channel has had very low baseflows since RY2006 and therefore has supported relatively few fish the past four years (Figure 18). Between 2008 and 2009, the estimated density of age-1 and older brown trout (1,083.4 kg/ha) in the main channel of Lee Vining Creek decreased by 16%; however the 2009 estimate was the 5th highest in the 11 sample seasons (Figure 18).

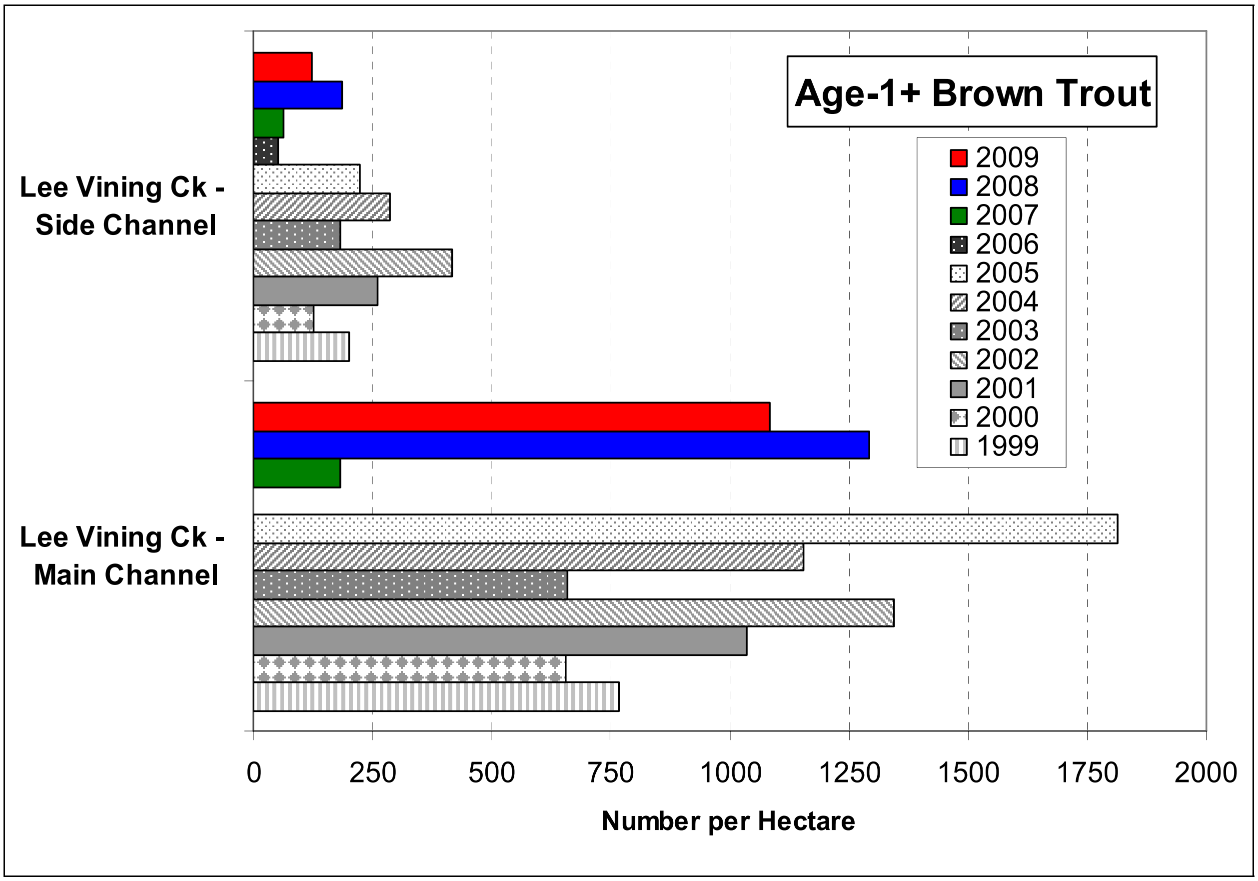


Figure 18. Estimated number of age-1 and older brown trout per hectare in sections of Lee Vining Creek from 1999 to 2009.

Estimated densities of age-1 and older rainbow trout during 2009 in the Lee Vining Creek main channel section were the second highest recorded for the 11 years of annual sampling (Figure 19). For Lee Vining Creek, the 2009 main channel density estimate was the second rainbow trout density estimate derived from a population estimate since the 2002 sampling season. For the years 1999-2001, 2003-2005 and 2007 insufficient numbers of age-1 and older rainbow trout were captured to generate population estimates, thus these density estimates were derived from catch data. In 2006 the flow was too high to safely electro-fish the main channel.

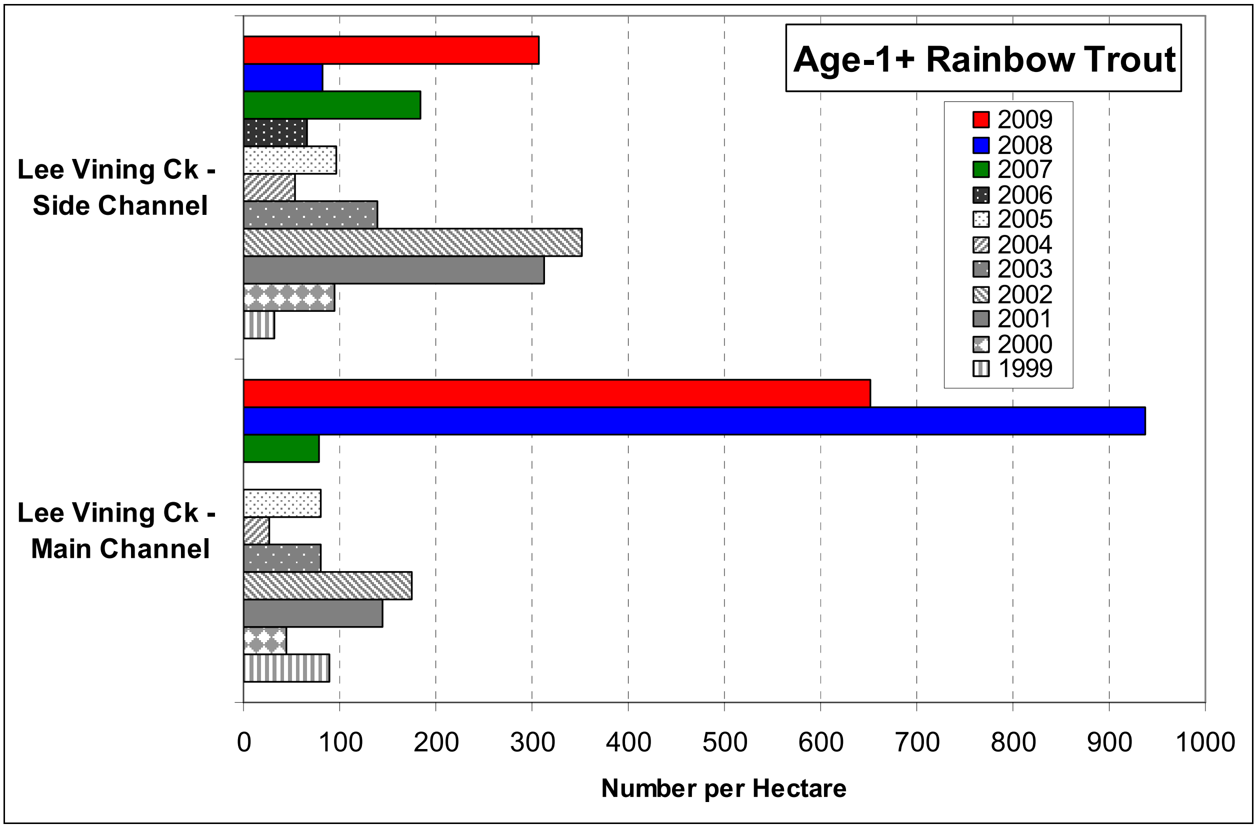


Figure 19. Estimated number of age-1 and older rainbow trout per hectare in sections of Lee Vining Creek from 1999 to 2009.

Between 2008 and 2009, estimated densities of age-0 brown trout dropped in all three Rush Creek sections (Figure 20). The Upper section’s 2009 density estimate (2,509 age-0 brown trout/ha) dropped by 5% from the 2008 estimate to the lowest estimate ever recorded for this section. The new Rush Creek Bottomlands section had an estimated density of 2,357 age-0 brown trout/ha in 2009, which was an 11% drop from the 2008 estimate (Figure 20).

In Walker Creek age-0 densities of brown trout decreased by 54% in 2009 from 2008; however the 2009 density estimate of 8,478 age-0 brown trout/ha was still greater than any section of Rush Creek during the past eight years (Figure 20).

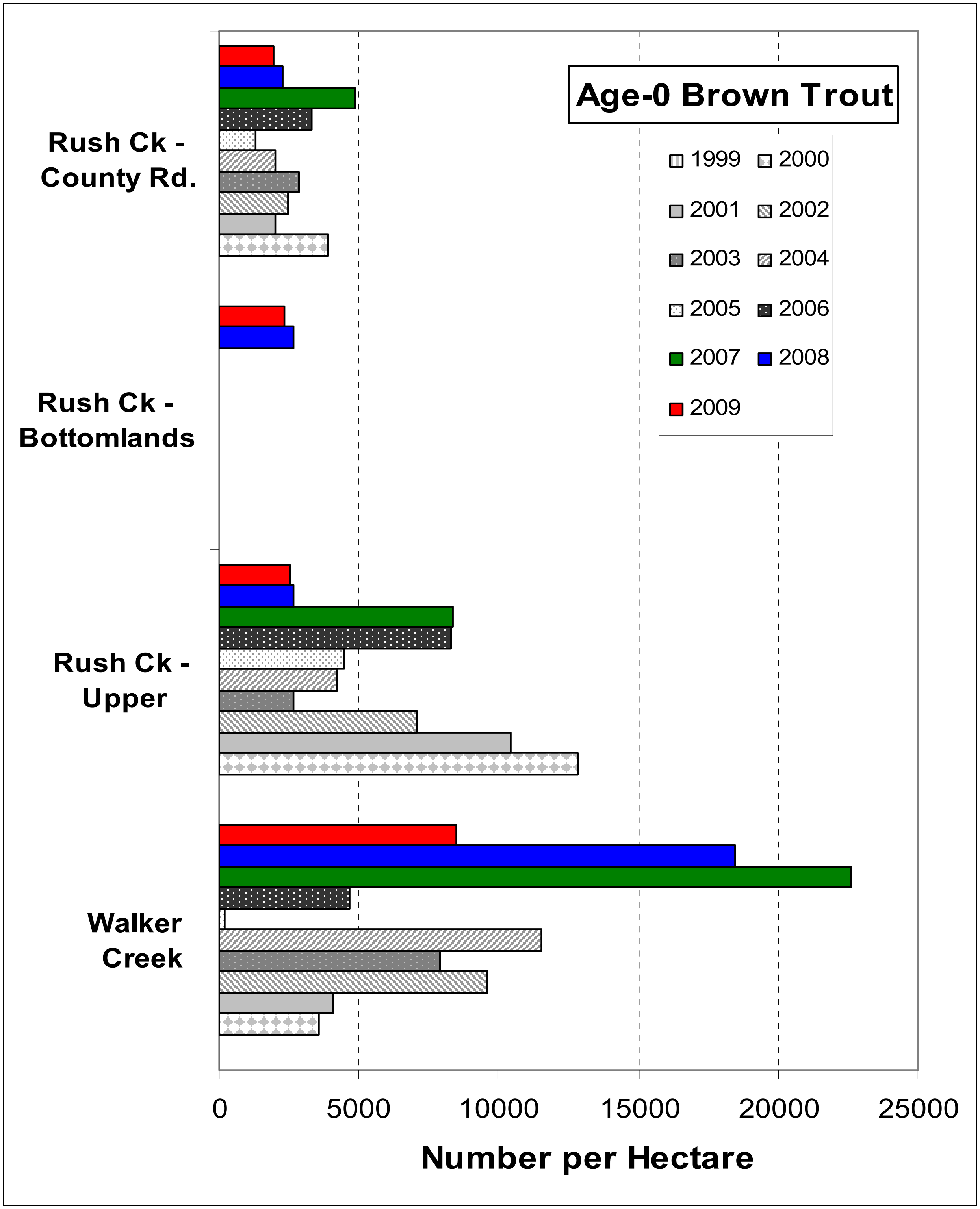


Figure 20. Estimated number of age-0 brown trout per hectare in sections of Rush Creek (bottom) and Walker creeks (top) from 1999 to 2009.

In 2009, the age-0 brown trout density estimate in the main channel section of Lee Vining Creek dropped by 93% from densities estimated in 2008 (Figure 21). Five age-0 brown trout were captured in 2009 within the Lee Vining Creek side channel which generated a density estimate of 102.6 age-0 brown trout/ha (Figure 21).

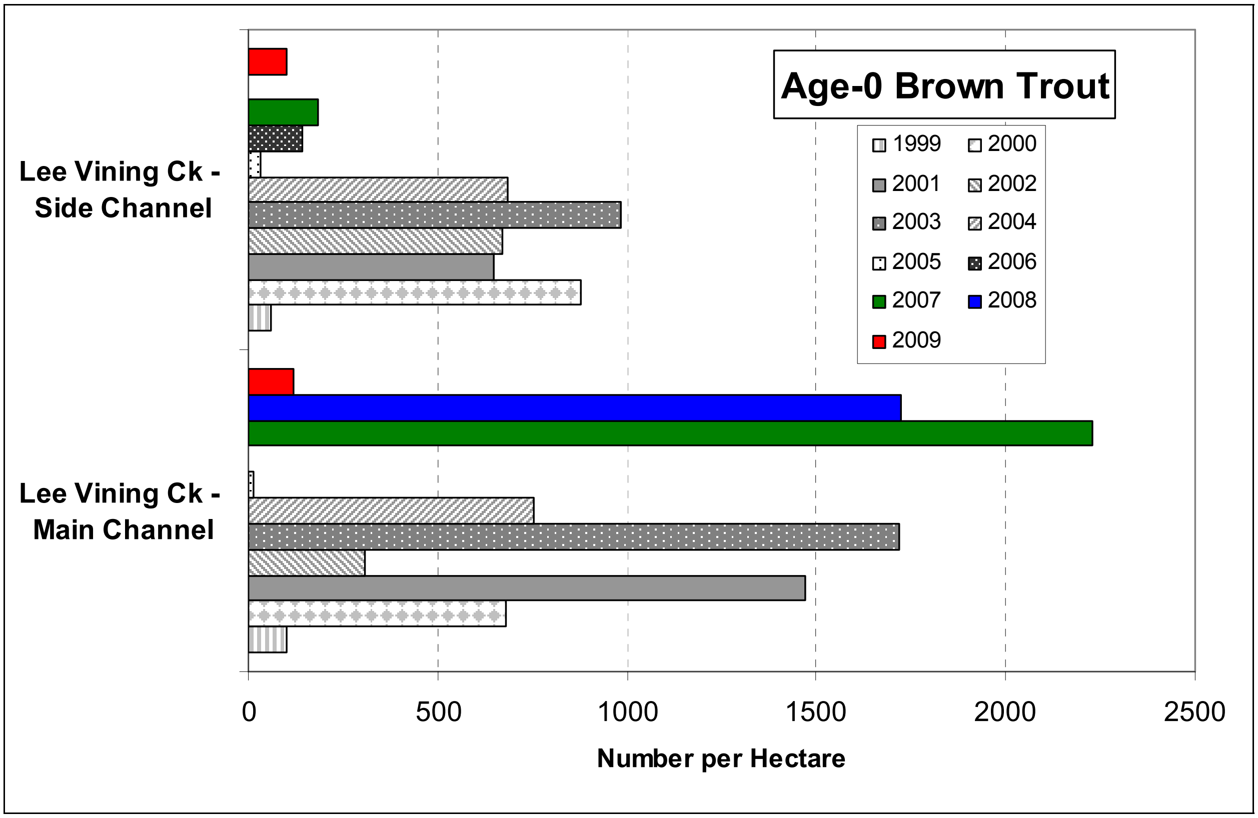


Figure 21. Estimated number of age-0 brown trout per hectare in sections of Lee Vining Creek from 1999 to 2009.

In 2008, the age-0 rainbow trout density estimate in the main channel section of Lee Vining Creek dropped by 86% from densities estimated in 2008. This was the second straight year in which a large decrease in age-0 rainbow trout densities decreased (a decrease of 65% occurred between 2007 and 2008) (Figure 22). In 2009, no age-0 rainbow trout were sampled in the side channel section of Lee Vining Creek (Figure 22).

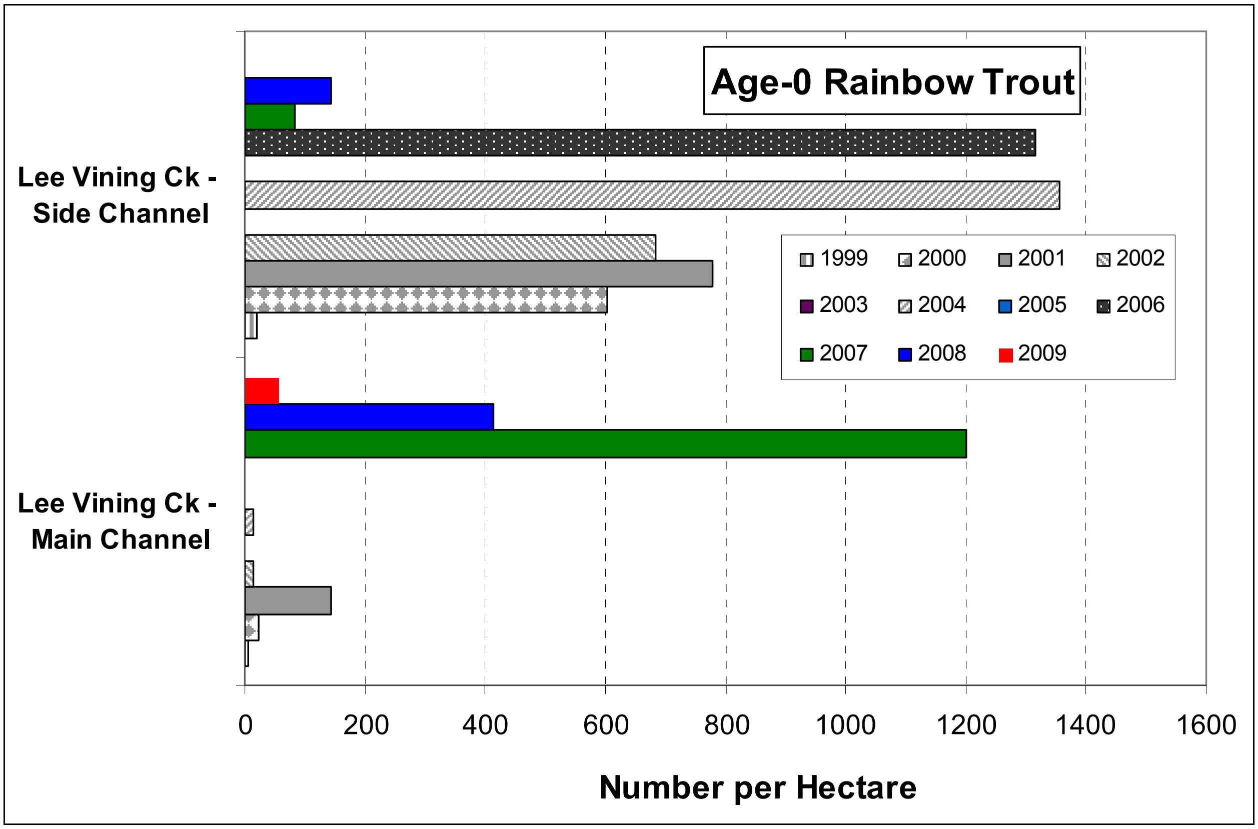


Figure 22. Estimated number of age-0 rainbow trout per hectare in sections of Lee Vining Creek from 1999 to 2009. Note: the 2009 main channel density estimate was derived from catch data.

Estimated Trout Densities Expressed in Numbers per Unit Length

For termination criteria purposes, trout density estimates were also calculated by number of fish per kilometer of stream channel. In the Rush Creek sections the numbers of fish per kilometer were estimated for brown trout only (Table 15). In the Lee Vining Creek sections the numbers of fish per kilometer were estimated for brown and rainbow trout combined (Table 16). In Rush Creek from 2008 to 2009, the County Road section experienced a 4% drop in total numbers of brown trout per km, but a 20% increase in the numbers of age-1 and older brown trout per km (Table 15). The Bottomlands section of Rush Creek experienced a 17% decrease in total numbers of brown trout per km, which included a 22% decrease in the numbers of age-1 and older brown trout per km (Table 15). The Upper section experienced a 5% drop in total numbers of brown trout per km and a 6% decrease in the numbers of age-1 and older brown trout per km (Table 15).

In Lee Vining Creek from 2008 to 2009, the main channel section experienced a 49% decrease in the total numbers of trout per km and the numbers of age-1 and older trout per km decreased by 15% (Table 16). In 2009, the estimate of 1,023 age-1 and older trout per km in the main channel section was the second highest estimate for this section (Table 16). From 2008 to 2009, the side channel section experienced a 29% increase in the total numbers of trout per km and the numbers of age-1 and older trout per km increased by 61% (Table 16).

Table 15. Total number of brown trout per kilometer of stream channel for Rush Creek sample sections, 2000 - 2009. The value within (#) denotes the number of age-1 and older trout per kilometer.

Collection Location	2000 Total Number of Brown Trout per Km	2001 Total Number of Brown Trout	2002 Total Number of Brown Trout	2003 Total Number of Brown Trout	2004 Total Number of Brown Trout	2005 Total Number of Brown Trout	2006 Total Number of Brown Trout	2007 Total Number of Brown Trout	2008 Total Number of Brown Trout	2009 Total Number of Brown Trout
Rush Ck-County Road	3,832 (725)	2,530 (942)	2,618 (536)	3,136 (764)	2,095 (641)	1,737 (641)	3,242 (702)	5,011 (1,402)	3,186 (1,346)	3,064 (1,611)
Rush Ck – Bottomland	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3,579 (1,467)	2,961 (1,146)
Rush Ck-Upper	11,054 (1,547)	8,535 (837)	6,137 (900)	2,740 (791)	3,881 (495)	5,032 (1,167)	7,905 (1,100)	8,698 (1,621)	3,607 (1,267)	3,444 (1,186)

Table 16. Total number of brown and rainbow trout per kilometer of stream channel for Lee Vining Creek sample sections, 2000 – 2009. The value within (#) denotes the number of age-1 and older trout per kilometer.

Collection Location	2000 Total Number of Brown and Rainbow Trout per Km	2001 Total Number of Brown and Rainbow Trout	2002 Total Number of Brown and Rainbow Trout	2003 Total Number of Brown and Rainbow Trout	2004 Total Number of Brown and Rainbow Trout	2005 Total Number of Brown and Rainbow Trout	2006 Total Number of Brown and Rainbow Trout	2007 Total Number of Brown and Rainbow Trout	2008 Total Number of Brown and Rainbow Trout	2009 Total Number of Brown and Rainbow Trout
Lee Vining - Main Channel	674 (337)	1,333 (567)	883 (729)	1,181 (355)	936 (568)	917 (910)	Not Sampled – high flow	2,103 (148)	2,357 (1,204)	1,192 (1,023)
Lee Vining - Side Channel	853 (112)	623 (287)	731 (369)	626 (154)	1,144 (165)	169 (154)	618 (48)	129 (62)	103 (67)	133 (108)
LV Main and Side Averaged	764 (225)	978 (427)	807 (549)	904 (255)	1,040 (367)	543 (532)	Not Averaged In 2006	1,116 (105)	1,230 (636)	663 (54)

Estimated Trout Standing Crop Comparisons

In Rush Creek, brown trout standing crop estimates increased from 2008 to 2009 in all sample sections (Table 17 and Figure 23). In the County Road section, the 2008 estimated standing crop of 143.9 kg/ha was the highest value ever recorded in this section and was a 68% increase from the 2008 estimate (Table 17 and Figure 23). In the Bottomlands section, the 2009 estimated standing crop of 129.1 kg/ha was a 32% increase from the 2008 estimate (Table 17). In the Upper Rush section, the 2009 estimated standing crop of 131.2 kg/ha was a 22% increase from the 2008 estimate (Table 17). However; 2009 was the first year in the eleven year study period when brown trout standing crop values were higher at the County Road section compared to the Upper Rush section (Figure 23). Between 2008 and 2009, Walker Creek experienced a decrease of 16% in estimated standing crop; however both of these years had estimates greater than 400 kg/ha (Table 17 and Figure 23). In Lee Vining Creek total standing crops (brown and rainbow trout combined) increased by 114% between 2008 and 2009 in the side channel area, but in the main channel total standing crops decreased by 25% between 2008 and 2009 (Table 18 and Figure 24).

Total standing crops (all age classes and species combined) have been estimated since 1999 to determine potential trends (Figures 23 and 24). Total standing crop takes into account the total biomass of fish per unit area, not necessarily the age-class structure of the trout populations. In Rush Creek, where brown trout have dominated the fish community, the County Road section's estimated total standing crop remained fairly constant from 2000 through 2005; followed by two straight seasons of increased production in 2006 and 2007; a nearly 30% decrease in 2008 (although this value was still higher than any estimated from 2000 through 2005); and finally a nearly 70% increase in 2009 (Figure 23). In the Rush Creek Upper section after the peak standing crop estimate in 2000; estimates declined for four straight years (2001 - 2004); followed by three consecutive seasons with estimates greater than 150 kg/ha; and in 2008 a 34% decrease to 107.2 kg/ha (Figure 23). In the Upper section, total standing crop estimates declined for three consecutive sample years (2006 -2008) until the 22% increased recorded in 2009 (Figure 23). The relatively new Rush Creek Bottomlands section experienced an increase for the first time a comparison between sampling years was possible (Figure 23).

In Walker Creek, total standing crop estimates have generally increased since annual sampling started in 1999 and has recorded estimates greater than 300 kg/ha for the past four years (Figure 23). Although the 2009 total standing crop estimate was a 16% decrease from 2008, the 2009 estimate of 420.6 kg/ha was still higher than the maximum value for any other section of Rush Creek in the 11 years of annual sampling (Figure 23).

In Lee Vining Creek, although the main channel section's total standing crop estimate decreased by 25% between 2008 and 2009, the 2009 estimate was the fifth greatest for 11 years of annual sampling (Figure 24). As in 2008, the 2009 total standing crop estimate included a relatively large contribution of rainbow trout biomass (42% of the 2009 estimate) (Figure 24). The Lee Vining Creek side channel section's total standing crop estimate in 2009 of 49.5 kg/ha was the first significant increase since 2005, when the main channel started capturing a larger portion of the total summer base flow (Figure 24).

Table 17. Comparison of 2008-2009 brown trout standing crop (kg/ha) estimates in Rush Creek study sections.

Collection Location	2008 Total Standing Crop (kg/ha)	2009 Total Standing Crop (kg/ha)	Percent Change Between 2008 and 2009
Rush Creek - County Road	85.7	143.9	+ 68%
Rush Creek - Bottomlands	98.2	129.1	+ 32%
Rush Creek – Upper	107.2	131.2	+ 22%
Walker Creek	501.6	420.6	- 16%

Table 18. Comparison of 2008-2009 total (brown and rainbow trout) standing crop (kg/ha) estimates in Lee Vining Creek study sections.

Collection Location	2008 Total Standing Crop (kg/ha)	2009 Total Standing Crop (kg/ha)	Percent Change Between 2008 and 2009
Lee Vining Creek - Main Channel	181.9	136.1	- 25%
Lee Vining Creek - Side Channel	23.1	49.5	+114%

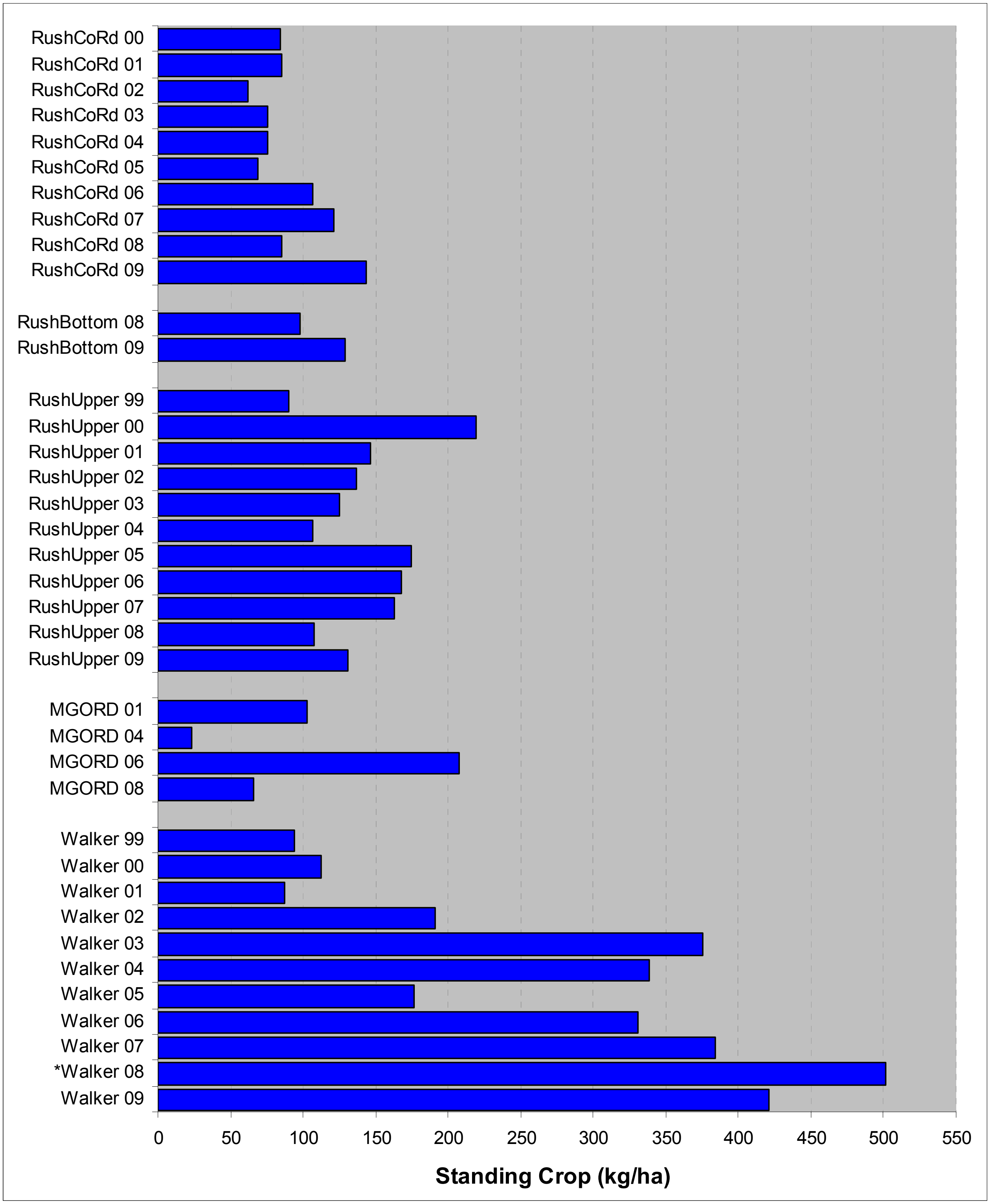


Figure 23. Estimated total standing crop (kilograms per hectare) of brown trout in all sample sections within the Rush Creek drainage, 1999 – 2009. Section and year are shown on the y-axis. *Walker Creek 2008 was originally reported as 290.1 kg/ha, but a computational error was found and corrected.

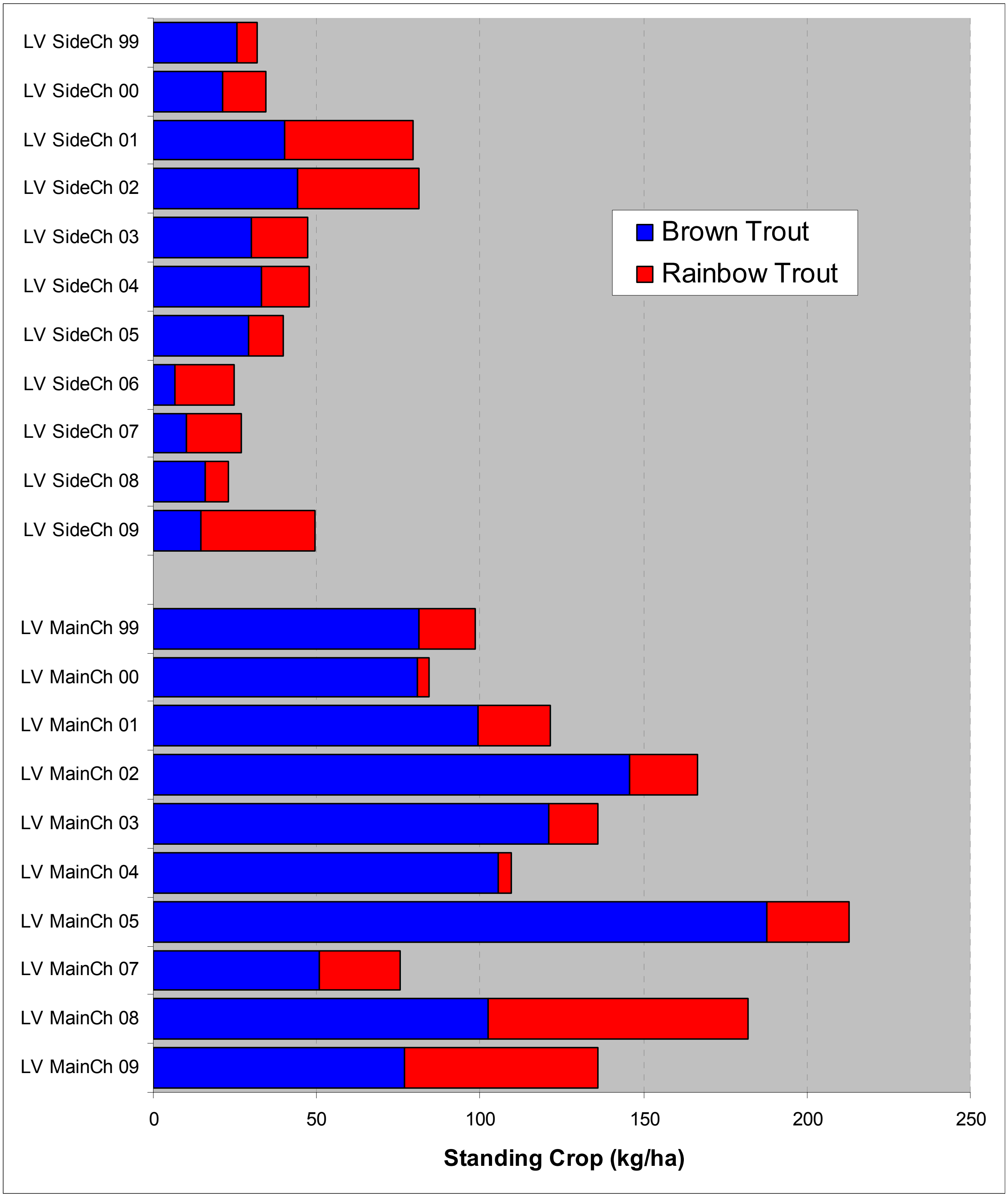


Figure 24. Estimated total standing crop (kilograms per hectare) of brown trout and rainbow trout in all sample sections within the Lee Vining Creek drainage, 1999 – 2009. Section and year are shown on the y-axis.

Relative Stock Density (RSD) Results for Rush and Lee Vining Creeks

RSD-225 values for brown trout in two of three Rush Creek sample sections decreased between 2008 and 2009, including a 22% drop in the County Road section and a 24% decrease in the Upper section (Table 19). This decrease can be attributed to higher numbers of brown trout in the 150-224 mm range at both sections, which reduced the proportion of fish >225 mm at these sections, since both sections had higher population estimates of brown trout >200 mm in 2009 than in 2008. The RSD-225 values for the County Road and Upper sample sections were the lowest values recorded for these sections during the past 10 sampling seasons and 2009 was the third consecutive year that values decreased in these two sections (Table 19). This drop in RSD-225 values during three straight low run-off years appears consistent with the relatively low RSD-225 values recorded between 2000 and 2003 in Rush Creek. Conversely in 2004-2006, which were years with relatively high stream run-off volumes, RSD-225 values were typically greater than 30. Between 2008 and 2009, the Bottomlands section of Rush Creek experienced a 20% increase in RSD-225 (Table 19).

RSD-300 values remained low in the Upper Rush Creek section, with a drop from 3 to 2 between 2008 and 2009; however two brown trout greater than 375 mm in length were sampled (Table 19). The Rush Creek County Road section has had an RSD-300 value of 0 since 2002, in other words, no fish greater than 300 mm (~12") have been captured in this section in the past eight seasons (Table 19). The Bottomlands section had an RSD-300 value of 1 in 2009, which included one fish greater than 375 mm in length (Table 19).

The RSD-225, RSD-300, and RSD-375 values in the MGORD section of Rush Creek all increased between 2008 and 2009 (Table 19). The RSD-225 value increased by 32% between 2008 and 2009, and the 338 brown trout between the lengths of 225-299 mm was the most fish ever sampled within this size class (Table 19). The RSD-300 value experienced a 30% increase between 2008 and 2009 (Table 19). The RSD-375 value for 2009 was 4 and has been 4 or less for three consecutive sampling years (Table 19).

In the Lee Vining Creek main channel sample section, the RSD-225 value for all trout (brown and rainbow trout combined) increased by 70% between 2008 and 2009, after a 75% drop occurred between 2007 and 2008 (Table 20). In 2009, the Lee Vining Creek main channel section had a RSD-300 value of 1 after two consecutive years where no fish greater than 300 mm were sampled (Table 20).

Table 19. RSD values for brown trout in Rush Creek study sections, for 2000-2009.

Sampling Location	Sample Year	Number of Fish ≥150 mm	Number of Fish ≥150-224 mm	Number of Fish 225-299 mm	Number of Fish 300-374 mm	Number of Fish ≥375 mm	RSD-225	RSD-300	RSD-375
Rush Ck – Co Rd	2009	356	331	25	0	0	7	0	
Rush Ck – Co Rd	2008*	97	88	9	0	0	9	0	
Rush Ck – Co Rd	2007	591	518	73	0	0	12	0	
Rush Ck – Co Rd	2006	265	187	78	0	0	29	0	
Rush Ck – Co Rd	2005	209	162	47	0	0	22	0	
Rush Ck – Co Rd	2004	409	355	54	0	0	13	0	
Rush Ck – Co Rd	2003	449	384	64	1	0	14	0	
Rush Ck – Co Rd	2002	303	262	40	1	0	14	0	
Rush Ck – Co Rd	2001	418	378	37	3	0	10	1	
Rush Ck – Co Rd	2000	320	277	43	0	0	13	0	
Rush Ck - Bottomlands	2009	379	321	56	1	1	15	1	
Rush Ck - Bottomlands	2008	160	141	19	0	0	12	0	
Rush Ck – Upper	2009	372	322	43	5	2	13	2	1
Rush Ck – Upper	2008	227	189	31	6	1	17	3	
Rush Ck – Upper	2007	282	210	61	9	2	26	4	1
Rush Ck – Upper	2006	233	154	69	10	0	34	4	
Rush Ck – Upper	2005	202	139	56	5	2	31	3	
Rush Ck – Upper	2004	179	112	64	2	1	37	2	
Rush Ck – Upper	2003	264	216	45	2	1	18	1	
Rush Ck – Upper	2002	220	181	35	1	2	18	2	1
Rush Ck – Upper	2001	223	190	27	6	0	15	3	
Rush Ck – Upper	2000	182	158	22	2	0	13	1	
Rush Ck - MGORD	2009	643	156	338	123	26	76	23	4
Rush Ck - MGORD	2008	856	415	301	118	22	52	16	3
Rush Ck - MGORD	2007	621	144	191	259	27	77	46	4
Rush Ck - MGORD	2006	567	60	200	280	27	89	54	5
Rush Ck - MGORD	2004	424	130	197	64	33	69	23	8
Rush Ck - MGORD	2001	774	330	217	119	108	57	29	14

*The relatively low number of fish captured ≥150 mm in 2008 is due to the shortening of the County Road section.

Table 20. RSD values for brown and rainbow trout in the Lee Vining Creek study section, for 2000-2009.

Sampling Location	Sample Year	Number of Fish ≥150 mm	Number of Fish ≥150-224 mm	Number of Fish 225-299 mm	Number of Fish 300-374 mm	Number of Fish ≥375 mm	RSD-225	RSD-300
Lee Vining Creek	2009	137	106	30	1	0	23	1
Lee Vining Creek	2008	149	138	11	0	0	7	0
Lee Vining Creek	2007	21	16	5	0	0	24	0
Lee Vining Creek	2006	NS	NS	NS	NS	NS	-	-
Lee Vining Creek	2005	60	37	20	2	1	38	5
Lee Vining Creek	2004	70	60	8	2	0	14	3
Lee Vining Creek	2003	52	27	23	2	0	48	4
Lee Vining Creek	2002	100	74	23	3	0	26	3
Lee Vining Creek	2001	90	71	16	3	0	21	3
Lee Vining Creek	2000	51	32	18	1	0	37	2

NS = not sampled due to high flow.

Termination Criteria Results

The following four tables summarize the termination criteria analyses of three-year running averages for the Rush Creek and Lee Vining Creek sample sections (Tables 21-24). In Rush Creek, none of the annually sampled sections met the target of meeting four out of five termination criteria (Tables 21 and 22). The County Road and Upper sections met only one of the five the termination criteria (density) (Tables 21 and 22).

Table 21. Termination criteria analyses for the County Road section of Rush Creek.

Termination Criteria	2007 – 2009 Average	2006 – 2008 Average	2005 – 2007 Average
Biomass (≥175 kg/ha)	116.8	104.4	98.9
Density (≥3,000 fish/km	**3,753.7**	**3,813.0**	**3,330.0**
Condition Factor (≥1.00)	0.94	0.94	**1.00**
RSD-225 (≥35)	9	17	21
RSD-300 (≥5)	0	0	0
Conclusion	**Met one of five TC**	**Met one of five TC**	**Met two of five TC**

Table 22. Termination criteria analyses for the Upper section of Rush Creek.

Termination Criteria	2007 – 2009 Average	2006 – 2008 Average	2005 – 2007 Average
Biomass (≥175 kg/ha)	133.7	145.8	168.2
Density (≥3,000 fish/km	**5,249.7**	**6,736.7**	**7,211.7**
Condition Factor (≥1.00)	0.99	0.99	**1.00**
RSD-225 (≥35)	19	26	30
RSD-300 (≥5)	3	4	4
Conclusion	**Met one of five TC**	**Met one of five TC**	**Met two of five TC**

The MGORD section of Rush Creek met only one of three RSD termination criteria (RSD-225) for the average of years 2007-2009 (Table 23). The RSD-375 average for 2007-2009 failed to meet termination criteria due to three consecutive years where low (less than 5) values were recorded (Table 23).

Table 23. Termination criteria analyses for the MGORD section of Rush Creek.

Termination Criteria	**2007 - 2009 Average**	**2006 - 2008 Average**	**2004/2006/2007 Average**
RSD-225 (≥60)	**68**	**73**	**78**
RSD-300 (≥30)	28	**39**	**41**
RSD-375 (≥5)	4	4	**6**
Conclusion	**Met TC one of three RSD values**	**Met TC two of three RSD values**	**Met TC for all three RSD values**

Because the Lee Vining Creek main channel section was not sampled in 2006, two of the three, three-year running averages were comprised of data collected in 2004, 2005 and 2007. In Lee Vining Creek, the current sampling section failed to achieve the target of meeting three out of four termination criteria (Table 24). The current sampling section has met the same two of the four termination criteria (biomass and condition factor) for the past three sets of three-year running averages (Table 24).

Table 24. Termination criteria analyses for the Lee Vining Creek sample section.

Termination Criteria	**2007 - 2009 Average**	**2005/2007/2008 Average**	**2004/2005/2007 Average**
Biomass (≥150 kg/ha)	**164.3**	**186.6**	**170.6**
Density (≥1,400 fish/km	1,003.0	963.0	899.7
Condition Factor (≥1.00)	**1.10**	**1.16**	**1.17**
RSD-225 (≥30)	18	23	25
Conclusion	**Met two of four TC**	**Met two of four TC**	**Met two of four TC**

Discussion

The 2009 sampling year was the eleventh consecutive year in which fish population data were collected in Rush and Lee Vining creeks with the methods refined from the two years of pilot studies (1997 and 1998). The year 2009 was also marked by completion of four supplemental reports by the Fisheries Stream Scientists and the initiation of developing the Synthesis Report. The four supplemental reports were: Rush and Lee Vining Creeks Instream Flow Study (Taylor et al. 2009a), Effects of Flow, Reservoir Storage, and Water Temperature on Trout in Lower Rush and Lee Vining Creeks, Mono County, California (Shepard et al. 2009a), Calibration of a Water Temperature Model for Predicting Summer Water Temperatures in Rush Creek below Grant Lake Reservoir (Shepard et al. 2009b), Radio-Telemetry Movement Study of Brown Trout in Rush Creek (Taylor et al. 2009b), and Pool and Habitat Studies on Rush and Lee Vining Creeks (Knudson et al. 2009).

Because the Synthesis Report provides in-depth analyses of the four supplemental reports in concert with results from the 11 years of annual sampling, the discussion section of our 2009 annual is limited to the response of the Rush Creek trout population to the flow management decision to curtail a RY2009 SRF peak release, growth information from recaptures of adipose fin-clipped fish, and a methods evaluation. Upcoming monitoring in 2010 and beyond will be focused at evaluating responses of the fish populations to flow regimes recommended in the Synthesis Report.

Brown Trout Response to Rush Creek's 2009 Flow Regime

As previously described, the Stream Scientists were concerned about the low storage level of GLR in early 2009 and the implications to Rush Creek's trout population from another summer of warm water releases. The condition factor and water temperature data from 2007 and 2008 indicated that the fish population was affected. The GLR thermal study concluded that the most efficient method to provide cooler water releases from GLR in late summer was to increase the water surface elevation above 7,110' in early summer and maintain water surface elevation above 7,110' through August (Cullen and Railsback 1993). The flow, reservoir storage and water analysis confirmed that the body condition of brown trout (150 – 250 mm) was positively influenced by minimum annual flow and the numbers of days that water temperatures were ideal for growth (Shepard et al. 2009a). Using this information, a decision was made to forgo the Rush Creek SRF peak releases and instead prioritize filling GLR by holding back this water. The result of this management decision increased GLR storage from a low of 6,100 ac-ft on February 12, 2009 to approximately 37,000 ac-ft by July of 2009.

The 2009 condition factors of brown trout between 150 mm and 250 mm in length in all sections of Rush Creek were all ≥1.00 (Figure 15). In the County Road and Upper sections, the 2009 condition factors were ≥1.00 for the first time since 2006, and 2007 and 2008 were the lowest condition factors for these two sections for the 11 years of annual sampling (Figure 15). Although the densities of age-0 brown trout decreased in all three Rush Creek sections between 2008 and 2009, and densities of age-1 and older brown trout declined in two of three Rush Creek sections, estimated standing crops (biomass) of brown trout increased in all three sections between 2008 and 2009. These data suggest that the decision to forgo the RY2009 SRF Rush Creek release and fill GLR resulted in fish in average-to-good condition as well as increases in estimated standing crops. The substantial increase in brown trout standing crops (biomass) and in densities of age-1 and older brown trout at the County Road section from 2007 though 2009 compared to 2000 though 2006 (Figures 17 and 23) may also be a direct response to the increase in high-quality pool habitat formed by the 2005 and 2006 SRF flood events (Knudson et al. 2009).

The low test flows released into Rush from October 2008 through the spring of 2009 may have reduced the abundance of age-0 brown trout in all fish sample sections. Densities of age-0 brown trout in all sample sections of Rush Creek were the lowest seen for the 13 years of the recent sampling record. Monitoring of this 2009 year-class in 2010 will determine if this low age-0 recruitment translates to much lower densities of age-1 brown trout compared to previous years.

Trout Growth between Age-0 and Age-1

As previously described, the methods to track the growth of trout in Rush and Lee Vining creeks has involved clipping the adipose fins of age-0 fish, recapturing these fish at age-1, and then calculating the mean growth which occurred between age-0 and age-1. There were several limitations to these methods which eventually lead to the initiation of a PIT tagging program in 2009. The first limitation was that it was impracticable to mark age-0 each year because of the potential difficultly of correctly ageing older fish, especially differentiating between age-1 fish and older fish. Thus, we were limited to fin-clipping age-0 fish every other year. The second limitation was our analyses were limited to calculating mean growth rates between age-0 and age-1, and these mean growth rates also assumed that any age-1 fish recaptured within an annual sampling section was within that section as an age-0, that is, no movement had occurred. Further analysis of past data clearly showed that a wide range of growth occurred in Rush Creek brown trout between age-0 and age-1 (Table 25). The weights of age-1 fish recaptured in both 2007 and 2009 varied as much as three to four-fold, thus analyzing mean growth rates has provided, at best, a gross evaluation of growth (Table 25). Future recaptures of PIT tagged fish will allow us to calculate specific growth rates for individual fish and track any potential movement between annual sampling sections.

Mean growth rates of age-1 brown trout captured in 2007 and 2009 did provide valuable insights into growth differences between years with varying flow conditions and summer thermal regimes. RY2007 was one of the driest years on record; summer thermal conditions were poor for trout growth which was exhibited in condition factors (Figure 15) and in the growth of age-1 brown trout (Table 25). In contrast, RY2009 was an “average runoff type” plus the decision to forgo the SRF filled GLR to 37,000 ac-ft by July when thermal conditions often degrade when reservoir storage is low. Mean growth rates (g/year) of age-1 brown trout in RY2009 were approximately 60% greater than the growth rates exhibited in RY2007 (Table 26). The mean growth data from 2007 and 2009 also revealed more growth occurred in the Upper Rush sampling section than the County Road section, regardless of runoff-year type (Table 26). In RY2007 this difference in mean growth was 7.5 g (30%) and in RY2009 this difference was 10.8 g (26.5%) (Table 26). We suspect that the better growth exhibited in the Upper Rush sample section was related to summer water temperature, with the Upper section experiencing less time with temperatures above where brown trout growth occurs and also less-severe diurnal fluctuations than the County Road section.

The Synthesis Report includes detailed temperature modeling and growth-prediction analyses that were used to develop Rush Creek flow recommendations. Future monitoring of these flow recommendations will rely heavily on analyzing the growth of PIT tagged fish and continued monitoring of summer water temperatures.

Table 25. Growth of Rush Creek age-1 brown trout in 2007 and 2009 with adipose fin clips administered during the 2006 and 2008 sampling seasons, respectively.

	Upper Rush Creek 2007	Upper Rush Creek 2009	County Road Rush Creek 2007	County Road Rush Creek 2009
Number of Recaptures	51	39	92	29
Percent Recaptures	9.1%	11.2%	15.2%	26.6%
Ave. Length at Age-0 (mm)	80	91	91	88
Ave. Length at Age-1 (mm)	156	180	150	166
Growth (mm/year)	76	89	59	78
Ave. Weight at Age-0 (g)	5.5	7.8	8.1	7.2
Ave. Weight at Age-1 (g)	37.9	59.3	33	47.9
Growth (g/year)	32.4	51.5	24.9	40.7
Weight Range at Age-1 (g)	21 – 63	36 – 90	13 – 58	22 – 89
Growth Range (g/year)	16 – 58	28 – 82	5 – 50	15 – 82
Mean Condition Factor at Age-1	0.99	1.01	0.95	1.01

Table 26. Comparisons of age-1 brown trout growth rates from Rush Creek.

	Upper Rush Creek	Co. Rd. Rush Creek
2007 Growth (g)	32.4	24.9
2009 Growth (g)	51.5	40.7
Growth Difference (g/yr)	19.1	15.8
Percent Difference	59%	63.5%

Methods Evaluation

Electro-fishing to conduct mark-recapture estimates in larger streams and depletion estimates in smaller streams and side channels have consistently provided relatively reliable estimates. Having a field technician or biologists from LADWP's Bishop Office dedicated to maintaining block fences has reduced the frequency of block fence failures in recent years (2003-2009) compared to previous years. Maintaining block fences ensures that the assumption of population closure is met, thus estimates are more reliable. During the 2009 field season there were no block fence failures.

In 2009, no major changes to the stream channel were observed within the annual sample sections, as would be expected during a normal run-off year with no large, channel-forming, peaks in the hydrographs. However, continued subtle changes were observed in the County Road section, including a filling-in of pools. These channel changes were expected because of changes in the flow regime, Mono Lake levels, and continuing maturation of riparian vegetation.

We have consistently sampled within the three main reaches in Rush Creek (MGORD, Upper Rush, and Lower Rush) and have time-series fish abundance and condition data for the past 11 years that represent fish population responses to changing climatic and flow management regimes. The upstream and downstream boundaries of all sample sections have been permanently marked. While continued channel evolution within Rush and Lee Vining creeks is anticipated, channel lengths and widths will be re-measured annually.

Modifying the sections sampled could represent a loss of time-series data unless efforts are made to index relative changes between individual sample sections. Length-weight regression lines for the Bottomlands and County Road sections were nearly identical in 2009 (Figure 14), indicating that brown trout in these two sections were responding in a similar fashion to their environment. This response suggests that replacing the County Road section with the Bottomlands section should not result in any loss of time-series information related individual fish condition factor analyses. However, we recommend that the County Road section is sampled annually until sufficient data (five annual sampling events) are collected in the Bottomlands section to compute a series of three, three-year running averages.

Because rainbow trout have comprised such a minor portion of the Rush Creek trout population during the last ten years of annual sampling, we recommend reporting only numbers of rainbow trout sampled and not attempting to make estimates of density or biomass. In Lee Vining Creek, during years when sufficient numbers of fish are captured to generate reliable population estimates, these estimates will be used to compute density and biomass estimates. However; in years when relatively few fish are captured, catch numbers will be used to generate density and standing crop estimates.

During the past ten years we experimented in our selection of length class break points to provide the most precise estimates using mark-recapture estimators. While selection of different length class break points across years allows for slightly more precise estimates, we have found that standardizing length class break points provides for better data consistency at a very modest loss of precision. Another issue in selection of length class break points was our desires to have the lowest length class encompass all age-0 fish during any given year. However, we have found that brown trout from 120 to 130 mm could be either age-0 or age-1 depending upon the growth conditions during any given year. Consequently, in earlier annual reports, a variety of length categories were used, which lead to difficulties in comparing age-0 and age-1 and older density and biomass estimates across all sample years (Hunter et al. 2000, 2001, 2002, 2003). For the 2008 report, we re-adjusted earlier data sets and standardized estimates into three size class categories: <125mm, 125-199 mm, and ≥200 mm. We recommend that all future monitoring use these size categories to generate population estimates and associated population metrics. Although we may misclassify a few large age-0 fish or a few small age-1 fish, we feel that consistency in managing the long-term data sets is more important.

Starting in 2009 the use of small passive integrated transponder tags (PIT tags) will allow us to track the survival, growth, and movement of individual age-0 brown trout. We will also be able to more accurately determine the size ranges of age-1 (and eventually age-2, 3 and 4) fish in subsequent years. The continued use of PIT tags will be an important component of continued long-term monitoring of Rush and Lee Vining creeks' trout populations in evaluating the effectiveness of flow recommendations made by the Stream Scientists in the Synthesis Report.

In 2009 there were no safety issues in wading and sampling the Rush Creek and Lee Vining Creek sections. However, to avoid potential problems caused by last-minute requests in reducing flows to safely sample during high run-off years, the Fisheries Stream Scientist recommends that maximum flow criteria be set for both creeks in early September to ensure that electro-fishing sampling is safe and efficient. We recommend that flows in Rush and Lee Vining creeks not exceed 40 c.f.s. (± 5 c.f.s.) during the annual sampling period (two week-period of September starting the Wednesday after Labor Day holiday).

Over the past several seasons, the biological staff from LADWP's Bishop Office has increased their role in participating with the annual fisheries population sampling. They also provided assistance with the Instream Flow Studies, pool surveys, temperature monitoring, and winter icing monitoring. The Bishop Office's report describing the icing study on Lee Vining Creek during the winter of 2009–2010 is included as an appendix to this annual report (Appendix C). This gradual increase in the participation of the Bishop

Office staff in conducting the annual fisheries monitoring is also described in the Synthesis Report and ushers in a diminished role of the consulting Stream Scientists as future monitoring is conducted to assess the revised streamflows recommended in the Synthesis Report.

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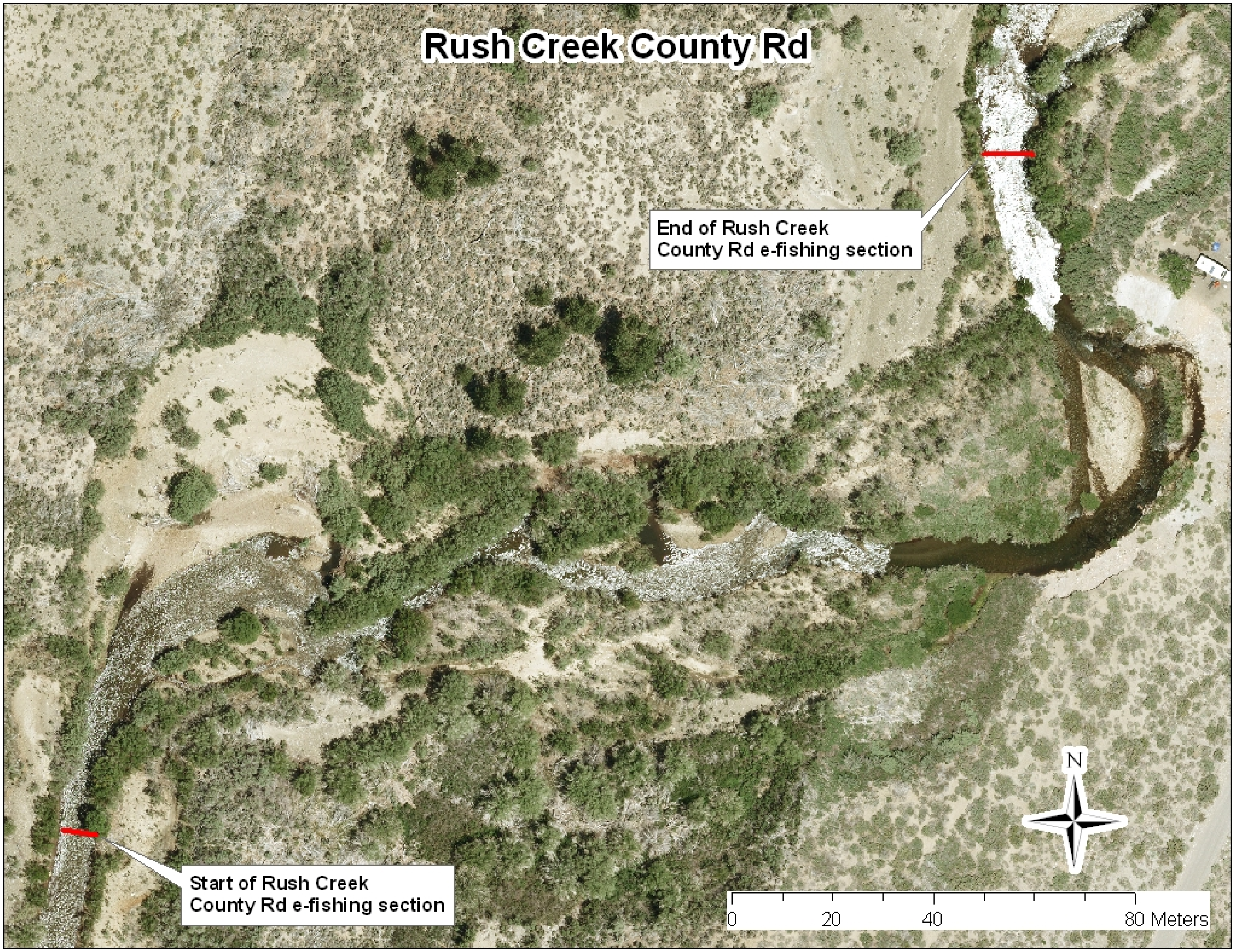
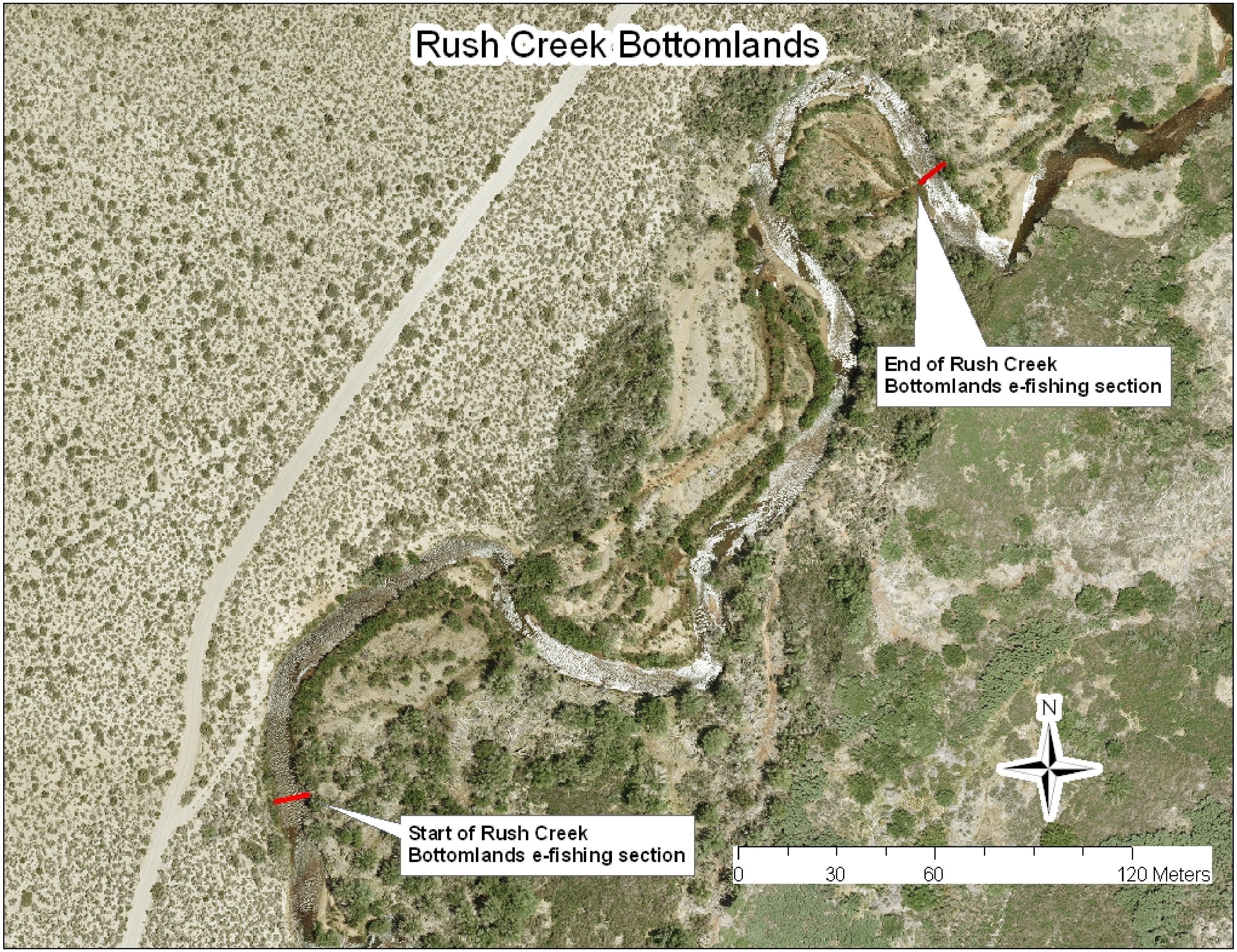
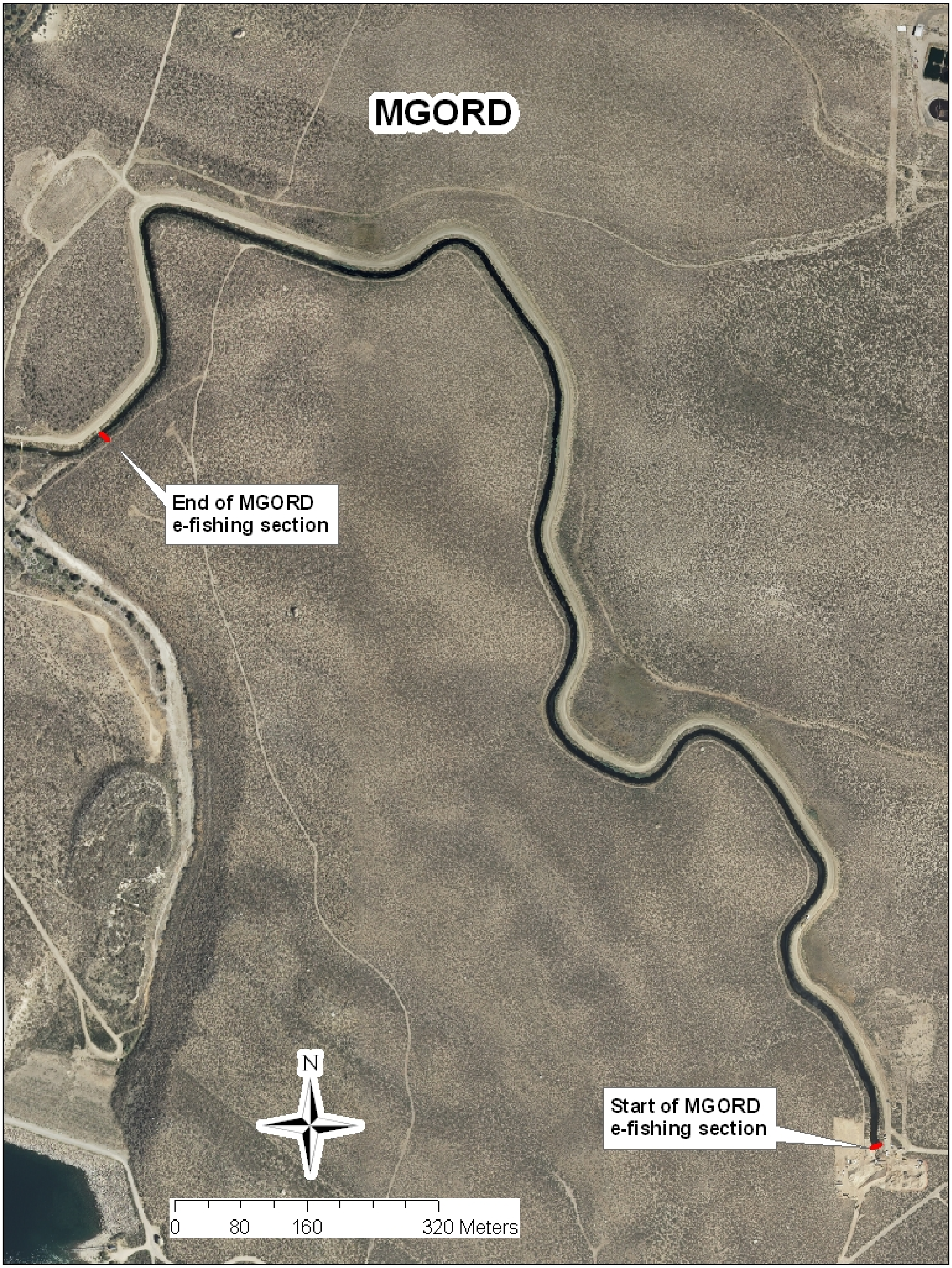
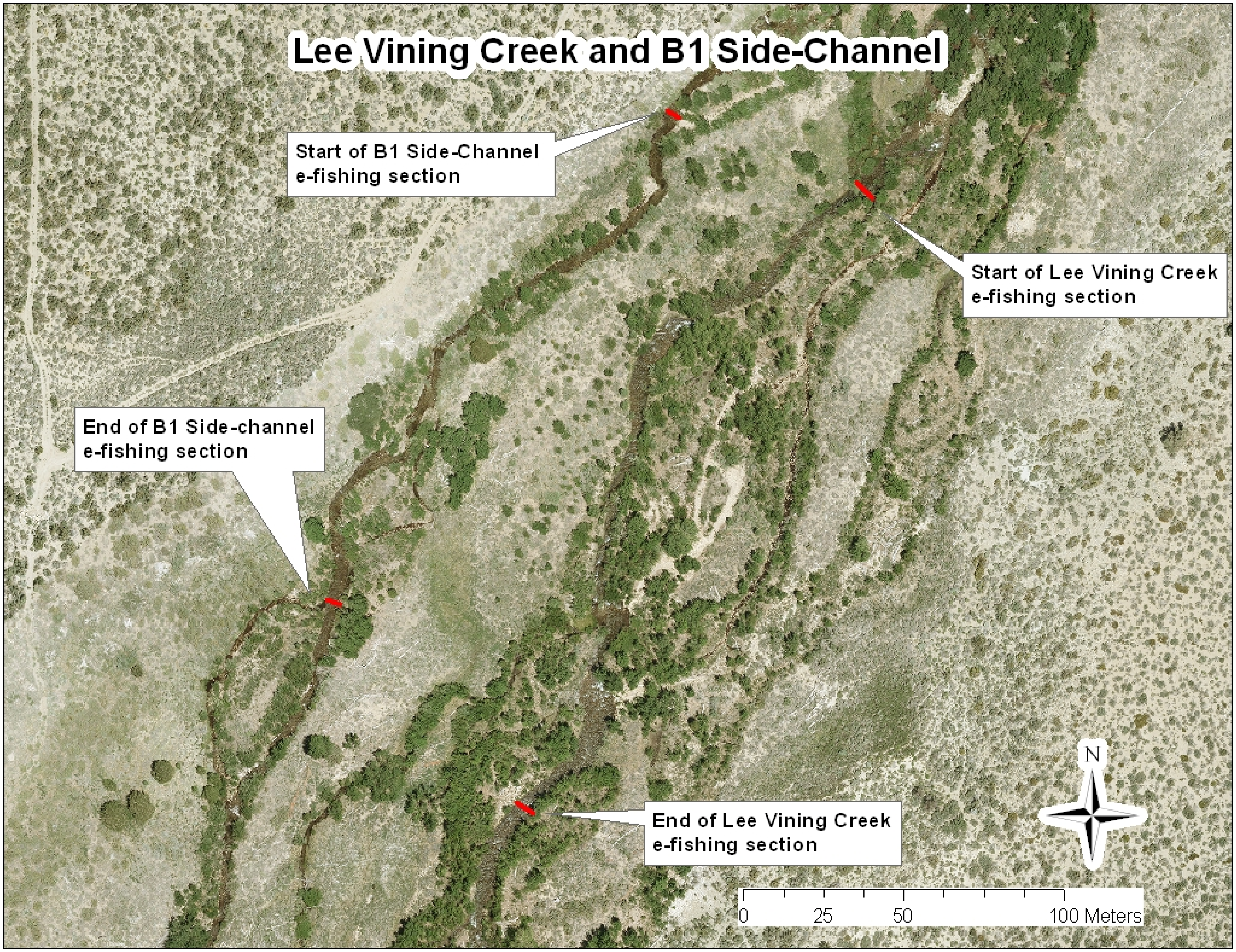
Appendix A: Aerial Photographs of Long-term Monitoring Sections


Rush Creek County Rd
End of Rush Creek
County Rd e-fishing section
Start of Rush Creek
County Rd e-fishing section
N
0
20
40
80 Meters


Rush Creek Bottomlands
End of Rush Creek
Bottomlands e-fishing section
Start of Rush Creek
Bottomlands e-fishing section
N
0
30
60
120 Meters


Upper Rush above old 395
End of Upper Rush Creek e-fishing section
Start of Upper Rush Creek e-fishing section
N
0
30
60
120 Meters


MGORD
End of MGORD e-fishing section
Start of MGORD e-fishing section
N
0 80 160 320 Meters


Lee Vining Creek and B1 Side-Channel
Start of B1 Side-Channel e-fishing section
Start of Lee Vining Creek e-fishing section
End of B1 Side-channel e-fishing section
End of Lee Vining Creek e-fishing section
N
0 25 50 100 Meters

Appendix B: Letters from the Stream Scientists to LADWP Concerning Grant Lake Reservoir Storage Levels in 2009

January 30, 2009

Dear Paul and Bruk,

We have recently been tracking the elevation and storage volume of Grant Lake, which has reached extremely low levels, and Darren Mierau spoke to Bruk on January 23 about these conditions. Bruk informed us that DWP has contingency plans in place to curtail water exports if Grant Lake elevation reaches 7080 ft, even if this occurs prior to DWP's fulfillment of its total water allocation. We appreciate DWP's advanced planning in this matter, and as Stream Scientists appointed by the State Water Board to oversee stream and fisheries recovery in the Mono Basin, we share your concerns regarding the conditions of Grant Lake. With this letter, we would like to express those concerns, and request that DWP pursue additional information that may help make better decisions with regard to Grant Lake and Rush Creek management in the coming weeks and months.

As you are aware from our monitoring reports, the previous two years' dry runoff conditions and the lower Grant Lake pool have resulted in flow releases from Grant Lake with warmer water temperatures than occurred when Grant Lake elevation was higher, and has likely resulted in poor condition factor for trout in Rush Creek, compared to previous years' monitoring. Our monitoring data have also demonstrated relatively poor recruitment of 2 year-old trout to reproductive age over the past two years. Thus a third year of stressful water temperatures, poor trout condition factor, and low recruitment could severely impair the trout populations and jeopardize long-term recovery goals. With this information in mind, our primary objective for the upcoming summer season should be to minimize impacts to the trout populations, to the greatest practical extent, that would result from warm water temperature releases from Grant Lake. We also have concerns that extremely low Grant Lake elevations for extended periods of time increases the likelihood of turbidity becoming an issue in Rush Creek.

During Darren's conversation with Bruk, they discussed the importance of communications with SCE, and specifically knowing what their current and anticipated flow release plans are. As Bruk informed us that DWP has not received an update from SCE for several months, we recommend (#1) that DWP contact SCE at your earliest convenience, describe the current situation with respect to Grant Lake, and request that they provide an update on their expected flow releases to Grant Lake for the foreseeable future. With this information, we recommend (#2) that DWP apply your MBOM model and other available tools to predict what Grant Lake elevation is likely to be through the remainder of the winter season, and predict a worst-case scenario for Grant Lake elevations. In the meantime, given the primary objective of minimizing impacts to the fishery in 2009, as an emergency measure, we recommend (#3) that the current flow of 37 cfs down Rush Creek is immediately reduced to 22 cfs. We feel this 15 cfs flow reduction will initiate an important banking of approximately 30 acre-feet of water daily while additional information regarding SCE release schedules and MBOM forecasting is gathered and reviewed. We would be receptive to a conference call to discuss these recommendations and other alternatives to minimize impacts to the Rush Creek trout populations.

We hope you share our concerns and recognize the need for timely response to prevent Grant Lake conditions from jeopardizing the trout populations. Please contact the Stream Scientists if you would like to discuss this with us, or need any additional information.

Thank You,
Sincerely,
Chris Hunter and Bill Trush

February 10, 2009

Bruk:

Since last week's conference call, myself and the fish team has had the opportunity to review the Grant Reservoir thermal report (Cullen and Railsback 1993) and complete a rough analysis of potential temperature relief gained by reducing flows down Rush Creek and/or halting exports. We feel that the relatively small increase in reservoir level that would result from these two management options would probably not result in a measureable difference towards providing better water temperatures for trout in Rush Creek this coming summer. Part of this analysis included reviewing the period between July 28th and August 10th 2008 when daily peak temperatures exceeded 72°F, including eight days when temperatures were greater than 76°F. During this two-week period, Grant Reservoir storage was between 18,000 and 19,000 acre-feet. However, it is reasonable to expect that water temperatures will probably be more severe this summer than in 2008 if Grant Reservoir starts at a lower storage elevation due to the fact that a smaller body of water will heat quicker than a larger body of water. This relationship of water volume versus heating potential was clearly described in the reservoir thermal report (Cullen and Railsback 1993).

We still have concerns that a low storage level in Grant Reservoir poses other potentially serious impacts to the Rush Creek trout population. We are concerned that a low storage level increases the likelihood that turbidity may become an issue either through bottom sediments becoming suspended through wave action or a potential flush of sediments from the lake bottom near the intake culvert. A variety of direct, sub-lethal effects of elevated suspended sediment on stream fishes is well documented (Newcombe and MacDonald 1991) and includes: impaired respiration (Berg and Northecote 1985), increased physiological stress (Redding et al. 1987) and reduced feeding success via reduced reactive distance (Barrett et al. 1992; Sweka and Hartman 2001). Elevated sediment in streams is also a concern because it also affects loss of habitat through changes in channel morphology, reduction in spawning success, and changes in the abundance and diversity of available prey organisms (Waters 1995). We are concerned that the above mentioned turbidity effects may occur in concert with a poor temperature regime during the summer of 2009.

Also, in my 30 plus years of fisheries management work in the State of Montana I have witnessed the longer-term impacts of severe reservoir draw-downs by managers in which several years were required (post draw-down) before levels were restored to the point of providing adequate temperature regimes to the downstream tailwater trout fisheries. Again, I will caution LADWP that a severe draw-down of Grant Reservoir in 2009 may affect the downstream trout fishery well beyond the summer of 2009. These draw-downs can also adversely affect reservoir fisheries by affecting water temperatures, dissolved oxygen, biological productivity and access.

Finally, Brad Shepard has informed me that the preliminary statistical analysis of the effects Rush Creek flows and water temperature versus brown trout condition factor and densities indicates that there is a strong correlation between Grant Reservoir's level and the condition factor of 150-250 mm brown trout and the densities of all size classes of fish. That is, the lower the elevation Grant Reservoir, the poorer the condition factor of 150-250 mm fish and lower densities of all size classes of brown trout in Rush Creek.

I and the fish team appreciate the concern that LADWP has for the situation at hand and we also understand the pressures on the Department to reliably deliver water to the City of Los Angeles. The intent of this letter is to better describe the potential biological effects that a lower level in Grant Reservoir may have on Rush Creek's trout population. We look forward to working with the Department and all of the stakeholders towards a solution that best meets of the needs of the Department and the Mono Basin restoration program.

Sincerely,
Chris Hunter

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Appendix C: Lee Vining Creek Ice Survey 2009 - 2010

Lee Vining Creek Ice Survey 2009-2010

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April 9, 2010

Executive Summary

Ice formations in rivers and streams are natural phenomena in cold and alpine regions throughout the world. Extensive formations and subsequent breakups of anchor ice dams can result in high mortality among fish populations, and the extensive formations of hanging dams in preferred winter holding habitat can expose fish to many dangers, which directly or indirectly could lead to fish mortality. Regulation of rivers and streams by dams can be used to reduce ice formations which could adversely affect fish population. Lee Vining Creek, located in the Eastern Sierra of California, is a highly regulated stream with naturally spawning brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*). The objective of this study was to investigate 1) whether the revised winter baseflows proposed by the Stream Scientists would lead to severe ice events, and 2) the extent of various ice formations in different sections of Lee Vining Creek downstream of LADWP's point of diversion. For the 2009-2010 winter period, two experimental baseflows were released by Los Angeles Department of Water and Power (LADWP) for the icing study: 18 cfs was released from November 30, 2009 to January 1, 2010 and 14 cfs was released from January 2 to March 8, 2010. This study found that surface cover, which included surface ice, shelf ice, and snow cover, was the most dominant form of ice mainly along the channel edges, and that extensive anchor ice formations were limited to only one section. Based on the air temperature data, we speculate that extensive anchor ice formation at this site would have lasted no more than five days. The timing and extent of ice cover generally coincided with cold weather events, but factors such as timing of the cold weather relative to precipitation, canopy cover, substrate, gradient, and turbulence were also important in determining what type and how much ice formation occurred and how long the formations persisted. The experimental winter baseflow of 14 cfs is not likely to cause extreme winter ice conditions that would adversely affect the fish population in Lee Vining Creek under the winter temperature regime similar to the one observed during 2009-2010 winter.

Introduction

The Instream Flow Study (IFS; Taylor et al. 2009a) was used to help revise the Stream Restoration Flows and baseflow provisions of Order WR 98-05 (SWRCB 1998). One of the objectives was to evaluate the relationship between a range of test flows and habitat availability of holding habitats in order to find what flow would provide increased amounts of winter holding habitat for larger, adult brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) in Rush and Lee Vining creeks, Mono County, California. The IFS on Lee Vining Creek was conducted in April, 2009, with test flows ranging from 12 cfs to 54 cfs (Taylor et al. 2009a). The lowest test flow (12 cfs) was found to provide the largest total area of winter holding habitat. However, the concern was raised by Stream Scientists on possible exacerbation of stream ice formations with lower winter baseflows because Lee Vining Creek has characteristics which may contribute to ice formations, such as a shallow channel with large/coarse substrate, transitional reaches from steeper to milder channel slopes, and channel reaches located immediately downstream of more turbulent reaches (Prowse 2001, Bradford and Heinonen 2008).

Brown trout seek refuges such as the bottom of deep pools or under shelf ice near the edges of a stream as winter progresses (Cunjak and Power 1986, Brown et al. 2000, Simkins et al. 2000, Taylor et al. 2009b). Stream ice formation, particularly frazil and anchor ice formations, can adversely affect winter holding habitat resulting in direct and indirect mortality of trout. Frazil ice forms when the water becomes supercooled (<32ºF) during clear cold nights, and occurrence of frazil ice is common in streams and rivers through out the cold and alpine regions (Hicks 2009). As ice crystals grow in number and size, larger frazil ice clusters adhere to the stream bed forming anchor ice or adhere beneath surface ice, creating hanging dams. Ice dams that block fish movement and divert flows onto the floodplain can result when either anchor ice builds from the bottom to the surface, or when frazil ice builds from the surface down to the streambed. The diversion of the stream's flow by ice dams, even for relatively short time-periods, can cause significant fish kills by dewatering a reach of stream (Jenkins et al. 1991). Formation of hanging dams can cause indirect mortality of trout by forcing them out of preferred winter holding habitat and exposing them to potential dangers, such as frazil ice, predators, and higher energy expenditures (Heggenes et al. 1993, Brown et al. 1994, Cunjak 1996, Brown et al. 2000). Downstream movement of fish in winter was recorded by several authors during dynamic cycles of ice formations and thaws and also when preferred habitat became unavailable (Jakober et al. 1998, Brown et al. 2000, Palm et al. 2009). Therefore, it was important to understand the extent and duration of ice formation under these lower recommended flow levels before prescribing these winter base flows.

Previous studies in Lee Vining Creek and Convict Creek in the Eastern Sierra documented that anchor ice and ice dams could form and subsequently fail in these streams (Maciolek and Needham 1952, Jenkins et al. 1991, CDFG 1993). However, the relationship between discharge and anchor ice formation was not very clear. In general, these studies suggested that lower flows lead to ice cap formations, which, in turn, prevented or limited the formation of anchor ice in Lee Vining and Convict creeks (Jenkins et al. 1991, CDFG 1993). In Lee Vining Creek more extensive anchor ice formations were found in January and February when flows were raised above 40 cfs (CDFG 1993). However, shallower water is more susceptible to anchor ice formations and complete freeze-up through decreased velocities and increased surface area to depth ratio and heat loss (Prowse 2001, Bradford and Heinonen 2008). Thus, it is important to investigate whether the low winter baseflow would cause extensive ice formations, particularly anchor ice. The Stream Scientists chose to increase the 12 cfs baseflow to a final recommended baseflow of 16 cfs in dry year-types due to concerns about fish passage through riffle crests, especially if much ice formed along these riffle crest areas during colder periods of the winter. The main objective of this study was to investigate whether the lower baseflows would lead to severe ice events that could adversely affect trout and their winter holding habitat. The second objective was to investigate the extent of the ice formations in different sections of Lee Vining Creek. These two objectives should provide the Stream Scientists with the missing data they need to make a final recommendation on the winter baseflows for Lee Vining Creek.

Methods

Lee Vining Creek is one of the major tributaries to Mono Lake located in the eastern side of Sierra Nevada Mountains with the drainage area of 40.2 mi^2 (104.1 km^2) originating from the Ansel Adams Wilderness Area. The average annual runoff between 1941 and 2008 was 46,543 ac-ft (E.Tillemans. pers. comm.). There are three high elevation reservoirs operated by Southern California Edison (SCE) in the upper portion of the Lee Vining Creek watershed. Flows of lower Lee Vining Creek have been diverted by LADWP above State Highway 120 (Intake; 37°56'09", 119°08'03") since 1941. The study area is located in this lower 4.3 mile section of Lee Vining Creek between Intake and the Mono Lake delta (Delta; 37°58'40", 119°06'10").

Five study sections were identified in Lee Vining Creek between Intake and the Delta. Three sections (referred to as B, C, and D) overlapped the original California Department of Fish and Game's ice survey sections (CDFG 1993), and two sections (E and F) were added for this study (Figure 1). The stream below Intake was divided into two general reaches, upper and lower (above and below US Highway 395). In the upper reach, Section B was located in the meadow between Intake and State Highway 120, while Section C was located in the canyon between State Highway 120 and US Highway 395. In the lower reach, Section D was located between the County Road ford crossing and the Delta while Section E and F were located in the main channel and B1 side channel of the long-term Lower Lee Vining Creek fish monitoring section, respectively. Each section contained two transects, one crossing fast moving water (riffle) and the other transect crossing slowing moving water (pool or glide) (Figure 2 a through j, Table 1).

Each transect was marked for the study with T-posts that were driven into the streambed just above the wetted edges demarcated by the 18 cfs experimental base flow. Depth and velocity profiles were collected at 18 cfs prior to any ice forming event for 18 cfs baseline data. Because ice formations in the creek from January 2 through March prevented accurate measurements after flows were reduced from 18 to 14 cfs, baseline data for 14 cfs were estimated by using depth profiles along transects when they were relatively ice free to calculate differences in water depths between 18 and 14 cfs at the same locations along each transect. The average value of the depth differences was subtracted from the 18 cfs water surface elevation, and the new water surface elevation (14 cfs) was projected on each channel cross-section. The intersections at both ends were used as estimates of the wetted edges for 14 cfs. The differences in water surface elevations between 18 and 14 cfs were less than 0.1 ft except for Tran_FP (pool transect in section F), where the difference was 0.17 ft. This 0.1 ft is within the errors associated with flow measurements and cross-sectional profile surveys.

Transects were visited at weekly intervals unless it was unsafe due to a winter storm (January 19 through 22, 2010). During each visit, the presence of ice was documented and when present, ice types were classified into surface, shelf, anchor, and contour ice (CDFG 1993). Overhanging snow cover was added as an additional category. The extent of each ice type was measured to the nearest 1/10 foot. Total lengths of each ice type were converted to percent cover based on the measured and calculated wetted widths for 18 (from November 30, 2009 to January 1, 2010) and 14 cfs (from January 2 to March 8, 2010) respectively. Only ice that was observed within the wetted edges was included because ice outside this baseline wetted width area would inflate the percent cover such that cover computations could be over 100%. Water depths and average velocities (60% of total depth) were measured at the boundary edges of each observed ice type and at one-foot increments of open water along each transect. The ice types and cover within the wetted channel were estimated for approximately 200 ft upstream and downstream of each transect. Water temperatures were recorded every fifteen minutes by water temperature loggers (HOBO Water Temp Pro v2, Onset) in the each section, and daily maximum, minimum, and average water temperatures were obtained. Meteorological data (daily maximum and minimum air temperature, and precipitation) were obtained from LADWP weather stations in Cain Ranch and Paoha Island in Mono Lake. The data from Cain Ranch were used for upper sections (section B and C) and the data from Paoha Island were used for lower sections (section D, E, and F). Air temperature inversions caused extensive buildup of fog over Mono Lake that appeared to insulate the lower sections from the extreme weather event. Cain Ranch is located approximately 3.6 miles south of the upper sections and Paoha Island is located approximately 4 miles north-east of the lower sections. Daily discharge below the Intake was obtained from LADWP. For the 2009-2010 winter period (November through March) two experimental baseflows were released by LADWP for the icing study: 18 cfs was released from November 30, 2009 to January 1, 2010 and 14 cfs was released from January 2 to March 8, 2010 (Figure 3).

Results

Surface cover, including surface ice, shelf ice and snow cover, predominated (Figure 4). In the pool transects, surface ice, shelf ice and snow cover were found mainly along the channel's edges. Formation of anchor ice coincided with cold weather events, but not with stream discharges (flows), and extensive anchor ice formations were limited in both space and time (Figure 5). Anchor ice was found in three riffle cross sections (Tran_BR, Tran_CR, and Tran_DR), but Tran_DR was the only transect where anchor ice extended across more than 50% of its width. Extensive anchor ice formations, or other adverse effects of frazil ice, were never observed in consecutive weekly visits, suggesting that extensive ice formations occurred over relatively brief time periods, when they did occur. Extensive ice formations generally coincided with periods of extreme cold air temperatures, but dominance of a particular ice type did not follow temperature patterns closely. Factors such as timing of the cold weather and precipitation, antecedent ice conditions, canopy cover, substrate, gradient, and turbulence were also important determinants for type and extent of the ice cover.

There were numerous cold air temperature periods interrupted by brief mild periods. During five such cold spells, the minimum air temperature dropped below 0°F at Cain Ranch and 20°F at Paoha Island. The two lowest air temperatures of the winter were recorded at Cain Ranch on December 9 at -11°F and on January 25 at -8°F. The two lowest air temperatures on Paoha Island were recorded on December 7 at 8°F and on December 23 at 12°F. The maximum air temperatures measured at Cain Ranch were 6°F higher than those measured at Paoha Island while the minimum air temperatures were 12°F lower at Cain Ranch, and correlations between two weather stations were poor ($r = 0.622$ and 0.459 for the maximum and minimum air temperatures), indicating potentially large temperature moderation effects by fog on Mono Lake and the higher specific heat of the water (Figure 6). However, the upper sections generally showed lower daily maximum and minimum water temperatures and smaller daily fluctuations with Section C having the lowest and most stable water temperatures. Section F in the B1 side channel showed the highest daily maximum and minimum water temperatures and largest fluctuations followed by Section D and E (Table 2 and 3). A series of storms hit the central part of Sierra Nevada from January 19 through 22, resulted in large accumulations of snow in the channel and on the banks (Figure 7).

Extensive ice formations that might have impacted fish seldom occurred and when they did occur they never lasted more a week. The maximum air temperatures did not drop below 40°F at Cain Ranch for more than three consecutive days except during the late January cold spell during which no anchor ice was found. During all anchor ice forming events in the upper section, the maximum air temperature remained above 40°F except December 8 at Tran_CR (Figure 8-b and e). Thus, most of the observed anchor ice formations likely were dislodged during the same day they formed. In the lower section temperatures below 40°F lasted up to six consecutive days in early December and late January and eight consecutive days in late December (Figure 8-f). Maximum air temperatures remained around 40°F during the period when the most extensive anchor ice formation was observed on January 5, thus the anchor ice would have dislodged daily. The maximum air temperature was slightly below 32°F for only two consecutive days in early December during the six day period of below 40°F, suggesting the anchor ice and anchor ice dam would have lasted only a few days at most. The longest lasting anchor ice event would have occurred in late December, during which the below freezing temperatures were recorded for five consecutive days until a slight warming trend started on December 27. The low ice cover on December 29 (6%) support this conclusion. Because of very warm temperature on December 21 (48°F), the anchor ice and anchor ice dam most likely did not form until December 22 or 23. Thus, the longest lasting anchor ice event would have lasted four to five days. The anchor ice build up was less severe than during the other anchor events as the depth change was 0.35 ft, and no flooding was observed.

Surface ice was more dominant in November and early January in all pools except Tran_EP and three riffles. From mid-January to March consistent surface ice cover only occurred in Tran_DP, while other forms of surface cover (shelf ice and snow cover) became dominant in other transects (Figure 8-a to j). Surface ice formation generally followed the weather patterns peaking in early December during the first and most severe cold spell. Consistent extensive surface cover was only found in large deep pools, but this ice cover was periodically disrupted by warm periods. Surface ice initially formed as border shelf ice and this shelf ice persisted in seven of ten transects. Snow and shelf ice covered portions of the channel more persistently during the second half of the study (surface ice for Tran_BP, Tran_DP, and Tran_FP, shelf ice for Tran_BR, Tran_DR, and Tran_EP, and snow cover for Tran_FR). Increases in surface cover in mid-January occurred right after the winter storm events, but not during a period of cold air temperatures. The cold spell in the end of February did not increase surface ice extents except the large pool transects. No hanging dams were observed in the pool section. No complete freeze up of the channel transect was observed throughout the study.

Section B: Shelf ice and snow cover dominated both riffle (Tran_BR) and pool (Tran_BP) transects in Section B. Border ice, mostly in the form of shelf ice, was common in Tran_BR while consistent surface cover was found over Tran_BP from December to January (Figure 8-a and b).

In the pool transect, surface ice formed at the beginning of the study and persisted intermittently throughout the winter with periodic breakups of this surface ice occurring in late December, late January, and again in early February. After the first breakup of the surface ice on December 21, the surface ice formed again in December 28. This surface ice collapsed to form shelf ice which persisted on the channel's edges until late January. At that time, this shelf ice was replaced by overhanging snow. During the cold spell in late February, surface ice temporarily extended across the entire channel. No surface ice was observed during the last visit on March 8. Neither a buildup of frazil ice underneath this surface ice nor hanging dams were observed in Tran_BP except during one visit on December 28. At that time an ice ridge was observed along the thalweg of the channel from a beaver dam at the lower boundary upstream approximately 50 ft where the surface ice disappeared (Figure 9). At that time the elevation of the surface ice was much higher than during subsequent visits, when the edges of this surface ice cover had collapsed to form shelf ice.

In the riffle transect, anchor ice was found during three visits (December 14, January 4, and January 14), but this surface ice cover less than 10% of area. On December 28 and January 26 surface ice and a snow/shelf ice bridge covered significant portions of this transect. The snow/shelf ice bridge formed after a large accumulation of snow.

Section C: After the initial surface ice formation on December 7, border ice in the form of shelf ice persisted at a constant percent cover for both the pool (Tran_CP) and the riffle (Tran_CR) transects around 55% and 25%, respectively; however, the amount of area covered by this ice started to decline in February (Figure 8-c and d). For both cross sections, border ice formations (approximately combined transect length of six feet for Tran_CR and ten to twelve feet for Tran CP) covered the channel's edges. This ice cover would have provided increased winter holding habitat for fish throughout the winter, if water velocities were slow enough (IFS; Taylor et al. 2009b). Water temperature data for Section C indicated this section had the lowest average, standard deviation, and range in temperatures (Table 2). We suspect these narrower fluctuations were most likely due to increased canopy cover within Section C, relative to the other sections.

In Tran_CP, surface ice was initially formed on December 8 and this ice collapsed to form shelf ice, which persisted throughout the study as 50% cover along the stream's edges. Surface ice never extended toward the middle of the creek because of turbulent flows entering the pool.

In Tran_CR, ice free portions were always present in both transects even with the formation of anchor ice. There were two events in which anchor ice formed in this transect. One on December 7 and the other on February 22. Anchor covered a similar proportion of the area during these two events (32% and 26%, respectively). No anchor ice was observed in Tran_BR, located immediately upstream, during the study period. The first event of anchor ice formation coincided with the coldest air temperatures that were recorded during this winter, while cold air temperatures that occurred in February spell did not last as long and were not as cold. During both events, the maximum air temperatures remained above 40°F, suggesting daily dislodging of the anchor ice. There was a very little change in cross-sectional profiles with the formation of this anchor ice (Figure 10).

Section D: The pool section (Tran_DP, Unit #13) was covered by surface ice throughout most of the study period, except during two thawing air temperature events in January 12 and February 8. The surface cover reformed briefly on February 22. No ice was found afterward. No hanging dam formations were observed in Tran_DP as the surface ice elevation appeared remained similar throughout the winter (Figure 11). No sign of flow restriction were observed. Ice formed and melted out of the riffle section (Tran_DR) periodically during the early winter. Three ice types (surface ice, shelf ice, and anchor ice) were present. Surface ice and anchor alternated its dominance until mid-January, and surface ice collapsed into more stable shelf ice after the large snow storm in January (Figure 8-e and f). Water temperatures in this section had the second widest range or fluctuations of all the sections.

In Tran_DR anchor ice formed during the first half of the study and this anchor ice covered 50% or more of the transect from November 30 to January 5, with 65% and 86%, of the transect covered by anchor ice on December 23 and January 5, respectively. These anchor ice formations were periodically disrupted until the last major formation event in January 5, after which only one minor formation event (32% on February 22) was observed. A heavy snow fall starting on January 19 appeared to facilitate surface ice development in Tran_DR, and this surface ice collapsed to form shelf ice by the subsequent visit. The extensive surface cover and snow accumulation had most likely insulated the creek from low night temperatures.

More than 50% of the channel was covered by anchor ice during three visits (December 9, December 23, and January 5), but the extent of anchor ice was reduced to less than 25% after these visits, indicating short durations of the extensive anchor ice formation. For the first two events (December 9 and 23), the maximum air temperature at Paola Island reached almost 40°F by December 12, and the high of 37°F was recorded in December 27. It is likely that anchor ice had started to be dislodged periodically (probably daily) after three or four days of extensive formations on December 12 and December 27. For the January 5 anchor ice event (86% coverage), the weather was not as extreme as during either of the previous events. Maximum air temperatures at Paola Island remained above 39°F throughout this cold spell, and the minimum temperature did not drop below 20°F. The previous events coincided with minimum temperatures of 8°F and 12°F, respectively. Relatively milder weather during early January suggests that the 86% anchor ice cover seen on January 5 probably broke free periodically (probably even on a daily basis).

Channel cross-sectional profiles were altered considerably by ice during the first half of the study period (Figure 12). Flows were constrained by anchor ice formations and frazil ice buildup underneath surface ice. In addition, an ice dam developed downstream of Tran_DR, which contributed to as much as a one foot increase in the depth. Thalweg depths increased from 0.65 ft (November 11) to 0.75 ft (November 30), 0.9 ft (December 7), 1.6 ft (December 9), 1.0 ft (December 23), 1.15 ft (December 29), and 0.9 ft (January 5). Frazil ice formed on top of the existing surface ice, likely due to the increasing height of the ice dam downstream that caused an increase in water levels. This further constrained the overflow resulting in a depth of 1.6 ft, observed on December 9. Velocities within the thalweg remained below 2 ft/s, and the discharge calculation showed as much as 10 cfs was flowing under the surface or shelf ice during these anchor ice events (Table 4). Thus, neither complete freezing of the channel was observed at this transect during the study.

Periodic anchor ice dam formations downstream could have prevented downstream fish movement to Tran_DP (Unit #13, a primary winter habitat) from Tran_DR. There were two ice dams observed between Tran_DR and Tran_DP during sampling visits (Figure 13). Between the County Road and Tran_DR there are numerous narrow and steep riffles, which are susceptible for ice dam formations. The status, presence or absence, of two ice dams between Tran_DR and DP were recorded during each sampling visit. Occurrence of these ice dams coincided with the formation of anchor ice in Tran_DR. The ice dam at the bottom of Tran_DR increased in height on December 9, raising water levels upstream and spreading the creek's flow over and around the dam downstream (Figure 13).

Section E: The extent of ice formed in Section E was generally much less than that of other sections, and no anchor ice was observed (Figure 8-g and h). Water temperatures remained above 32.0°F through most of the winter and supercooling of water was only recorded during three days. The water temperature regime was more stable in this section than in the other two sections within lower Lee Vining (a range of 8.7°F comparing 11.1°F for Section D and 13.1°F. Section E lacked the dense canopy cover of the upper section. Tran_EP is located in a glide with an average velocity of 0.8 ft/s, rather than a pool unlike other pool transects whose average velocities ranged between 0.2 and 0.5 ft/s. Higher minimum and more stable water temperature regimes most likely prevented anchor ice formation, while relatively faster water velocities and increased solar radiation due to less canopy cover may have prevented persistence of the surface cover in Section E.

Surface cover, including surface and shelf ice, was most commonly found, but the extensive cover never persisted for more than a week in the pool transect (Tran_EP). More than 50% of the channel was periodically covered by surface and shelf ice in December. This transect remained relatively ice free until January 25 when 100% of shelf ice was observed, most likely due to the mid-January snow storms. After January 25, this shelf ice gradually disappeared until only relatively narrow bands of this shelf ice remained along the edges of the channel.

The riffle pool transect (Tran_ER) remained almost ice free throughout the study. Ice formations never covered more than 20% of the channel, even during the coldest days of the winter.

Section F: The widest water temperature fluctuations occurred in Section F, probably due to shallower water depths and lower flows in this side channel. The mean difference between maximum and minimum water temperatures was between 0.4°F and13.1°F. A relative lack of canopy cover also contributed to this large fluctuation. Even though minimum water temperatures dropped below 32°F for 33 days, the large fluctuation should have precluded persistence of the anchor ice formation for more than a day.

In the pool transect (Tran_FP), stable shelf ice cover of over 60% was found from December through early January, and then this surface cover gradually decreased after the mid-January winter storm event. There was a piece of large woody debris (LWD) lying diagonally to the flow near the middle of the channel. This piece of debris divided the channel into fast flowing (left-bank) and slow flowing (right-bank) longitudinal sections (Figure 8-i and j). The slow flowing right side of the channel was completely covered by ice, mainly shelf ice, throughout the study period. This constituted approximately 25 to 30% of the total ice cover. Slow or still water velocities and the exposed surface of the LWD obstruction likely contributed to the persistence of this shelf ice throughout the study. The ice extent over the fast flowing portion of this transect coincided with the weather pattern and the mid-January snow storms.

A majority of Tran_FR consisted of very shallow and rocky substrate (>84%), thus the remainder of this transect, where most of the water was being conveyed, remained open except on December 23 and January 25. The late December cold air temperatures and the mid-January snow storms resulted in the complete coverage of this transect. This surface cover did not persist for more than two weeks.

Discussion

Observed formations of ice in Lee Vining Creek were strongly influenced by ambient temperatures, but other factors also influenced the extent, timing, and persistence of ice cover. Even though the temperature data from two weather stations showed a more extreme temperature regime in the upper section than the lower section, the lower section exhibited more fluctuation in ice cover and water temperatures. Extensive formations of anchor ice and anchor ice dams occurred only in the lower reach (downstream of Highway 395). In the upper reach it is likely that a denser canopy cover shielded the creek from extreme temperature swings, resulting in formation of stable shelf ice along the edges, but fewer instances of bank-to-bank coverage by ice. This buffering capacity was offset by geomorphic features such gradient, substrate size, and LWD. Anchor ice formed where the water rarely experienced the supercooling. Conversely in the lower reach, where the canopy cover was generally much less and the gradient was less steep, water temperature fluctuations were far greater. In some cases daily fluctuations were greater than 10°F, even though the air temperature regime near Mono Lake fluctuated much less. Periodic breakup of ice formations were more common in sample sections with less canopy cover and in riffle and glide transects than in pool transects. Penetration of short wave radiation, emission of long wave radiation by large trees, velocity of water, and channel obstructions appeared to be variables that influenced ice formation. These factors may change over time, especially in the lower section once trees become more mature, providing more insulation and also increasing the frequency of LWD recruitment to the stream's channel.

A series of snow storms and associated cold air temperatures during and after these snow storms provided insight into how this type of weather pattern results in snow accumulations that create extensive surface ice formations that become covered with snow, which subsequently insulated the creek from very low ambient temperatures. No anchor ice was found in any transect during this period. The surface cover formed during the snow storms acted as ice caps similar to those described by Jenkins et al. (1991) and CDFG (1993). Border shelf ice along the channel's edges was abundantly and consistently found, but it is not clear how much insulation this border ice would have provided, especially in Tran_DR whose wetted width was widest at 18 cfs and where most extensive anchor ice was found. The wetted width decreased by 3.7 ft with the discharge dropping to 14 cfs comparing to averages of 0.6 ft for the rest of the transects. Thus lower flow could potentially increase the relative extents of the border ice in this transect insulating larger portion of the creek. Snow cover was found between boulders in Section C, and extended the entire transect length for Tran_EP and Tran_FP, suggesting objects in the channel and narrower channels enhance the likelihood and extent of ice capping of the stream (in this case snow cap) for more insulation. Lower flows, therefore, may be preferred to enhance ice cap formation and also increase the influence of the border ice considering limited spatial and temporal extent of anchor ice during slightly below average winter of 2009-2010.

Extensive formations of anchor ice occurred in only the lowest transects of the study area, closest to Mono Lake, but these extensive formations of anchor ice, or ice dams, likely only persisted for periods of less than five days during this study, except during one occasion in late December during which anchor ice could have lasted up to five days. Air temperatures during the formation of anchor ice were below the freezing point, but air temperatures soon after the formation of anchor ice often rose above the freezing point and quite often exceeded 40°F. Rising air temperatures resulted in warmer water temperatures that weakened anchor ice, and floating, dislodged anchor ice was observed on more than one occasion. We observed that some anchor ice clusters were easily dislodged from the stream bed by barely touching them. Because of very little canopy cover, a lack of large trees insulating the creek, and the type of anchor ice that formed, anchor ice periodically forms and breaks up in lower Lee Vining. For this reason anchor ice or ice dams are unlikely to persist for more than a week in this reach of Lee Vining Creek if winter air temperatures follow a similar pattern as that observed during the winter of 2009-2010. Filling and dewatering of the creek resulting from the formation and breaking of ice dams have been identified as factors that could lead to winter fish kills (Jenkins et al. 1991), but no kills nor persistent ice dams were observed in Lee Vining Creek during this single-season study.

Fish movement in the lower section could have been periodically disrupted by anchor ice and ice dam formations located between Tran_DR and Tran_DP. With the onset of winter, fish seek refuges on deeper pools and remain there during most of the winter (Cunjak and Power 1986, Brown et al. 2000, Simpkens et al. 2000), but development of hanging dams in deep pools can force fish out of these winter habitat and expose them to dangers (Brown et al. 2000). No hanging dams were observed in the pool transects during the study. Tran_DP (unit #13), the primary winter holding habitat, was covered extensively with surface ice with occasional breakups, but with presence of submerged willow roots and branches providing cover during those breakup events, and limited frazil accumulation under surface ice, Tran_DP should have remained as preferred winter holding habitat through out the winter. As long as Tran_DP remained free of a hanging ice dam, fish would not need to move. In Tran_BP, the ridge appeared along the thalweg during one visit and the surface ice level was estimated higher than during other visits by comparing pictures taken during visits, indicating some flow restrictions underneath. But this flow restriction was most likely caused by buildup of ice on the beaver dam. Freezing of water on the outside surface of the downstream side of the dam would have greatly impeded the flow of water through the dam. Presence of a beaver dam will raise water levels and slow flows, increasing the likelihood of ice formation, especially surface ice. Beaver dams also create an exposed surface where ice can more easily form. Ice dams were also observed in the steep canyon section (Section C) because of numerous flow restrictions by boulders and LWD. However, big pools including Tran_CP are present within this section. Section C is also the most insulated section and prone to ice cap formations, thus once ice caps form between boulders and LWD they are most likely to persist throughout the winter. Higher flows in Section C will not only discourage ice cap formations (Jenkins et al. 1991, CDFG 1993) but also could reduce low water velocity overwinter habitat. Increased turbulence in Tran_CP was observed toward the end of March, when flows were being augmented to meet the spring Stream Restoration Flows. If the flow had remained around 30 cfs, then the section may have been a major source of frazil ice as described by CDFG (1993).

Less ice cover and fewer ice forming events were observed after January 2, when the flow was dropped to 14 cfs. The occurrence of surface ice and shelf ice cover was also lower after January 2, likely because periodic warmer air temperatures caused ice to melt and break up. Only minor anchor ice formations were found after January 2 except the most extensive development in Tran_DR on January 5. The temperatures (air and water) differed significantly between the two periods, and higher temperatures were found in the later period (Table 5). Total precipitation was much higher for the second half of the winter than the first half. We suggest that our observations of lower ice cover in the later period were likely driven more by weather than differences in flows. For that reason we suggest that the difference between 14 and 18 cfs may not be very important as far as formation and persistence of ice in the Lee Vining Creek channel. Since we did not evaluate flows higher than 18 cfs, we cannot make inferences about higher flows, but data collected by CDFG (1993) suggest lower flows (15 cfs) contributed to more extensive ice cap formation while higher flows (> 30 cfs) resulted in more anchor ice formations.

Air temperatures for November 2009 were above average, but air temperatures for December 2009 through March 2010 were below average, with the monthly average of 2009 December being 5°F below the 21 year average while 2010 averages from January to February were 1°F and 0.8°F lower than 21 year averages (Lee Vining 044881). In this study, the ice cover in December and early January was much higher than that observed throughout the rest of the winter. It is likely that the creek would maintain more extensive ice cover than was observed in 2009-2010 if much colder temperatures had persisted after December. Thus, during very severe winters, more ice formation should be expected. On the other hand, climatic warming trends predicted for the western United States would likely result in less frequent severely cold winters. Less severe winters would decrease ice cover extents, as well as the frequency and duration of such ice forming events. Therefore, the extent and types of the ice cover found in this study will not be applicable under different winter temperature regimes, and the frequency, extent, type, and duration of ice formed in Lee Vining Creek will most likely vary year to year.

Surface cover, which includes surface ice, shelf ice, and snow cover, was the most dominant form of ice in Lee Vining Creek. This surface ice occurred mainly along the channel's edges. Extensive formation of anchor ice was limited to only the lowest section of the creek. The most extensive anchor ice event would have lasted no more than five days. The timing and extent of the ice cover generally coincided with cold weather events, but factors such as timing of the cold weather relative to precipitation, canopy cover, substrate, gradient, and turbulence were also related to what type and how much ice formation occurred and how long they persisted. Ice formations, such as anchor ice dams and hanging dams, affect fish population adversely. But these types of formations were not found in the case of hanging dams and were very limited in space and time in this study. The proposed 14 cfs winter base flow is not likely to adversely affect the fish population in Lee Vining Creek.

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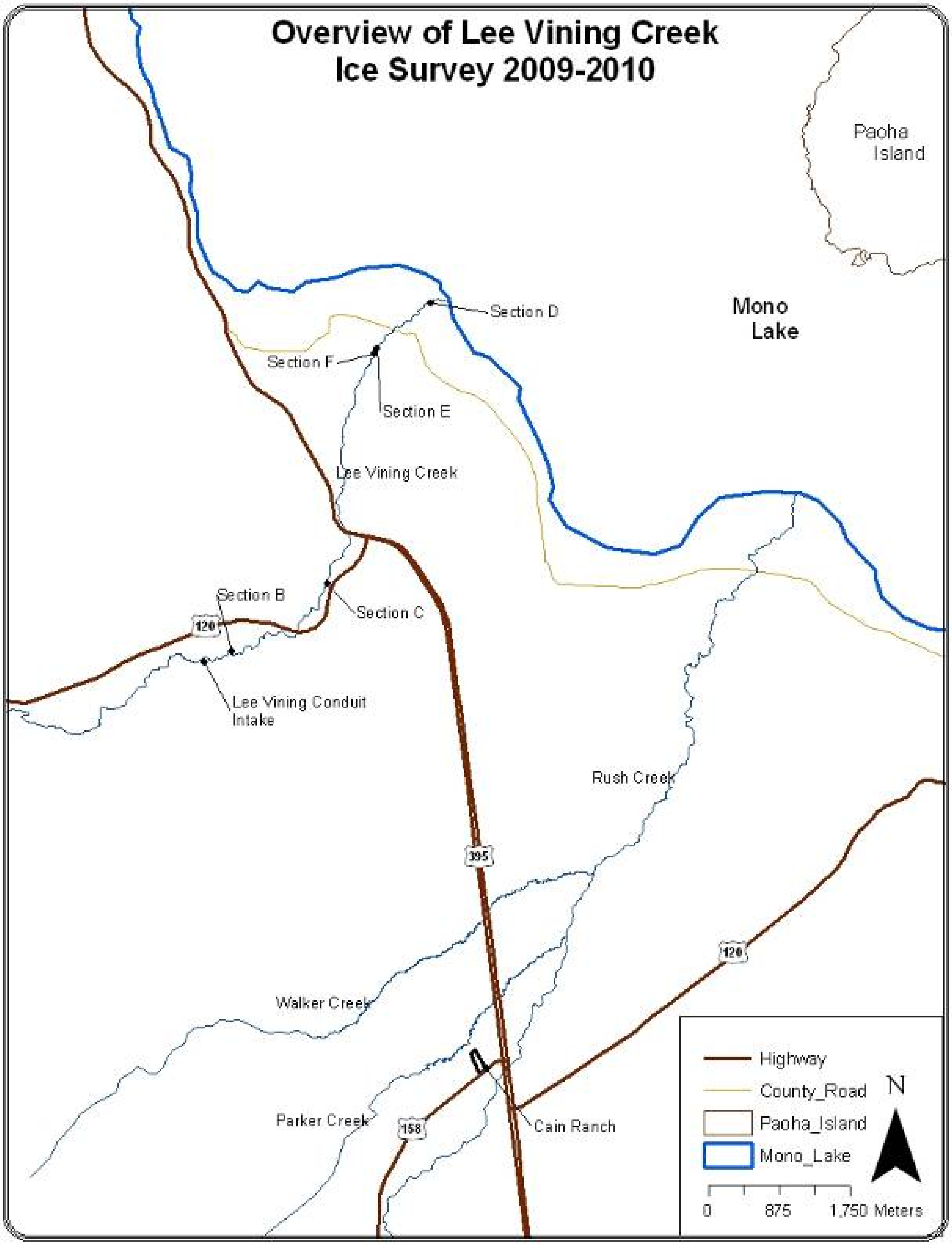


Figure 1. A map of the Lee Vining Creek winter icing study sites.

Figure 2. Baseline pictures of the study transects: a) Section B pool (Tran BP), b) Section B riffle (Tran BR), c) Section C pool (Tran CP), d) Section C riffle (Tran CR), e) Section D pool (Tran DP), f) Section D riffle (Tran DR), g) Section E glide (Tran EP), h) Section E riffle (Tran ER), i) Section F (Tran FP), and j) Section F riffle (Tran FR).

a) Section B pool (Tran BP)

b) Section B riffle (Tran BR)

c) Section C pool (Tran CP)

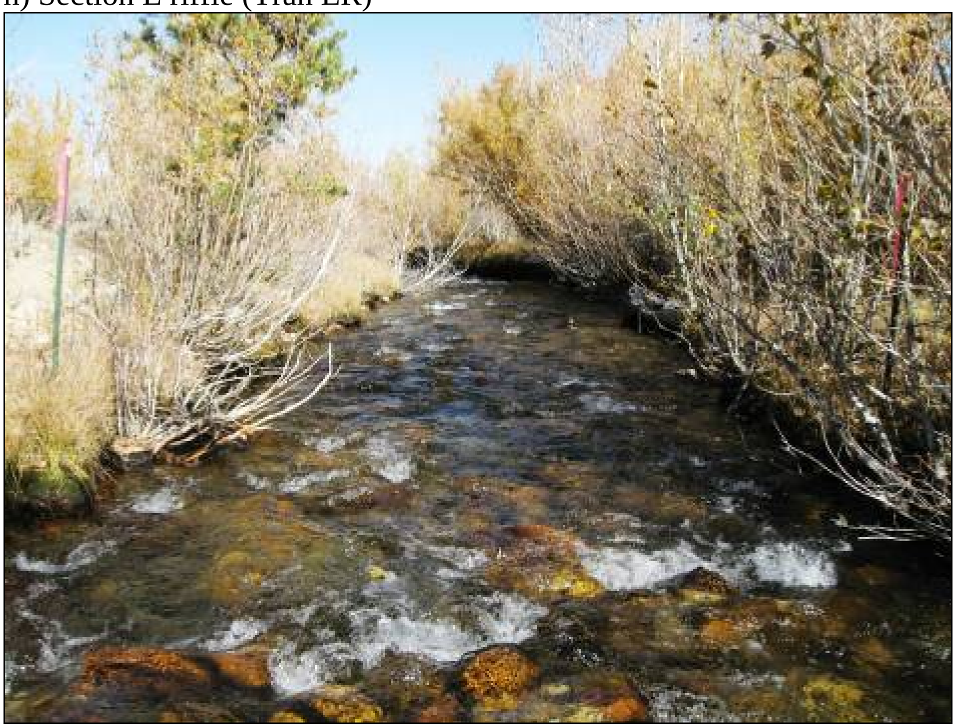
d) Section C riffle (Tran CR)

e) Section D pool (Tran DP)

f) Section D riffle (Tran DR)

g) Section E glide (Tran EP)

h) Section E riffle (Tran ER)



i) Section F (Tran FP)

j) Section F riffle (Tran FR).

Figure 3. Daily average discharge of Lee Vining Creek below LADWP Intake from November 18, 2009, to March 8, 2010.

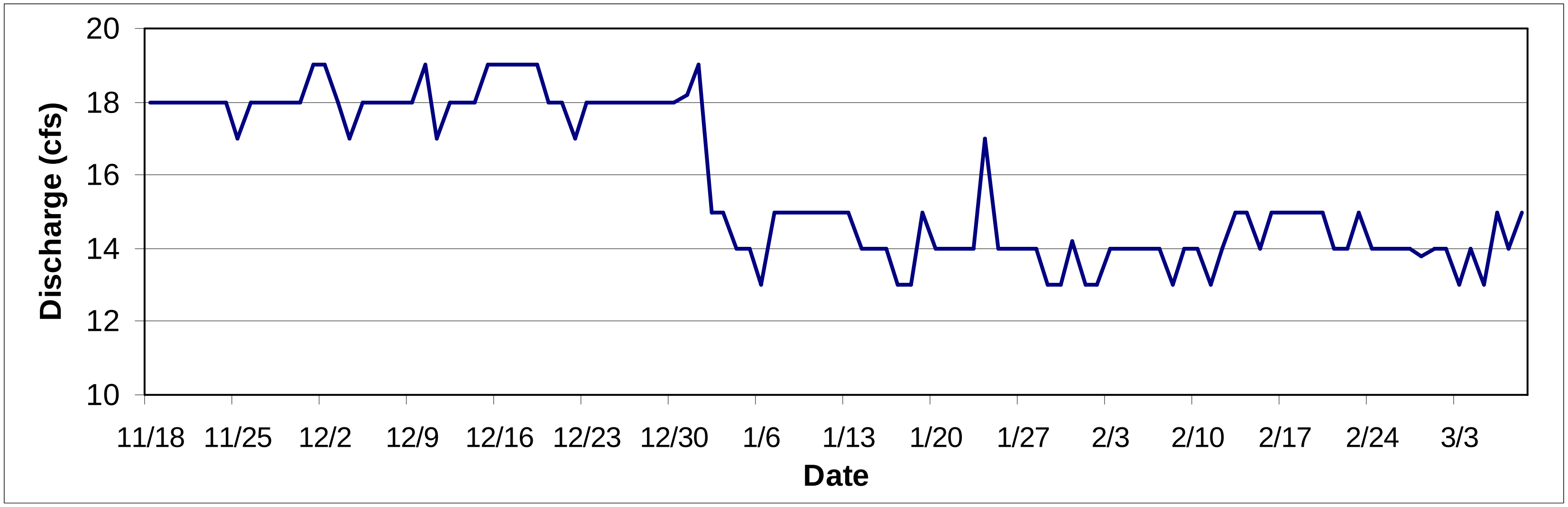
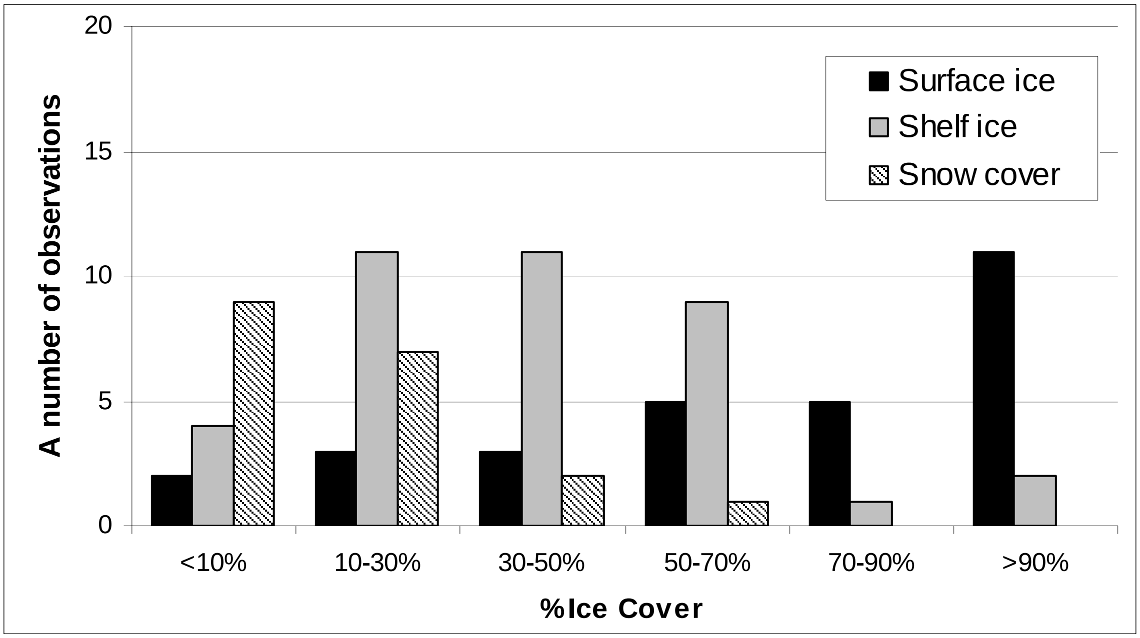


Figure 4. Histogram of the percent covers for each ice type observed during each visit for a) pool transects and b) riffle transects. The y-axis indicates the number of observations.

a) Pool transects.



b) Riffle transects.

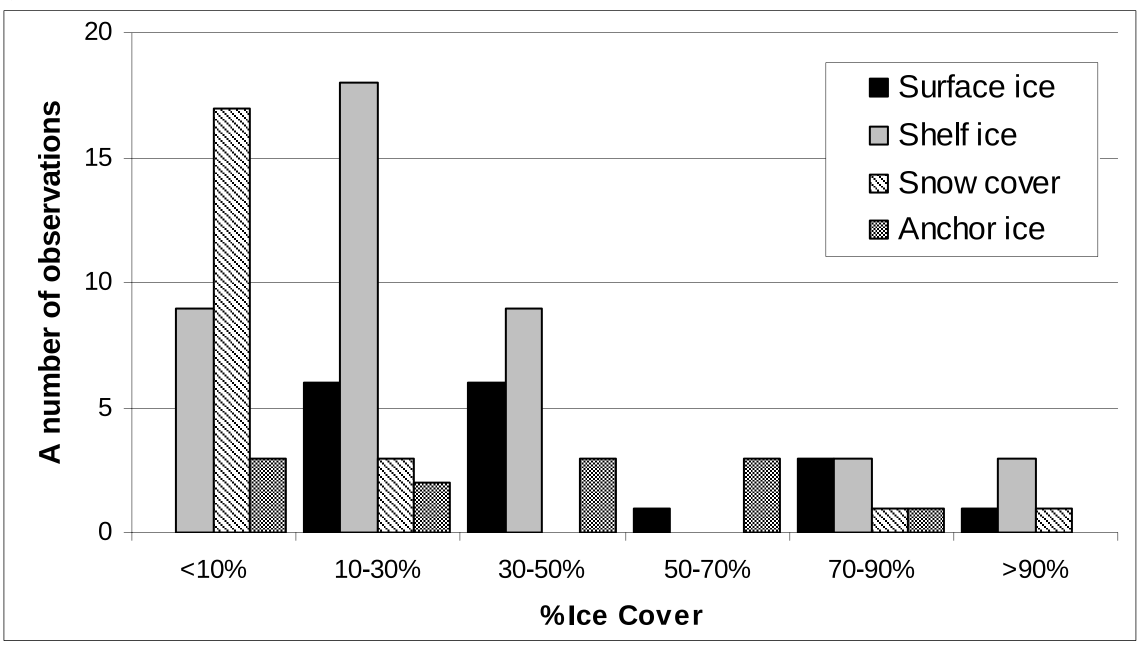


Figure 5. Anchor ice formations during the study period for three riffle transects (Tran_BR, Tran_CR, and Tran_DR).

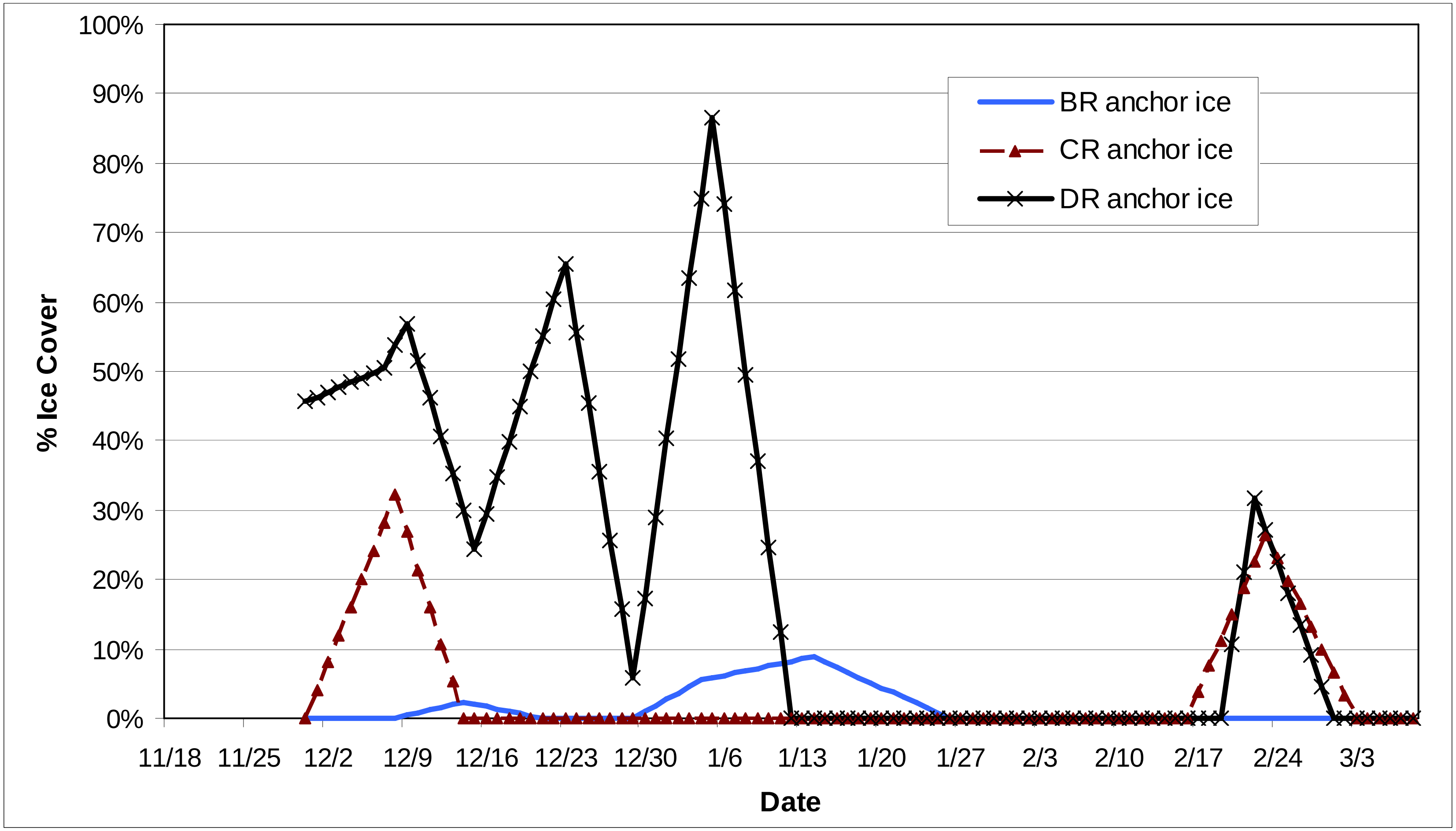


Figure 6. Daily maximum and minimum air temperatures from Cain Ranch and Paoha Island weather stations from November 18, 2009, to March 8, 2010.

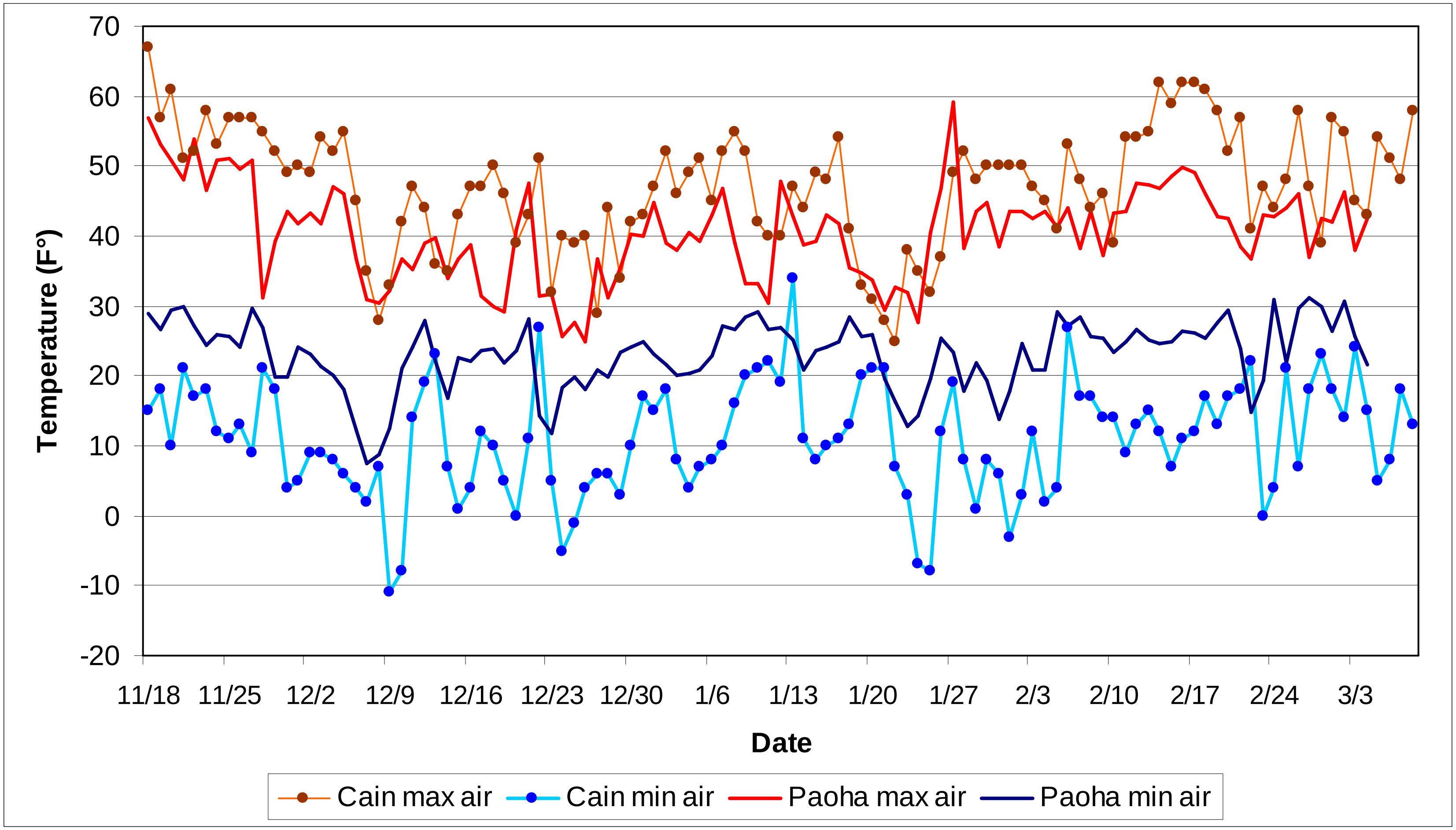


Figure 7. Daily precipitation recorded at Cain Ranch from November 18, 2009, to March 8, 2010.

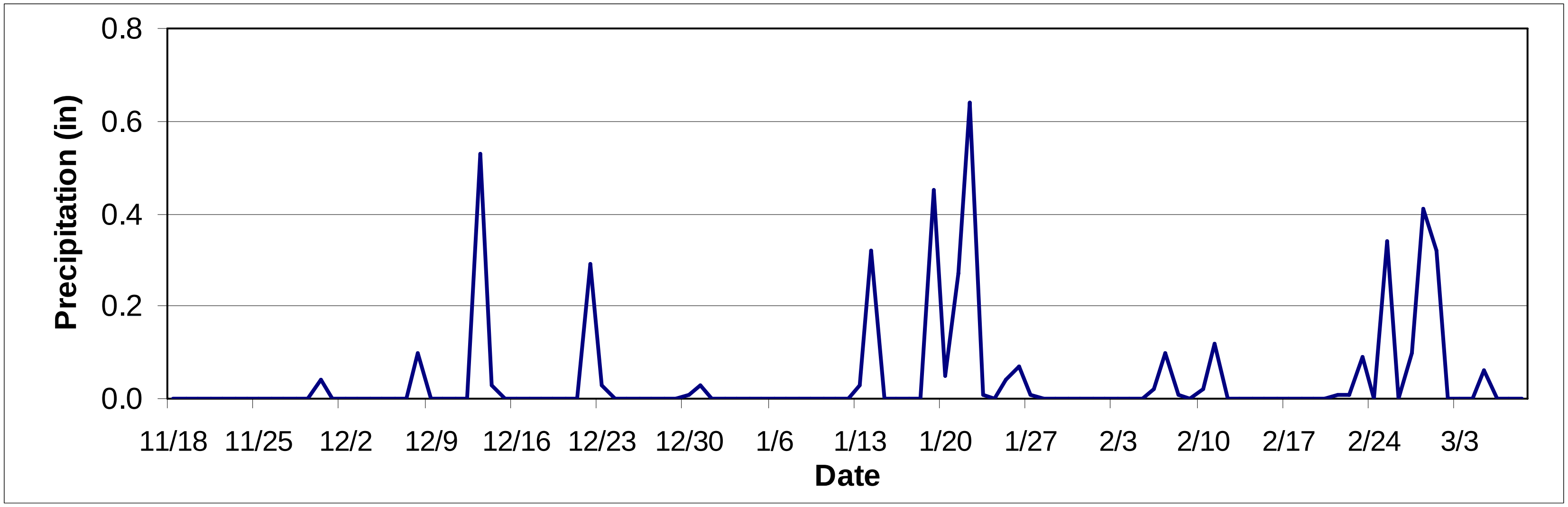


Figure 8-a. Tran_BP percent ice cover, air temperature, and water temperature from November 30 to March 8. Maximum and minimum temperatures are shown as red and blue lines, respectively, for air and water temperatures. The percent ice cover was calculated over the wetted width for each ice type (by ice cover type as different lines). The air temperature data were obtained from Paoha Island. The water temperatures were recorded at Tran_BP.

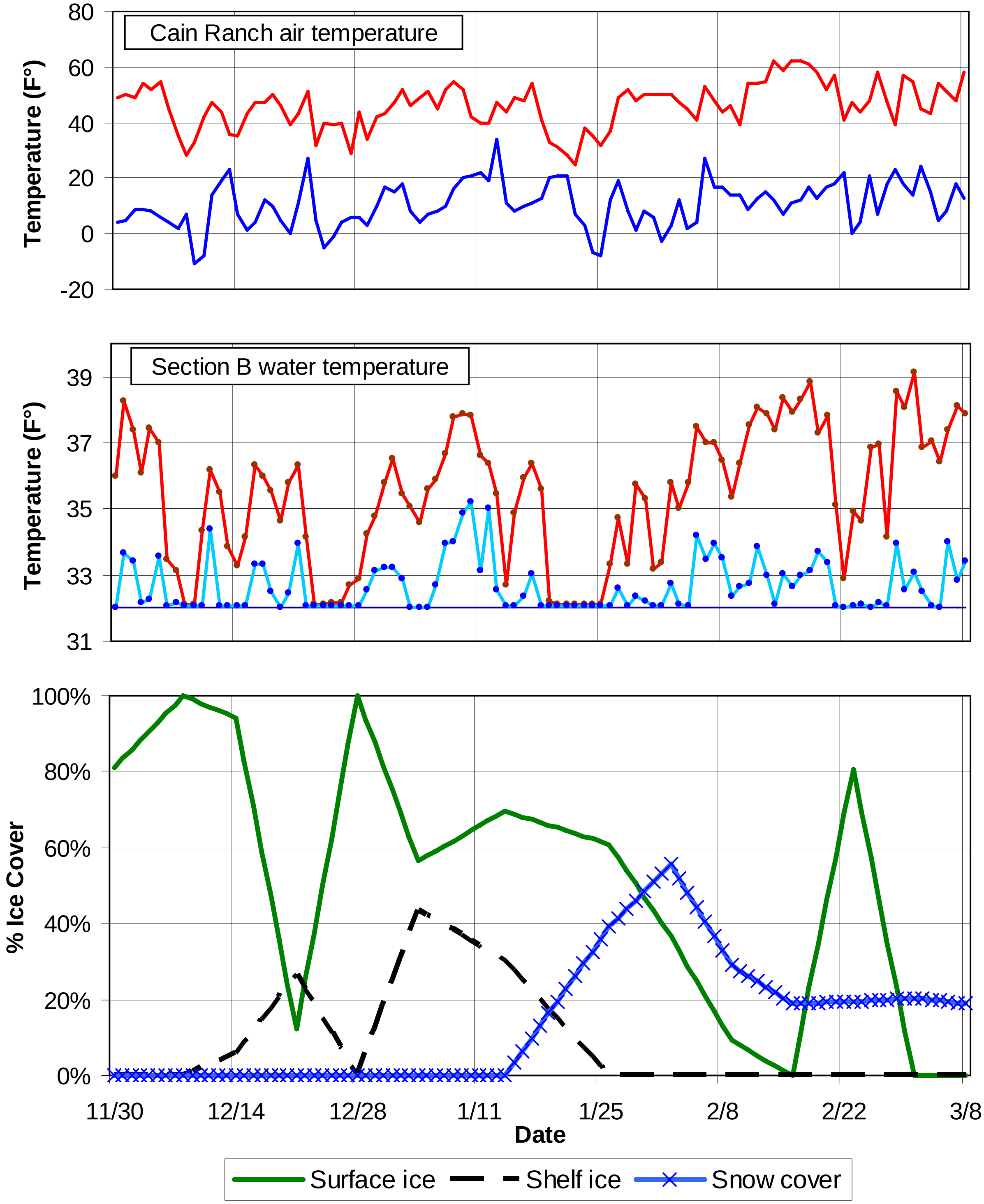


Figure 8-b. Tran_BR percent ice cover, air temperature, and water temperature from November 30 to March 8. Maximum and minimum temperatures are shown as red and blue lines, respectively, for air and water temperatures. The percent ice cover was calculated over the wetted width for each ice type (by ice cover type as different lines). The air temperature data were obtained from Paoha Island. The water temperatures were recorded at Tran_BP.

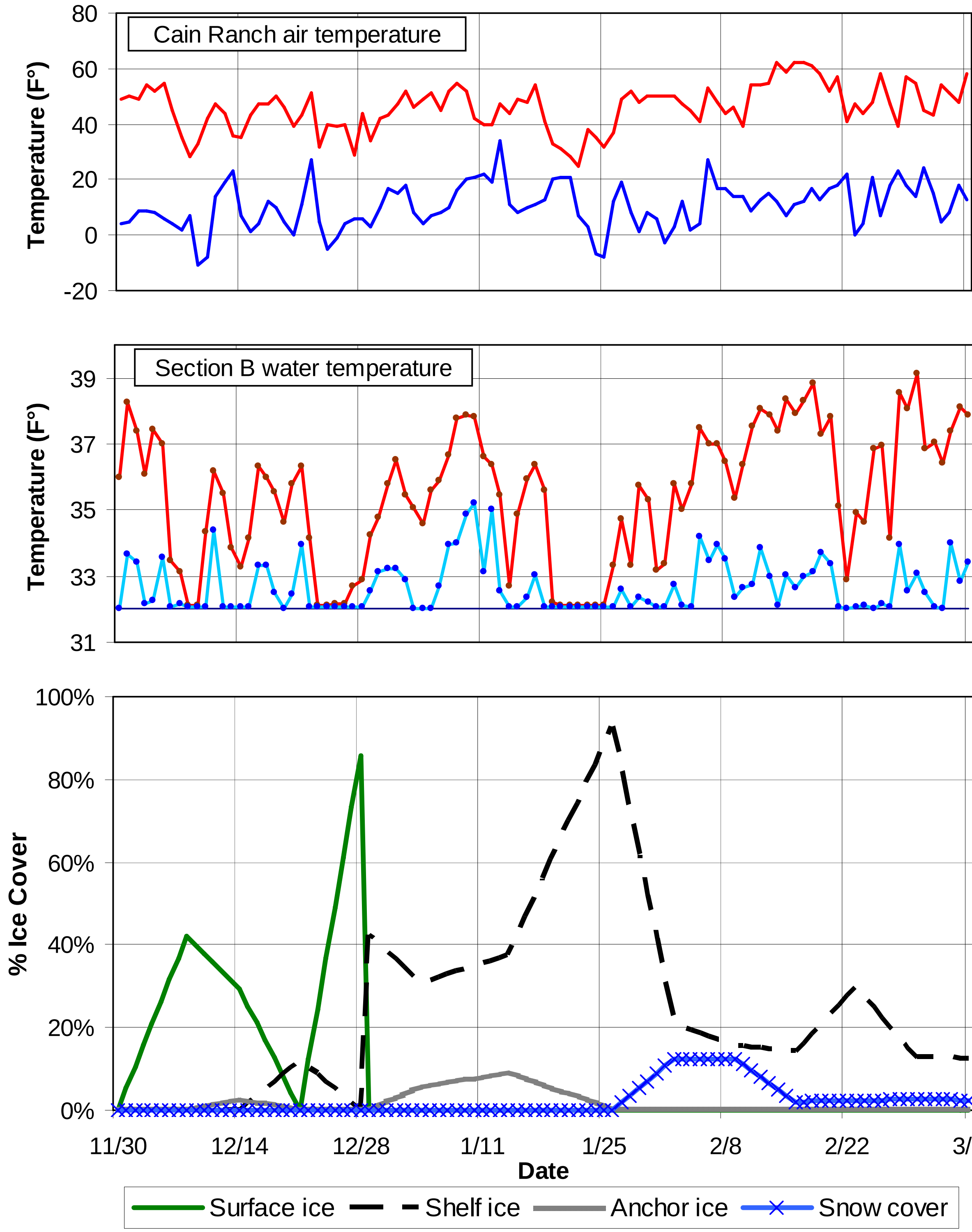


Figure 8-c. Tran_CP percent ice cover, air temperature, and water temperature from November 30 to March 8. Maximum and minimum temperatures are shown as red and blue lines, respectively, for air and water temperatures. The percent ice cover was calculated over the wetted width for each ice type (by ice cover type as different lines). The air temperature data were obtained from Paoha Island. The water temperatures were recorded at Tran_CP.

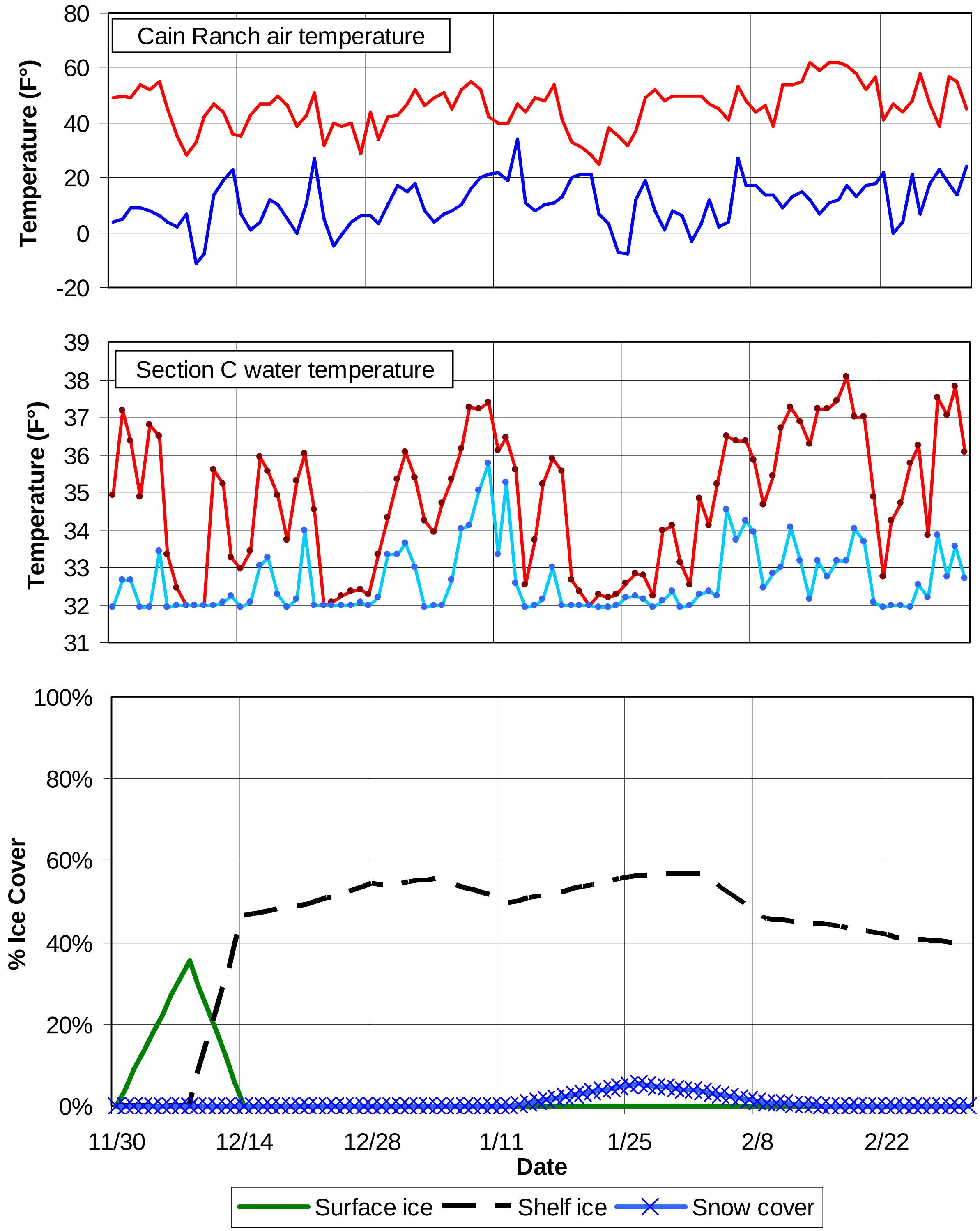


Figure 8-d. Tran_CR percent ice cover, air temperature, and water temperature from November 30 to March 8. Maximum and minimum temperatures are shown as red and blue lines, respectively, for air and water temperatures. The percent ice cover was calculated over the wetted width for each ice type (by ice cover type as different lines). The air temperature data were obtained from Paoha Island. The water temperatures were recorded at Tran_CP.

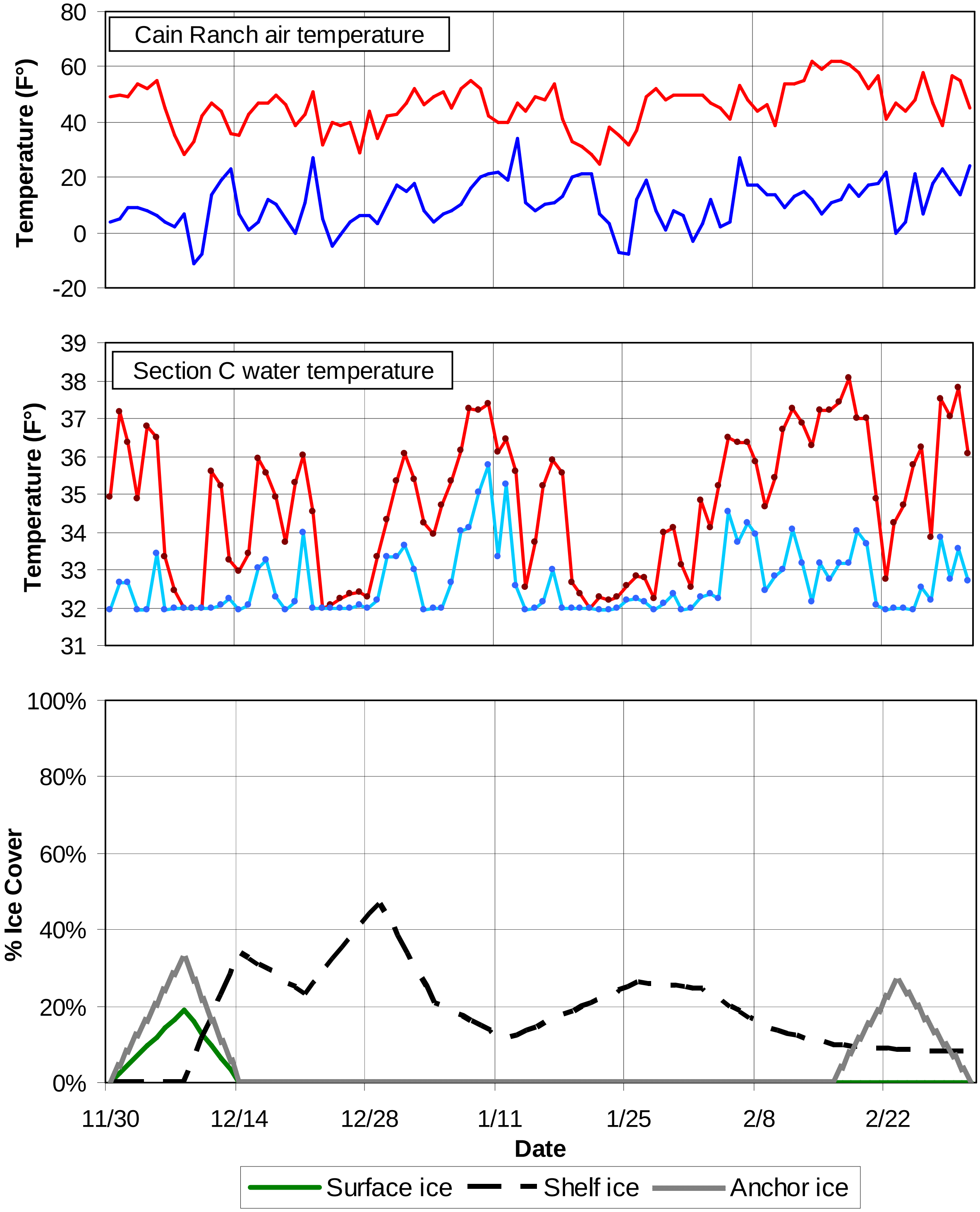


Figure 8-e. Tran_DP percent ice cover, air temperature, and water temperature from November 30 to March 8. Maximum and minimum temperatures are shown as red and blue lines, respectively, for air and water temperatures. The percent ice cover was calculated over the wetted width for each ice type (by ice cover type as different lines). The air temperature data were obtained from Paoha Island. The water temperatures were recorded at Tran_DP.

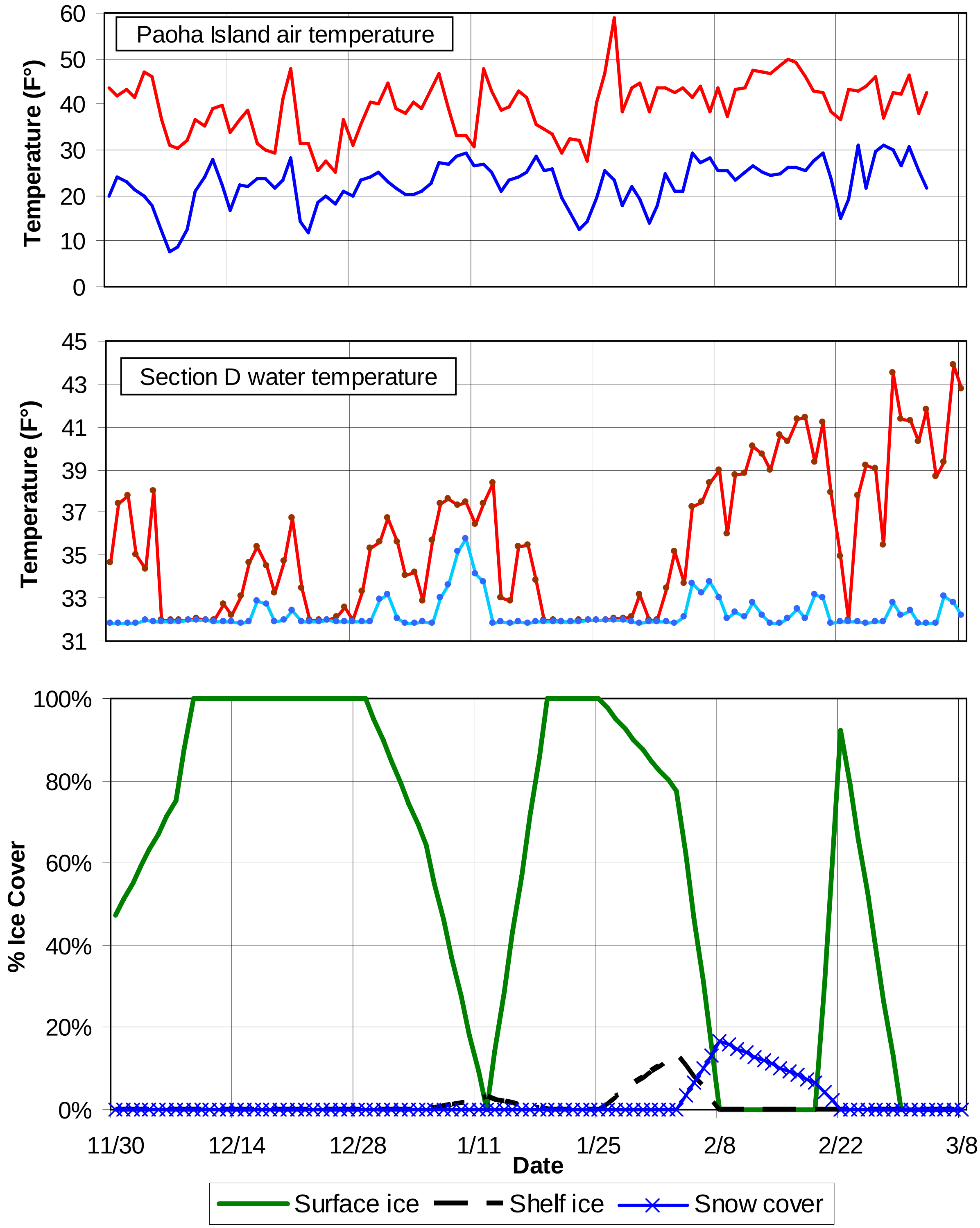


Figure 8-f. Tran_DR percent ice cover, air temperature, and water temperature from November 30 to March 8. Maximum and minimum temperatures are shown as red and blue lines, respectively, for air and water temperatures. The percent ice cover was calculated over the wetted width for each ice type (by ice cover type as different lines). The air temperature data were obtained from Paoha Island. The water temperatures were recorded at Tran_DP.

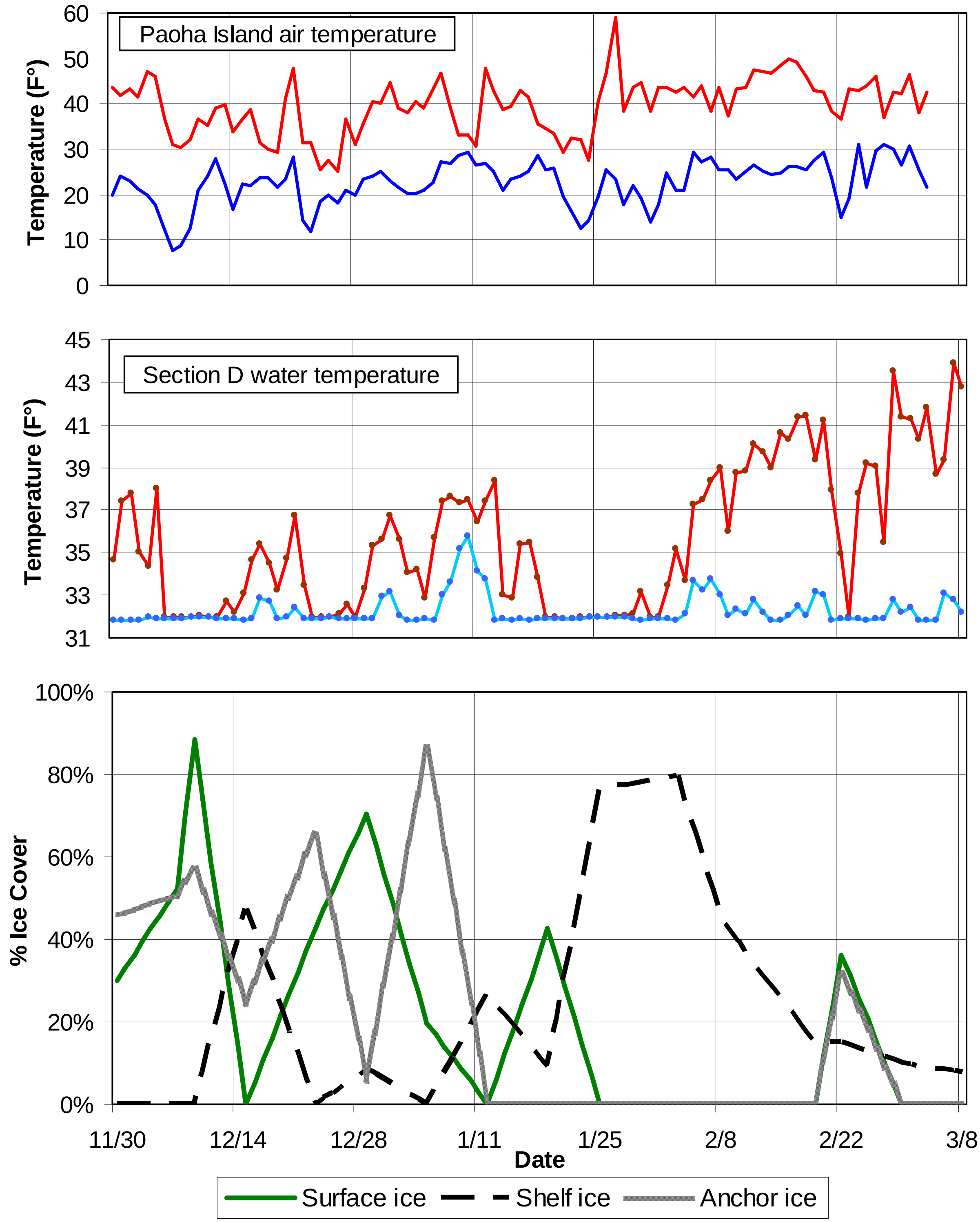


Figure 8-g. Tran_EP percent ice cover, air temperature, and water temperature from November 30 to March 8. Maximum and minimum temperatures are shown as red and blue lines, respectively, for air and water temperatures. The percent ice cover was calculated over the wetted width for each ice type (by ice cover type as different lines). The air temperature data were obtained from Paoha Island. The water temperatures were recorded at Tran_EP.

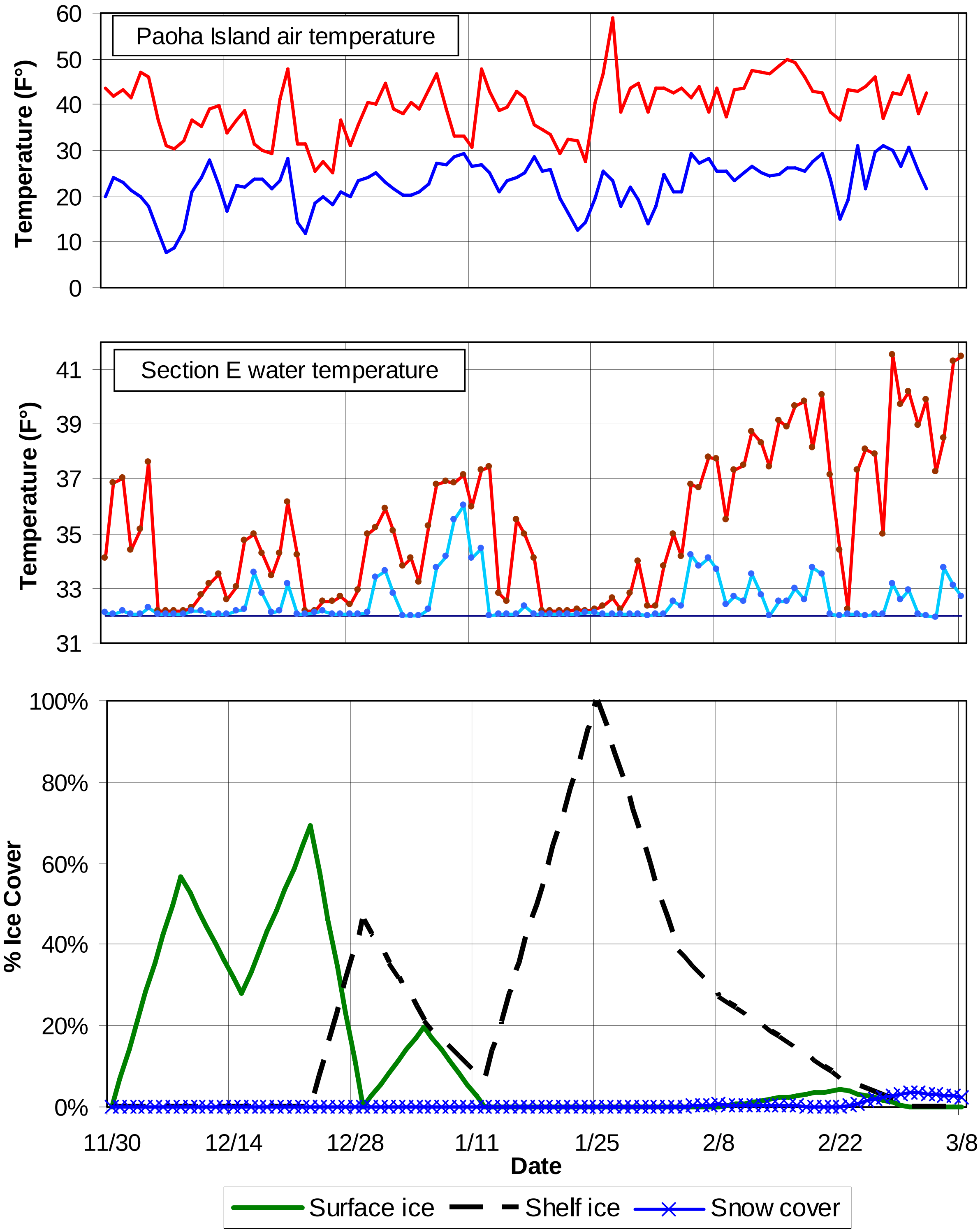


Figure 8-h. Tran_ER percent ice cover, air temperature, and water temperature from November 30 to March 8. Maximum and minimum temperatures are shown as red and blue lines, respectively, for air and water temperatures. The percent ice cover was calculated over the wetted width for each ice type (by ice cover type as different lines). The air temperature data were obtained from Paoha Island. The water temperatures were recorded at Tran_EP.

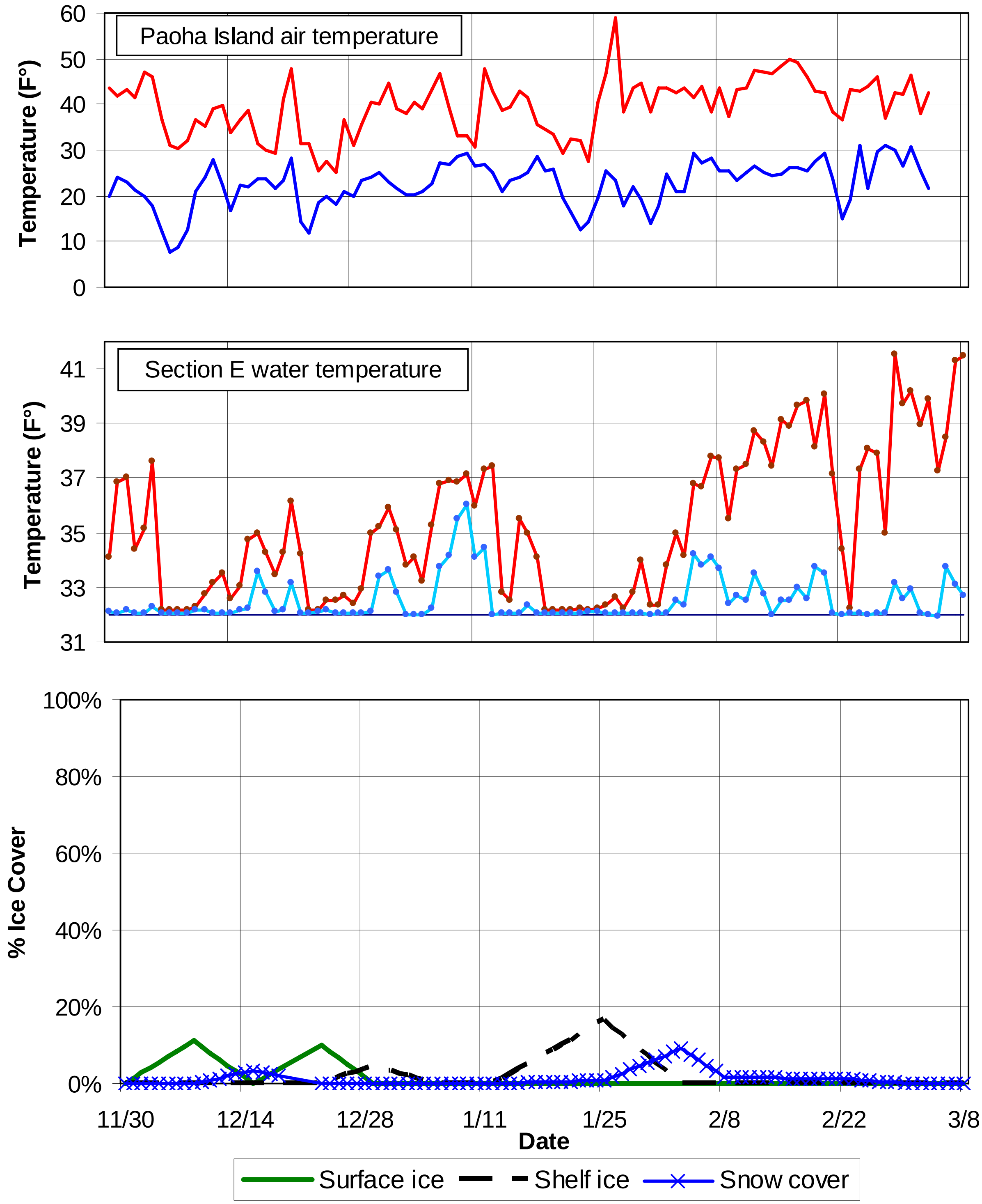


Figure 8-i. Tran_FP percent ice cover, air temperature, and water temperature from November 30 to March 8. Maximum and minimum temperatures are shown as red and blue lines, respectively, for air and water temperatures. The percent ice cover was calculated over the wetted width for each ice type (by ice cover type as different lines). The air temperature data were obtained from Paoha Island. The water temperatures were recorded between Tran_FP and Tran_FR.

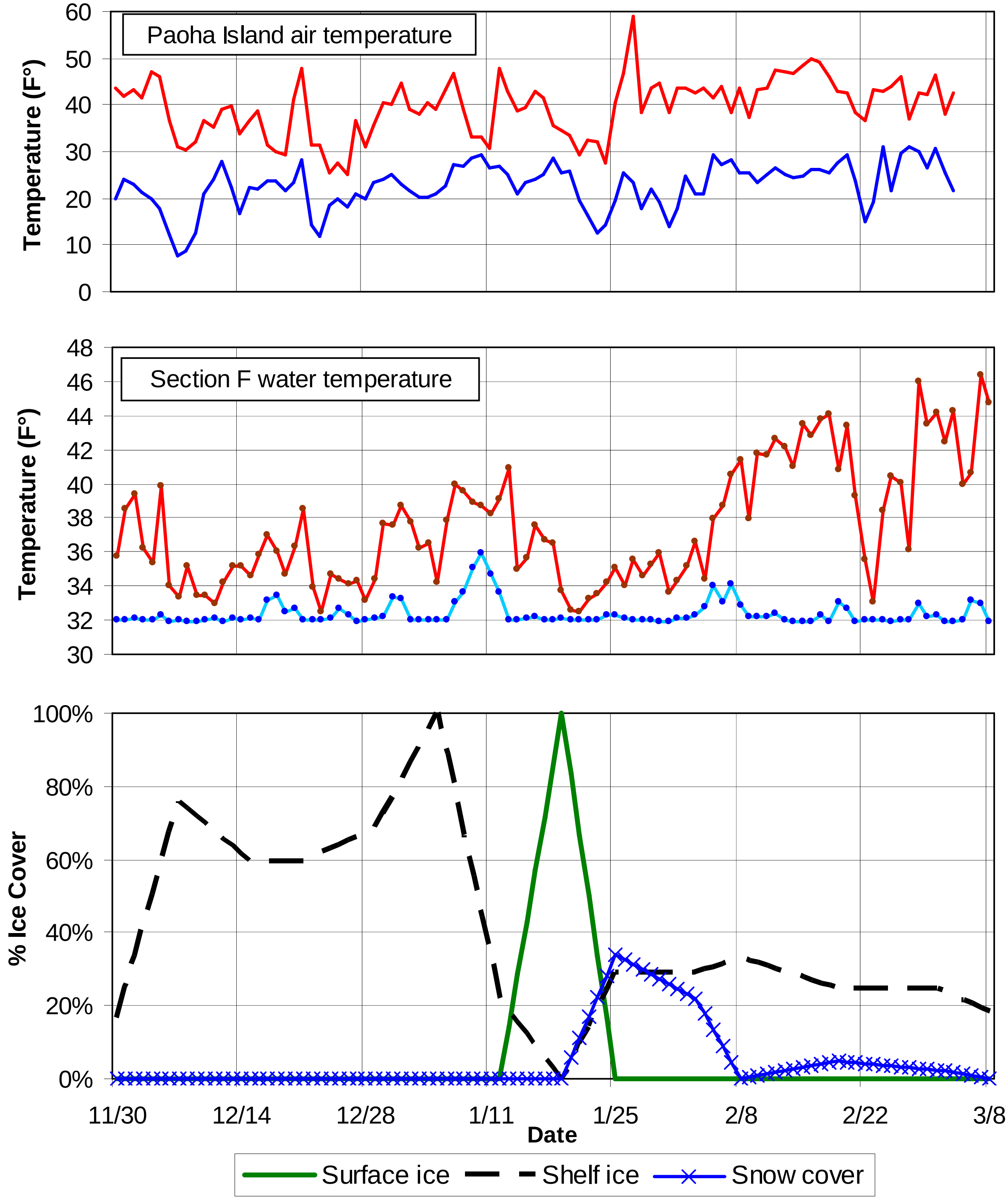


Figure 8-j. Tran_FR percent ice cover, air temperature, and water temperature from November 30 to March 8. Maximum and minimum temperatures are shown as red and blue lines, respectively, for air and water temperatures. The percent ice cover was calculated over the wetted width for each ice type (by ice cover type as different lines). The air temperature data were obtained from Paoha Island. The water temperatures were recorded between Tran_FP and Tran_FR.

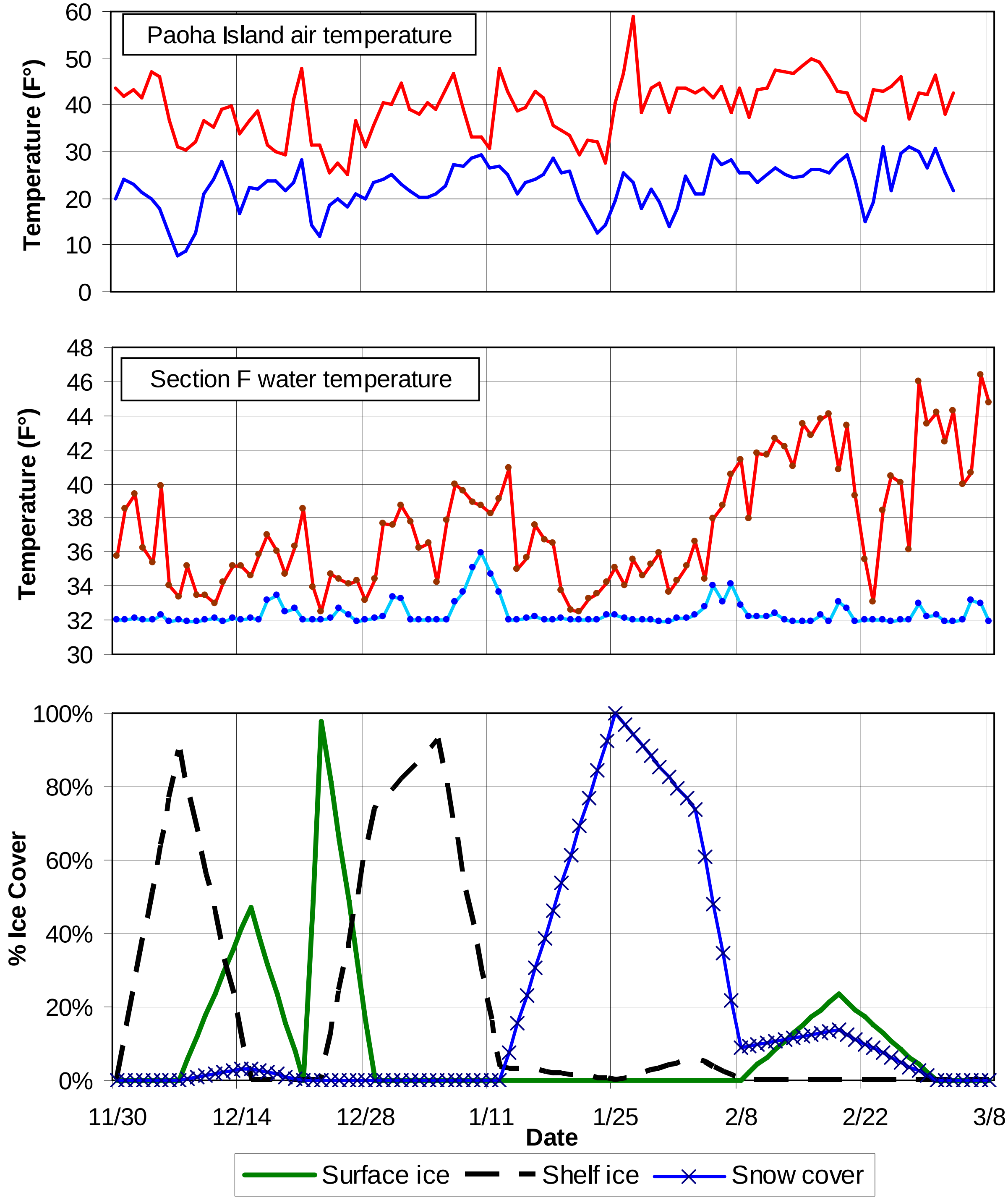


Figure 9. The ice ridge over Tran_BP along the thalweg on December 28.

a) Looking toward upstream. The Ice ridge is a white band stretching along the thalweg.

b) Looking toward downstream. The extensive ice development over the beaver dam most likely had caused flow restriction and increase in surface ice elevation.

Figure 10. Channel cross section profile change during the anchor ice formation events in Tran CR.

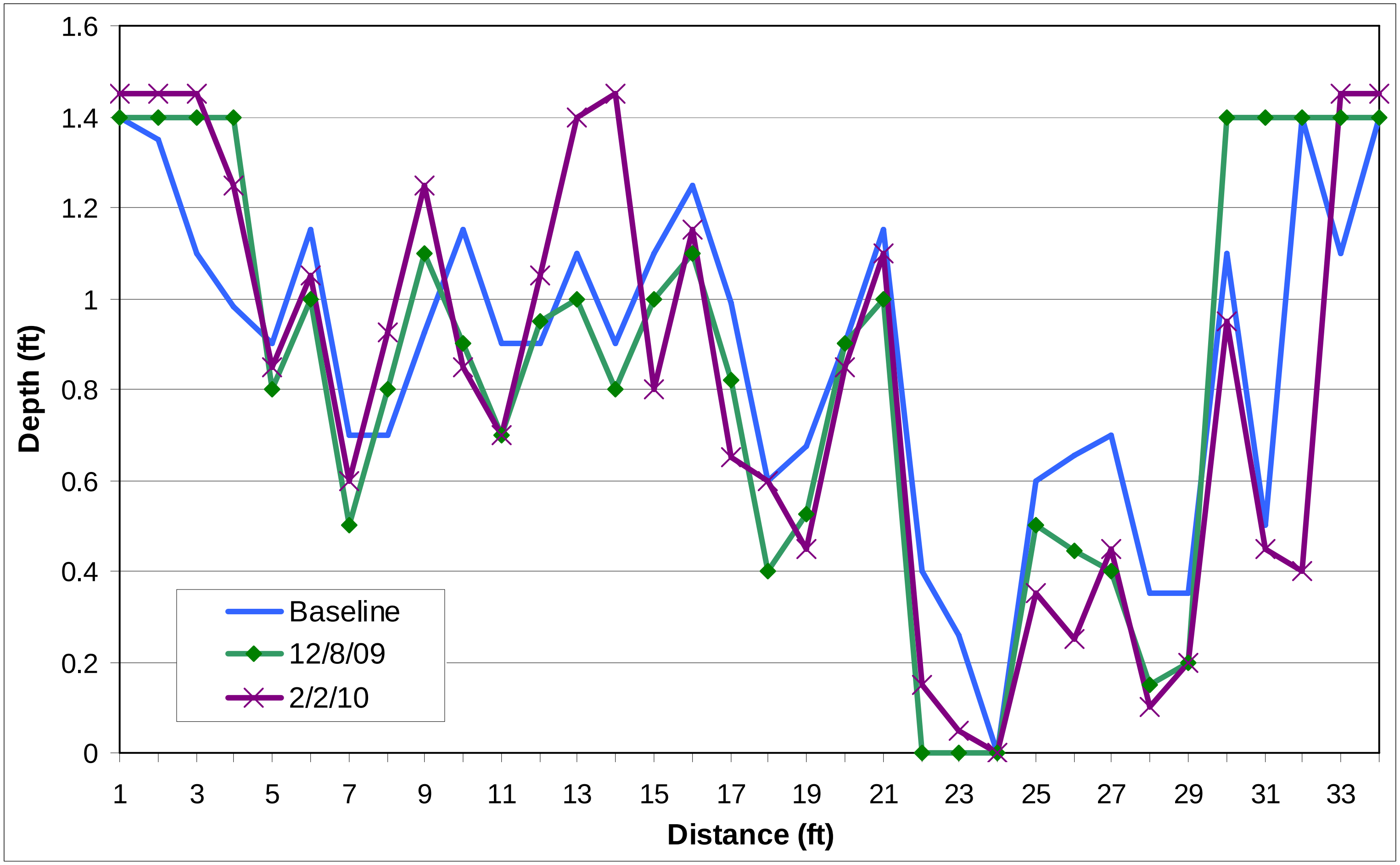


Figure 11. Pictures of Tran_DP. The water surface and surface ice elevations were relatively stable through out the study.

a) October 26, 2009.

b) December 15, 2009.

c) December 28, 2009.

d) January 5, 2010.

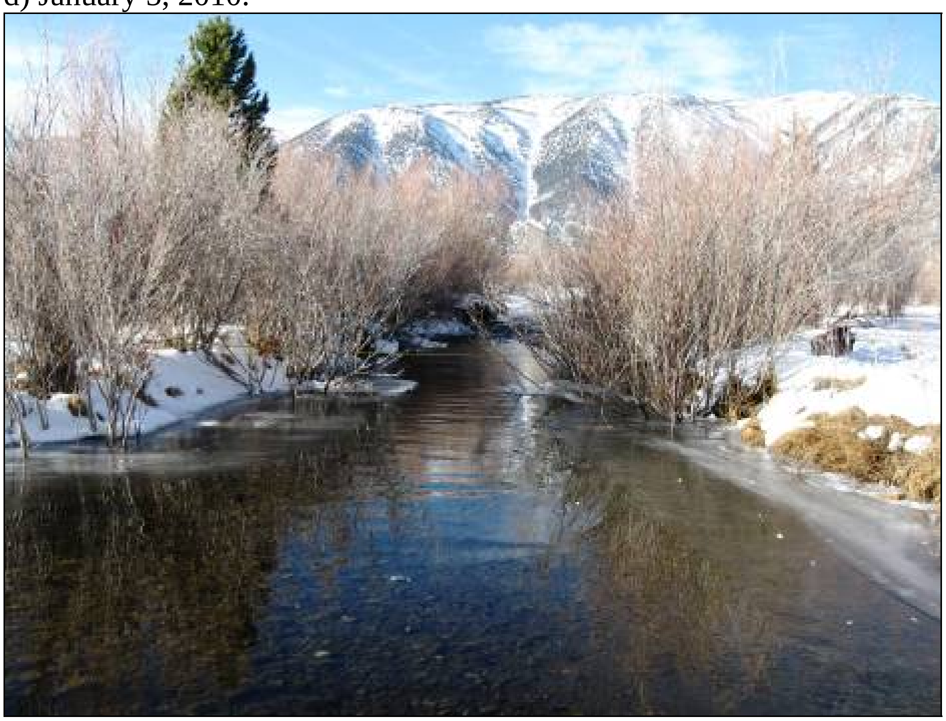


Figure 12. Channel cross section profile change during the anchor ice formation events in Tran DR.

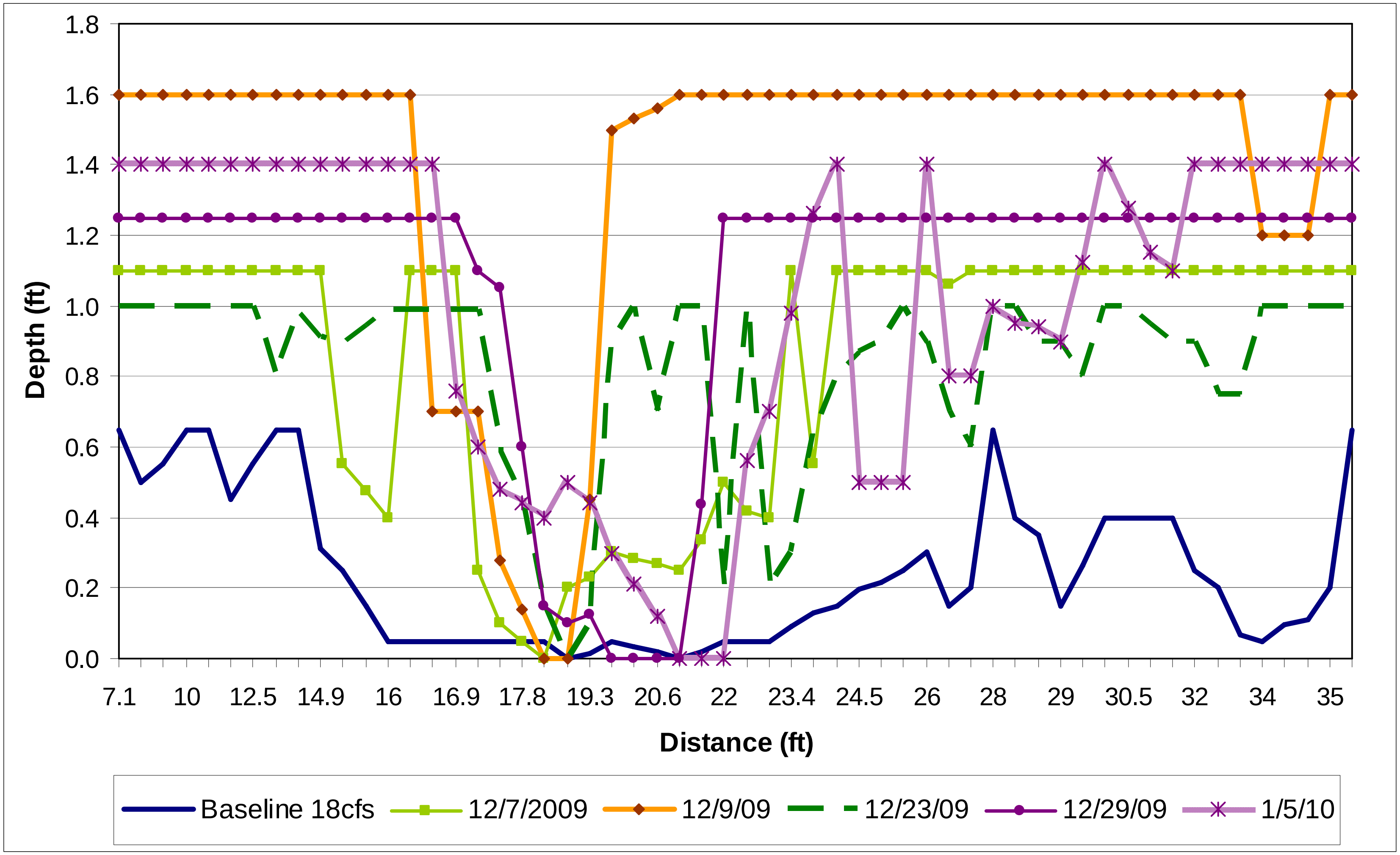


Figure 13. The anchor ice dams formed between Tran_DR and Tran_DP on December 9. The dam height reached 1.6 ft resulting in flooding and subsequent freezing over and around the dam. This was the worst anchor ice forming event during the study.

a) The anchor ice dam formed downstream of Tran_DR.

b) The second anchor ice dam downstream of Tran_DR.

Table 1. Baseline hydraulic characteristics of each transect.

Section	Transect	Average depth (ft)	Average velocity (ft)	Wetted width (ft)*	Slope
B (Below the Intake above Hwy 120)	BP (pool)	2.35	0.22	23.1 (21.8)	0.018
	BR (riffle)	0.48	1.27	29.2 (28.8)	0.012
C (Canyon Section)	CP (pool)	1.85	0.51	22.45 (22.45)	0.045
	CR (riffle)	0.54	1.65	23.65 (23.1)	0.03
D (Delta Section)	DP (pool)	2.03	0.37	17.45 (17.25)	0.014
	DR (riffle)	0.36	1.87	29.5 (25.8)	0.02
E (Main channel electro-fishing section)	EP (glide)	0.97	0.8	16.2 (16.05)	0.01
	ER (riffle)	0.75	1.98	12.2 (12.1)	0.021
F (B1 channel electro- fishing section)	FP (pool/glide)	0.46	0.29	10.4 (8.15)	0.014
	FR (riffle)	0.15	0.9	15.7 (15.3)	0.015

* Numbers inside the parentheses indicate the measured or calculated wetted widths for the proposed 14 cfs winter baseflow.

Table 2. Water temperature summary.

Section	Daily Maximum			Daily Minimum			Number of days below 32°F (super cooling)	Number of consecutive days below 32°F
	Mean	Max	Min	Mean	Max	Min		
B	35.75	40.35	32.09	32.83	35.69	31.99	8	3
C	35.15	39.78	31.99	32.78	35.78	31.94	38	7
D	36.05	43.90	31.89	32.28	35.73	31.84	69	22, 18
E	35.65	41.51	32.14	32.58	36.03	31.94	10	3
F	37.92	46.39	32.44	32.46	35.98	31.94	33	4

Table 3. Daily fluctuation of water temperature. Statistics were calculated based on differences between daily maximum and minimum water temperatures for each section.

Section	Average	SD	Max	Min	Range	Max - Min < 1*
B	2.96	1.61	6.04	0.05	5.99	18
C	2.41	1.40	5.27	0.00	5.27	26
D	3.90	3.27	11.11	0.00	11.11	30
E	3.17	2.52	8.77	0.10	8.67	31
F	5.59	3.51	13.45	0.40	13.05	4

* indicates a number of days when a difference between daily maximum and minimum water temperatures was less than 1°F.

Table 4. Discharge measured in the ice free section of Tran_DR during the anchor ice formation events.

Date of the extensive anchor ice formation	Daily average flow below Intake	Measurable discharge at cross section	Open channel width
11/17/09*	18	18.9	29.5
11/30/2009	18	17.5	20.65
12/7/2009	18	14.3	14.10
12/9/2009	18	4.1	3.40
12/23/2009	18	5.9	16.90
12/29/2009	18	9.9	8.77
1/5/2010	14	9.6	20.71
2/22/2010	14	11.29	16.42
14 cfs baseline	14	-	25.8

* indicates 18 cfs.

Table 5. Comparisons of air and water temperatures between 18 and 14 cfs experimental winter baseflows based on t-statistics. Maximum and minimum air temperatures and maximum, minimum, and average water temperatures between two periods (November 30 to January 1 for 18 cfs and January 2 to March 8 for 14 cfs) were compared using two-sample t-test assuming equal variances. Negative t-statistics indicate lower air and water temperatures for the period during which the flow was 14 cfs.

		Maximum		Minimum		Average	
Air temperature	Cain Ranch	-2.96	**	-3.20	**		
	Paoha Island	-3.84	***	-3.83	***		
Water temperature	Section B	-2.80	**	-1.05		-2.27	*
	Section C	-2.85	**	-2.46	*	-3.02	**
	Section D	-4.21		-2.08		-3.90	
	Section E	-4.10	****	-2.25	*	-3.70	
	Section F	-4.43	****	-1.20		-3.62	***

* indicates $p < 0.05$. ** indicates $p < 0.01$. *** indicates $p < 0.001$. **** indicates $p < 0.0001$.