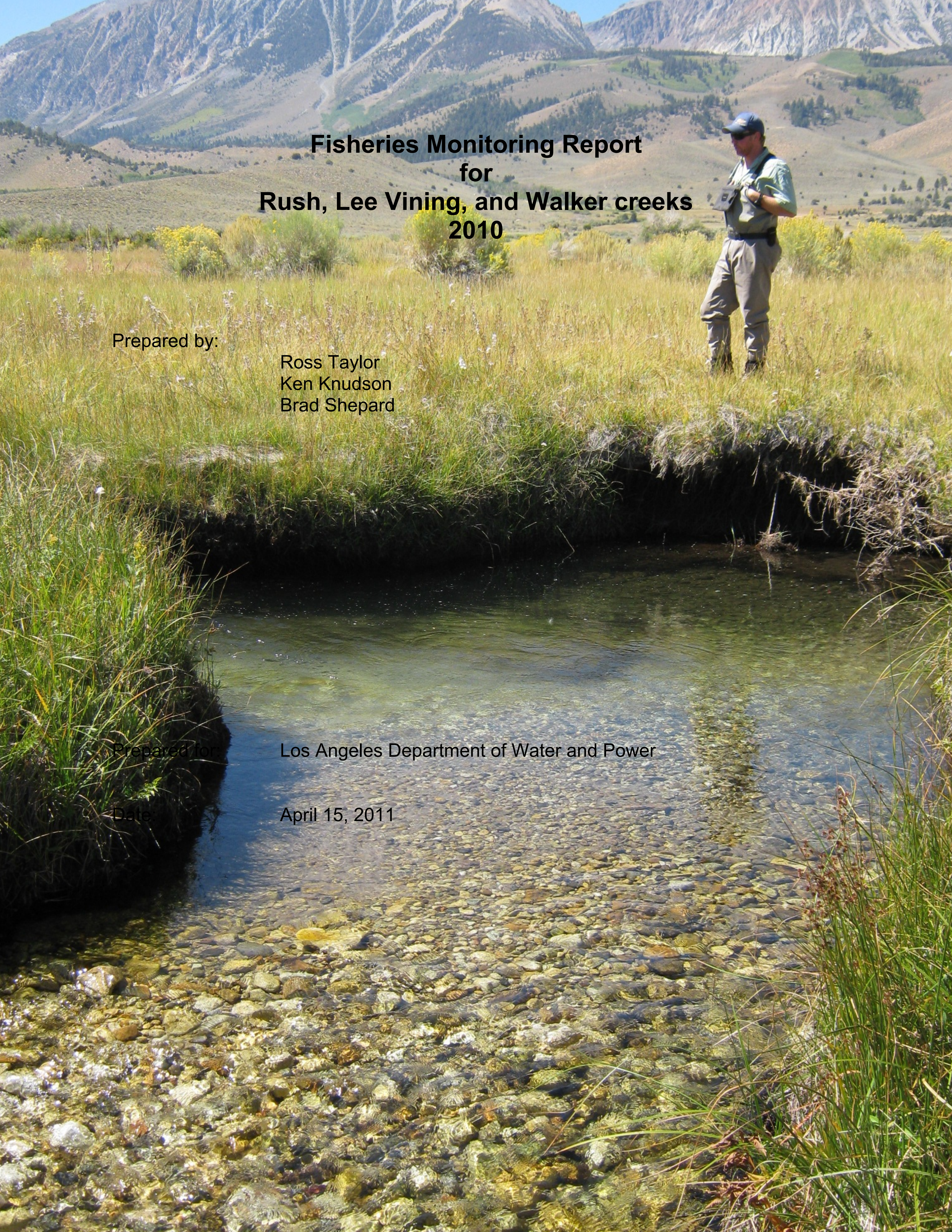
Section 3

Fisheries Monitoring Report for
Rush, Lee Vining, Parker, and Walker Creeks
2010-11



Fisheries Monitoring Report for Rush, Lee Vining, and Walker creeks 2010

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Executive Summary

This report presents results of the fourteenth year of fish population monitoring for Rush, Lee Vining, and Walker creeks pursuant to State Water Resources Control Board (SWRCB) Decision #1631 and the twelfth 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 2010 electro-fishing sampling occurred between September 10th and 21st. Mark-recapture electro-fishing techniques were utilized to estimate trout populations in four sections of Rush Creek and one section of Lee Vining Creek. The lengths of the 2010 sampling sections were the same as those modified in 2009. Fish population estimates for the Lower Lee Vining Creek side channel and Walker Creek were made using electro-fishing depletion methods. In 2010, the MGORD section of Rush Creek was sampled for the purpose of generating a population estimate, relative stock density (RSD) values, condition factors and implanting passive integrated transponder (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 2010, the estimated densities (number per hectare) of age-1 and older brown trout in the County Road section of Rush Creek was 1,490 fish/ha. This estimate was a 32% decrease from the record high estimate of 2,177 fish/ha in 2009. Between 2009 and 2010, 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 1,235 age-1 and older brown trout/ha. The Upper section of Rush Creek had an estimated density of 1,062 age-1 and older brown trout/ha.

In Walker Creek the 2010 density estimate was 28% less than the 2009 estimate; however the 2009 density estimate of 2,784 age-1 and older brown trout/ha was the highest estimate for the twelve-year sampling period. In this report, all previous density estimates of age-1 and older brown trout in Walker Creek reflect corrections made to sample reach lengths and areas.

The six age-1 and older brown trout captured in the side channel section of Lee Vining Creek produced an estimated density of 118.3 fish/ha in 2010. This side channel has had very low baseflows since RY2006 and therefore has supported relatively few fish the past five years. Between 2009 and 2010, the estimated density of age-1 and older brown trout in the main channel of Lee Vining Creek decreased by 58% from 1,083.4 fish/ha to 452.0 fish/ha. The 2010 density estimate of age-1 and older brown trout in the main channel section was the second-lowest estimate for this section in 12 years of sampling.

Density Estimates of Age-0 Brown Trout

Between 2009 and 2010, estimated densities of age-0 brown trout increased in all three Rush Creek sections. The Upper section's 2010 density estimate of 5,836.4 age-0 brown trout/ha was more than double the 2009 estimate of 2,509.0 age-0 brown trout/ha. The Bottomlands section had an estimated density of 3,130.3 age-0 brown trout/ha in 2010, which was a 33% increase from the 2009 estimate. The County Road section had an estimated 2,776.3 age-0 brown trout/ha in 2010, which was a 41% increase from the 2009 estimate.

In Walker Creek the density estimate of age-0 of brown trout decreased by 36% in 2010 (2,391.8 fish/ha) from 2009 (3,718.5 fish/ha); this was the third consecutive decrease in age-0 brown trout densities since the estimate of 9,899.8 fish/ha in 2007. In this report, all previous density estimates of age-0 brown trout in Walker Creek reflect corrections made to sample reach lengths and areas.

In 2010, the age-0 brown trout density estimate in the main channel section of Lee Vining Creek was more than double the density estimated in 2009; however the 2010 density of age-0 brown trout was relatively low when compared to values for the past 12 years. Thirteen age-0 brown trout were captured in 2010 within the Lee Vining Creek side channel which generated a density estimate of 256.4 age-0 brown trout/ha, which was more than double the 2009 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 2010, less than two percent of the trout sampled in Rush Creek were rainbow trout.

Estimated densities of age-1 and older rainbow trout during 2010 in the Lee Vining Creek side channel section were the lowest recorded for the 12 years of annual sampling. For the Lee Vining Creek main channel section, the estimated densities of age-1 and older rainbow trout dropped by 85% from 651.4 fish/ha in 2009 to only 99.7 fish/ha in 2010.

Density Estimates of Age-0 Rainbow Trout

In 2010, no age-0 rainbow trout were captured in the main channel and side channel sections of Lee Vining Creek, thus the density estimate for both sections was zero. This was the second straight year in which 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 decreased between 2009 and 2010 in the County Road and Bottomlands sample sections. In the County Road section, the 2010 estimated standing crop of 137.1 kg/ha was the second highest value ever recorded in this section and was a slight 5% drop from the 2009 estimate of 143.9 kg/ha. In the Bottomlands section, the 2010 estimated standing crop of 115.1 kg/ha was an 11% decrease from the 2009 estimate. In the Upper Rush section, the 2010 estimated standing crop of 153.4 kg/ha was a 17% increase from the 2009 estimate, and exceeded 150 kg/ha for the first time since 2007. In the MGORD section of Rush Creek, the 2010 estimated standing crop of 77.3 kg/ha was a 17% increase from the 2008 estimate of 66.2 kg/ha.

Between 2009 and 2010, Walker Creek experienced a decrease of 31% in estimated standing crop.

In Lee Vining Creek total standing crops (brown and rainbow trout combined) decreased by 55% between 2009 and 2010 in the side channel section, and decreased by 37% in the main channel section.

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

Mean condition factors for brown trout 150 to 250 mm were <1.00 for all sections in Rush Creek indicating that brown trout condition was below average in these sections during 2010. The 2010 season was the third year that the Bottomlands section of Rush Creek was sampled and the condition factor was 0.98, down slightly from 0.99 computed for 2009. In the MGORD section of Rush Creek, the 2010 average condition factor of brown trout 150 to 250 mm was 0.99, down slightly from 1.02 in 2009.

The mean condition factor for 150 to 250 mm brown trout in Lee Vining Creek during 2010 was >1.00 in both the main and side channel sections, indicating that brown trout condition was good. In the main channel section, the mean condition factor of 1.21 in 2010 was the second straight year of increased condition after the low value of 1.03 in 2008. The 2010 mean condition factor was also the first value to exceed 1.20 since the 2005 sampling season. For this annual report, conditions factors for rainbow trout between 150 and 250 mm were calculated in Lee Vining Creek. For the 10 sample seasons in which data were available, rainbow trout had higher condition factors than brown trout in nine of the seasons.

Relative Stock Densities (RSD's)

RSD-225 values for brown trout in the three annually-sampled sections of Rush Creek increased between 2009 and 2010, including a more than three-fold increase in the County Road section, an 80% increase in the Bottomlands section and a 161% increase in the Upper section. Within the County Road section three brown trout with lengths >300 mm were captured, which has not occurred since the 2001 season.

RSD-300 values remained low in the Upper Rush Creek section, with an increase from 2 to 3 between 2009 and 2010, and two brown trout greater than 375 mm in length were sampled. In 2010, the Rush Creek County Road section had an RSD-300 value of 1, the first RSD-300 value greater than 0 since the 2001 season. The Bottomlands section had an RSD-300 value of 0 in 2010, even though one fish greater than 300 mm in length was captured.

The RSD-225 and RSD-300, values in the MGORD section of Rush Creek decreased between 2009 and 2010, due primarily to the increase in numbers of fish between 150-224 mm in length. The RSD-375 value for 2010 was 5, the highest value since 2006.

In the Lee Vining Creek main channel sample section, the RSD-225 value for all trout (brown and rainbow trout combined) increased by 139% between 2009 and 2010. The increase of the RSD-225 value was due to the large overall drop in numbers of fish >150 mm and the large drop in the numbers of fish between 150-224 mm. In 2010, 34 fish ≥225 mm were captured, the largest number of fish ≥225 mm ever caught in this section of Lee Vining Creek. The Lee Vining Creek main channel section had a RSD-300 value of 3 in 2010, the highest RSD-300 value since 2005.

Termination Criteria

In Rush Creek, none of the annually sampled sections met the target of meeting four out of five termination criteria for the most-recent three-year average which encompassed 2008-2010. The County Road section met only one of the five termination criteria (density) and the Upper Rush section met two of the five termination criteria (density and condition factor).

The MGORD section of Rush Creek met only one of three RSD termination criteria (RSD-225 = 64) for the three-year average of sampling years 2008-2010.

In Lee Vining Creek, the main channel section failed to achieve the target of meeting three out of four termination criteria. The main channel section has only met one of the four termination criteria (condition factor) for the past two sets of three-year running averages. The 2005/2007/2008 set of data met two of the four termination criteria. For the 2010 annual report we have also provided separate condition factors for brown trout and rainbow trout.

Introduction

This report presents results of the fourteenth 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 twelfth 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 or upon approval of the SWRCB following public notice and opportunity for public comment. 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 as total length 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

In 2010, the annual sampling sections were similar to the sections sampled in 2009. In Rush Creek the MGORD, Upper and Bottomlands sections were the same as those sampled in 2009. The County Road section of Rush Creek was modified by three meters because the lower block fence had to be moved upstream due to changes in channel configuration; however the upper block fence was moved three meters upstream so there was no net change in length. In Lee Vining Creek the main channel and side channel sections sampled in 2010 were the same as sampled in 2009.

In Walker Creek, the same reach of channel was sampled as in past years; however the sample section was re-measured in 2010 because two meander bends had been cut-off by high flows. A change in channel length affects the total area of the sample section, thus also affects the computations of density and standing crop estimates. When the sample section was re-measured in September of 2010, we realized that incorrect channel lengths had been utilized for all of the past estimates. Looking back on field notes from 1999, the sample section in Parker Creek was established as100 m and the sample section in Walker Creek was established as 135 m. For some unknown reason, all density and standing crop estimates assumed that Walker Creek was the same length as Parker Creek.

In September of 2003, the upper boundary on Walker Creek was misidentified and the temporary block net was set farther upstream than the previous years. The 2003 field notes also indicated the difficulty in locating the upper boundary, so in 2003 the upper boundary was marked with a pile of large cobbles set on the meadow next to the stream channel. This upper boundary has been used consistently since 2003. When the error in sample section length was realized, we had LADWP's Bishop biological staff re-measure the Walker Creek sample section in two different manners. First by following the thalweg of the current wetted channel to provide the section length for the 2010 sampling and second by including the thalweg of the recently cut-off meander bends to provide the section length for sampling years 2003-2009.

In the Results section we have recalculated density and standing crop estimates for Walker Creek using the following three different section length measurements:

For sample years 1999-2002 = 135 m.
For sample years 2003-2009 = 228 m.
For sample year 2010 = 194 m.

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

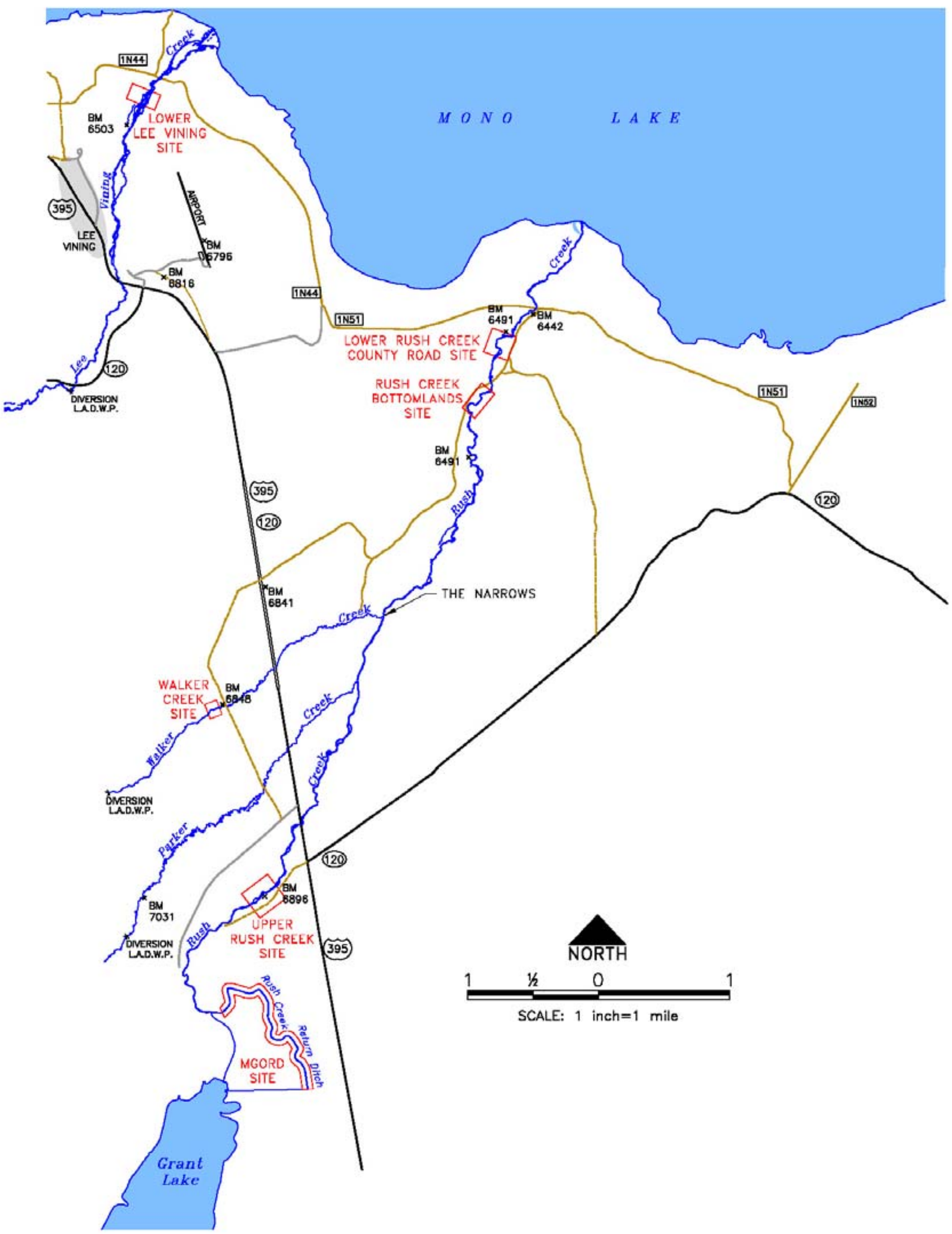


Figure 1. Map of Mono Basin study area with 2009 fish sampling sites displayed (created by McBain and Trush 2009).

For the 2010 runoff year (from April 1, 2010 to March 31, 2011) the April 1st forecast was 97.6% (119,200 acre-feet). The May 1st forecast update was 104.3% (127,400 acre-feet). Thus, the 2010 runoff year was the second officially "Normal" runoff year in a row.

Flows released into the MGORD from Grant Lake Reservoir were in the 40-50 c.f.s. range for most of April and May (Figure 2). The ascension of snowmelt-driven peak flows started in late June and peak flows occurred throughout the month of July (Figure 2). Grant Lake Reservoir also spilled for 30 days from July 2nd to July 31st. Flows in Rush Creek downstream of the Narrows were also augmented by the snowmelt peaks of Parker and Walker creeks (Figure 1). The peak flow below the Narrows was approximately 492 c.f.s. on July 11, 2010 (Figure 2).

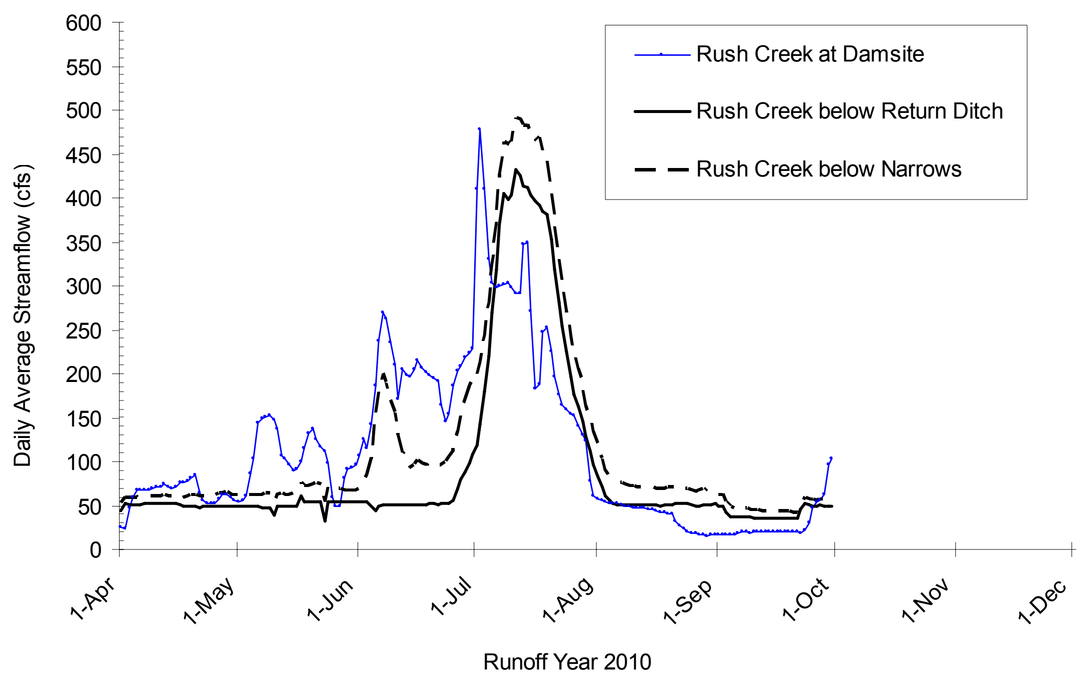


Figure 2. Daily stream flows (c.f.s.) in Rush Creek at three locations between April and September 2010. Data were provided by LADWP.

The peak flow in Lee Vining Creek below the LADWP diversion in 2010 was approximately 511 c.f.s. and occurred on June 7, 2010 (Figure 3). During the primary peak, flows exceeded 200 c.f.s. for nine days. 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 275 c.f.s. occurred on June 27th and a third peak occurred of 214 c.f.s. on July 17th (Figure 3). These smaller peaks were diverted to Grant Lake Reservior and by early July flows in lower Lee Vining Creek were generally less than 60 c.f.s. (Figure 3).

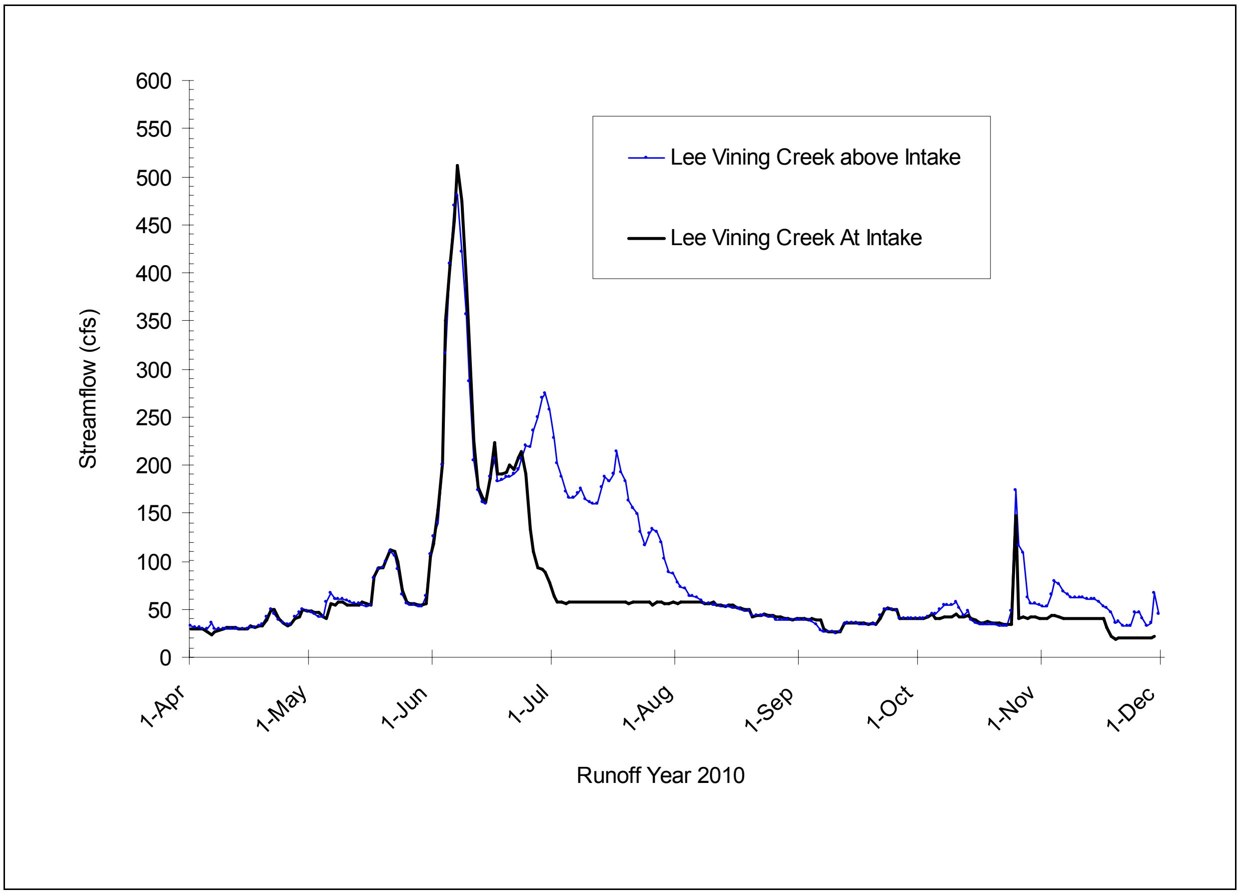


Figure 3. Daily stream flows (c.f.s.) in Lee Vining at the LADWP diversion between March and September 2010. Data were provided by LADWP.

Methods

Field sampling for generating fish population estimates occurred during the late summer between September 10th and 21st, 2010. Mark-recapture estimates were made in four sections of Rush Creek – MGORD, Upper, Bottomlands and County Road and in the 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 4). 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 5). 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 (models SR-24 and SR-20B). 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. A single electro-fisher was used to sample the Lee Vining Creek side-channel and

Walker Creek. One dip-netter accompanied the 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 nearly all the sections sampled for mark-recapture estimates 12 mm mesh hardware cloth fences were installed at the upper and lower boundaries of the sections. The exception was the MGORD section which was infeasible to effectively block the lower boundary. 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 nylon 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 and Upper sections of Rush Creek and in Lee Vining Creek. The anal fin was clipped to mark fish in the MGORD and Bottomlands section of Rush Creek. Fin clips were made by using a scissors 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 fin's posterior edge.

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 Excel spreadsheets with the appropriate equations. All mark-recapture estimates employed the modified Peterson estimator's equations embedded within Excel spreadsheets (Chapman 1951, as cited in Ricker 1975).

Figure 4. Anode operators and netters sampling Rush Creek's Upper section, 2009.

Figure 5. 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. 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. However, factors such as runoff year-type, water temperature and climatic conditions affect the length and quality of each year's potential growth season leading up to the September sampling period.

Fin Clips, PIT Tags and Growth Estimates

Starting in 2009, PIT tags were implanted in all age-0 brown trout (>80 mm) captured during the recapture run 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 could be scanned with a tag reader. In 2010, PIT tags were also implanted in any recaptured trout that had an adipose fin clip, but did not have a PIT tag when scanned by the tag reader. Finally, PIT tags were implanted in nearly all of the trout captured during the recapture electrofishing pass conducted in the MGORD section of Rush Creek.

During the 2010 sampling, all captured fish were carefully examined for previously clipped adipose fins (adipose fin-clip recaptures). Those fish that were missing their adipose fin were scanned with a PIT tag reader. For fish that had retained their PIT tag, the tag number and current length and weight were recorded. In many cases, partially regenerated adipose fins were re-clipped to make future identification easier.

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. 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 et al. 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 was to sustain a fishery for naturally-produced brown trout that averaged eight to 10 inches in length (200 to 250 mm) with some fish reaching 13 to 15 inches (325 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 (325 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 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 are now 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 are applied to all trout (brown and rainbow combined) in the Lee Vining Creek sample section. A fifth metric of RSD-300 for brown trout (percentage of brown trout ≥300 mm or ≥12”) is also applied to only Rush Creek sample sections. The values for these fisheries metrics, as discussed below, represent realistic recovery goals for the streams.

Finally, three termination criteria RSD metrics are now applied to the MGORD portion of Rush Creek – 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 calculated 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. 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. 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 1.00 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 calculated 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. 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. 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 Lake Reservoir has unique spring creek-like characteristics that support the growth of large brown trout similar to the pre-1941 productivity of the human-influenced springs below the Rush Creek Narrows. Two years of movement study data demonstrated that approximately 40 to 50% of the large (>300 mm) radio-tagged brown trout migrated between the MGORD and downstream 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.

Primary Productivity Study

Introduction

Periphyton are single-celled aquatic plants (algae) that attach and grow on stream channel substrates. The rate at which communities of these microscopic plants convert dissolved inorganic compounds into living (organic) matter is referred to as primary production. The principal inorganic compounds necessary for periphyton growth and reproduction are "macro-nutrients" such as calcium carbonate (reported as Total Alkalinity concentrations by most laboratories), and "micro-nutrients" such as phosphorus and nitrogen compounds.

Primary production provides much of the food base for aquatic communities and ecosystems. The sun's energy that is captured during the growth of these microscopic plants is cycled through the interrelated food chains of an ecosystem, when the aquatic insects and crustaceans that graze on the periphyton are consumed by predacious beetles, stoneflies and other large macroinvertebrates, which in turn are ultimately consumed by fish. Evaluation of a trout stream's primary productivity rates, as well as the concentrations of micro and macro-nutrient "fertilizers" present in the stream during various seasons, are useful in determining a stream's potential for producing fish biomass.

Many researchers have reported direct correlations between stream fertility and fish biomass and production. In their studies of ten native brown trout streams in Spain, Almodovar et al. (2006) found that brown trout production (kg/ha/year) was positively related to the concentrations of certain inorganic nutrients present in the streams. For example, brown trout production rates on streams where total alkalinity concentrations ranged from 252-303 mg/l were as much as four times higher than for streams with total alkalinity values ranging from 12-20 mg/l. These findings were consistent with studies of brown trout populations in other parts of Europe (Power 1973; Mortensen 1977; Le Cren 1969) and the United States (Kwak and Waters 1997). The latter study also found a linear relationship between mean alkalinity and mean brown trout production rates for U.S. trout streams that was very similar to the correlations found in the European studies.

The Fisheries Team recently completed studies which evaluated instream flow effects on habitat availability and temperature effects on growth rates; however little work has been focused on stream productivity. The purpose of investigating the primary production of Rush and Lee Vining creeks was to better evaluate the ability of these creeks to produce trout of the sizes described in the Settlement Agreement's termination criteria (see page 12). The primary productivity study in the Mono Basin was initiated in September of 2010 and will continue through the summer of 2011. For the 2010 annual report, we are providing an overview of our methods and preliminary results. The 2011 annual report will include more comprehensive results and discussion sections regarding the primary productivity study.

Methods

Surface water samples will be collected for analyses of the following major algal growth stimulating nutrients: Total Phosphorous, Orthophosphate, Nitrate+Nitrite, Kjeldahl Nitrogen, Ammonia and Total Alkalinity (as $CaCO_3$). Analyses will also be conducted for Specific Conductivity, which provides an estimate of dissolved solids concentrations. Samples will be collected during five time periods between September 2010 and September 2011 at the following stations:

1. Rush Creek MGORD (at Grant Lake Reservoir outfall).
2. Upper Rush Creek (just upstream of the Upper Rush electrofishing section).
3. Lower Rush Creek (just upstream of the Bottomlands electrofishing section).
4. Upper Lee Vining Creek (approximately 200 meters upstream of the sewage ponds).
5. Lower Lee Vining Creek (just upstream of the electrofishing section).

6. Owens River above Hot Creek (approximately 1.5 miles upstream of Benton Crossing).
7. Owens River below Hot Creek (approximately 300 meters upstream of Benton Crossing).

Two stations were established in the Owens River for the purpose of providing a regional comparison with a watershed known for its high quality brown trout fishery. The Owens River stations were strategically located upstream and downstream of the Hot Creek confluence to better evaluate the influence of Hot Creek's known high productivity.

The primary productivity rates of the periphyton communities at the selected stations were measured during September 2010 and will be measured again in 2011, utilizing periphytometers (floating microscope slide trays). After being placed in the streams for approximately two weeks, the amount of organic matter (measured as ash free dry weight) and chlorophyll-a concentrations of the periphyton that have attached to the slides will be determined in the laboratory, and reported as mg/m^2. By factoring in the number of days that the slides were left in the streams, the results provide an estimate of the streams' primary productivity rates (mg/m^2/week or month).

Periphyton, like all living vegetation, produce oxygen during the day via photosynthesis, but only take up oxygen (respire) during darkness. High levels of primary productivity can cause daily fluctuations in dissolved oxygen (DO) concentrations in a stream. If primary productivity levels become high enough, DO concentrations may become low enough during the early morning hours to effect the growth and survival of trout and other aquatic life. Conversely, during the late afternoon on these streams, DO concentrations often become elevated because of high levels of periphyton photosynthesis. Comparing the DO concentrations found at a station during the early morning verses late afternoon can establish whether or not some level of primary production is present in a stream. However, this proceedure is best conducted on standing waters or low-gradient streams, because the agitation caused by water flowing around objects causes oxygen exchange between the stream's water and the atmosphere.

Results

Channel Lengths and Widths

Slight differences in channel widths between sample years may be attributable to the varying locations where each width measurement was taken to generate a sample reach's average width, as well as slight differences in the September streamflow between 2009 and 2010 (Table 1). Previous channel measurements are presented to illustrate the differences in some sections' channel widths and the corrected lengths of the Walker Creek section for 2009 and 2010 (Table 1).

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 -21, 2010. Values for 2009 provided for comparisons.

Section	Length (m) 2009	Width (m) 2009	Area (m^2) 2009	Length (m) 2010	Width (m) 2010	Area (m^2) 2010
Rush – Co. Road	329	7.4	2,434.6	329	8.2	2,697.8
Rush - Bottomlands	437	7.7	3,364.9	437	7.8	3,408.6
Rush – Upper	430	9.0	3,870.0	430	8.3	3,569.0
Rush - MGORD	*N/S	*N/S	*N/S	2,230	12.0	26,760.0
Lee Vining – Main	255	5.9	1,504.5	255	5.9	1,504.5
Lee Vining - Side	195	2.5	488.0	195	2.6	507.0
Walker Creek	228	2.3	524.4	194	2.5	485.0

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

Fish Population Abundance

Rush Creek – County Road Section

In 2010 approximately 57% of the 740 brown trout captured in the County Road section of Rush Creek were young-of-the-year (age-0) fish between 64 and 111 mm in length; and the longest brown trout captured was 455 mm (Figure 6). This section supported an estimated 740 age-0 and 402 age-1 and older brown trout (Table 2); about 59% of the latter were brown trout ranging from 126-199 mm, which (based on the recapture of PIT tagged cohorts in 2010) were primarily age-1 fish. Estimates of brown trout were more precise than previous years with standard errors ranging from 5% to 7% of the estimates.

Only three rainbow trout were sampled in 2010 and these were 147 mm, 165 mm and 295 mm in length (Figure 8). No population estimates were generated for rainbow trout due to insufficient numbers of recaptures.

Rush Creek – Bottomlands Section

In 2010 approximately 63% of the 917 brown trout captured in the Bottomlands section of Rush Creek were young-of-the-year (age-0) fish between 61 and 119 mm and the longest brown trout captured was 346 mm (Figure 6). This section supported an estimated 1,057 age-0 and 419 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 6% of the estimates.

Only three rainbow trout were sampled in 2010 and these were 152 mm, 178 mm and 219 mm in length (Figure 8). No population estimates were generated for rainbow trout due to insufficient numbers of recaptures.

Rush Creek – Upper Section

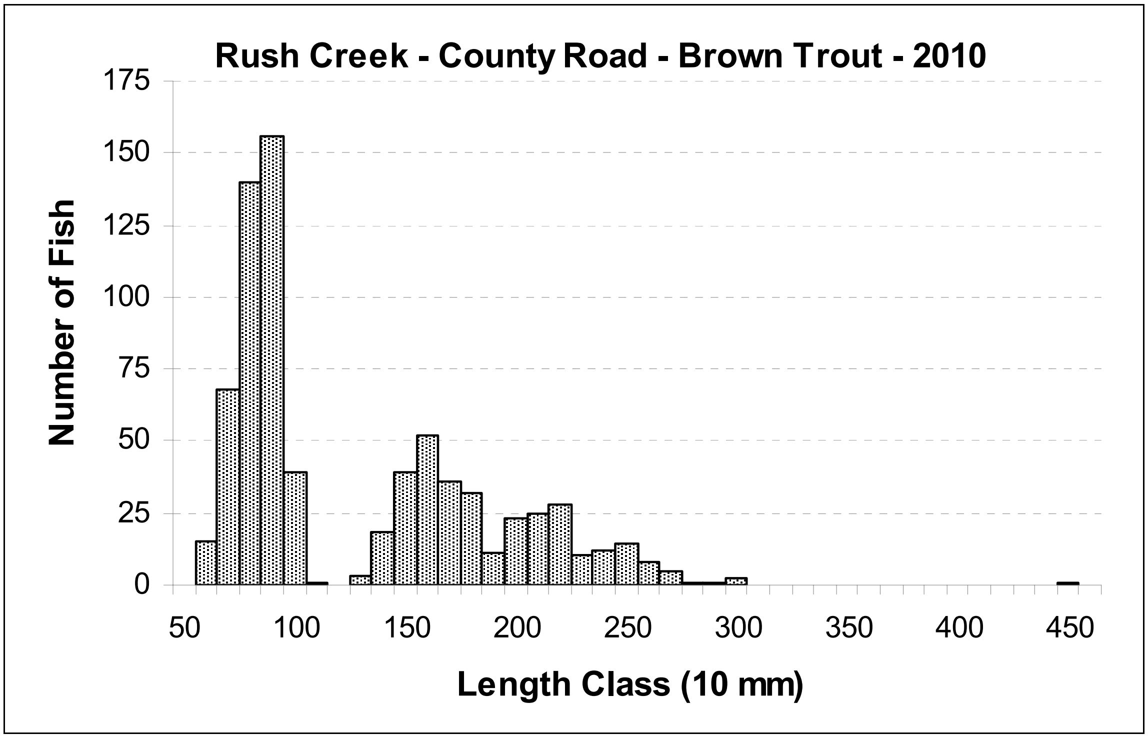
In 2010 approximately 63% of the 852 brown trout captured in the Upper section of Rush Creek were young-of-the-year (age-0) fish between 69 and 121 mm and the longest brown trout captured was 451 mm (Figure 7). Nine brown trout greater than 300 mm were sampled in 2010, including two fish greater than 350 mm. This section supported an estimated 2,043 age-0 and 366 age-1 and older brown trout (Table 2). Estimates of brown trout were less precise than previous years with standard errors ranging from 5% to 15% of the estimates.

Thirty-six rainbow trout (nine age-0 fish) were sampled in 2010 that ranged in length from 75 to 322 mm (Figure 9). An estimated 27 age-0 (<125 mm in length) and 21 age-1 and older rainbow trout inhabited this section during 2010, but these estimates were unreliable due to the relatively small number of recaptures (less than seven fish per age class). Also, no estimates of rainbow trout density or standing crop were made for any Rush Creek sample sections.

Rush Creek – MGORD Section

In 2010 only three age-0 brown trout were captured during the two electrofishing passes made on the MGORD section of Rush Creek, thus no population estimate was generated for age-0 brown trout. This section supported an estimated 1,099 age-1 and older brown trout (Table 2). Thirty-five of these brown trout were at least 375 mm in length, 20 of these fish were greater than 400 mm in length, and two of these fish exceeded 500 mm in length (Figure 7).

Twenty-five rainbow trout were captured in the MGORD in 2010 (Figure 9). These rainbow trout ranged from 180 mm to 398 mm in length.



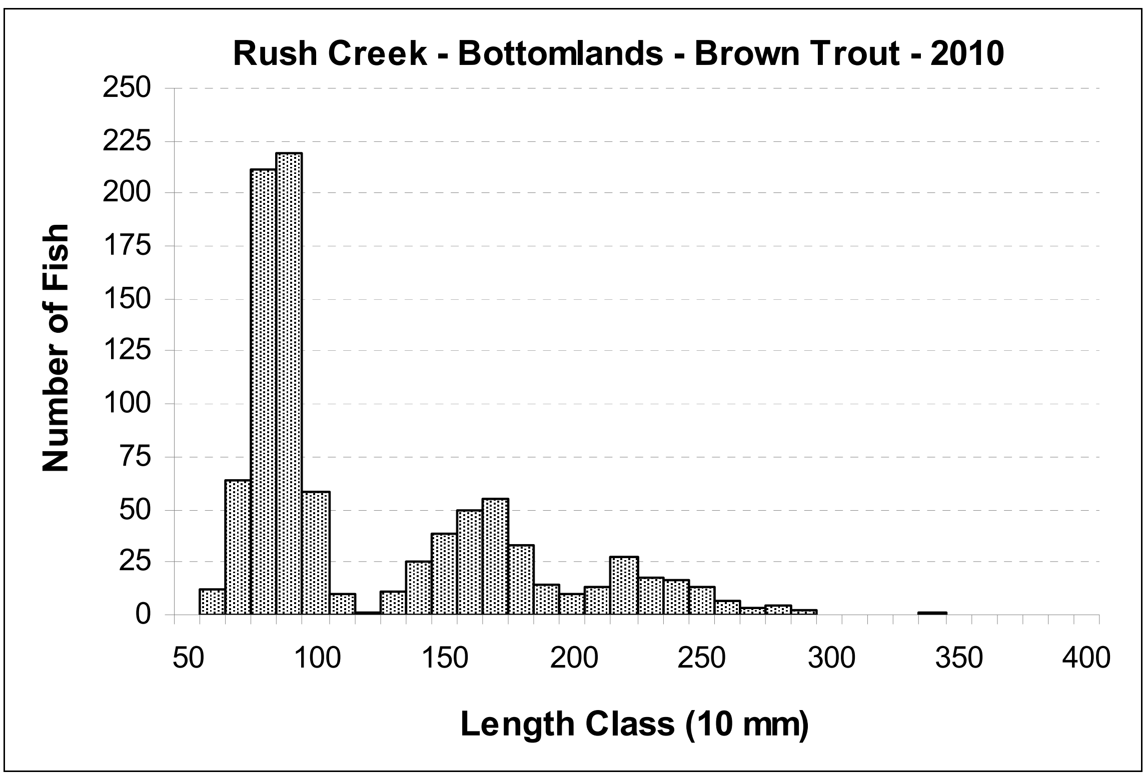


Figure 6. Length-frequency histograms of brown trout captured in the County Road (top) and Bottomlands (bottom) sections of Rush Creek between September 10th and 21st, 2010. Note different scales on both x-axes and y-axes.

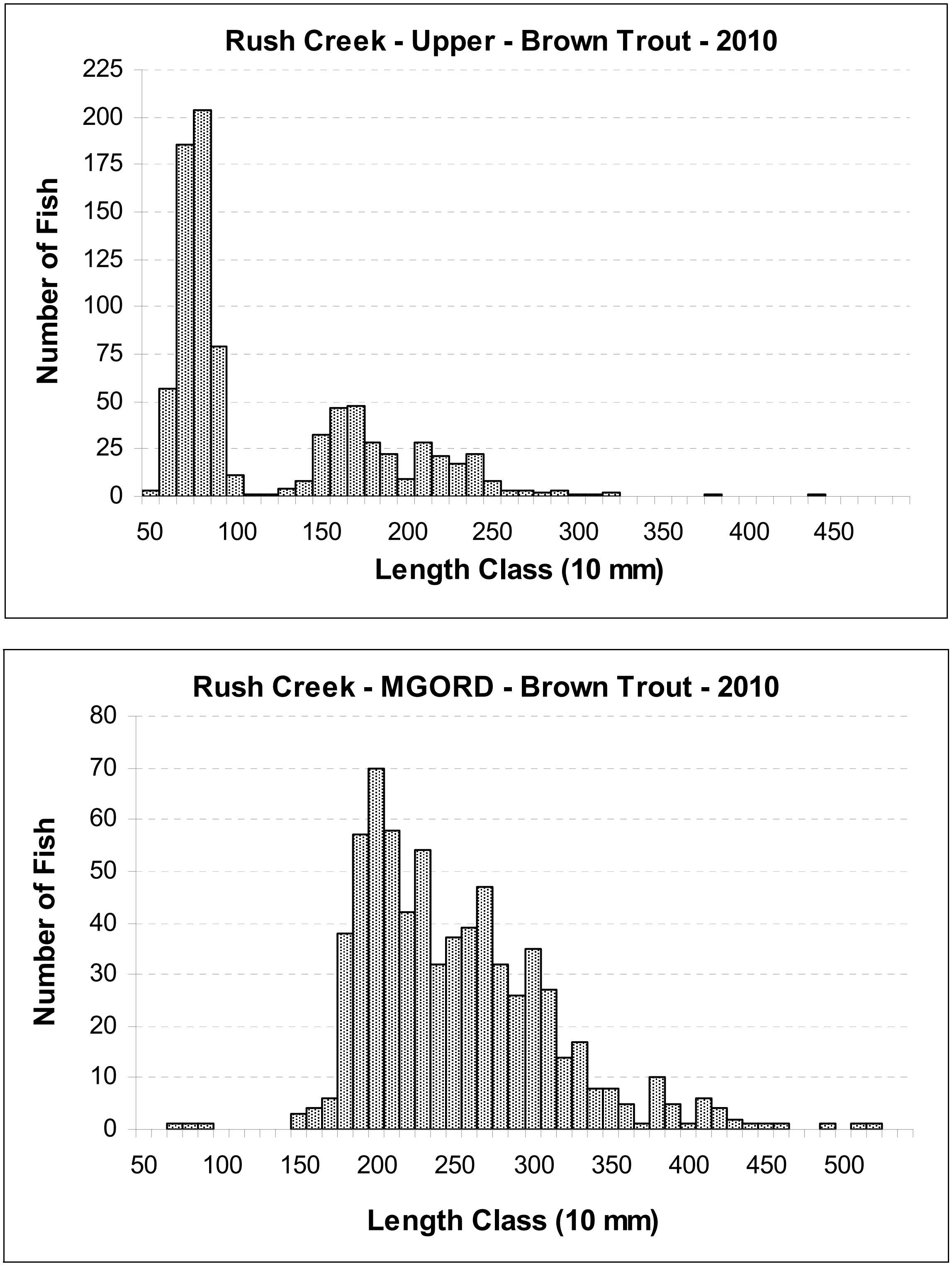


Figure 7. Length-frequency histograms of brown trout captured in the Upper (top) and MGORD (bottom) sections of Rush Creek between September 10th and 21st, 2010. Note different scales on both x-axes and y-axes.

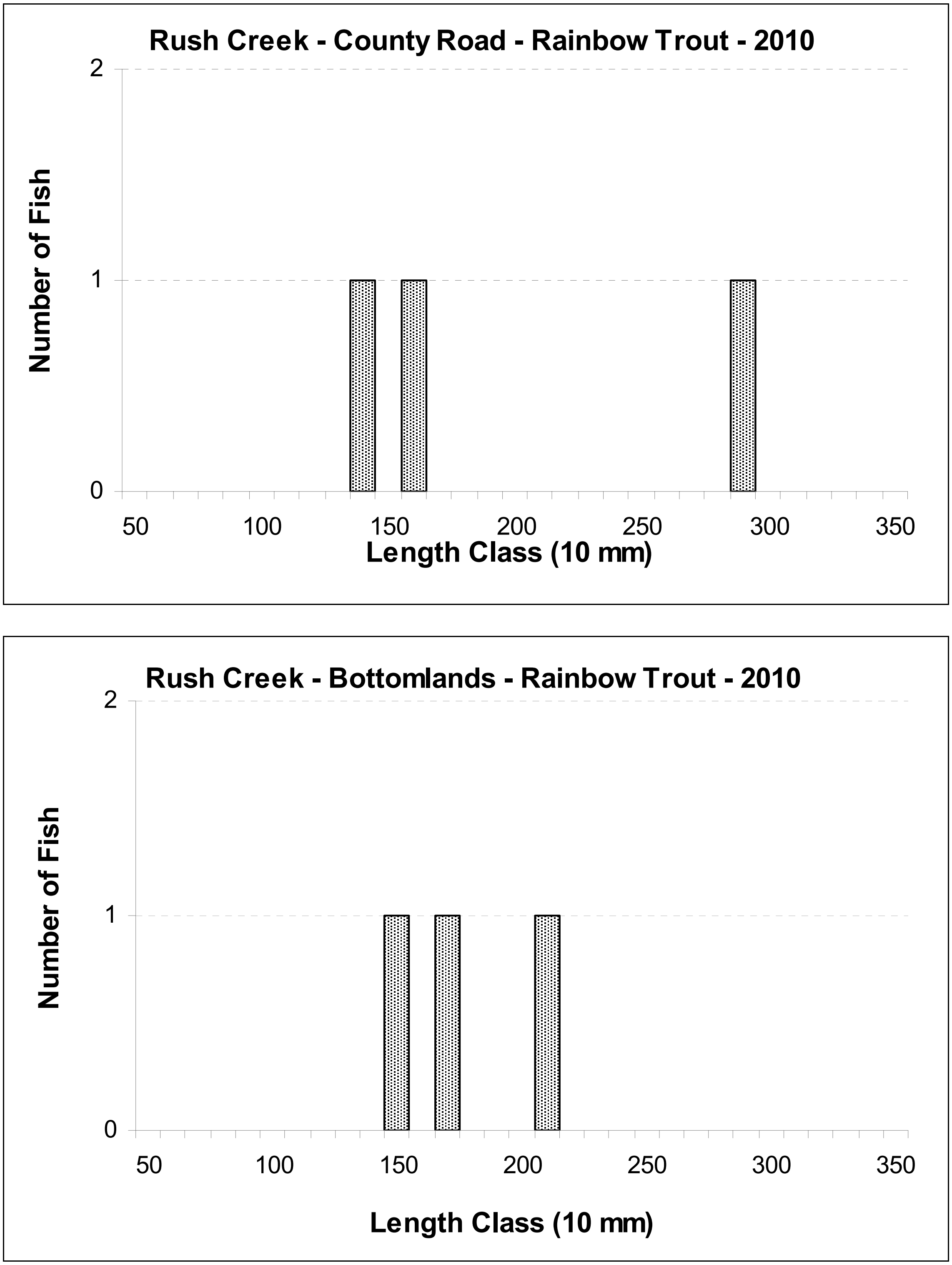
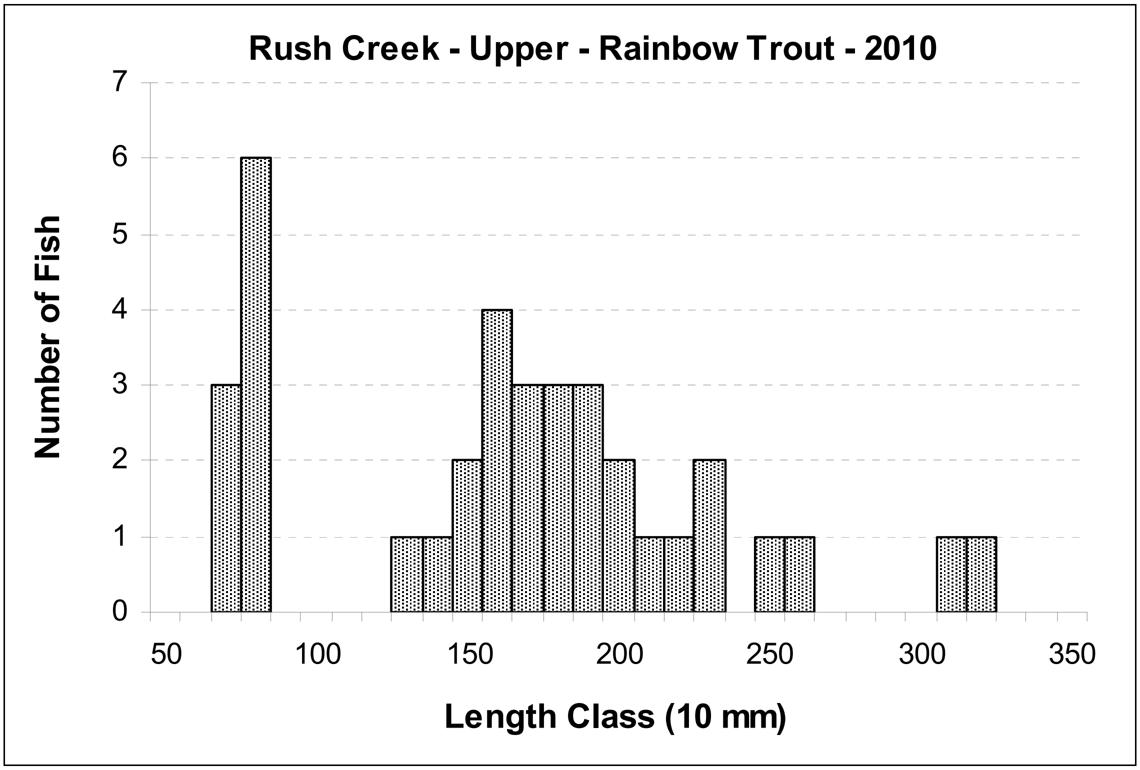


Figure 8. Length-frequency histograms of rainbow trout captured in the County Road (top) and Bottomlands (bottom) sections of Rush Creek between September 10^{th} and 21^{st}, 2010.



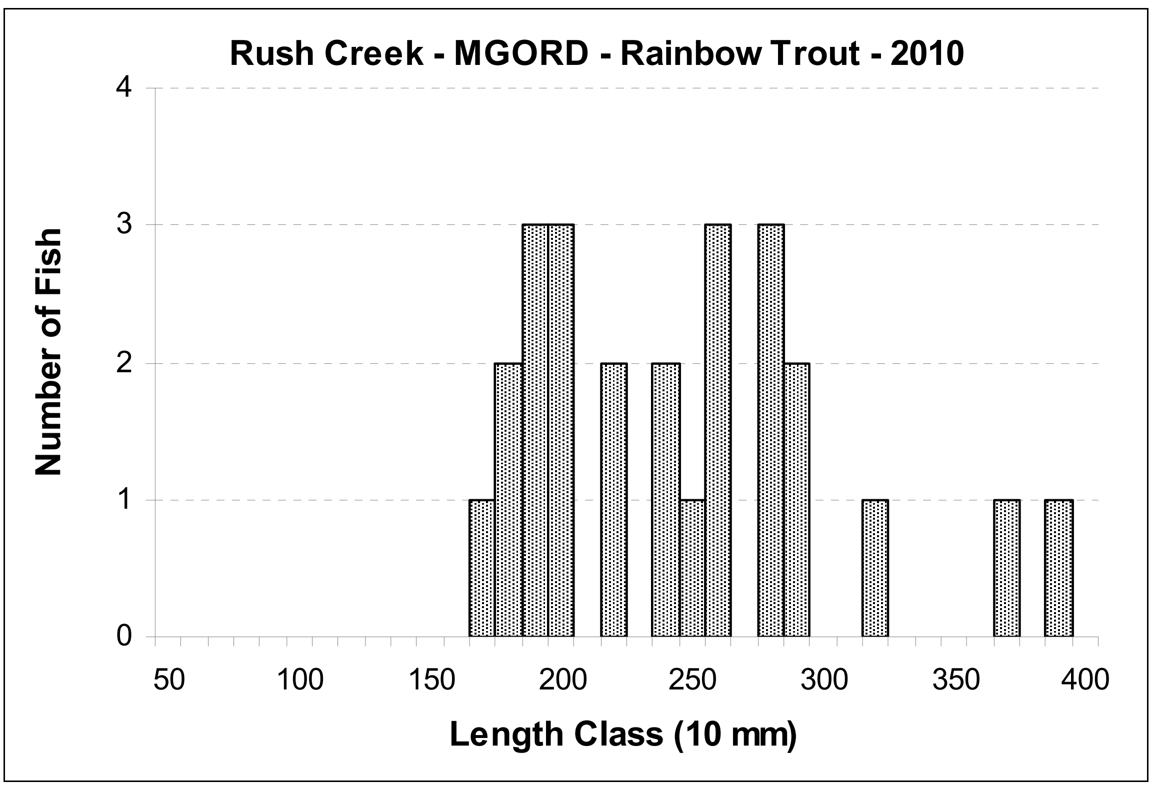


Figure 9. Length-frequency histogram of rainbow trout captured in the Upper section of Rush Creek between September 10th and 21st, 2010. Note different scales on both x-axes and y-axes.

Table 2. Rush Creek and Lee Vining Creek mark-recapture estimates for 2010 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+19/10							
Brown Trout							
	0 - 124 mm	240	251	81	9	**740**	54.2
	125 - 199 mm	128	125	63	0	**253**	15.7
	>200 mm	112	76	57	0	**149**	6.8
Bottomlands							
9/11+18/10							
Brown Trout							
	0 - 124 mm	354	315	105	10	**1,057**	69.9
	125 - 199 mm	153	147	77	1	**291**	15.9
	>200 mm	99	83	64	1	**128**	4.5
Upper Rush							
09/10+17/10							
Brown Trout							
	0 - 124 mm	250	284	34	40	**2,043**	296.0
	125 - 199 mm	123	104	68	7	**188**	8.8
	>200 mm	111	79	49	5	**178**	11.4
MGORD							
09/13+20/10							
Brown Trout							
	0 - 124 mm	2	1	0	0	**NP**	NP
	125 - 199 mm	60	57	18	1	**185**	28.3
	>200 mm	383	359	150	2	**914**	44.1
Lee Vining Creek							
Main Channel							
9/14+21/10							
Brown Trout							
	0 - 124 mm	17	10	3	0	**49**[b]	15.6
	125 - 199 mm	11	8	2	0	**35**[b]	12.7
	>200 mm	28	17	12	0	**39**	4.2
Rainbow Trout							
	0 - 124 mm	0	0	0	0	**0**	0
	125 - 199 mm	6	4	3	0	**8**[b]	1.1
	>200 mm	6	5	4	0	**7**[b]	0.7

b/ These estimates have fewer than 7 recaptures.

Lee Vining Creek – Main Channel Section

In 2010 approximately 32% of the 74 brown trout captured in the main channel section of Lee Vining Creek were young-of-the-year (age-0) fish between 67 and 100 mm and the longest brown trout captured was 275 mm in length (Figure 10). The estimate of 49 age-0 brown trout at this section was unreliable, since only three fish in this size range were recaptured (Table 2). Estimates of brown trout in the 125-199 mm length class (35 fish) and the >200 mm length class (39 fish) yielded standard errors ranging from 11% to 36% of the estimates (Table 2).

Only 14 rainbow trout were captured in 2010 and none of these fish were age-0 fish (Figure 11). This section supported an estimated 15 age-1 and older rainbow trout (Table 2). Estimates of rainbow trout yielded standard errors ranging from 10% to 14% of the estimates; however the age-1 and older estimates were generated with less than seven recaptures (Table 2).

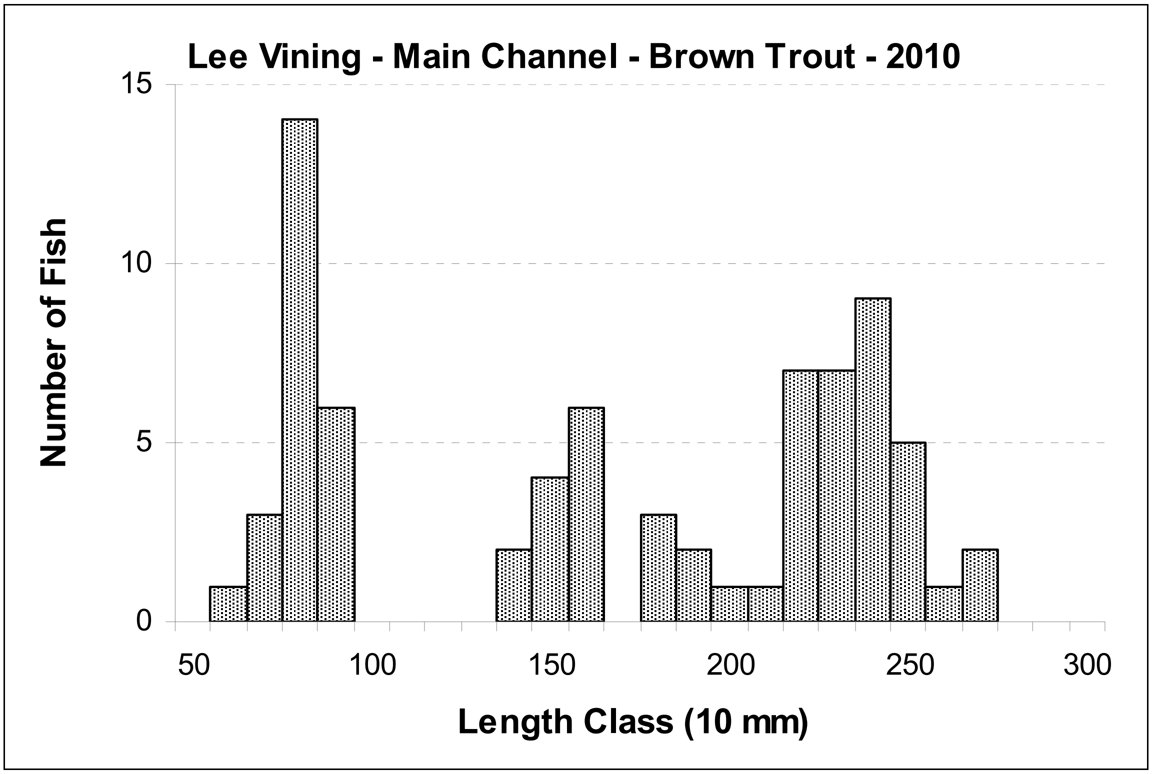
Lee Vining Creek – Side Channel Section

In 2010, a total of 19 brown trout were captured in the side channel section of Lee Vining Creek; 13 fish were age-0 and six fish were age-1 and older (Figure 10).The longest brown trout captured was 270 mm (Figure 10). Seventeen fish were captured on the first of two electro-fishing depletion passes made. This section supported an estimated 13 age-0 brown trout and six age-1 and older brown trout (Table 3).

For rainbow trout, only a single 230 mm fish was sampled in 2010 (Figure 11). The lone rainbow trout was captured on the first of the two electro-fishing depletion passes. This was the second straight sample year that no age-0 rainbow trout were captured in the Lee Vining Creek side channel.

Walker Creek

In 2010, 211 brown trout were captured in two electro-fishing passes and 114 of these brown trout were age-0 fish between 64 and 124 mm in length (Figure 12). For the past seven years, age-0 brown trout numbers have fluctuated widely in Walker Creek with very high numbers (>300) captured in 2007 and 2008, 203 captured in 2004, 113 captured in 2009, 80 captured in 2006, and four captured in 2005. In 2010, Walker Creek supported an estimated 116 age-0 and 97 age-1 and older brown trout (Table 3).



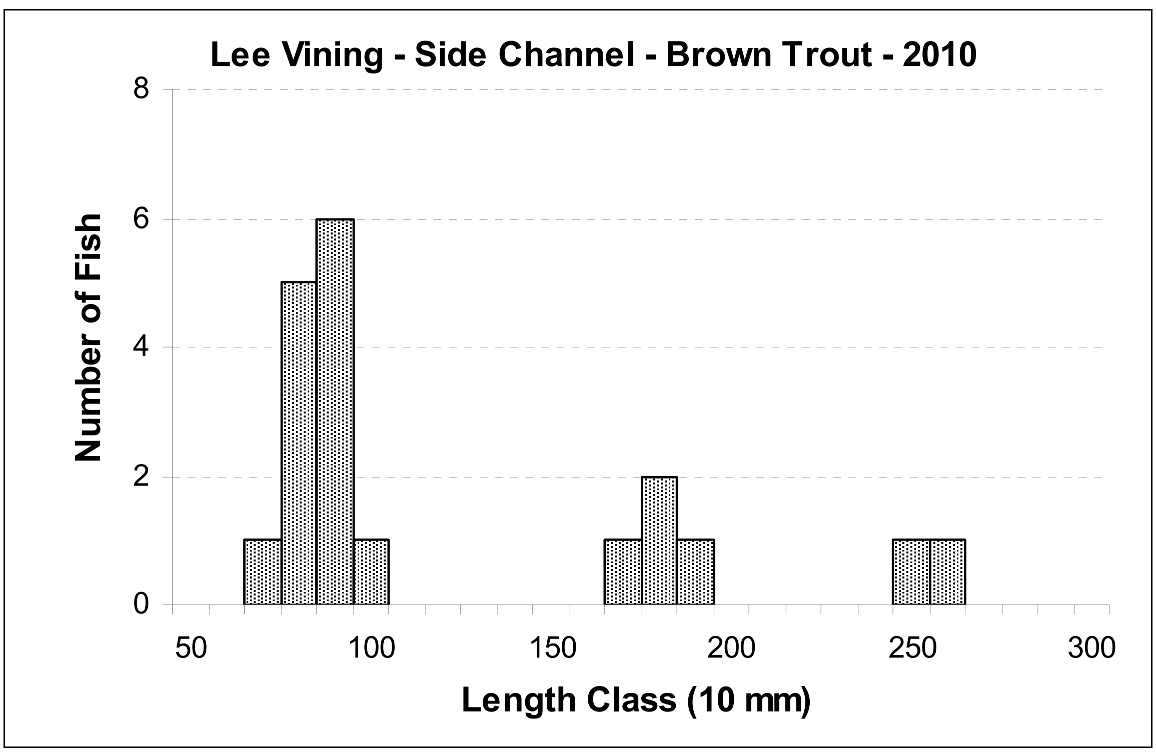
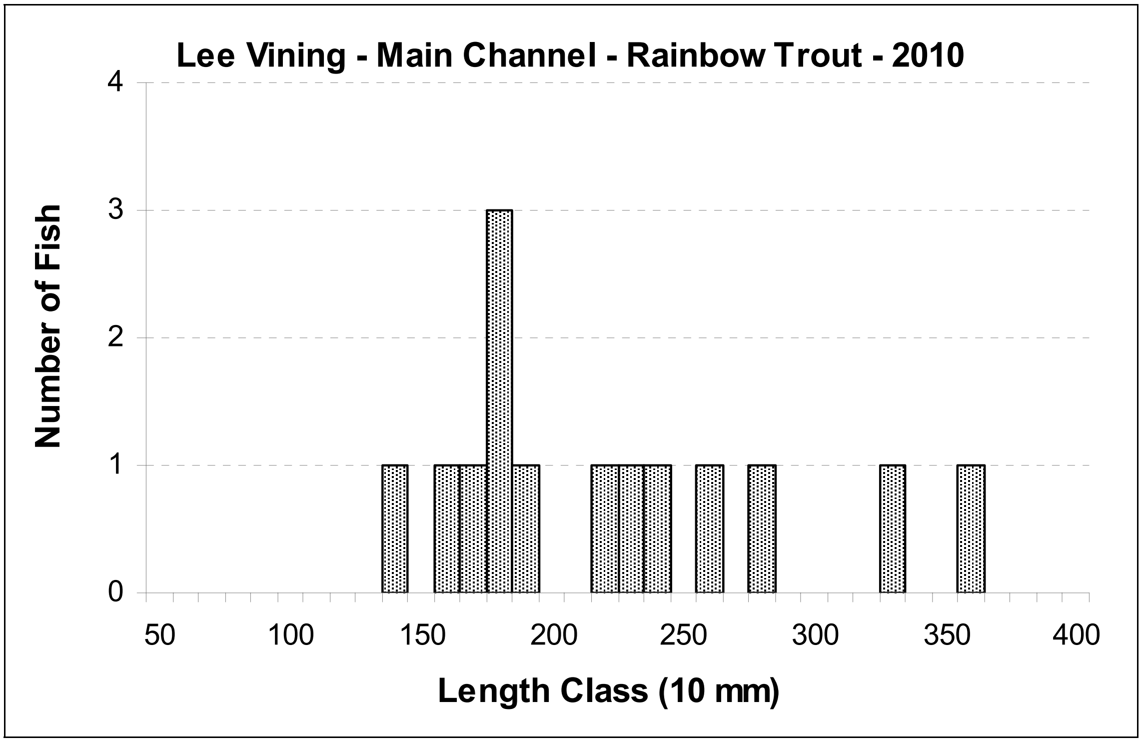


Figure 10. Length-frequency histograms of brown trout captured in the Main channel (top) and Side channel (bottom) sections of Lee Vining Creek between September 10th and 21st, 2010. Note different scales on the y-axes.



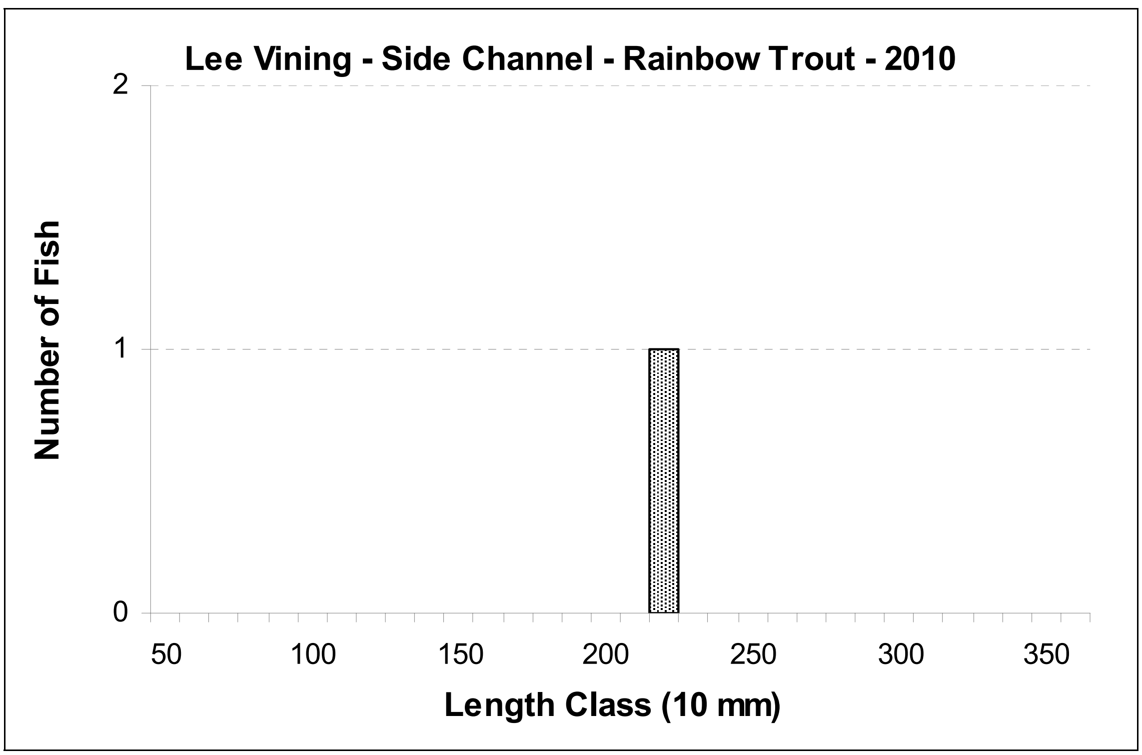


Figure 11. Length-frequency histograms of rainbow trout captured in the Main channel (top) and Side channel (bottom) sections of Lee Vining Creek between September 10th and 21st, 2010. Note different scales on both x-axes and y-axes.

Table 3. Depletion estimates made in the Lower side channel section of Lee Vining Creek and Walker Creek during September 2010 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 - 9/15/2010					
Brown Trout					
	0 - 124 mm	2	11 2	**13**	0.63
	125 - 199 mm	2	2 0	**2**	0.0
	200 + mm	2	4 0	**4**	0.0
Rainbow Trout					
	0 - 124 mm	2	0 0	**0**	0.0
	125 - 199 mm	2	0 0	**0**	0.0
	200 + mm	2	1 0	**1**	0.0
Walker Creek - above old Hwy 395 - 9/15/2010					
Brown Trout					
	0 - 124 mm	2	99 15	**116**	2.07
	125 - 199 mm	2	72 7	**79**	0.86
	200 + mm	2	16 2	**18**	0.52

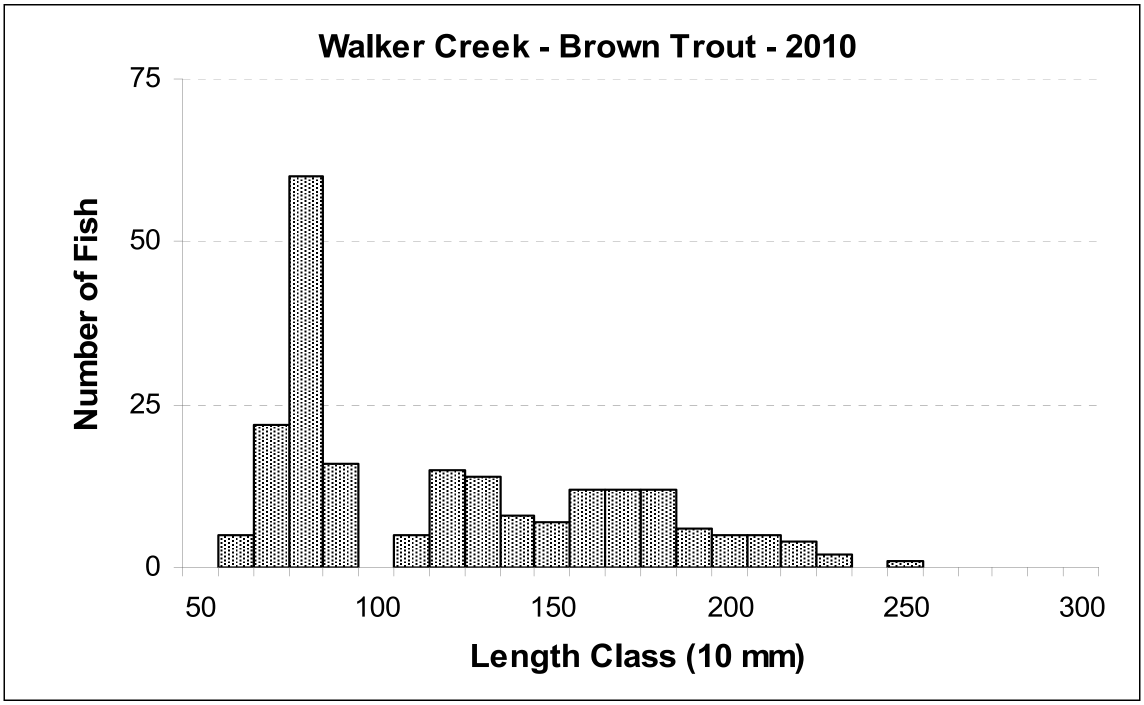


Figure 12. Length-frequency histogram of brown trout captured in Walker Creek on September 15, 2010.

Catch of Rainbow Trout in Rush and Lee Vining Creeks

For the past twelve 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. In 2010, 3,903 trout were captured in Rush Creek and 67 of these were rainbow trout (or 1.7% of the catch). 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 eleven 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 11 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 four out of 11 years (Table 5). Using depletion electrofishing, sufficient numbers of age-0 rainbow trout were captured in the Lee Vining Creek side channel section to generate population estimates in 10 of 11 years (Table 6). In the side channel, population estimates of age-1 and older rainbow were generated in six of 11 years (Table 7).

Because rainbow trout constitute a significant component of the Lee Vining Creek 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, 2000-2010.

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
2010	0.1505	0	0	0	0	0	0	0
2009	0.1505	4	4	0	NP	NP	8	53
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, 2000-2010.

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
2010	0.1505	12	9	7	15	100	14	93
2009	0.1505	39	32	12	98	651	59	392
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, 2000-2010.

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
2010	0.0507	0	0	--	0	0	0	0
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, 2000-2010.

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
2010	0.0507	1	0	--	1	20	1	20
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 2010 indicated condition of brown trout 100 mm and longer in Rush Creek declined from the improved conditions that occurred in 2009 after condition factors in 2007 and 2008 were less than 1.00 (Table 8 and Figure 13). Brown trout in Lee Vining Creek appeared to be in good condition in 2010 (>1.00) and in the main channel section, the 2010 condition improved from the previous year (Figure 13).

A fish condition factor of 1.00 is considered average (Reimers 1963; Blackwell et al. 2000) and mean condition factors for brown trout 150 to 250 mm were <1.00 for all sections in Rush Creek indicating that brown trout condition was below average in these sections during 2010 (Figure 13). Generally, condition factors in all sections of Rush Creek declined between 2005 and 2008, with poor condition factors in 2007 and 2008, followed by the increase in 2009 to condition factors indicative of fair-to-good conditions (Figure 13). The 2010 season was the third year that the Bottomlands section of Rush Creek was sampled and the condition factor was 0.98, down slightly from 0.99 computed for 2009 (Figure 13).

In the MGORD section of Rush Creek, the 2010 average condition factor of brown trout 150 to 250 mm was 0.99, down slightly from 1.02 in 2009 (Figure 13). When the MGORD condition factor data were examined more closely, a wide range in condition factors was evident, as well as varying condition by size class of brown trout. For the past five sample seasons, the condition factor of brown trout between 150 and 299 mm has been consistently higher than the condition factor of brown trout ≥300 mm.

The mean condition factor for 150 to 250 mm brown trout in Lee Vining Creek during 2010 was over 1.00 in both the main and side channel sections, indicating that brown trout condition was good. In the main channel section, the mean condition factor of 1.21 in 2010 was the second straight year of increased condition after the low value of 1.03 in 2008 (Figure 13). The 2010 mean condition factor was also the first value to exceed 1.20 since the 2005 sampling season (Figure 13).

Over the past 12 years when handling fish in Lee Vining Creek we have visually noted that most of the rainbow trout appeared “chunkier” than the brown trout, thus probably having higher condition factor values. For this annual report, conditions factors for rainbow trout between 150 and 250 mm were calculated for Lee Vining Creek (Figure 14). For the ten sample seasons in which data were available, rainbow trout had higher condition factors than brown trout in nine of the seasons (Figure 14). Sample season 2004 was the only year in which brown trout had a slightly higher condition factor than rainbow trout, 1.06 versus 1.05 (Figure 14).

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 2010 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	$Log_{10}(WT) = 2.994*Log_{10}(L) – 4.898$	0.99	<0.01
	2010	**375**	$\mathbf{Log_{10}(WT) = 3.014*Log_{10}(L) – 5.044}$	**0.99**	**<0.01**
Bottomlands	2008	611	$Log_{10}(WT) = 2.773*Log_{10}(L) – 4.524$	0.99	<0.01
	2009	511	$Log_{10}(WT) = 2.920*Log_{10}(L) – 4.821$	0.99	<0.01
	2010	**425**	$\mathbf{Log_{10}(WT) = 2.999*Log_{10}(L) – 5.005}$	**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	$Log_{10}(WT) = 2.941*Log_{10}(L) – 4.855$	0.99	<0.01
	2010	**420**	$\mathbf{Log_{10}(WT) = 2.995*Log_{10}(L) – 4.994}$	**0.99**	**<0.01**

Table 8 (continued).

Section	Year	N	Equation	R^2	P
MGORD	2000	82	$\text{Log}_{10}(\text{WT}) = 2.909*\text{Log}_{10}(\text{L}) - 4.733$	0.98	<0.01
	2001	769	$\text{Log}_{10}(\text{WT}) = 2.873*\text{Log}_{10}(\text{L}) - 4.719$	0.99	<0.01
	2004	449	$\text{Log}_{10}(\text{WT}) = 2.984*\text{Log}_{10}(\text{L}) - 4.973$	0.99	<0.01
	2006	593	$\text{Log}_{10}(\text{WT}) = 2.956*\text{Log}_{10}(\text{L}) - 4.872$	0.98	<0.01
	2007	643	$\text{Log}_{10}(\text{WT}) = 2.914*\text{Log}_{10}(\text{L}) - 4.825$	0.98	<0.01
	2008	862	$\text{Log}_{10}(\text{WT}) = 2.827*\text{Log}_{10}(\text{L}) - 4.602$	0.98	<0.01
	2009	689	$\text{Log}_{10}(\text{WT}) = 2.974*\text{Log}_{10}(\text{L}) - 4.933$	0.99	<0.01
	2010	**694**	$\mathbf{Log_{10}(WT) = 2.892*Log_{10}(L) - 4.756}$	**0.98**	**<0.01**

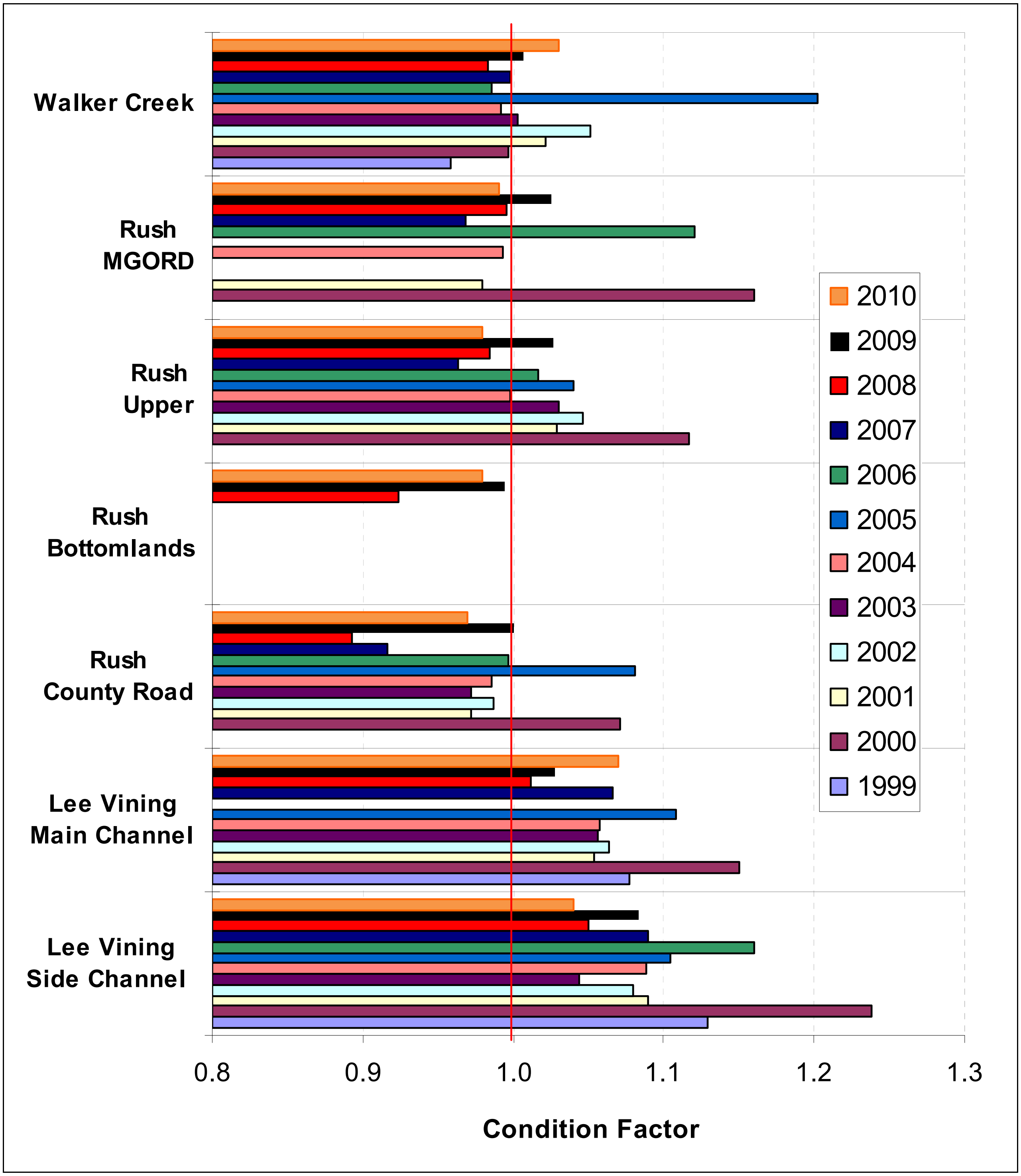


Figure 13. Condition factors for brown trout 150 to 250 mm long in sample sections of Rush, Lee Vining, and Walker creeks from 1999 to 2010. Note the x-scale starts at 0.8 and red vertical line indicates condition factor of 1.0.

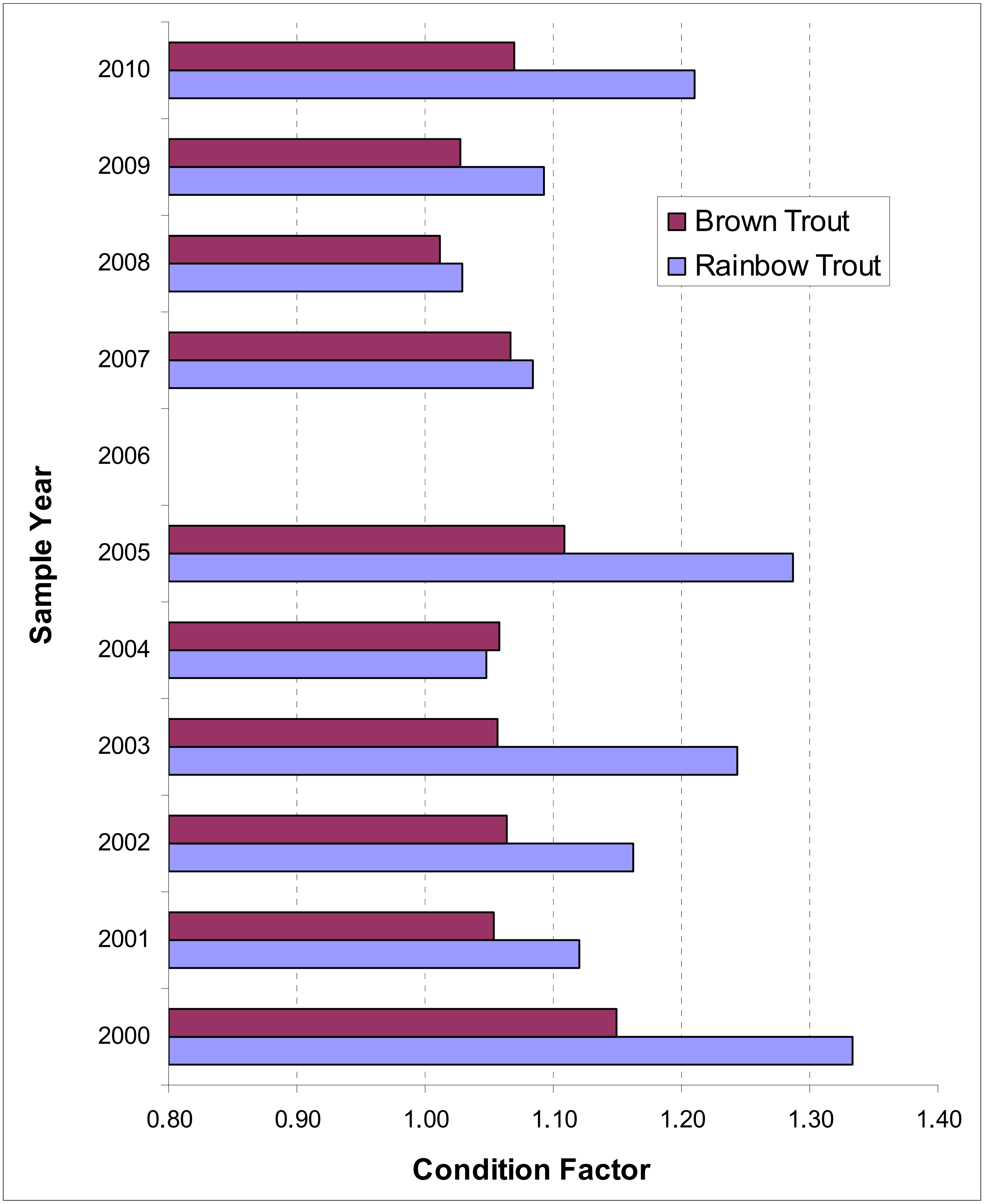


Figure 14. Comparison of condition factors for rainbow trout and brown trout 150 to 250 mm long in main channel sample section of Lee Vining Creek from 2000 to 2010. Note the x-scale starts at 0.8. Note: main channel was not sampled in 2006 due to high flows.

PIT Tag Recaptures and Measured Growth Rates

During the 2009 sampling season, a total of 1,596 trout received adipose fin clips and PIT tags, 1,572 were brown trout and 24 were rainbow trout (Table 9). 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 9).

<u>Growth of Age-0 Trout Between 2009 and 2010</u>

In 2010, 215 fish with adipose fin-clips were recaptured that had PIT tags when scanned with a tag reader, for an overall recapture rate of 13.5% (Table 10). Ninety-six of these recaptured fish were tagged as age-0 fish in 2009 (Table 10). In the three annually-sampled sections of Rush Creek and in Walker Creek the average growth rates of age-0 to age-1 fish for the one year between 2009 and 2010 were lower than growth rates of age-0 fish to age-1 fish for the one year between 2008 and 2009. For the County Road section of Rush Creek the average growth for age-0 brown trout between 2009 and 2010 was 73 mm in length and 36 g in weight (Table 11) versus 78 mm and 41 g between 2008 and 2009. For the Bottomlands section of Rush Creek the average growth for age-0 brown trout between 2009 and 2010 was 77 mm and 40 g (Table 11) versus 84 mm and 43 g between 2008 and 2009. For the Upper Rush Creek section the average growth for age-0 brown trout between 2009 and 2010 was 80 mm and 48 g (Table 11) versus 89 mm and 51 g between 2008 and 2009. In Walker Creek, the average growth of age-0 to age-1 brown trout between 2009 and 2010 was 51 mm and 20 g (Table 11) versus 68 mm and 27 g between 2008 and 2009.

In the MGORD section of Rush Creek, seven age-1 brown trout were recaptured that were PIT tagged as age-0 fish in 2009 (Table 10). Interestingly, five of these brown trout were tagged as age-0 fish in the Upper Rush sample section and migrated upstream to the MGORD sometime between September of 2009 and September of 2010 (Table 11). All seven of these age-1 fish exhibited excellent growth between age-0 and age-1 with an average growth of 107 mm in length and an average weight gain of 85 g (Table 11).

In Lee Vining Creek, the single PIT tagged brown trout recaptured as an age-1 fish in 2010 grew 80 mm in length and gained 42 g in weight (Table 11). The lone rainbow trout captured in Lee Vining Creek as an age-1 fish grew 107 mm in length and 62 g in weight (Table 11).

<u>Growth of Age-1 and older Trout Between 2009 and 2010</u>

In the County Road section of Rush Creek, nine PIT tagged brown trout were recaptured in 2010 that were tagged as known age-1 fish in 2009. These nine fish grew an average of 55 mm in length (range = 36 to 74 mm) and gained an average of 56 g in weight (range = 39 to 75 g) (Table 12).

In the Bottomlands section of Rush Creek, nine PIT tagged brown trout were recaptured in 2010 that were tagged as known age-1 fish in 2009. These nine fish grew an average of 50 mm in length (range = 41 to 62 mm) and gained an average of 54 g in weight (range = 39 to 67 g) (Table 12).

In the Upper Rush Creek section, three PIT tagged brown trout were recaptured in 2010 that were tagged as known age-1 fish in 2009. These three fish grew an average of 58 mm in length (range = 51 to 71 mm) and gained an average of 74 g in weight (range = 63 to 94 g) (Table 12).

In the MGORD, 18 of the PIT tagged brown trout recaptured in 2010 were between 185-230 mm at the time of tagging in 2009 and were probably age-1 fish when tagged. This assumption was based on the length range of known, PIT tagged, age-1 fish caught in the MGORD (208-231 mm). Between 2009 and 2010, these 18 fish grew an average of 50 mm in length (range = 17 to 80 mm) and gained an average of 79 g (range = 0 to 121g) (Table 12).

As the size class of the MGORD recaptured fish increased, their growth rates between 2009 and 2010 decreased. For example, the 72 PIT tagged fish recaptured in 2010 that were between 185-462 mm in 2009, grew an average of only 30 mm (range = -20 to 94 mm) and gained an average of 48 g (range = -251 to 209 g). Average growth of the 21 PIT tagged fish recaptured in 2010 that were >300 mm in length when tagged in 2009 was 15 mm in length (range = -20 to 80 mm) and a mere 2 g in weight (range = -251 to 347 g). In fact, 11 of these 21 fish <u>lost</u> weight between 2009 and 2010. The average weight <u>loss</u> was -75 g with a range of -25 to -251 g. Several of these fish were obviously in very poor condition (Figure 15).

Apparent one-year survivals (2009 to 2010) were based on the number originally PIT tagged with an assumption that any fish that left the sampling area died ("apparent mortality") unless fish were recaptured in another sample section. Any PIT tagged fish recaptured in a different section were counted in the apparent survival calculation for the section where they were originally tagged. The apparent 2009-2010 survivals were approximately 21% for the County Road section, 19% for the Bottomlands section, 11% for the Upper section of Rush Creek, 11% for the MGORD section of Rush Creek and 15% for Walker Creek. In Lee Vining Creek, the apparent one-year survival of PIT tagged fish between September 2009 and 2010 was approximately 15%.

For all sample reaches the growth range of fish varied widely, even for similar age and size (at time of tagging) fish within sample sections. Tables with individual growth data for the 215 PIT tagged fish recaptured in 2010 are provided in Appendix B.

<u>Shed Rate of PIT Tags Between 2009 and 2010</u>

In 2010, a total of 45 trout with adipose fins were captured that lacked PIT tags when scanned with a tag reader. Many of these fish had visible scars on their bellies from where tags had been implanted in 2009. The calculated shed rate of PIT tags between 2009 and 2010 was 2.8% (45÷1,596). This rate is consistent with other tagging studies (Ombredane et al. 1998; Bateman and Gresswell 2006).

Table 9. 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 Brown Trout	Number of Age-1 Brown Trout	Number of Age-0 Rainbow Trout	Number of Age-1 Rainbow Trout	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 10. Fish recaptured in 2010 with PIT tags implanted during the 2009 sampling season, by stream reach.

Stream	Sample Section	Number of Age-1 Brown Trout	Number of Age-2+ Brown Trout	Number of Age-1 Rainbow Trout	Number of Age-2+ Rainbow Trout	Reach Totals
Lee Vining Creek	Main Channel	1	7	1	0	9 fish
Lee Vining Creek	Side Channel	0	0	0	0	0 fish
Rush Creek	County Road	20	9	0	0	29 fish
Rush Creek	Bottom-lands	36	9	0	0	45 fish
Rush Creek	Upper	23	4*	0	0	27 fish
Rush Creek	MGORD	7	72**	0	0	79 fish
Walker Creek	Above old 395	9	17***	0	0	26 fish
Species and Age-class Totals:		**96**	**118**	**1**		**Grand Total: 215 fish**

*One of these fish was >age-2.
**Most of these fish were >age-2.
***One of these fish was >age-2.

Table 11. Growth of 97 age-1 fish recaptured in 2010 that were implanted with PIT tags as age-0 fish during the 2009 sampling season, by stream reach. Fish within ( ) are rainbow trout.

Collection Location	Number of Fish Recap.	Growth Ave. Length (mm)	Min. Growth Length (mm)	Max. Growth Length (mm)	Growth Ave. Weight (g)	Min. Growth Weight (g)	Max. Growth Weight (g)
Lee Vining Ck - Main	1 (1)	80 (107)	N/A	N/A	42 (62)	N/A	N/A
Rush - Co. Road	20	73	56	105	36	20	73
Rush - Bottomlands	36	77	63	96	40	24	72
Rush - Upper	23	80	60	102	48	26	74
Rush – MGORD	7*	107	96	118	85	58	103
Walker Creek	9	51	35	60	20	10	26

* Five of these fish were tagged in the Upper Rush in 2009.

Table 12. Growth of 39 age-2 fish recaptured in 2010 that were implanted with PIT tags as age-1 fish during the 2009 sampling season, for three Rush Creek sample reaches.

Collection Location	PIT Tag Number	2009 Length (mm)	2010 Length (mm)	2009 Weight (g)	2010 Weight (g)	Growth in Length (mm)	Growth in Weight (g)
Rush Creek County Road	106769	134	208	22	79	74	57
	931106	142	210	29	86	68	57
	917329	152	202	34	88	50	54
	933486	154	211	38	101	57	63
	904480	161	211	39	86	50	47
	938028	168	209	51	102	41	51
	906504	168	229	51	113	61	62
	100865	173	227	52	127	54	75
	908804	174	210	55	94	36	39
Average Growth in the County Road Section Between 2009 and 2010						**55**	**56**
Rush Creek Bottomlands	943071	157	201	38	77	44	39
	100755	161	209	42	90	48	48
	103525	163	210	42	95	47	53
	906224	163	221	40	99	58	59
	908422	165	224	44	104	59	60
	905245	165	212	47	103	47	56
	921335	171	212	56	106	41	50
	924548	176	238	53	120	62	67
	904696	186	234	65	123	48	58
Average Growth in the Bottomlands Section Between 2009 and 2010						**50**	**54**
Upper Rush Creek	927961	168	239	45	139	71	94
	941237	173	224	53	116	51	63
	938419	183	235	64	128	52	64
Average Growth in the Upper Section Between 2009 and 2010						**58**	**74**

Table 12 (continued).

Collection Location	PIT Tag Number	2009 Length (mm)	2010 Length (mm)	2009 Weight (g)	2010 Weight (g)	Growth in Length (mm)	Growth in Weight (g)
Rush Creek MGORD	*0921539	185	265	62	173	80	111
	0936552	201	243	77	131	42	54
	0917971	201	256	83	148	55	65
	0905354	204	258	89	171	54	82
	0903370	207	266	91	167	59	76
	0098013	213	259	95	163	46	68
	0920349	214	275	104	191	61	87
	0101394	215	253	93	174	38	81
	0909295	217	280	104	214	63	110
	0903631	220	238	117	133	18	16
	0907600	221	280	104	222	59	118
	0918696	222	293	116	237	71	121
	0904177	223	278	109	218	55	109
	0923184	223	277	113	216	54	103
	7101281	226	256	127	181	30	54
	0922135	227	244	141	141	17	0
	0925533	228	277	108	211	49	103
	0098970	228	284	120	190	56	70
Average Growth in the MGORD Section Between 2009 and 2010						**50**	**79**

*This fish was PIT tagged in the Upper Rush section in 2009 and recaptured in the MGORD in 2010.

Figure 15. Brown trout, in poor condition, captured in the MGORD on 9/20/10.

2010 PIT Tagging of Trout in Rush and Lee Vining Creeks

In 2010, a total of 1,274 PIT tags were implanted in Rush, Walker and Lee Vining creeks; of these only 17 tags were implanted in rainbow trout (Table 13). Forty-five of the 1,274 PIT tags were implanted in fish that had previously clipped adipose fins, but no tag number was read when the fish were scanned with a tag reader. A total of 859 age-0 fish had PIT tags implanted in 2010, of these only four were rainbow trout (Table 14).

Table 13. Total numbers of trout implanted with PIT tags during the 2010 sampling season, by stream, sample section, age-class and species.

Stream	Sample Section	Number of Age-0 Brown Trout (<125 mm)	Number of Age-1 and older Brown Trout	Number of Age-0 Rainbow Trout (<125 mm)	Number of Age-1 and older Rainbow Trout	Reach Totals
Lee Vining Creek	Main Channel	24	8	0	1	33 fish
Lee Vining Creek	Side Channel	13	0	0	0	13 fish
Rush Creek	County Road	210	7	0	0	217 fish
Rush Creek	Bottom-lands	284	3	0	0	287 fish
Rush Creek	Upper	242	11	4	0	257 fish
Rush Creek	MGORD	1	359*	0	12	372 fish
Walker Creek	Above old 395	81	14	0	0	95 fish
Species and Age-class Totals:		**855**	**402**	**4**	**13**	**Grand Total: 1,274 fish**

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

Table 14. Average length (mm), minimum length, maximum length, average weight (g), and number (859 total fish) of age-0 trout implanted with PIT tags during the 2010 sampling season, by stream, sample section, and species.

Stream	Sample Section	Species	Number of Fish Tagged	Mean Length (mm)	Mean Weight (g)	Minimum Length (mm)	Maximum Length (mm)
Lee Vining Creek	Main Channel	Brown Trout	24	86	7	67	100
Lee Vining Creek	Side Channel	Brown Trout	13	90	8	73	103
Rush Creek	County Road	Brown Trout	210	93	8	80	114
Rush Creek	Bottom-lands	Brown Trout	284	93	8	80	120
Rush Creek	Upper	Rainbow Trout	4	91	8	84	108
Rush Creek	Upper	Brown Trout	242	94	8	80	118
Rush Creek	MGORD	Brown Trout	1	80	5	N/A	N/A
Walker Creek	Above old 395	Brown Trout	81	88	7	80	119

Estimated Trout Density Comparisons

In 2010, the estimated densities (number per hectare) of age-1 and older brown trout in the County Road section of Rush Creek was 1,490 fish/ha (Figure 16). The 2010 estimate was a 32% decrease from the record high estimate of 2,177 fish/ha in 2009. For the past four sampling seasons, the density estimates of age-1 and older brown trout in the County Road section have been nearly double the estimates for sample years 2000-2006 (Figure 16).

Between 2009 and 2010, the Bottomlands and Upper sections of Rush Creek both experienced slight decreases in the estimated densities of age-1 and older brown trout. In 2010, the Bottomlands section of Rush Creek had an estimated density of 1,235 age-1 and older brown trout/ha, a 17% drop from the 2009 estimate (Figure 16). The Upper section of Rush Creek had an estimated density of 1,062 age-1 and older brown trout/ha in 2010, a 19% decrease from the 2009 estimate. The 2010 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 2010 (Figure 16).

In Walker Creek the 2010 density estimate was 28% less than the 2009 estimate; however the 2009 density estimate of 2,784 age-1 and older brown trout/ha was the highest estimate for the twelve-year sampling period (Figure 16). In this report, all previous density estimates of age-1 and older brown trout in Walker Creek reflect the corrections made to sample reach lengths and areas (Figure 16). For example, in 2008 and 2009 we incorrectly reported density estimates of approximately 6,300 and 5,500 fish/ha, respectively, when in reality these values were 2,778 and 2,784 fish/ha.

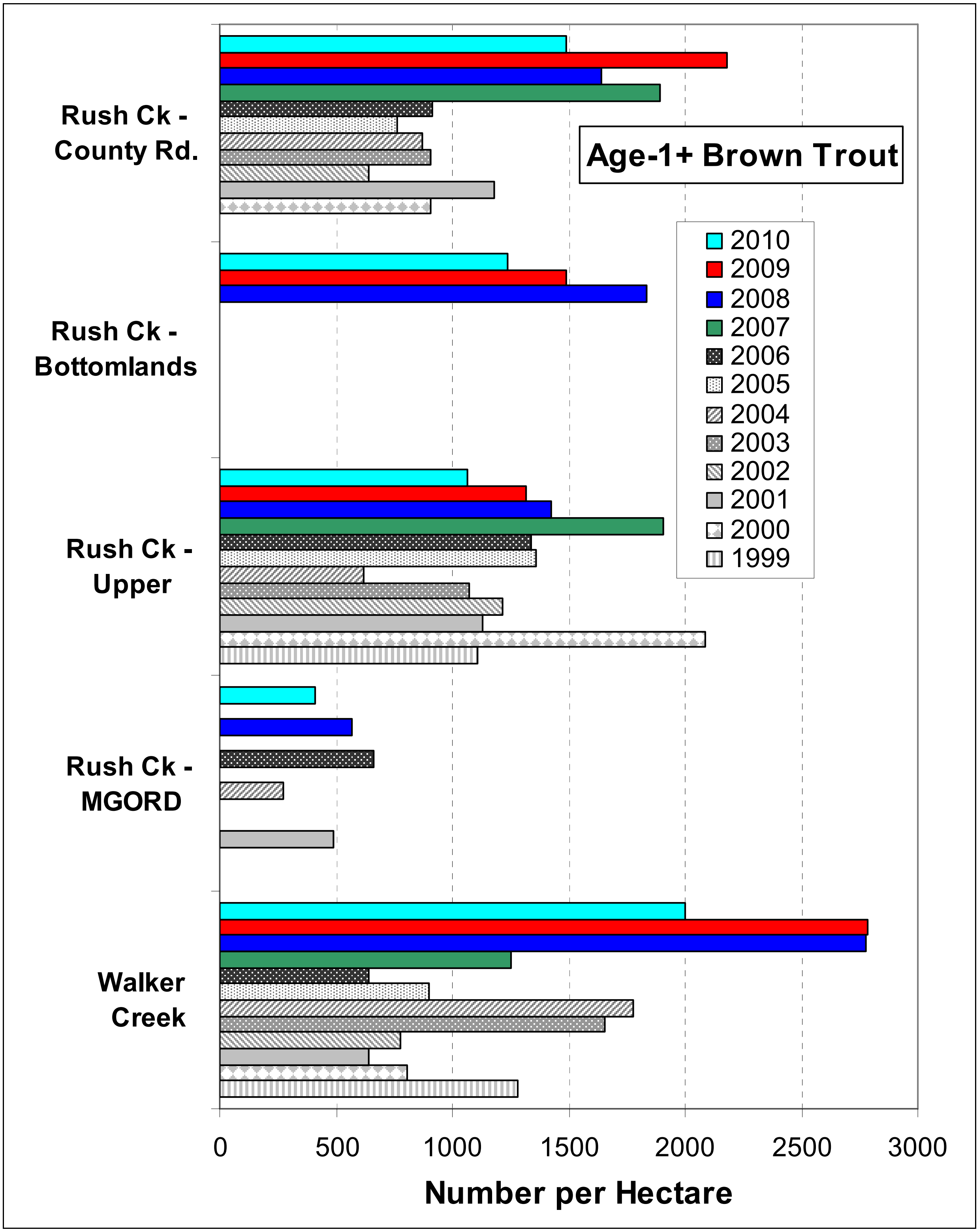


Figure 16. Estimated number of age-1 and older brown trout per hectare in sections of Rush and Walker creeks from 1999 to 2010.

The six age-1 and older brown trout captured in the side channel section of Lee Vining Creek produced an estimated density of 118.3 fish/ha in 2010 (Figure 17). This side channel has had very low baseflows since RY2006 and therefore has supported relatively few fish the past five years (Figure 17). Between 2009 and 2010, the estimated density of age-1 and older brown trout in the main channel of Lee Vining Creek decreased dramatically (-58%) from 1,083 fish/ha to 452.0 fish/ha (Figure 17). The 2010 density estimate of age-1 and older brown trout in the main channel section was the second-lowest estimate for this section in 12 years of sampling (Figure 17).

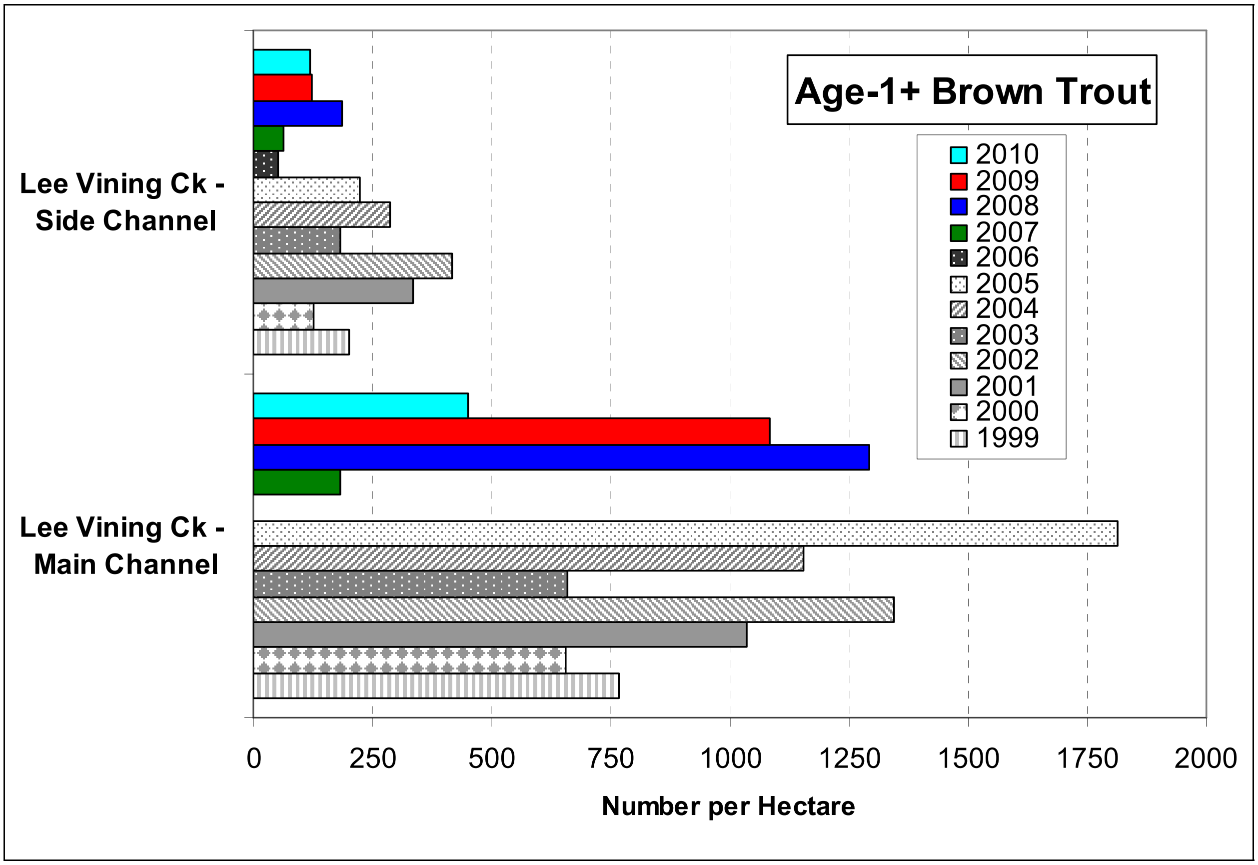


Figure 17. Estimated number of age-1 and older brown trout per hectare in sections of Lee Vining Creek from 1999 to 2010.

Estimated densities of age-1 and older rainbow trout during 2010 in the Lee Vining Creek side channel section were the lowest recorded for the 12 years of annual sampling (Figure 18). For the Lee Vining Creek main channel section, the estimated densities of age-1 and older rainbow trout dropped dramatically from 651.4 fish/ha in 2009 to only 99.7 fish/ha in 2010 (Figure 18). 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.

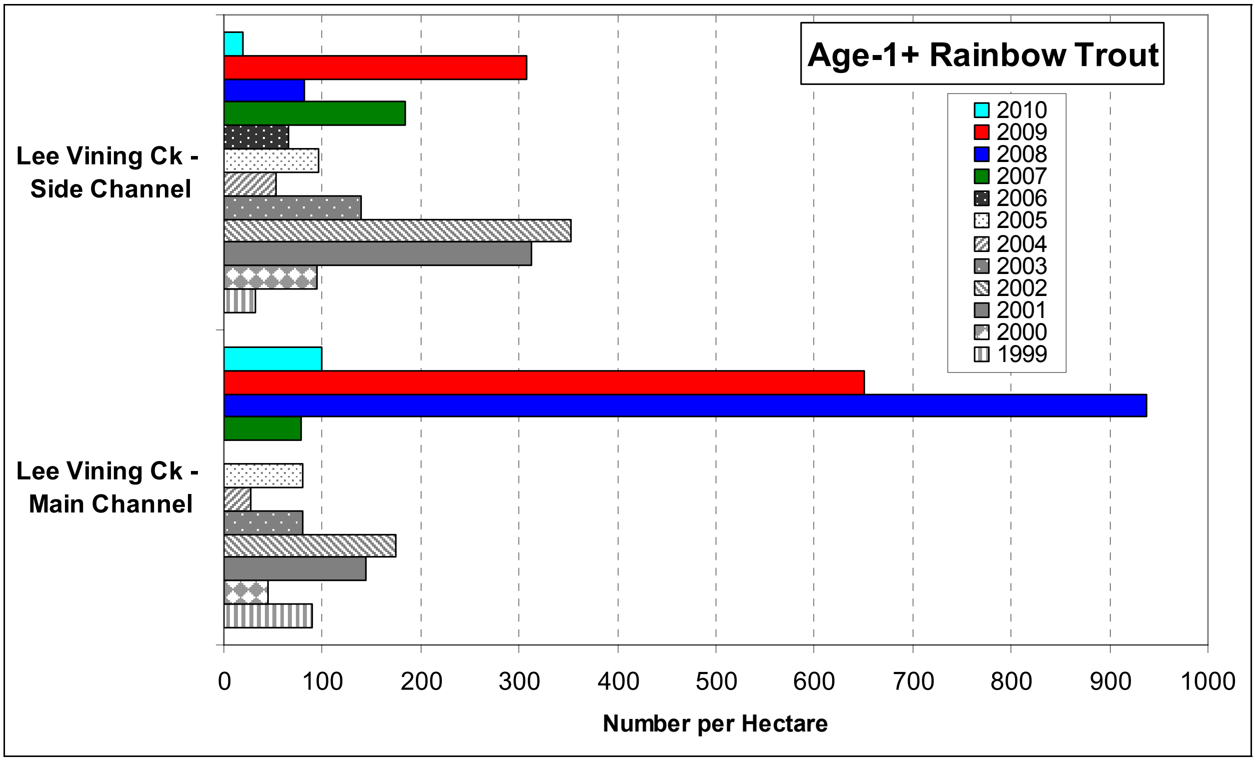


Figure 18. Estimated number of age-1 and older rainbow trout per hectare in sections of Lee Vining Creek from 1999 to 2010.

Between 2009 and 2010, estimated densities of age-0 brown trout increased in all three Rush Creek sections (Figure 19). The Upper section's 2010 density estimate of 5,836.4 age-0 brown trout/ha was more than double the 2009 estimate of 2,509.0 age-0 brown trout/ha, which was the lowest estimate ever recorded for this section. The new Rush Creek Bottomlands section had an estimated density of 3,130.3 age-0 brown trout/ha in 2010, which was a 33% increase from the 2009 estimate (Figure 19). The County Road section had an estimated 2,776.3 age-0 brown trout/ha in 2010, which was a 41% increase from the 2009 estimate (Figure 19).

In Walker Creek the density estimate of age-0 of brown trout decreased by 36% in 2010 (2,391.8 fish/ha) from 2009 (3,718.5 fish/ha); this was the third consecutive decrease in age-0 brown trout densities since the estimate of 9,899.8 fish/ha in 2007 (Figure 19). In this report, all previous density estimates of age-0 brown trout in Walker Creek reflect the corrections made to sample reach lengths and areas (Figure 19).

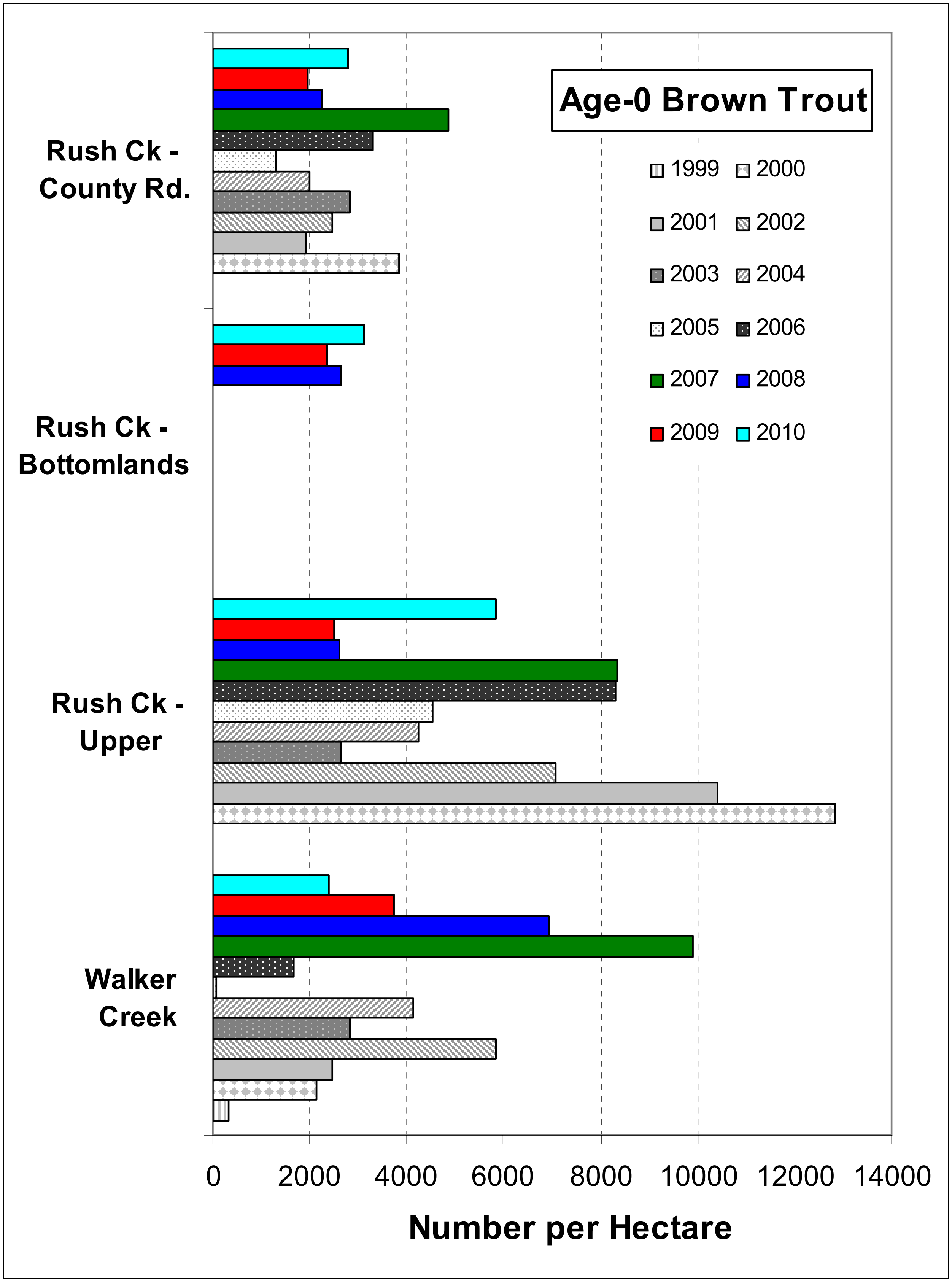


Figure 19. Estimated number of age-0 brown trout per hectare in sections of Rush Creek (bottom) and Walker creeks (top) from 1999 to 2010.

In 2010, the age-0 brown trout density estimate in the main channel section of Lee Vining Creek was more than double the density estimated in 2009; however the 2010 density of age-0 brown trout was relatively low when compared to values for the past 12 years (Figure 20). Thirteen age-0 brown trout were captured in 2010 within the Lee Vining Creek side channel which generated a density estimate of 256.4 age-0 brown trout/ha, which was more than double the 2009 density estimate of 102.6 age-0 brown trout/ha (Figure 20). The Lee Vining Creek side channel has supported very low densities of age-0 brown trout since the 2005 sampling season (Figure 20).

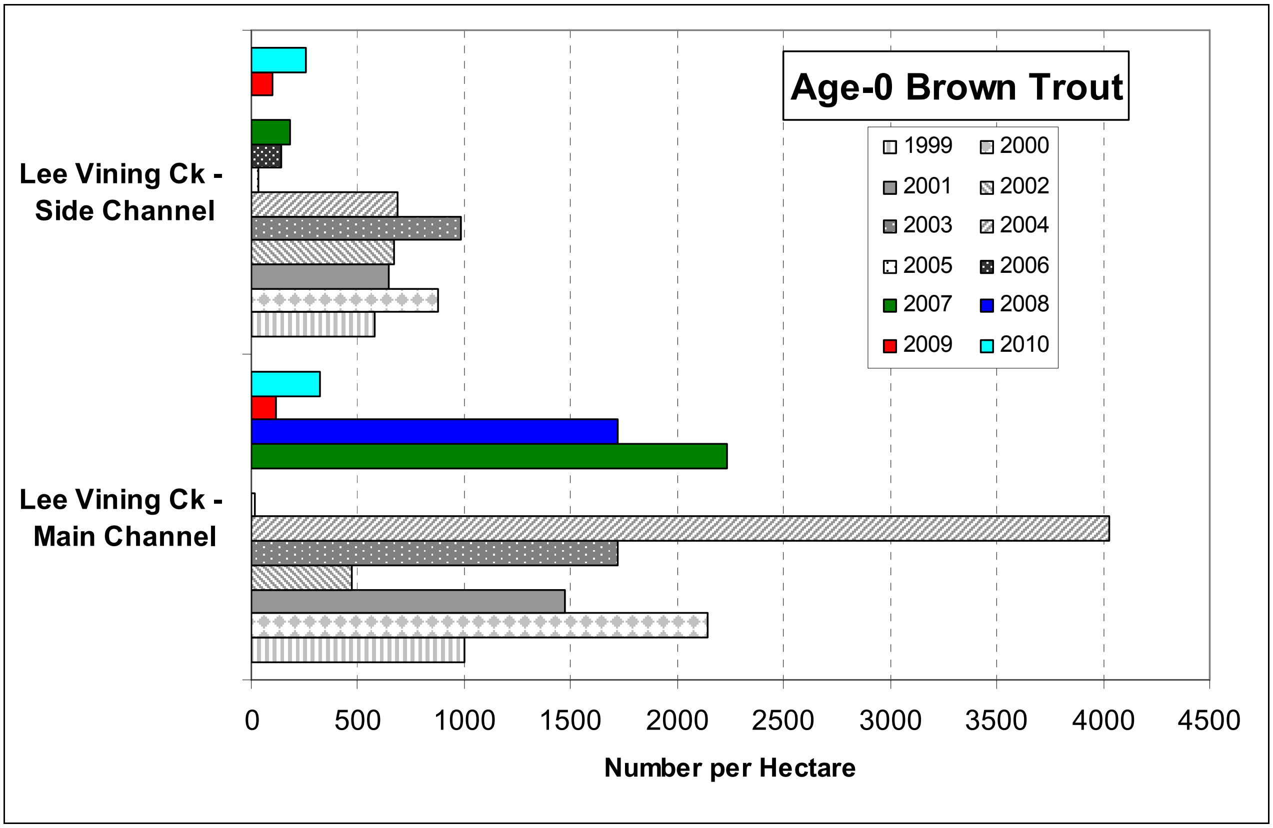


Figure 20. Estimated number of age-0 brown trout per hectare in sections of Lee Vining Creek from 1999 to 2010.

In 2010, no age-0 rainbow trout were captured in the main channel and side channel sections of Lee Vining Creek, thus the density estimates for both sections was zero (Figure 21). This was the second straight year in which no age-0 rainbow trout were sampled in the side channel section of Lee Vining Creek (Figure 21).

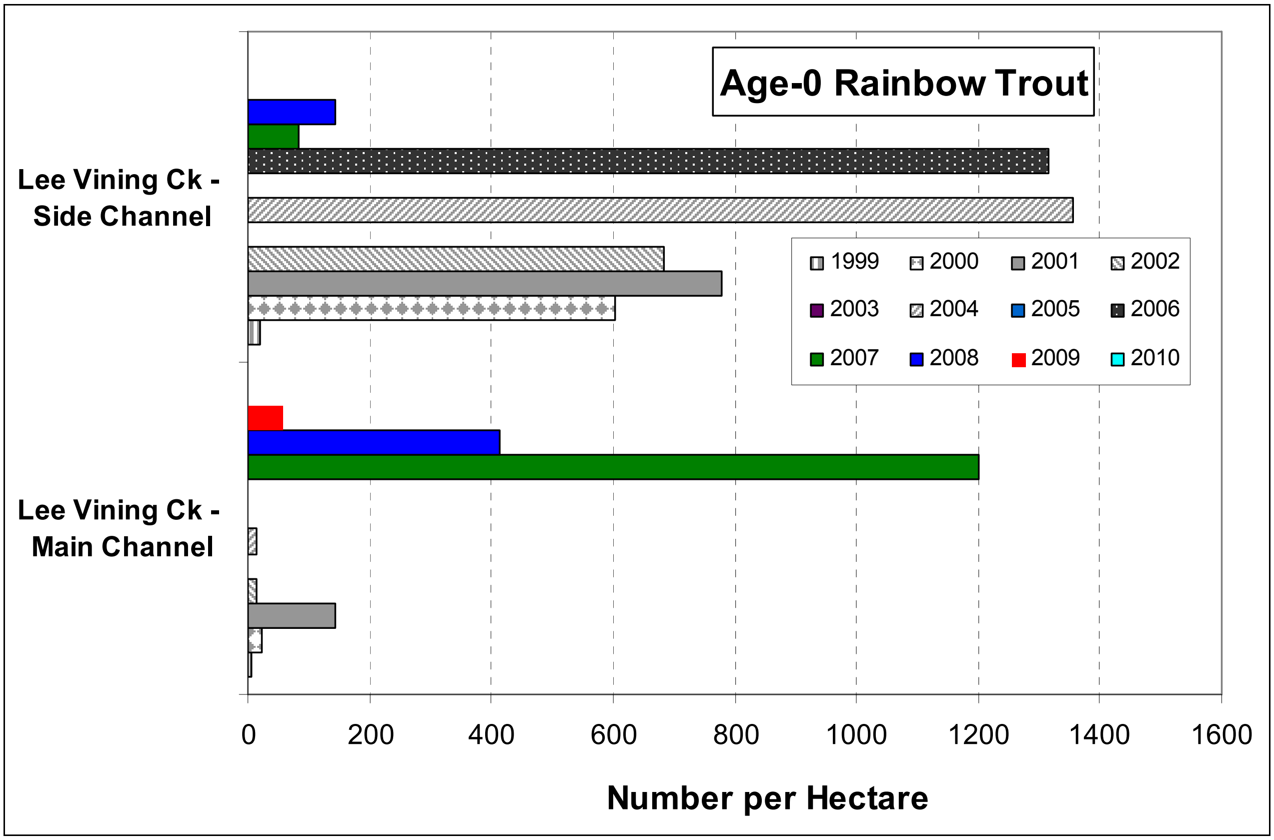


Figure 21. Estimated number of age-0 rainbow trout per hectare in sections of Lee Vining Creek from 1999 to 2010.

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 2009 to 2010, the County Road section experienced a 14% increase in total numbers of brown trout per km, but a 24% decrease in the numbers of age-1 and older brown trout per km (Table 15). The Bottomlands section of Rush Creek experienced a 15% increase in total numbers of brown trout per km, but a 16% drop in the numbers of age-1 and older brown trout per km (Table 15). The Upper section experienced a 66% increase in total numbers of brown trout per km, but a 26% decrease in the numbers of age-1 and older brown trout per km (Table 15).

In Lee Vining Creek from 2009 to 2010, the main channel section experienced a 57% decrease in the total numbers of trout per km and the numbers of age-1 and older trout per km decreased by 68% (Table 16). In 2010, the estimate of 326 age-1 and older trout per km in the main channel section was the second lowest estimate for this section (Table 16). From 2009 to 2010, the side channel section experienced a 23% decrease in the total numbers of trout per km and the numbers of age-1 and older trout per km decreased by 67% (Table 16).

Table 15. Total number of brown trout per kilometer of stream channel for Rush Creek sample sections, 2000 - 2010. 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	2010 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)	3,498 (1,222)
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)	3,405 (963)
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)	5,726 (881)

Table 16. Total number of brown and rainbow trout per kilometer of stream channel for Lee Vining Creek sample sections, 2000 – 2010. 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	2010 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)	518 (326)
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)	103 (36)
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 (566)	311 (181)

Estimated Trout Standing Crop Comparisons

In Rush Creek, brown trout standing crop estimates decreased from 2009 to 2010 in the County Road and Bottomlands sample sections (Table 17 and Figure 22). In the County Road section, the 2010 estimated standing crop of 137.1 kg/ha was the second highest value ever recorded in this section and was only a 5% decrease from the 2009 estimate (Table 17 and Figure 22). In the Bottomlands section, the 2010 estimated standing crop of 115.1 kg/ha was an 11% decrease from the 2009 estimate (Table 17). In the Upper Rush section, the 2010 estimated standing crop of 153.4 kg/ha was a 17% increase from the 2009 estimate, and exceeded 150 kg/ha for the first time since 2007 (Table 17). Between 2009 and 2010, Walker Creek experienced a decrease of 31% in estimated standing crop (Table 17 and Figure 22). In Lee Vining Creek total standing crops (brown and rainbow trout combined) decreased by 55% between 2009 and 2010 in the side channel section, and decreased by 37% in the main channel section (Table 18 and Figure 23).

Total standing crops have been estimated since 1999 to determine potential trends (Figures 22 and 23). 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); a nearly 70% increase in 2009; and finally a slight decrease in 2010 (still the second highest estimate) (Figure 22). 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; a 34% decrease in 2008 to 107.2 kg/ha; followed by two straight years of increases in 2009 and 2010 (Figure 22). The relatively new Rush Creek Bottomlands section experienced a slight decrease in estimated standing crop between 2009 and 2010 after an increase between the first and second years of sampling (Figure 22).

In the MGORD section of Rush Creek, the 2010 estimated standing crop of 77.3 kg/ha was a 17% increase from the 2008 estimate of 66.2 kg/ha (Figure 22). However, the 2010 estimate was still a 63% drop from the standing crop estimate of 208.0 kg/ha recorded in 2006. Standing crops estimates in the MGORD have generally been lower than estimates from other sections of Rush Creek, probably because substantial sections of the MGORD lack suitable cover habitat (i.e. elodea beds and willows along the stream banks) for brown trout, which significantly contribute to the overall surface area calculation for this section.

In Walker Creek, total standing crop estimates for all past sampling years were adjusted according to the sampling reach's corrected areas (length x width) (Figure 22). Although the corrected estimates for Walker Creek were significantly lower than the previously reported values, the five-year average (2006-2010) of 157.7 kg/ha was still higher than any of the five-year averages for the Rush Creek sample sections (Figure 22).

The Lee Vining Creek main channel section's total standing crop estimate decreased by 25% between 2008 and 2009 and then decreased by another 37% between 2009 and 2010 (Figure 23). Unlike the past two years, the 2010 total standing crop estimate included a relatively small contribution of rainbow trout biomass (19% of the 2010 estimate compared to 44% in 2008 and 2009) (Figure 23). The Lee Vining Creek side channel section's total standing crop estimate in 2010 of 22.3 kg/ha was a 55% drop from the 2009 estimate of 49.5 kg/ha (Figure 23).

Table 17. Comparison of 2009-2010 brown trout standing crop (kg/ha) estimates in Rush Creek study sections.

Collection Location	2009 Total Standing Crop (kg/ha)	2010 Total Standing Crop (kg/ha)	Percent Change Between 2009 and 2010
Rush Creek - County Road	143.9	137.1	- 5%
Rush Creek - Bottomlands	129.1	115.1	- 11%
Rush Creek – Upper	131.2	153.4	+ 17%
Walker Creek	184.5	128.2	- 31%

Table 18. Comparison of 2009-2010 total (brown and rainbow trout) standing crop (kg/ha) estimates in Lee Vining Creek study sections.

Collection Location	2009 Total Standing Crop (kg/ha)	2010 Total Standing Crop (kg/ha)	Percent Change Between 2009 and 2010
Lee Vining Creek - Main Channel	136.1	85.7	- 37%
Lee Vining Creek - Side Channel	49.5	22.3	-55%

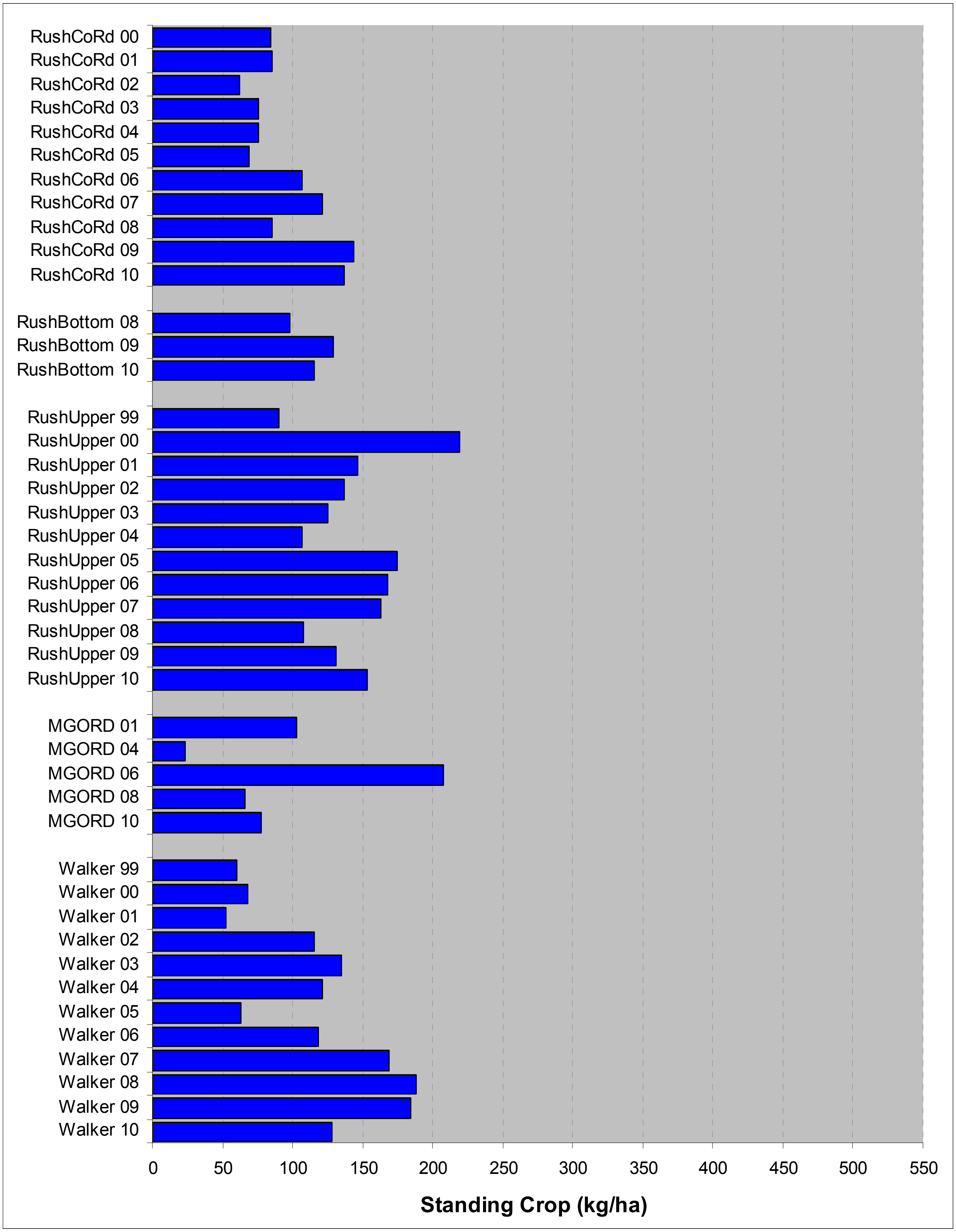


Figure 22. Estimated total standing crop (kilograms per hectare) of brown trout in all sample sections within Rush Creek, 1999-2010. Section and year are shown on the y-axis.

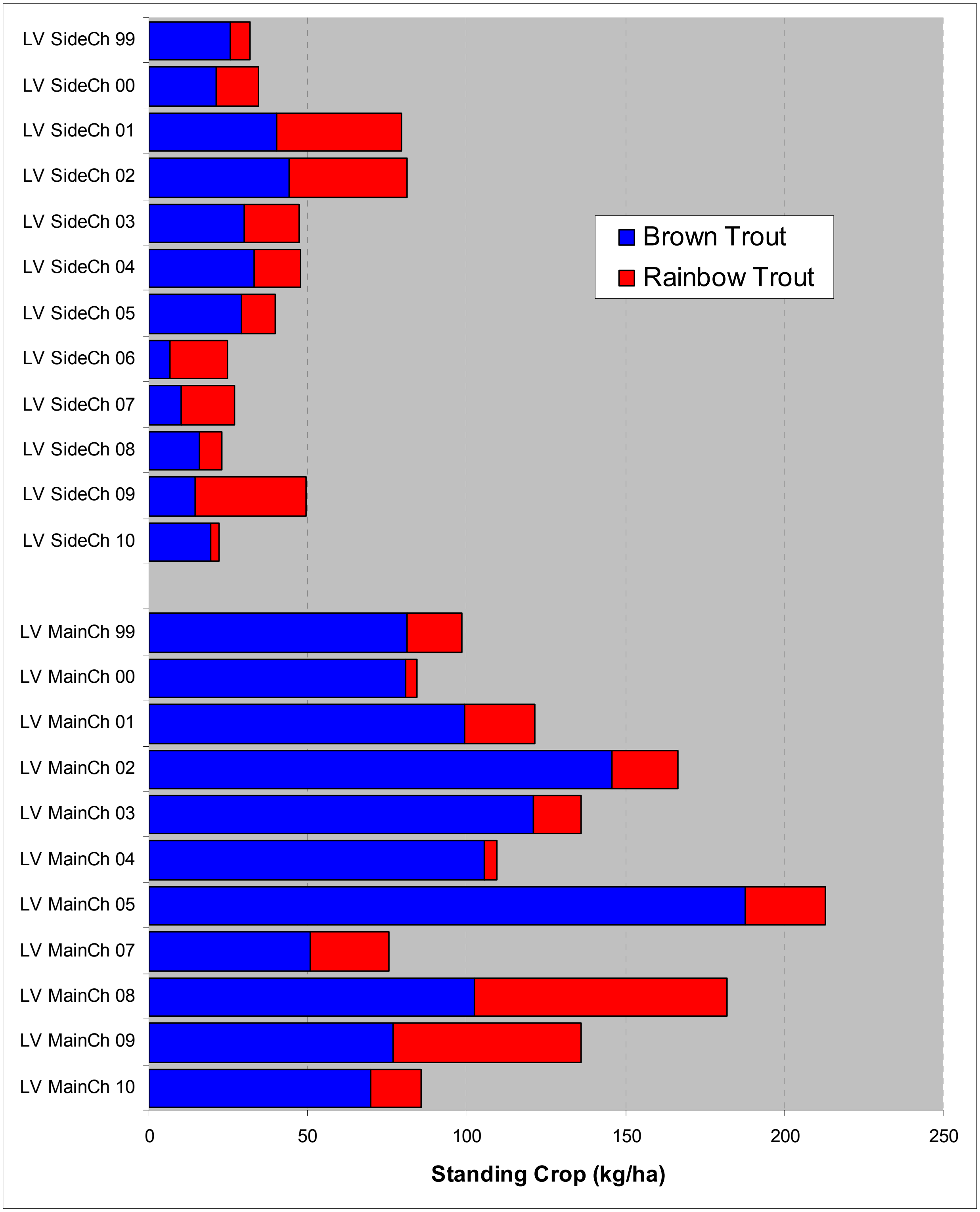


Figure 23. Estimated total standing crop (kilograms per hectare) of brown trout and rainbow trout in all sample sections within the Lee Vining Creek drainage, 1999-2010. Section and year are shown on the y-axis.

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

RSD-225 values for brown trout in the three annually-sampled sections of Rush Creek increased between 2009 and 2010, including a more than three-fold increase in the County Road section, an 80% increase in the Bottomlands section and a 161% increase in the Upper section (Table 19). These increases can be attributed to higher numbers of brown trout in the 225-299 mm range in all three sections, which increased the proportion of fish >225 mm at these sections. Within the County Road section three brown trout with lengths >300 mm were captured, which has not occurred since the 2001 season (Table 19).

RSD-300 values remained low in the Upper Rush Creek section, with an increase from 2 to 3 between 2009 and 2010, and two brown trout greater than 375 mm in length were sampled (Table 19). In 2010, the Rush Creek County Road section had an RSD-300 value of 1, the first RSD-300 value greater than 0 since the 2001 season (Table 19). The Bottomlands section had an RSD-300 value of 0 in 2010, even though one fish greater than 300 mm in length was captured (Table 19).

The RSD-225 and RSD-300, values in the MGORD section of Rush Creek decreased between 2009 and 2010, due primarily to the increase in numbers of fish between 150-224 mm in length (Table 19). The RSD-375 value for 2010 was 5, above a value of 4 for the first time since the 2006 sampling season (Table 19). The 35 brown trout >375 mm captured in 2010 was the second highest number of larger fish ever caught in the MGORD section (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 139% between 2009 and 2010, after a 70% increase between 2008 and 2009 (Table 20). The increase of the RSD-225 value was due to the large overall drop in numbers of fish >150 mm and the large drop in the numbers of fish between 150-224 mm (Table 20). In 2010, 34 fish ≥225 mm were captured, the largest number of fish ≥225 mm ever caught in this section of Lee Vining Creek (Table 20). In 2010, the Lee Vining Creek main channel section had a RSD-300 value of 3, the highest RSD-300 value since the 2005 sample season (Table 20).

Table 19. RSD values for brown trout in Rush Creek study sections, for 2000-2010.

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	2010	302	228	71	2	1	25	1	
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	2010	307	225	81	1	0	27	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	2010	308	202	97	7	2	34	3	1
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	

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

Table 19 (continued).

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 - MGORD	2010	694	252	292	115	35	64	22	5
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

Table 20. RSD values for brown and rainbow trout in the Lee Vining Creek main channel study section, for 2000-2010.

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	2010	62	28	32	2	0	55	3
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	29	24	5	0	0	17	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 for the most-recent three-year average which encompassed 2008-2010 (Tables 21 and 22). The County Road section met only one of the five termination criteria (density) and the Upper Rush section met two of the five termination criteria (density and condition factor) (Tables 21 and 22).

Table 21. Termination criteria analyses for the County Road section of Rush Creek. Bold values indicate that an estimated value met the termination criterion.

Termination Criteria	**2008 – 2010 Average**	**2007 – 2009 Average**	**2006 – 2008 Average**
Biomass (≥175 kg/ha)	122.2	116.8	104.4
Density (≥3,000 fish/km	**3,249.3**	**3,753.7**	**3,813.0**
Condition Factor (≥1.00)	0.95	0.94	0.94
RSD-225 (≥35)	14	9	17
RSD-300 (≥5)	0	0	0
Conclusion	**Met one of five TC**	**Met one of five TC**	**Met one of five TC**

Table 22. Termination criteria analyses for the Upper section of Rush Creek. Bold values indicate that an estimated value met the termination criterion.

Termination Criteria	**2008 – 2010 Average**	**2007 – 2009 Average**	**2006 – 2008 Average**
Biomass (≥175 kg/ha)	130.6	133.7	145.8
Density (≥3,000 fish/km	**4,259.0**	**5,249.7**	**6,736.7**
Condition Factor (≥1.00)	**1.00**	0.99	0.99
RSD-225 (≥35)	34	19	26
RSD-300 (≥5)	3	3	4
Conclusion	**Met two of five TC**	**Met one of five TC**	**Met one of five TC**

The MGORD section of Rush Creek met only one of three RSD termination criteria (RSD-225) for the average of years 2008-2010 (Table 23). The RSD-375 average for 2008-2010 failed to meet termination criteria due to two consecutive years (2008 and 2009) where low (less than 5) values were recorded (Table 23).

Table 23. Termination criteria analyses for the MGORD section of Rush Creek. Bold values indicate that an estimated value met the termination criterion.

Termination Criteria	2008 - 2010 Average	2007 - 2009 Average	2006 - 2008 Average
RSD-225 (≥60)	**64**	**68**	**73**
RSD-300 (≥30)	20	28	**39**
RSD-375 (≥5)	4	4	4
Conclusion	**Met TC one of three RSD values**	**Met TC one of three RSD values**	**Met TC two of three RSD values**

Because the Lee Vining Creek main channel section was not sampled in 2006, one of the three, three-year running averages was comprised of data collected in 2005, 2007 and 2008. In Lee Vining Creek, the main channel section failed to achieve the target of meeting three out of four termination criteria (Table 24). The main channel section has met the same one of the four termination criteria (condition factor) for the past two sets of three-year running averages (Table 24). The 2005/2007/2008 set of data met two of the four termination criteria (Table 24). For the 2010 annual report we have also provided separate condition factors for brown trout and rainbow trout (Table 24).

Table 24. Termination criteria analyses for the Lee Vining Creek sample section. Bold values indicate that an estimated value met the termination criterion.

Termination Criteria	2008 - 2010 Average	2007 - 2009 Average	2005/2007/2008 Average
Biomass (≥150 kg/ha)	134.6	131.1	**156.7**
Density (≥1,400 fish/km	734.7	1,003.0	963.0
Condition Factor (≥1.00)	Browns = **1.04** Rainbows = **1.11**	Browns = **1.04** Rainbows = **1.07**	Browns = **1.06** Rainbows = **1.13**
RSD-225 (≥30)	28	16	21
Conclusion	**Met one of four TC**	**Met one of four TC**	**Met two of four TC**

Primary Productivity Preliminary Results

During September 2010, an initial set of water samples for laboratory analyses, along with field water temperature and dissolved oxygen (DO) measurements, were collected. Field measurements, including early morning and late afternoon samples, were collected primarily at the two water quality sampling stations on Rush Creek and at the top and bottom of the MGORD. Field measurements at the Lee Vining and Owens River stations were only taken at the time when the water samples were collected.

Water temperatures and DO concentrations were most stable at the top of the MGORD (Table 25). Also shown on this table are the “DO Saturation” values, which are the DO concentrations that should be present at the water temperature, elevation, and barometric pressure present during the collection of the sample if no chemical or biological oxygen demands are present in the stream. The last column shows the “Percentage of Saturation” values, which are the actual field concentrations divided by the DO saturation values (Table 25). These percentages, especially “supersaturated” (>100%) values, enable us to at least determine if primary productivity is occurring at some level at the stations. The only supersaturated value (109%) was at the station near the bottom of the MGORD, late in the afternoon on 9/20/10; this station also had the lowest recorded percentage of saturation value (82%), which occurred during the morning of that day (Table 25). DO saturation values were more stable throughout the day at the other stations (Table 25).

Concentrations of micro-nutrients were not detectable (ND) at most of the stations, except for very low levels of total phosphorus and orthophosphate at the Owens River sites, and a low value for Kjedahl Nitrogen at the Lower Lee Vining station (Table 26). Total alkalinity concentrations ranged from 11-18 mg/l at the Lee Vining and Rush creek stations, compared to 91-130 mg/l at the Owens River stations. Specific conductivity values were also noticeably higher on the Owens (196-322 umhos/cm), compared to the values on Rush and Lee Vining creeks (36-50 umhos/cm) (Table 26).

Primary productivity rates, measured as the amount of algal biomass and chlorophyll-a accumulated on glass slide-substrates per unit time, were almost non-existent at the Lee Vining Creek stations, but fairly similar at the stations on Rush Creek and the Owens River (Table 26). However, these results were influenced by two factors. First, water temperatures were lower than normal during September 2010, and were actually declining during the time that the periphytometers were in the streams. Productivity rates were therefore not measured during the warmest time of year, which is when these rates are highest. Secondly, at least two of the periphytometers (at Upper Rush and the Owens below Hot Creek) showed evidence of having been disturbed, which - depending on how long that they were out of the water, would affect the growth and survival of the attached periphyton. All efforts will be made during 2011 to insure that primary productivity measurements are conducted during the warmest time of the year, with the periphytometers more carefully hidden.

Table 25. Water temperature and dissolved oxygen measurements at Rush Creek stations, September 17-21, 2010.

Rush Creek Section	Date	Time	Temp (F)	D.O. (mg/l)	D.O. Saturation (mg/l)	D.O. Percent Saturation
MGORD (top)	9/17/10	7:15 AM	61	7.3	7.7	95%
	9/20/10	7:20 AM	60	7.2	7.8	92%
	9/20/10	7:40 AM	60	7.2	7.8	92%
	9/20/10	4:35 PM	61	7.0	7.7	91%
	9/21/10	4:05 PM	60	6.8	7.8	87%
MGORD (bottom)	9/17/10	7:30 AM	60	6.4	7.8	82%
	9/20/10	6:50 AM	58	6.5	7.9	82%
	9/20/10	5:15 PM	62	8.2	7.5	109%
Upper	9/17/10	6:45 AM	55	7.4	8.3	89%
	9/17/10	9:00 AM	58	7.6	8.0	95%
	9/17/10	11:45 AM	61	7.3	7.8	94%
	9/17/10	2:00 PM	62	6.4	7.6	84%
	9/17/10	4:05 PM	64	6.5	7.4	88%
	9/21/10	4:30PM	62	6.6	7.6	87%
Bottom-lands	9/18/10	6:45 AM	51	7.8	8.8	89%
	9/18/10	9:20 AM	51	8.3	8.8	94%
	9/18/10	11:55 AM	56	7.5	8.3	90%
	9/18/10	1:50 PM	62	7.0	7.7	91%
	9/18/10	3:15 PM	64	6.8	7.5	91%
	9/20/10	3:45 PM	62	6.6	7.7	86%

Table 26. Concentrations of water quality parameters (mg/l) and estimates of primary productivity rates based on the accumulation of periphyton biomass and chlorophyll-a/unit area/unit time. Water samples were collected on 9/21/10. Periphtometers were in place from 9/9/10 to 9/21/10.

Station	Specific Conductivity	Total Alkalinity (mg/l)	Total Phosphorus (mg/l)	Ortho Phosphorus (mg/l)	Kjedahl Nitrogen (mg/l)	Nitrate + Nitrite (mg/l)	Ammonia Nitrogen (mg/l)	Algal Biomass (mg/m^2/month)	Chlorophyll - a (mg/m^2/month)
Rush MGORD	45	17	ND	ND	ND	ND	ND	49.6	6.2
Rush Upper	47	18	ND	ND	ND	ND	ND	73.8	1.7
Rush Lower	50	18	ND	ND	ND	ND	ND	196.8	5.9
LV Upper	36	11	ND	ND	ND	ND	ND	ND	ND
LV Lower	37	12	ND	ND	0.90	ND	ND	ND	0.5
Owens Above	196	91	0.12	0.05	ND	ND	ND	100.8	3.3
Owens Below	322	130	0.10	0.02	ND	ND	ND	76.3	1.8

Discussion

The 2010 sampling year was the twelfth 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 2010 was also marked by completion of the Synthesis Report in which the Stream Scientists made recommended changes to the flow regimes established in Orders 98-05 and 98-07 (M&T and RTA 2010). The recommended flow changes for improving the growth and survival of trout included: (1) lowering winter baseflows in both Rush and Lee Vining creeks to increase preferred holding habitat and to increase storage in Grant Lake Reservoir, (2) maintaining higher storage levels in Grant Lake Reservoir to improve summer thermal conditions in Rush Creek, and (3) modifying the receding limb of Rush Creek's hydrograph to improve summer thermal conditions.

As the Synthesis Report was being developed, extremely low storage levels in Grant Lake Reservoir resulted in Rush Creek flows during the winter of 2008-2009 that were close to winter baseflows eventually recommended by the Stream Scientists. LADWP was then granted a variance by the SWRCB to test the recommended winter baseflows during the winter of 2009–2010. Thus the Discussion section of this annual report focuses on the response of the Rush Creek trout population to the adjusted winter baseflows, growth information from recaptures of PIT tagged fish, and a methods evaluation. Upcoming fisheries monitoring in 2011 and beyond should focus at evaluating responses of the fish populations to flow regimes recommended in the Synthesis Report.

Brown Trout Response to Rush Creek's Winter Flow Regime

In the 2009 annual report we speculated that the low flows released into Rush Creek from October 2008 through the spring of 2009 may have caused a reduction in the abundance of age-0 brown trout as documented in September of 2009 (Taylor et al. 2010). For example, the 2009 estimated density of age-0 brown trout in the Upper section of Rush Creek was the lowest observed for the 12 years of the recent sampling record. In the 2009 report we suggested that an examination of the 2010 data could determine if the 2009 low age-0 recruitment translated into much lower densities of age-1 brown trout compared to previous years. In 2010, the densities of age-1 brown trout were reducted by 17% to 32% in the three annually sampled sections, so it does appear that the reduced numbers of age-0 fish in 2009 translated into lower densities of age-1 fish in 2010. However, reduced baseflows also occurred during the winter of 2009-2010 and the estimated densities of age-0 brown trout increased in 2010 from the 2009 values. The increases were quite large too, ranging from 33% in the Bottomlands section to 132% in the Upper section. Thus, from these two years of age-0 brown trout density data, it is inconclusive if lower winter baseflows have a negative impact on recruitment of age-0 fish.

The primary objective of the winter baseflow recommendation was to improve holding habitat for over-wintering brown trout that would translate into increasing the survival of older age classes of fish, ultimately increasing the numbers of larger fish. In 2010 the RSD-225 values increased by two to three-fold in all three annually sampled sections of Rush and in the Lee Vining Creek main channel. RSD-300 values also increased in the County Road and Upper sections of Rush Creek and in Lee Vining Creek. The Upper section of Rush Creek has also had an RSD-375 value of 1 for the past two years.

While these short-term increases in RSD values are encouraging, we believe that at least several additional years of fisheries data will be required to document if the winter baseflow recommendations continue to increase the proportion of older and larger trout, especially in the RSD-300 cateogry. We also acknowledge that factors such as severity of winter conditions and icing, summer water temperatures in drier year types and primary productivity may also influence the ability of Rush Creek, and to a lesser extent, Lee Vining Creek from consistently producing higher proportions of larger trout.

In Lee Vining Creek, the over-riding factor constaining the production of older and larger trout appears to be the scarcity of pools that provide suitable, low-velocity holding habitat. The Pool and Habitat Studies report documented the low abundance of pools within the lowermost 10,000 ft of Lee Vining Creek (Knudson et al. 2009). Low recruitment of age-0 trout during average and wetter runoff year types also affects the numbers of fish available for survival to older age classes. In past annual reports we have mentioned this as a probable cause of the sporadic up-and-down nature of age-0 recruitment in Lee Vining Creek and the carry-over to densities of age-1 and age-2 fish (Hunter et al. 2000; 2001; 2002; 2003; 2004; 2005; 2006; 2007; 2008). In Appendix D of the Synthesis Report we analyzed Lee Vining Creek water temperature data and determined that the emergence of brown trout frequently occurred during, or just after, the peak snowmelt period (M&T and RTA 2010). Thus, in average and wetter year types, age-0 brown trout are either still residing as alevins in the streambed substrate or are weak-swimming, newly emerged fry when peak flows moblize the channel bed. The typically sharp rising and falling limbs of Lee Vining Creek's hydrograph probably create unfavorable conditions for newly emerged fry to maintain positions along channel margins. For example, in 2010 Lee Vining Creek went from 56 c.f.s. on May 30th to a peak of 511 c.f.s on June 7th. As of mid-April 2011, it appears that Lee Vining Creek will experience high peaks flows during RY2011, and we should expect low recruitment of age-0 fish again. Due to the low densities of age-0 fish estimated in 2010, we also expect relatively low densities of age-1 fish in 2011.

Trout Growth between 2009 and 2010

In 2010, 96 age-1 fish with adipose fin-clips were recaptured that had PIT tags when scanned with a tag reader (Table 10). In the three annually-sampled sections of Rush Creek the average growth rates of age-0 to age-1 fish for the one year between 2009 and 2010 were slightly (3 to 5 g) lower than growth rates of age-0 to age-1 fish for the one year between 2008 and 2009 (Table 27). However, the 2009-2010 growth rates were still higher than the age-0 to age-1 growth rates documented during the dry

RY2007 (Table 27). Across all three years where we have data, growth rates of brown trout between age-0 and age -1 consistently increased from the County Road to the Bottomlands to the Upper sampling sections (Table 27). We speculate this gradient in growth may be attributed to one or more of the following reasons: 1) more food and nutrients occur closer to Grant Lake Reservoir, 2) more favorable thermal regimes for growth occur higher in the stream system, 3) differences in emergence timing with fish emerging earlier higher in the stream system, or 4) differences in parental genetics as in some age-0 fish in Upper Rush may be progeny of larger brown trout from the MGORD.

As previously mentioned in the Results section, seven age-1 brown trout were recaptured in the MGORD that were PIT tagged as age-0 fish in 2009. Five of these brown trout were tagged as age-0 fish in the Upper Rush sample section and migrated upstream to the MGORD sometime between September of 2009 and September of 2010. Without a fixed station to detect the movement of PIT tagged fish in and out of the MGORD, when these fish migrated to the MGORD was unknown. All seven of these fish exhibited excellent growth between age-0 and age-1 with an average growth of 107 mm in length and an average weight gain of 85 g, which was nearly double the average weight gain of 48 g between age-0 and age-1 at the Upper Rush section (Table 27).

The PIT tag data collected to date suggests that brown trout growth in the MGORD is excellent for younger fish, but tapers off as fish exceed 300 mm in length. As documented, many of the fish that were >300 mm when PIT tagged lost weight between 2009 and 2010. We suspect that habitat and flow conditions within the MGORD allow fish to live longer than fish from other sections of Rush Creek, and that some MGORD fish experience the effects of senescence (biological aging that occurs after an organism reaches maturity).

Table 27. Growth (g) comparisons of Rush Creek age-0 to age-1 brown trout in years 2006-2007, 2008-2009, and 2009-2010 with adipose fin clips administered during the 2006 and 2008 sampling seasons and PIT tags impanted in the 2009 season, respectively.

	Co. Rd. Rush Creek	Bottomlands Rush Creek	Upper Rush Creek
2007 Growth (g)	25	N/A	32
2009 Growth (g)	41	43	51
2010 Growth (g)	36	40	48

Actual Growth versus Predicted Growth

We predicted the weight changes (grams) in brown trout from age-0 to age-1 in the Upper, Bottomlands, and County Road sections of Rush Creek from September 15, 2009 to September 15, 2010 based on water temperatures measured at the County Road site (Bottomland and County Road sections) and at the old Highway 395 site (Upper section). These predictions used the potential growth equations developed by Elliot et al. (1995), which were used to evaluate thermal regimes of Rush Creek related to flows and Grant Lake Reservoir storage levels for making flow recommendations in the Synthesis Report (M&T and RTA 2010). These predicted weights were compared to the actual weights of age-0 brown trout that were PIT tagged in 2009 and recaptured in 2010. In general, predicted weights were lower than actual weights recorded for recaptured brown trout for all three sample sections (Figure 24). We speculate that these differences could be related to one or more of the following reasons: 1) the fish seeked out locations where water temperatures were more favorable for growth than where water temperatures were recorded by thermographs; 2) the Elliott et al. (1995) water temperature to growth prediction model under-estimated weight gains; 3) the food available to fish in Rush Creek was of higher quality than foods used in the Elliott et al. (1995) experiments, or 4) using average daily water temperatures may mask daily temperature fluctuations that may be important for predicting weight gains. Interestingly, there appears to be almost a bimodal distribution in weight differences with one group of fish having differences of about 0 to -10 grams, and another group of fish having differences mostly in the -12 to -20 grams. It may be possible that the Elliott et al. (1995) model under-estimated growth by about 10 grams, but that some fish also sought out more favorable water temperatures for growth during the year.

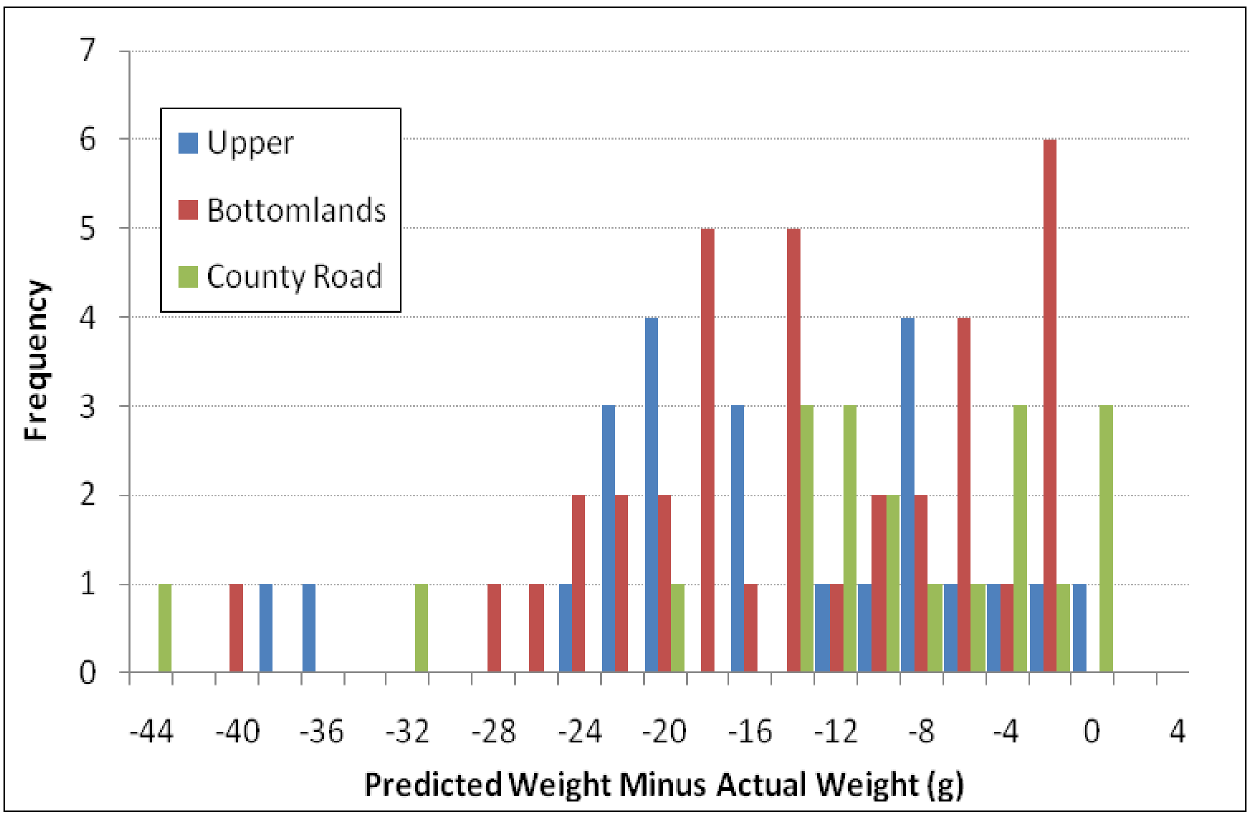


Figure 24. Frequency distribution of the differences in weights (g) that were predicted based on water temperature and measured for recaptured age-1 brown trout in three sample sections of Rush Creek (different colored bars).

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 (2003-2010) compared to previous years. Maintaining block fences ensures that the assumption of population closure is met, thus estimates are more reliable. During the 2010 field season there were no complete block fence failures.

In 2010, no major changes to the stream channel were observed within the annual sample sections on Rush and Lee Vining creeks. We did observe continued subtle changes 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. More apparent channel changes occurred within the Walker Creek sample section as high flows cut-off two meanders and shortened the sample section by approximately 34 meters. These high flows also left the channel as evidenced by bedload that was deposited on the meadow (Figure 25).

We have consistently sampled within the three main reaches in Rush Creek (MGORD, Upper Rush, and County Road) and have time-series fish abundance and condition data for the past 12 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 12), 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 twelve 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 annual 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.

Since 2009 the use of small passive integrated transponder tags (PIT tags) has allowed us to track the survival, growth, and movement of individual age-0 brown trout. We now will 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 future long-term monitoring of Rush and Lee Vining creeks' trout populations when evaluating the effectiveness of flow recommendations made by the Stream Scientists in the Synthesis Report.

In 2010 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 can be conducted safely and efficiently. 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 have also provided assistance with the Instream Flow Studies, pool surveys, temperature monitoring, winter icing monitoring, and water quality sampling. The Bishop Office's report describing the icing study on Lee Vining Creek during the winter of 2010-2011 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 was also described in the Synthesis Report and ushers in a diminished role of the consulting Stream Scientists when future monitoring is conducted to assess the revised streamflows recommended in the Synthesis Report.

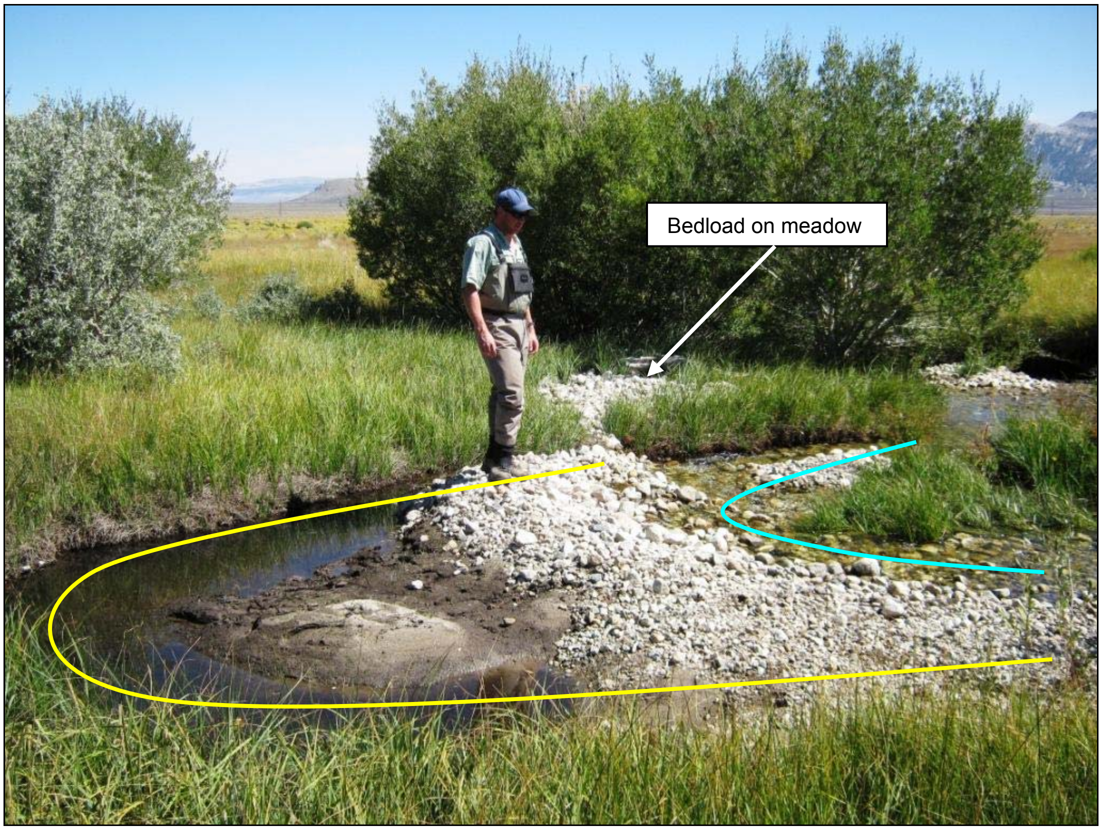


Figure 25. Meander cut-off on Walker Creek. Yellow line shows channel path prior to 2010 and blue line shows path occupied by flowing water during September 2010 sampling. Also note bedload deposited on meadow.

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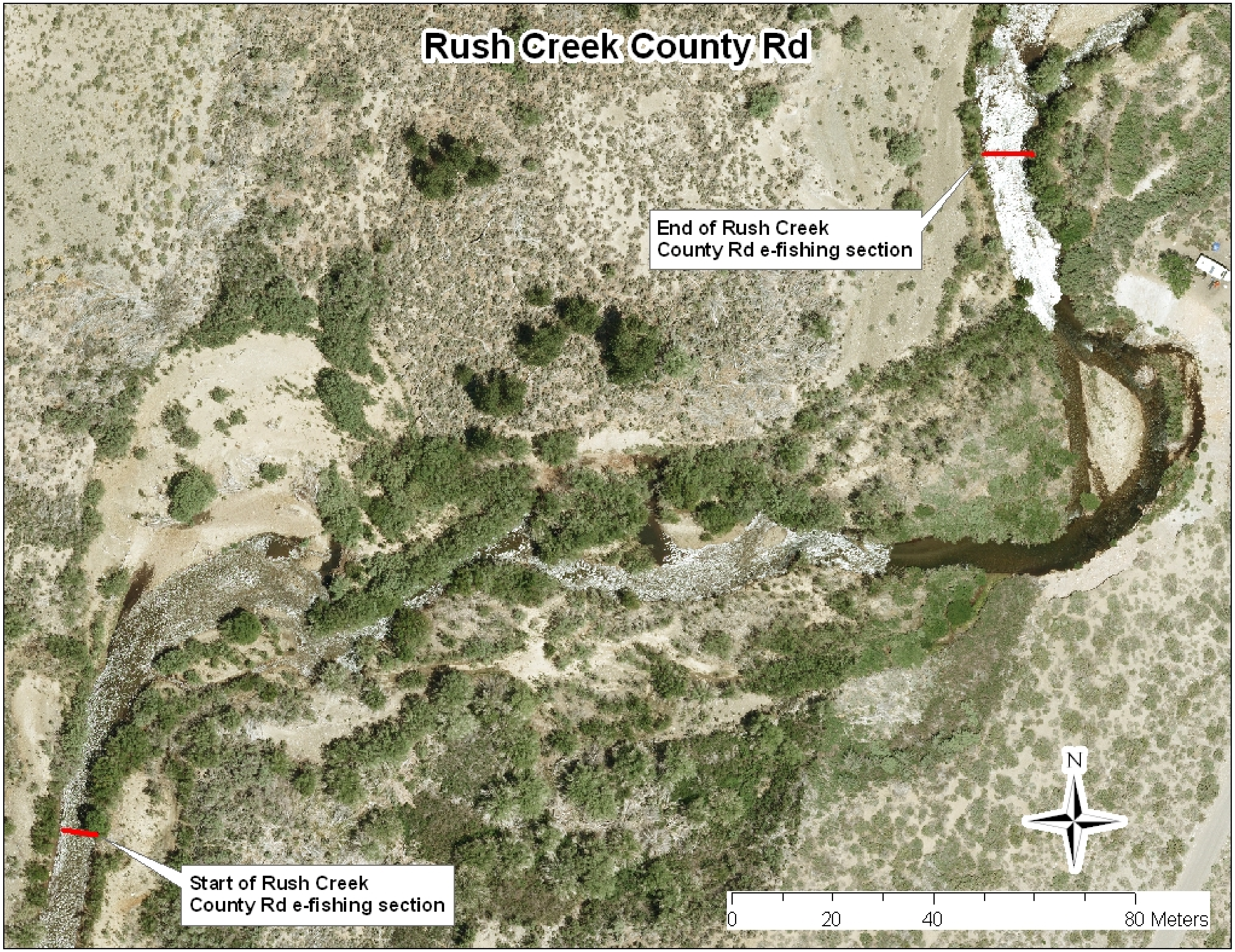
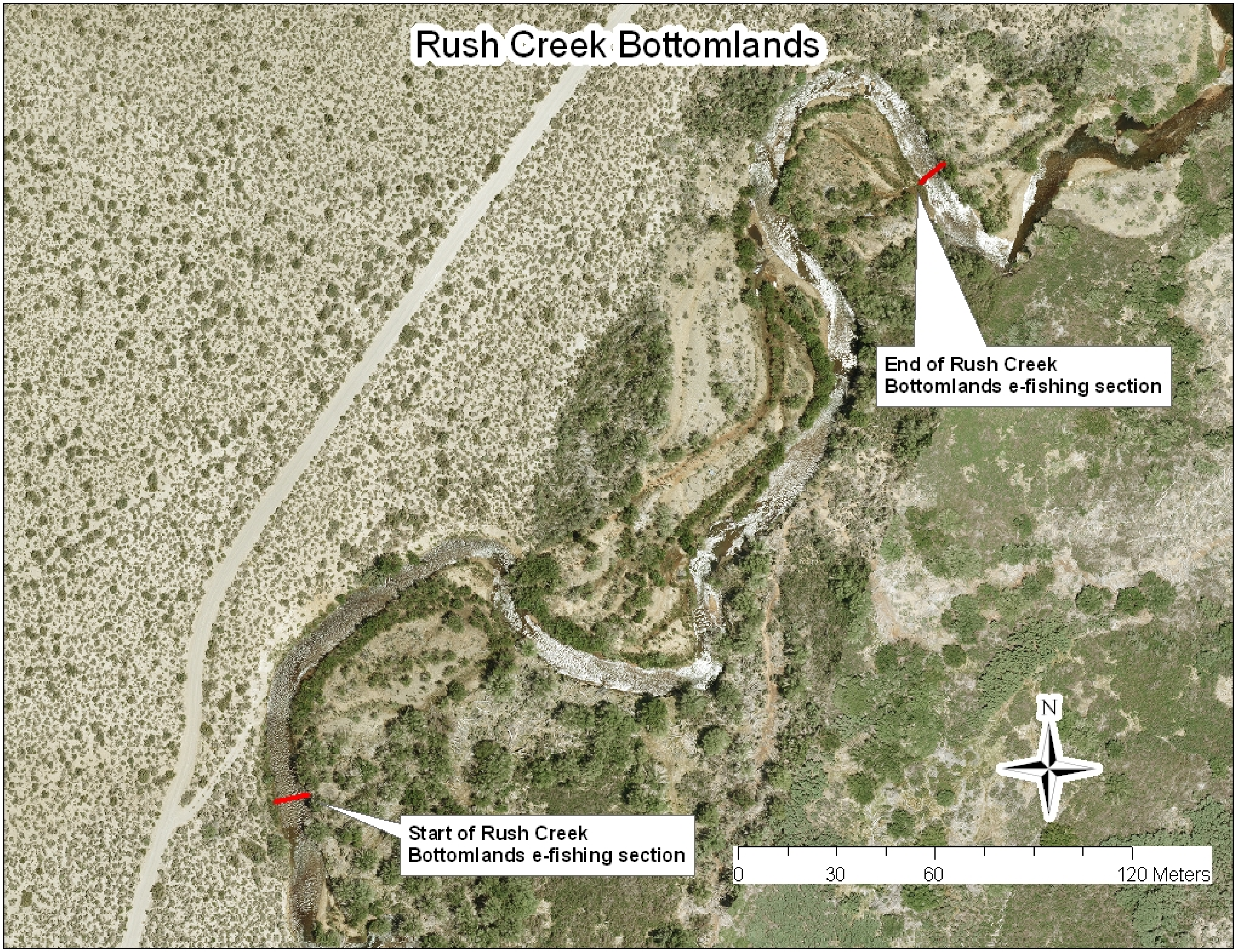
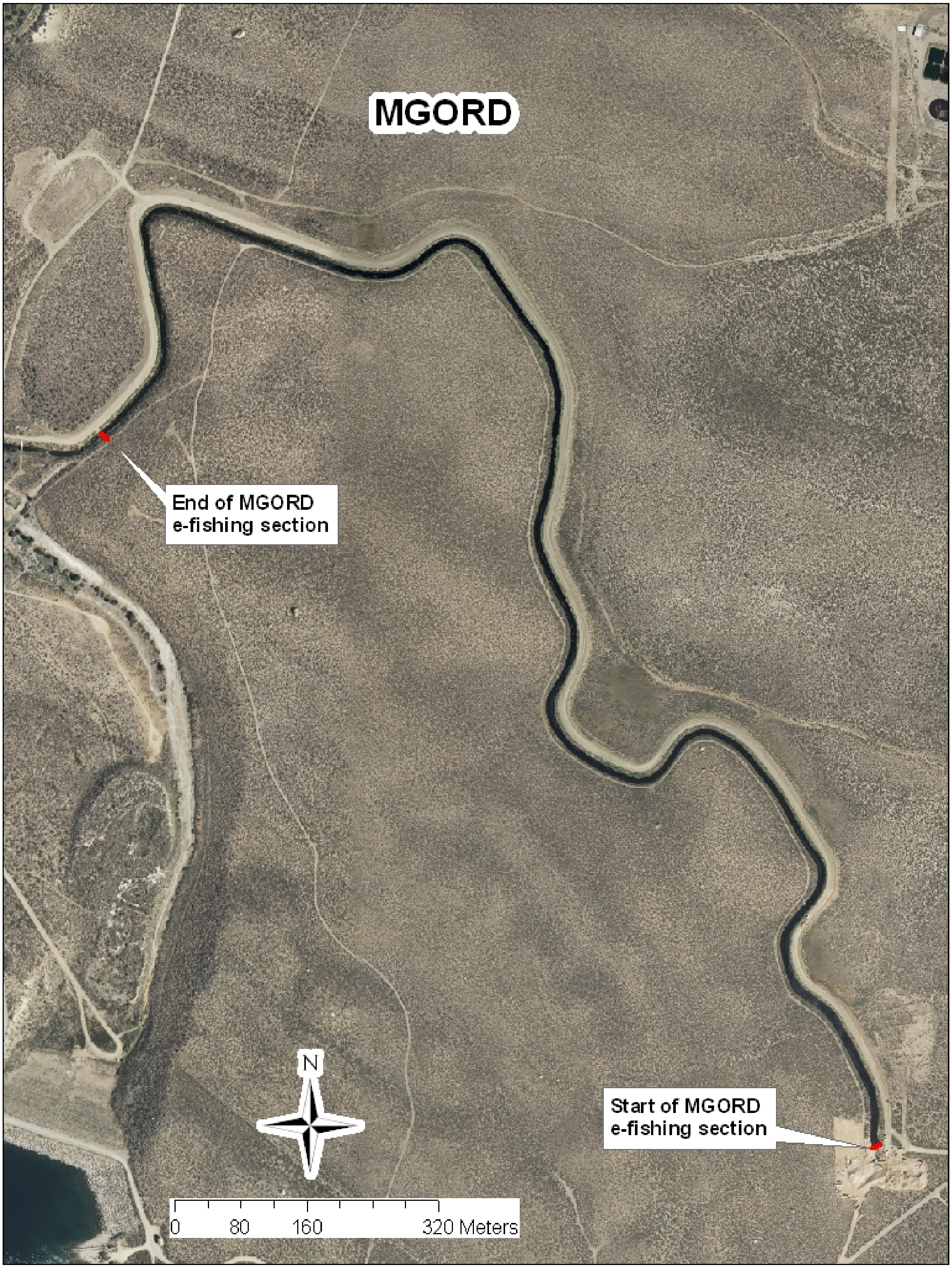
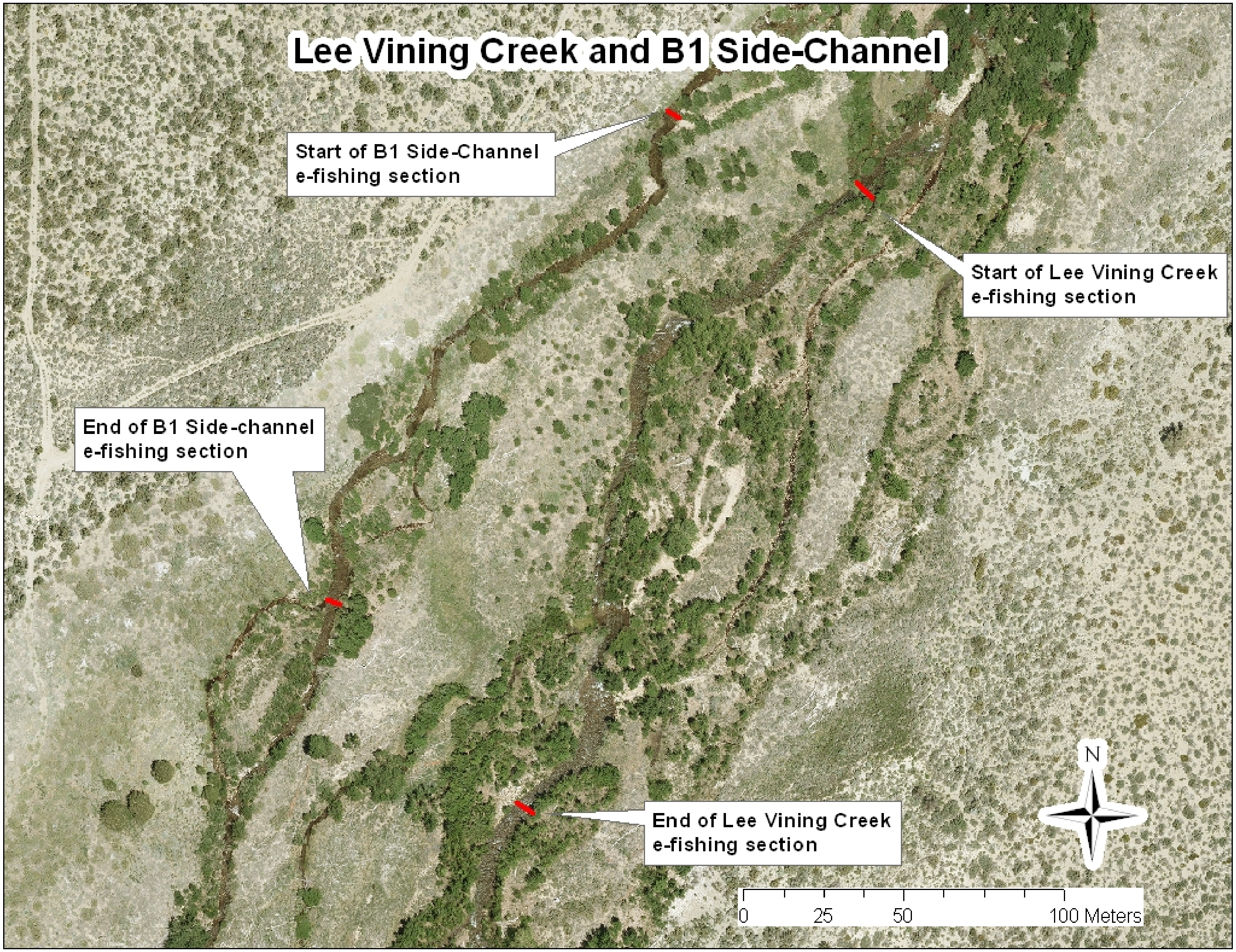
Appendix A: Aerial Photographs of Long-term Monitoring Sections


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


Walker Creek above old 395
Start of Walker Creek e-fishing section
End of Walker Creek e-fishing section
N
0
12.5
25
50 Meters

Appendix B: PIT Tag Recaptures from 2010 Sampling Season

RUSH CREEK - CO RD SECTION - GROWTH OF PIT TAGGED FISH BETWEEN 2009 AND 2010

Tag Number	2009 Length (mm)	2009 Weight (g)	2010 Length (mm)	2010 Weight (g)	Growth in Length (mm)	Growth in Weight (g)
931470	82	5	163	39	81	34
939478	83	5	140	25	57	20
939217	83	6	151	31	68	25
118520	84	6	153	37	69	31
943506	86	6	169	42	83	36
110095	89	6	145	28	56	22
932415	91	8	172	44	81	36
917695	91	7	164	44	73	37
114684	91	7	166	42	75	35
908605	92	8	166	45	74	37
933762	92	7	156	35	64	28
939986	92	8	164	42	72	34
940642	93	8	177	52	84	44
936299	93	9	160	39	67	30
110505	96	10	168	46	72	36
918063	97	8	157	35	60	27
110997	101	10	168	44	67	34
910924	102	10	195	71	93	61
109973	102	12	170	44	68	32
938535	103	11	208	84	105	73
					73	**36**
106769	134	22	208	79	74	57
931106	142	29	210	86	68	57
917329	152	34	202	88	50	54
933486	154	38	211	101	57	63
904480	161	39	211	86	50	47
938028	168	51	209	102	41	51
906504	168	51	229	113	61	62
100865	173	52	227	127	54	75
908804	174	55	210	94	36	39
					55	**56**

All Fish: Growth in Length: Range = 36-105 mm, Average = 68 mm

All Fish: Growth in Weight: Range = 20-75 g, Average = 42 g

Age-0 to Age-1 Growth in Length: Range = 56-105 mm, Average = 73 mm

Age-0 to Age-1 Growth in Weight: Range = 20-73 g, Average = 36 g

Age-1 to Age-2 Growth in Length: Range = 36-74 mm, Average = 55 mm

Age-1 to Age-2 Growth in Weight: Range = 39-75 g, Average = 56 g

Recapture Rate of Tagged Fish: 140 tagged in 2009 and 29 recaptured in 2010 = **20.7%**

RUSH CK - BOTTOMLAND SECTION - GROWTH OF PIT TAGGED FISH BETWEEN 2009 AND 2010

Tag Number	2009 Length (mm)	2009 Weight (g)	2010 Length (mm)	2010 Weight (g)	Growth in Length (mm)	Growth in Weight (g)
921945	80	5	148	31	68	26
114006	80	5	161	39	81	34
123570	82	6	155	35	73	29
935605	82	5	166	51	84	46
920952	83	6	146	30	63	24
936101	83	6	146	30	63	24
910138	85	6	155	37	70	31
118024	85	6	157	34	72	28
904493	85	6	168	47	83	41
942106	86	7	166	42	80	35
112302	86	7	167	45	81	38
932848	87	7	154	33	67	26
937007	88	7	161	44	73	37
920003	88	8	172	57	84	49
110423	90	8	160	39	70	31
933770	91	7	176	49	85	42
912832	91	7	157	38	66	31
111924	91	7	174	49	83	42
926589	95	8	178	50	83	42
932689	97	11	176	56	79	45
935592	97	10	180	53	83	43
924797	97	11	183	69	86	58
110490	98	9	178	50	80	41
121350	98	10	168	42	70	32
940699	99	9	167	42	68	33
925265	100	10	189	56	89	46
920914	101	12	169	45	68	33
119416	101	11	183	58	82	47
112154	102	11	186	64	84	53
944545	104	12	200	84	96	72
110827	105	12	186	65	81	53
924172	105	13	169	48	64	35
100993	105	12	180	54	75	42
925648	106	12	187	64	81	52
114060	106	13	174	48	68	35
114073	114	16	196	74	82	58
					77	**40**
943071	157	38	201	77	44	39
100755	161	42	209	90	48	48
103525	163	42	210	95	47	53
906224	163	40	221	99	58	59
908422	165	44	224	104	59	60
905245	165	47	212	103	47	56
921335	171	56	212	106	41	50

924548	176	53	238	120	62	67
904696	186	65	234	123	48	58
					50	**54**

All Fish: Growth in Length: Range = 41-96 mm, Average = 72 mm

All Fish: Growth in Weight: Range = 24-72 g, Average = 43 g

Age-0 to Age-1 Growth in Length: Range = 63-96 mm, Average = 77 mm

Age-0 to Age-1 Growth in Weight: Range = 24-72 g, Average = 40 g

Age-1 to Age-2 Growth in Length: Range = 41-62 mm, Average = 50 mm

Age-1 to Age-2 Growth in Weight: Range = 39-67 g, Average = 54 g

Recapture Rate of Tagged Fish: 232 tagged in 2009 and 45 recaptured in 2010 = **19.4%**

RUSH CREEK - UPPER SECTION - GROWTH OF PIT TAGGED FISH BETWEEN 2009 AND 2010

Tag Number	2009 Length (mm)	2009 Weight (g)	2010 Length (mm)	2010 Weight (g)	Growth in Length (mm)	Growth in Weight (g)
941792	83	6	151	32	68	26
935502	90	8	165	44	75	36
115182	91	8	174	51	83	43
113318	91	7	173	49	82	42
114282	91	7	175	52	84	45
936745	92	8	161	43	69	35
128509	96	10	175	53	79	43
939006	98	10	177	57	79	47
114049	99	10	182	61	83	51
117810	100	10	188	61	88	51
114149	100	11	189	67	89	56
913468	100	10	160	42	60	32
935610	102	12	190	69	88	57
109142	103	12	180	55	77	43
113231	107	12	209	84	102	72
110718	107	13	183	60	76	47
118914	107	13	189	69	82	56
932673	109	14	177	55	68	41
910463	110	15	195	76	85	61
910766	110	14	196	74	86	60
938134	112	14	184	57	72	43
933639	112	14	210	88	98	74
912366	112	15	179	62	67	47
					80	**48**
927961	168	45	239	139	71	94
941237	173	53	224	116	51	63
938419	183	64	235	128	52	64
					58	**74**
922419	284	220	307	277	23	57

All Fish: Growth in Length: Range = 23-102 mm, Average = 75 mm

All Fish: Growth in Weight: Range = 26-94 g, Average = 51 g

Age-0 to Age-1 Growth in Length: Range = 60-102 mm , Average = 80 mm

Age-0 to Age-1 Growth in Weight: Range = 26-74 g, Average = 48 g

Age-1 to Age-2 Growth in Length: Range = 51-71 mm, Average = 58 mm

Age-1 to Age-2 Growth in Weight: Range = 63-94 g, Average = 74 g

Recapture Rate of Tagged Fish: 301 tagged in 2009 and 27 recaptured in 2010 = **9%**

RUSH CREEK - MGORD SECTION - GROWTH OF PIT TAGGED FISH BETWEEN 2009 AND 2010

Tag Number	2009 Length (mm)	2009 Weight (g)	2010 Length (mm)	2010 Weight (g)	Growth in Length (mm)	Growth in Weight (g)	Comments
0113849	94	10	208	98	114	88	Tagged in Upper Rush
0940196	99	11	206	91	107	80	Tagged in Upper Rush
0929332	106	14	213	104	107	90	Tagged in Upper Rush
0938512	107	14	206	91	99	77	Tagged in Upper Rush
0943520	107	13	203	71	96	58	Tagged in Upper Rush
0100405	110	12	228	109	118	97	
0907528	122	22	231	125	109	103	
					107	**85**	
0921539	185	62	265	173	80	111	Tagged in Upper Rush
0936552	201	77	243	131	42	54	
0917971	201	83	256	148	55	65	
0905354	204	89	258	171	54	82	
0903370	207	91	266	167	59	76	
0098013	213	95	259	163	46	68	
0920349	214	104	275	191	61	87	
0101394	215	93	253	174	38	81	
0909295	217	104	280	214	63	110	
0903631	220	117	238	133	18	16	
0907600	221	104	280	222	59	118	
0918696	222	116	293	237	71	121	
0904177	223	109	278	218	55	109	
0923184	223	113	277	216	54	103	
7101281	226	127	256	181	30	54	
0922135	227	141	244	141	17	0	
0925533	228	108	277	211	49	103	
0098970	228	120	284	190	56	70	
7018633	237	147	286	220	49	73	
7025957	238	146	271	205	33	59	
7022723	238	139	285	238	47	99	
0920582	240	123	334	332	94	209	
7020136	240	127	271	195	31	68	
7024289	246	162	281	204	35	42	
7030661	247	140	266	168	19	28	
7022273	248	153	295	239	47	86	
7020458	251	153	295	233	44	80	
7018125	253	186	274	223	21	37	
7031354	257	169	289	237	32	68	
7027325	257	182	307	303	50	121	
7033595	259	190	279	218	20	28	
0105263	260	183	291	252	31	69	
7017896	262	198	288	261	26	63	
0922329	262	174	276	202	14	28	
7027024	266	195	280	232	14	37	

7029311	275	221	326	360	51	139	
7021482	276	246	293	255	17	9	
7031631	277	238	316	313	39	75	
7034074	282	218	313	255	31	37	
7023924	282	219	306	265	24	46	
7033593	283	229	302	254	19	25	
7030963	284	241	298	232	14	-9	
7028807	286	263	294	239	8	-24	
7017901	287	257	298	239	11	-18	
7029606	287	241	312	277	25	36	
7020439	292	253	310	244	18	-9	
7029289	292	228	325	318	33	90	
7022012	293	266	320	304	27	38	
0934293	294	226	354	422	60	196	
7025643	296	252	334	352	38	100	
7031436	296	266	319	347	23	81	
7031045	302	301	310	276	8	-25	
0925059	303	238	338	331	35	93	
7026970	311	294	348	379	37	85	
7029175	312	305	318	247	6	-58	
7024094	313	350	319	257	6	-93	
7031683	313	285	393	632	80	347	
7032768	313	351	327	316	14	-35	
7033190	317	330	318	296	1	-34	
7017161	318	313	313	267	-5	-46	
7029566	321	311	356	386	35	75	
7024168	326	328	331	291	5	-37	
7022992	326	355	340	373	14	18	
7029853	328	403	348	420	20	17	
7025228	338	357	340	313	2	-44	
0105641	338	364	364	419	26	55	
7033259	342	389	352	423	10	34	
7021391	358	463	388	540	30	77	
7030978	403	642	412	703	9	61	
7031332	435	763	434	695	-1	-68	
4371200	438	814	418	686	-20	-128	
7019380	462	1056	464	805	2	-251	

All Fish: Growth in Length: Range = -20-118 mm, Average = 38 mm

All Fish: Growth in Weight: Range = -251-209 g, Average = 52 g

Age-0 to Age-1 Growth in Length: Range = 96-118 mm , Average = 107 mm

Age-0 to Age-1 Growth in Weight: Range = 58-103 g, Average = 85 g

Recapture Rate of Tagged Fish: 696 tagged in 2009 and 79 recaptured in 2010 = **11.4%**

WALKER CREEK - GROWTH OF PIT TAGGED FISH BETWEEN 2009 AND 2010

Tag Number	2009 Length (mm)	2009 Weight (g)	2010 Length (mm)	2010 Weight (g)	Growth in Length (mm)	Growth in Weight (g)
944309	81	5	139	29	58	24
100436	82	8	125	18	43	10
107405	85	6	144	31	59	25
111159	86	7	146	33	60	26
929632	89	8	140	28	51	20
117459	90	8	145	33	55	25
925388	90	7	148	29	58	22
934081	90	9	126	19	36	10
905768	95	9	138	28	43	19
					51	**20**
940051	128	18	156	33	28	15
908415	130	22	160	44	30	22
109579	130	22	163	46	33	24
939403	136	26	174	50	38	24
914927	139	29	169	48	30	19
105197	144	30	174	52	30	22
919053	145	28	178	57	33	29
926127	146	29	183	64	37	35
103130	151	36	181	59	30	23
905968	151	39	179	60	28	21
110816	152	38	184	68	32	30
112608	153	36	176	62	23	26
904160	154	35	189	69	35	34
936228	156	38	193	74	37	36
904753	163	43	196	82	33	39
935465	164	49	183	58	19	9
932018	232	115	228	97	-4	-18

All Fish: Growth in Length: Range = -4-60 mm, Average = 37 mm

All Fish: Growth in Weight: Range = -18-39 g, Average = 22 g

Age-0 to Age-1 Growth in Length: Range = 35-60 mm , Average = 51 mm

Age-0 to Age-1 Growth in Weight: Range = 10-26 g, Average = 20 g

Recapture Rate of Tagged Fish: 169 tagged in 2009 and 26 recaptured in 2010 = **15.4%**

LEE VINING CREEK - GROWTH OF PIT TAGGED FISH BETWEEN 2009 AND 2010

Tag Number	2009 Length (mm)	2009 Weight (g)	2010 Length (mm)	2010 Weight (g)	Growth in Length (mm)	Growth in Weight (g)	Comments
943434	75	5	182	67	107	62	Rainbow trout
926612	85	6	165	48	80	42	
					94	**52**	
925996	164	44	222	110	58	66	
96917	168	52	235	145	67	93	
920076	169	50	229	136	60	86	
109582	174	54	249	148	75	94	
943740	177	54	243	153	66	99	
927890	182	57	249	172	67	115	
119523	186	67	254	180	68	113	
					66	**95**	

All Fish: Growth in Length: Range = 58-107 mm, Average = 72 mm

All Fish: Growth in Weight: Range = 42-115 g, Average = 86 g

Age-0 to Age-1 Growth in Length: Range = 80-107 mm , Average = 94 mm

Age-0 to Age-1 Growth in Weight: Range = 42-62 g, Average = 52 g

Age-1 to Age-2 Growth in Length: Range = 58-75 mm, Average = 66 mm

Age-1 to Age-2 Growth in Weight: Range = 66-115 g, Average = 95 g

Recapture Rate of Tagged Fish: 68 tagged in 2009 and 10 recaptured in 2010 = **14.7%**

Appendix C: Ice Monitoring Report for the Winter of 2010-2011

Mono Basin Ice Survey 2010-2011

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Of

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March 22, 2011

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. Based on the 2009-10 ice survey (Taylor et al. 2010), two of the five sections in Lee Vining Creek were surveyed again in the winter of 2010-11. A new section was added in Rush Creek in the winter of 2010-11. Both streams are located in the Eastern Sierra of California and are highly regulated 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, 2) spatial and temporal extent of subsurface ice formations, and 3) potential of extensive ice formations in historical and regional contexts. The survey found very dynamic ice forming and breakup processes in a very short time scale such that anchor ice formed and dislodged in the morning or afternoon of the same day, and surface and subsurface ice covers did not persist through out the winter. Spatially extensive occurrence of anchor ice and ice dam did not occur during every freeze-up event in Lee Vining Creek. Reduction in pool space by frazil slush ice accumulation was observed in pools along Rush Creek during freeze-up periods. A 20 year trend at Cain Ranch showed less fluctuation and less severe winters in the first decade of the twenty first century than in the last decade of the twentieth century. Subsurface ice formations which could adversely affect fish were found during two winters (2009-10 and 2010-11) in the Mono Basin, but their occurrence has been highly episodic and very short lived.

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 relationships between a range of test flows and habitat availability of holding habitats in order to find what flow would provide increased numbers and total area 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, and on Rush Creek in August, 2008, with test flows ranging from 15 to 90 (Taylor et al. 2009). The lowest test flow of 12 cfs was found to provide the largest total area of winter holding habitat for Lee Vining Creek while the second lowest flow of 30cfs was found to provide the largest total area of winter holding habitat for Rush Creek. The flow variance from Order WR 98-05 for winter baseflows has been slightly higher than those identified to maximum area of winter holding habitat to compensate for estimated flow losses. However, a concern was raised on possible exacerbation of stream ice formations with lower winter baseflows because Lee Vining Creek has geomorphic 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 2001b, Bradford and

Heinonen 2008). These geomorphic characteristics also exist along Rush Creek between US Hwy 395 and the Parker Creek confluence, where the largest flow loss per reach of 9 to 27% have been observed between the MGORD and County Road. The Synthesis Report specified the ice survey to be conducted for at least two winters. The first ice survey was conducted in Lee Vining during the winter of 2009-10 with the winter baseflows of 18 cfs (November 30 and January 1) and 14 cfs (between January 2 and March 31); however, the winter baseflow had been lowered in the previous two winters (2008-09 and 2009-10) for Rush Creek without any ice survey being conducted.

Lower flows during winter will result in larger areas of winter holding habitat for both Lee Vining and Rush creeks, but lower flows can also adversely affect trout population directly and indirectly. Frazil ice forms when the water becomes super-cooled (<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 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).

In Lee Vining Creek, lower flows (<40cfs) were shown to reduce subsurface ice cover (CDFG 1993), yet during freeze-up periods in the winter 2009-10 extensive subsurface ice cover (>65%) was found. However, ice forming and breakup in Lee Vining Creek was highly episodic and dynamic which appeared to be driven mainly by freeze-up. Unlike other colder regions, ice formations in Lee Vining Creek did not remain intact through out the winter of 2009-10 except in Section C where the same extent of shelf ice (approximately 55%) remained throughout the winter. Weekly visits and air temperature parameters revealed that extensive surface and subsurface ice covers did not last longer than five days. Previous studies in Lee Vining Creek also documented this high episodicity even with much higher winter flows (CDFG 1993). It is important to quantify more precisely how long ice cover would last and to observe subsurface ice formations in more extended area along with the method adopted last winter to record ice extent across transects. A strong relationship between air and water temperatures during winter was found in Convict Creek in the Eastern Sierra (Jenkins et al. 1991); however, the air temperature regime of Lee Vining and Rush creeks is influenced by lake fog over Mono Lake, which would potentially complicate relationships between air temperature and ice formations. Therefore, it is also important to take into account interactions of environmental variables that include air and water temperatures, precipitation, and lake fog.

The main purpose of this study was to continue recording ice formations for two sections in Lee Vining Creek and to record ice formations for a section of Rush Creek where flows were found lowest below Grant Lake Reservoir. The second objective was to more precisely determine occurrence and duration of subsurface ice formation and relate them to climatic factors, including the lake fog effect. The third objective was to investigate spatial extent of subsurface ice formation in the Lee Vining Creek Delta. The fourth objective was to investigate potential of extensive ice formations by analyzing historical climate record and severity of such events comparing to the lower 48 states. These objectives should clarify relationships among lower winter baseflows, ice formations, and fish populations, and provide the Stream Scientists with the missing data they need to make a final recommendation on the winter baseflows for Lee Vining and Rush creeks.

Methods

<u>*Study site*</u>

Rush and Lee Vining creeks are two major tributaries to Mono Lake located in the eastern side of Sierra Nevada Mountains with the drainage area of 141 mi^2 (365 km^2) and 47 mi^2 (122 km^2), respectively. Both creeks originate from the Ansel Adams Wilderness Area, with the average annual runoff between 1941 and 2008 of 59,262 ac-ft and 47,878 ac-ft, respectively (Figure 1). Rush and Lee Vining creeks are highly regulated by several high elevation reservoirs operated by Southern California Edison (SCE), and flows are diverted at Grant Lake Reservoir and Lee Vining Intake Facility (UTM 4200660, 312500) for Rush and Lee Vining creeks, respectively. Water is released from the bottom of Grant Lake Reservoir through Mono Gate One, and the flow is routed through an artificial channel, the Mono Gate One Return Ditch (MGORD), before returning to the original Rush Creek channel. Rush Creek flow downstream of Hwy 395 is augmented by two tributaries, Parker and Walker creeks. Flow into Lee Vining Creek below Intake is controlled by the Langemann Gate, and there is no tributary entering Lee Vining Creek except minor contribution by O Ditch Return above State Highway 120 Bridge.

During the winter of 2009-10 the ice survey on Lee Vining Creek was conducted in five sections between Intake and Mono Lake, and two sections (sections D and F, Figures 2-a through d, see Fisheries Monitoring Report 2009 Appendix C by Taylor et al. 2010) were selected for continuous monitoring in 2010-11. Sections D and F were identified as the critical areas to further understand effects of extensive subsurface ice formations on fish winter holding habitat in Lee Vining Creek below Intake because the most extensive subsurface ice formations were found in Section D and the largest water temperature fluctuation was found in Section E.

The study section in Rush Creek is located below US Hwy 395; the riffle transect located approximately 100m above Parker Confluence (UTM 4197200, 316880, Figure 2-e, and the pool transect located across P5-8 (the third Class 5 pool below the Rush/Walker confluence, UTM 4198541, 317809, Figure 2-f) (Figure 1, see Knudson et al. 2009 for descriptions of high quality pools). Both transects were initially planned to be set up between US Hwy 395 and Parker Confluence, which was identified as the largest losing reach based on the on-going synoptic flow measurement conducted by

LADWP. By the time Rush Creek reaches Parker Confluence, Rush Creek loses about 5 cfs under the proposed winter baseflow of 27 cfs coming out of MGORD. Rush Creek's flow then gets augmented by Parker and Walker creeks. However, a pool transect was moved out of the section because one of the locations for the monthly synoptic flow measurement was located a very short distance downstream from P4-5 (the only high quality pool between US Hwy395 and Parker Confluence), and ice has been broken during winter measurements. The next high quality pool downstream from the Parker Creek Confluence was located below the Narrows just downstream of the Walker Creek confluence (P4-6 and P4-7); however, the concern was raised to use those pools because of flow augmentation by Walker Creek immediately upstream of those pools. In order to avoid potential impacts from occasional ice breakages by the synoptic stream flow measurement, and also to minimize immediate impacts of flow augmentation by Walker Creek, a pool transect was moved to P5-8. Ice cove extent in P4-5 was, however, recorded by stretching a measuring tape during freeze-up events between two marked points.

Figure 1. A map of Mono Basin Ice Survey sites.

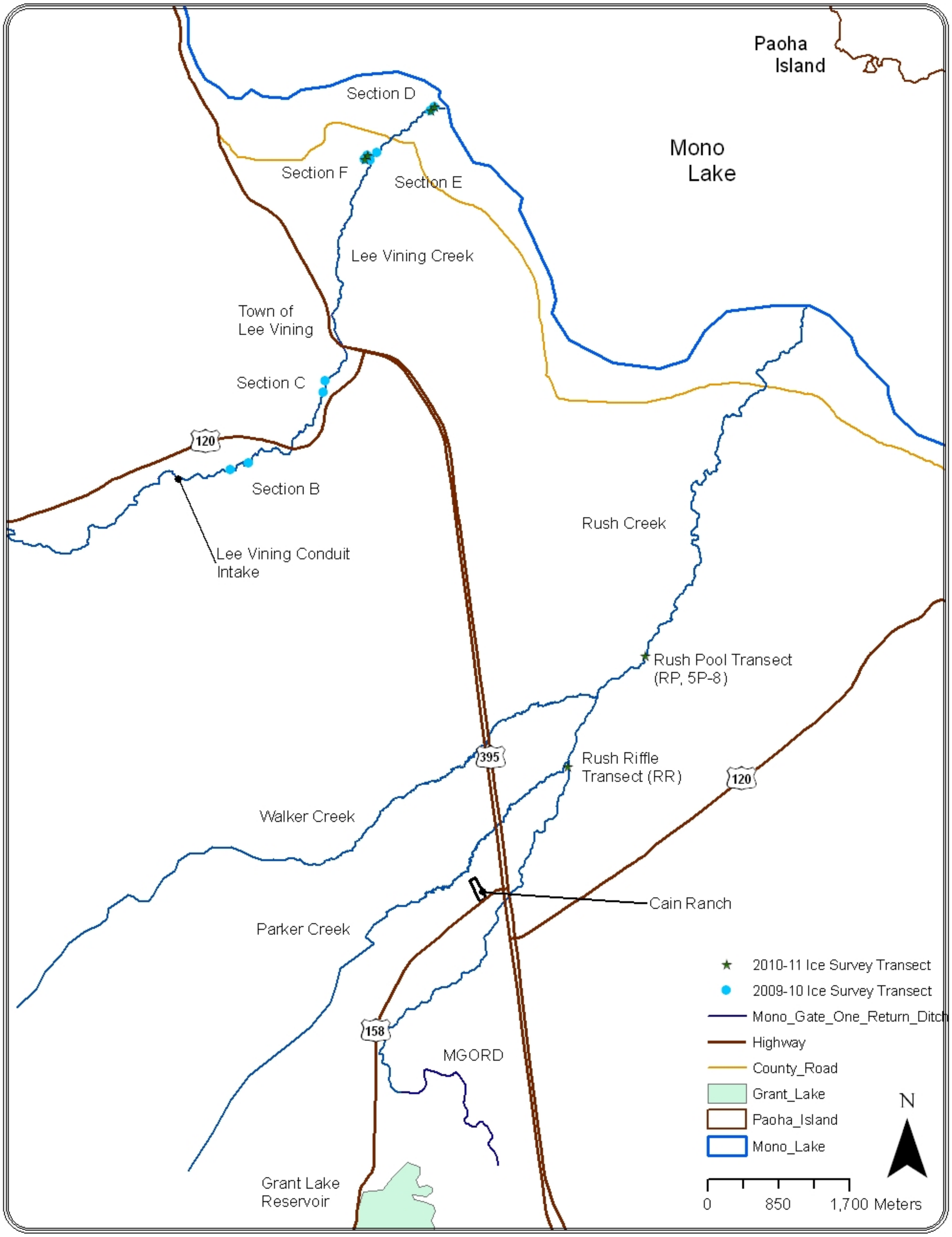


Figure 2. Baseline pictures of the study transects: a) LV Section D pool (Tran DP), b) LV Section D riffle (Tran DR), c) LV Section F (Tran FP), d) LV Section F riffle (Tran FR), e) Rush
Pool Transect (Tran RP), and f) Rush Riffle Transect (Tran RR).

2-a) LV Section D pool (Tran DP)

2-b) LV Section D riffle (Tran DR)

2-c) LV Section F glide (Tran FP)

2-d) Section F riffle (Tran FR)

2-e) Rush Pool Transect (Tran RP)

2-f) Rush Riffle Transect (Tran RR)

Ice survey

Two transects were established in each section with two T-posts being placed on opposing stream banks. One crossed fast moving water (riffle) and the other crossed slower moving water (pool or glide) (Figures 2 a through f, Table 1). Channel cross section, depth and velocity profiles were measured after the winter baseflows of 20 cfs for Lee Vining below Intake release and 30 cfs for Rush Creek at Mono Gate One. These winter baseflows were established on November 15, 2010, prior to any ice forming event.

Ice cover along each transect (when present) was classified into surface, shelf, and anchor ice (CDFG 1993) and overhanging snow, and extent of each ice type was measured to the nearest 1/10 foot during weekly survey. Surface and shelf ice were later combined into surface cover because distinguishing between these two ice types was not crucial in terms of fish cover and was greatly influenced by timing of visit. Total lengths of each ice type were converted to percent cover based on the measured wetted widths for the winter baseflow of 20 and 30 cfs. Only ice that was observed within the wetted edges was included. 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.

Table 1. Baseline hydraulic characteristics of each transect at the winter baseflow (20 cfs release for Lee Vining Creek and 30 cfs release for Rush Creek).

Section	Transect	Average depth (ft)	Average velocity (ft/sec)	Wetted width (ft)
D (Delta Section)	DP (pool)	1.98	0.25	17.5
	DR (riffle)	0.36	1.87	31.9
F (B1 channel electro - fishing section)	FP (pool/glide)	0.18	0.40	8.80
	FR (riffle)	0.14	0.73	15.4
Rush Pool	P5-8 (pool)	2.07	0.86	21.5
Rush Riffle	RR (riffle)	0.91	1.78	16.4

A time-lapse camera (BirdCam 2.0, WINGSCAPES) was placed on November 18, downstream of Tran_DR looking upstream toward that transect in Section D of Lee Vining Creek. The objective was to capture the occurrence and duration of anchor ice and ice dam in the Tran_DR area of Lee Vining Creek. During the 2009-10 ice survey, the water temperature was found consistently lowest at Section D and most extensive subsurface ice accumulation was observed across Tran_DR. The camera was set up to take a picture every hour. Pictures were then analyzed for presence/absence and duration of subsurface and surface ice covers. Subsurface ice formations (anchor ice and ice dam formations) were surveyed between County Ford and Section D (approximately 0.5 miles/800m) during freeze-up periods in order to observe spatial extent of subsurface ice formations in the Lee Vining Creek Delta. Locations of extensive anchor ice and ice dam formations were marked by a handheld GPS unit (Garmin eTrex Legend H), and pictures were taken from a photo point which was marked by flagging.

Environmental variables

Water temperatures were recorded every fifteen minutes by water temperature loggers (HOBO Water Temp Pro v2, Onset, ±0.2°C (±0.4°F), and Hobo Temperature/Alarm Pendant Data Logger UA-001-64, ±0.5°C/±0.9°F) in the Rush Creek section and five sections in Lee Vining Creek (Figure 3). One additional logger was placed above Section E of Lee Vining Creek, where groundwater recharge was suspected to create a thermal plume above the County Ford. There were five long-term temperature monitoring sites in Rush Creek and two in Lee Vining Creek. Data from these sites were also used to evaluate spatial variability of water temperature for each creek. A less accurate water temperature logger (Hobo Temperature/Alarm Pendant Data Logger UA-001-64, ±0.5°C) was placed to record water temperature at fifteen minute interval in Rush Pool section (P5-8). Daily maximum, minimum, and average water temperatures were calculated.

Meteorological data (daily maximum and minimum air temperatures (θ and ψ respectively), and precipitation) were obtained from LADWP weather stations in Cain Ranch (UTM 4195790, 315762). Data from Paoha Island in Mono Lake were not available for this report due to adverse weather conditions in February, which prevented data collection. Air temperature data recorded in the town of Lee Vining by Mono Lake Committee were also obtained from Mono Lake Committee website[*] from November 1, 2010 to February 28, 2011. Air temperature was measured by a temperature pendant logger in Section D of Lee Vining Creek and the Parker Creek Confluence with Rush Creek because large differences in maximum and minimum temperature readings were found between Cain Ranch and Paoha Island during the previous winter. Net Accumulated Freezing Degree Day (netAFDD) was calculated for each air temperature reading location (Cain Ranch, Lee Vining Section D, and Rush Parker Confluence) by using daily mean air temperatures. NetAFDD is often used to estimate thickness of ice (USACE 1994, Hirayama et al. 2002), and can be compared inter-annually and across different regions. Daily mean air temperature was calculated by taking an average of daily maximum and minimum temperatures because a true daily mean (average of all

[*] http://www.monobasinresearch.org/data/weather.htm

readings of the day) was not available for Cain Ranch. Freezing degree days were calculated by subtracting daily mean air temperatures from 32°F. NetAFDD was, then, obtained by summing freezing degree days such that the maximum value was obtained for each year (USACE 1994). NetAFDD values were compared among different stations for the winter of 2010-11. For Cain Ranch, historical netAFDD was also calculated since 1991 in order to detect any historical trend of netAFDD.

Daily discharge of Lee Vining and Rush creeks at study sections were adjusted according to the flow loss regression developed from the synoptic measurements (Table 2). The synoptic flow measurements since the winter of 2009 have made it possible to quantify the relationship between flow releases and flows at different reaches of the creeks. Simple linear regression equations were developed for flows at Lee Vining Creek County Road and Rush Creek above Parker Creek Confluence based on Lee Vining Creek at Intake (5009) and MGORD (5007) for Lee Vining and Rush creeks, respectively. Flows from Parker Creek above Conduit (5017) and Walker Creek above Conduit (5016) were added to flows estimated at Rush Creek above Parker Creek Confluence in order to estimate flows for Rush Creek below the Narrows (Table 2).

Figure 3. A map of water and air temperature sites for the winter of 2010-11.

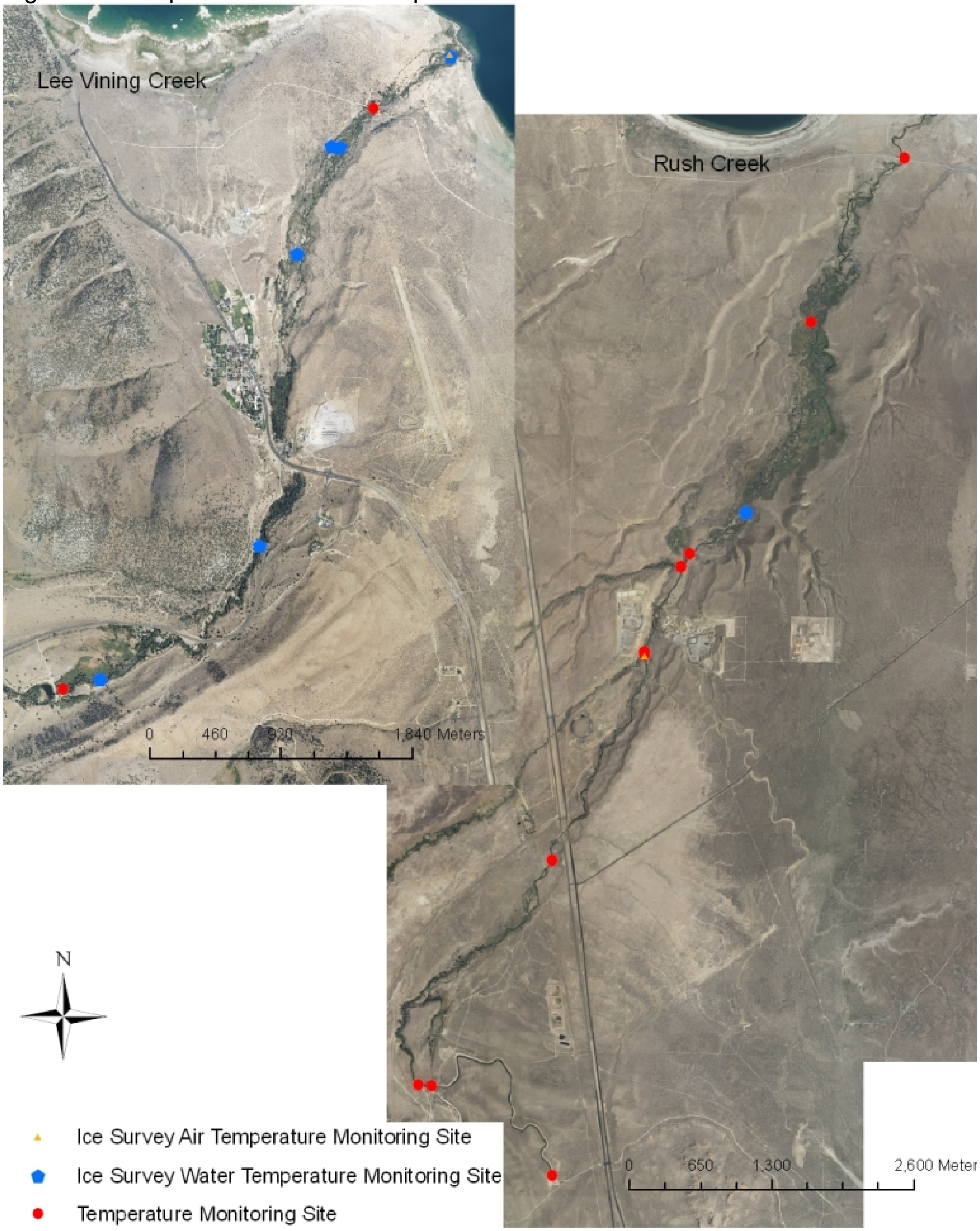


Table 2. Simple linear equations for Lee Vining Creek between Lee Vining at Intake (5009) and Lee Vining County Road, and between MGORD (5007) and Rush Creek above Parker Creek Confluence. For Lee Vining Creek, only flows under 50 cfs were used to develop the equation because the overall relationship is non-linear. For Rush Creek, all flows between November, 2009, and February, 2011, were used.

Creek	Location	Simple linear regression equation	Independent variable
Lee Vining	County Road	$y = 0.753x + 0.915$ $r^2 = 0.99$	Lee Vining at Conduit (5009)
Rush	Parker Confluence	$y = 0.925x - 2.675$ $r^2 = 0.96$	MGORD (5007)
	Narrows	Sum of Parker Creek Confluence, Parker Creek above Conduit (5017), and Walker Creek above Conduit (5016)	

Results

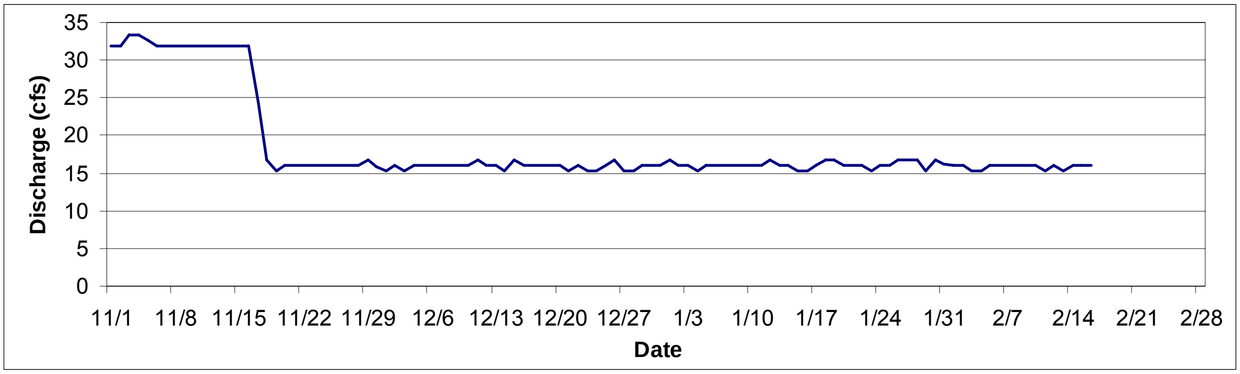
Winter Baseflow

The petition for temporal flow variation in RY2010 was approved by SWRCB on November 5, 2010, and the flows below Lee Vining Conduit (through the Langemann gate) and from Mono Gate One for Rush Creek were reduced to 20 cfs on November 18 and 30 cfs on November 18, respectively (Figure 4). The winter base flows were slightly higher in the winter of 2010-11 than the winter of 2009-10 (18 cfs vs. 14 to 16 cfs for Lee Vining and 30 cfs vs. 30 to 34 cfs for MGORD), and stable through out the winter*. The combined flow of Parker and Walker creeks started to increase on December 18 and again on December 31. The second peak exceeded 20 cfs for two days with Parker Creek peaking at 15.4 cfs on January 1. These peaks resulted in the estimated flow below the Narrows over 44 cfs for four days.

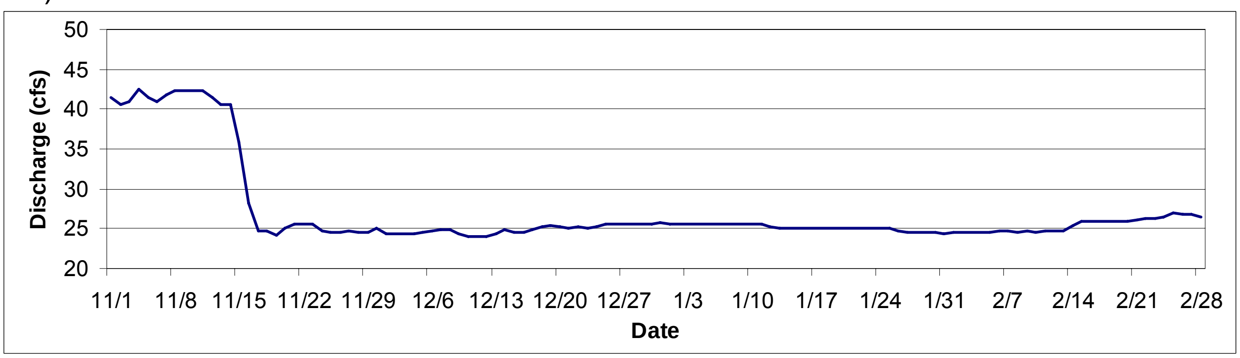
* Finalized flow data were available up to February 16 for Lee Vining Creek at Intake (5009), February 28 for MGORD (5007), February 20 for Parker Creek above Conduit (5017), and February 1 for Walker Creek above Conduit (5016).

Figure 4. Daily average discharge between November 1, 2010, and February 28, 2011, at a) Lee Vining Creek at County Road, b) Rush Creek above Parker Confluence, and c) Rush Creek below the Narrows. Finalized daily flow data were available only up to February 16 for Lee Vining Creek at Intake (5009) and February 1 for Walker Creek above Conduit (5016).

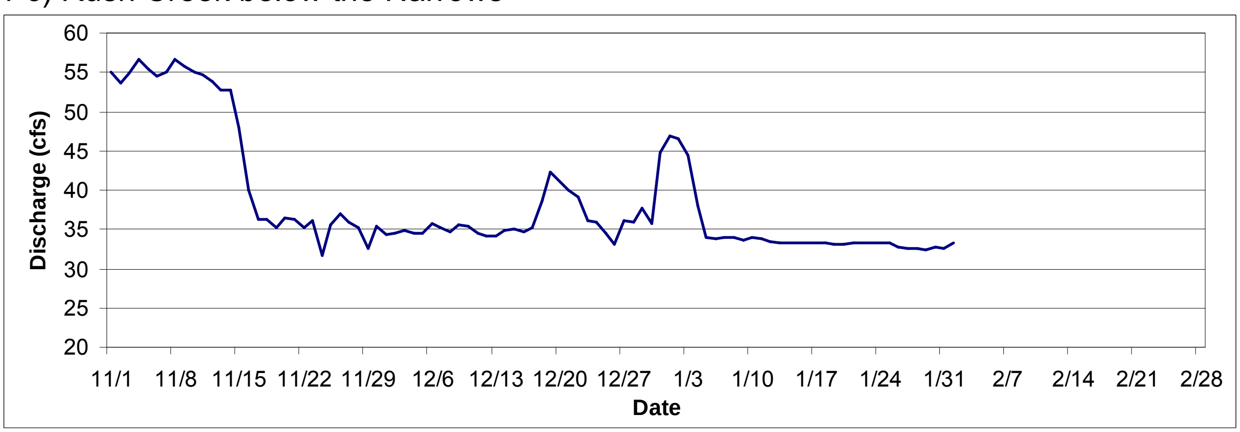
4-a) Lee Vining Creek



4-b) Rush Creek above Parker Confluence



4-c) Rush Creek below the Narrows*



* Rush Creek below the Narrows was calculated only up to February 1 because finalized flow data for Walker Creek above Conduit was available only up to February 1 even though finalized flow data for MGORD (5007) and Parker Creek above Conduit (5017) were available up to February 28 and February 20, respectively.

Meteorological Data – Air Temperature

During the winter of 2010-2011, three main freeze-up* periods were observed; 1) at the end of November, 2) the beginning of January, and 3) the end of February (Figure 5, Table 3). The first freeze-up created an isolated peak of AFDD which increased between 75 and 100 AFDD in ten days, but dropped to zero before the second freeze-up period began. The second freeze-up event was most severe during the winter of 2010-11 with AFDD reaching 168 at Rush above Parker, 209 at Cain Ranch, 214 at the town of Lee Vining (Lee Vining) approximately in 25 day period. Maximum daily air temperatures (θ) dropped below 32°F for 15 days at Lee Vining but mere two days at Cain Ranch and Rush Creek above Parker Creek (Figure 5). Daily maximum air temperatures (θ) dropped below 32°F for three nonconsecutive days at Lee Vining between the second and third freeze-up periods. The third freeze-up period began on February 16, but the magnitude of AFDD increase was much smaller than the second freeze-up. Except for Lee Vining, θ remained above 32°F during the third freeze-up and the rest of the winter.

Daily maximum temperatures (θ) dropped below 32°F only for seven and two days throughout this winter at Cain Ranch and Rush Creek above Parker Creek respectively, and only one occasion the temperature remained below 32°F for more than one day at both locations (Table 3). Daily maximum temperatures (θ) below 32°F were recorded for 22 days at Lee Vining, and during the second freeze-up θ remained below 32°F for ten days.

A number of freeze-up periods and average temperatures (daily mean (μ), maximum (θ), and minimum (ψ) at Cain Ranch and Lee Vining between this winter and the previous winter's were very similar, but values of netAFDDs were much higher during the previous winter than this winter (400 vs. 281 and 450 vs. 360† for Cain Ranch and Lee Vining, respectively) (Table 3). Onset of the continuous days of FDD accumulations was much later in this winter (December 16 vs. November 19 during the previous winter). AFDD graph reveals that netAFDD would have been very similar if the thaw between the first freeze up and the onset of the second freeze up had not occurred in the winter of 2010-11 (Figure 6). Duration of the mid-winter plateau was much longer during this winter, and AFDD decreased and remained around 175 at Cain Ranch and 215 at Lee Vining for almost a month after hitting the local maximum on January 15. Field observations from both winters and time lapse photos from 2010-11 confirm that a thaw period with a slight decrease in AFDD or flattening AFDD results in the reduction or disappearance of river ice. Unlike colder regions where ice remains in the river after the onset of freeze-up, Rush and Lee Vining creeks experience complete ice melt between rapid FDD accumulating periods (freeze-up).

* Freeze up in this study refers as a prolonged period in the winter between an on set of positive FDD accumulation and negative or no FDD accumulation.

† Daily temperature statistics were only available up to February 28 from Mono Lake Committee website. Thus, the maximum netAFDD on February 28 was presented in this report.

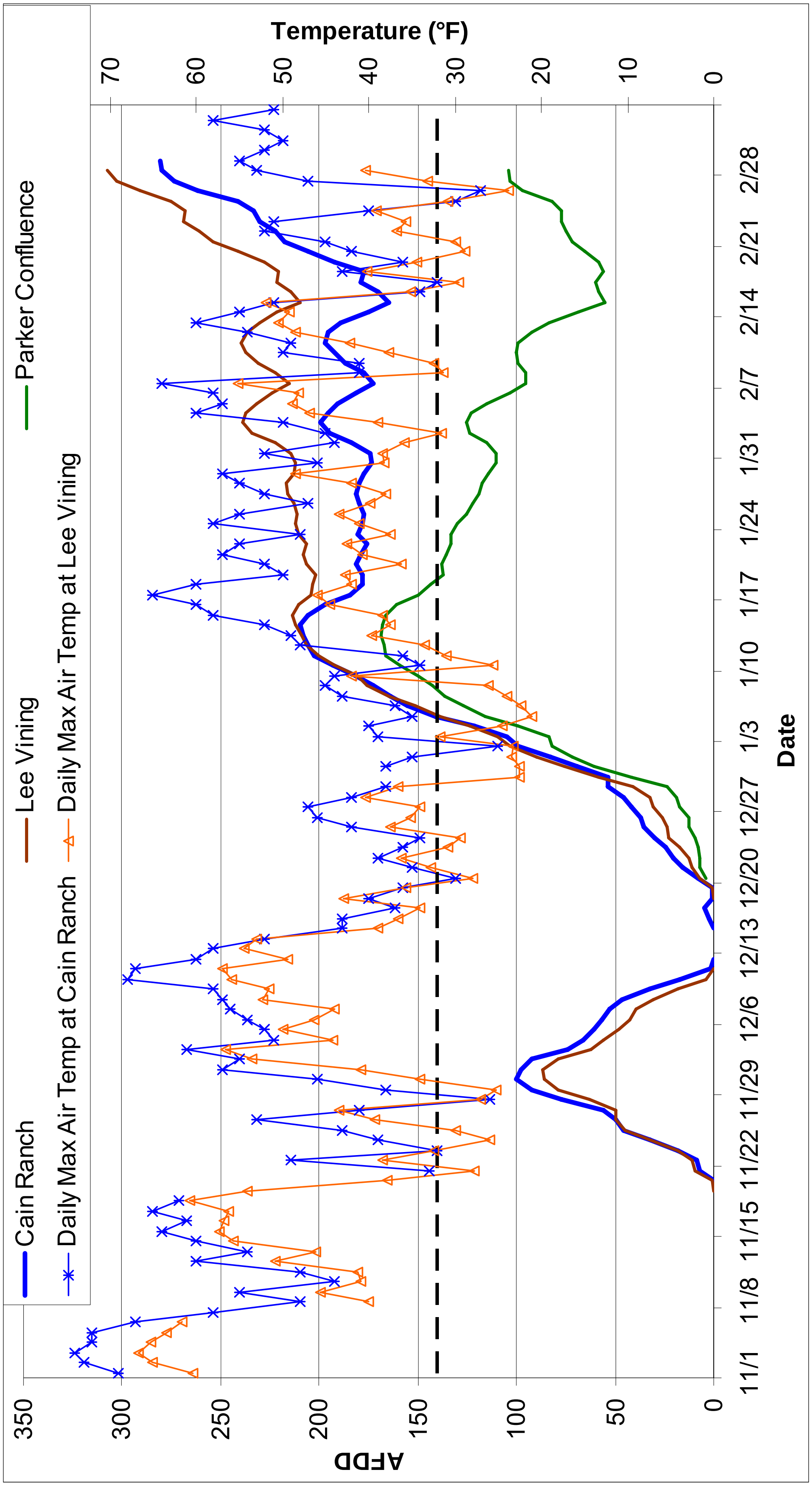


Figure 5. AFDD (accumulated freezing degree day) and daily maximum air temperature recorded at Cain Ranch, Lee Vining, and Rush above Parker Confluence. Lee Vining refers to temperature recordings by Mono Lake Committee in the town of Lee Vining. Missing data: November 19 and 20 and December 30 for Cain Ranch, November 7 for Lee Vining.

Table 3. Air temperature statistics and netAFDD at different stations for the winters of 2009-10 and 2010-11. The symbol θ indicates daily maximum air temperature, μ indicates daily mean air temperature, and ψ indicates minimum air temperature in Fahrenheit. Mean daily air temperatures were calculated with temperature readings between November 19 and February 28.

2009-10			
Station	Cain Ranch	Paoha Island	Lee Vining
netAFDD	400	170	378
Date of maximum AFDD	2/10/2010	1/25/2010	3/14/2010
A number of days with θ<32°F	7	16	24
Mean θ (°F)	29	32	29
Mean μ (°F)	47	40	37
Mean ψ (°F)	11	23	21

2010-11					
Station	Cain Ranch	Paoha Island*	Lee Vining**	Section D	Parker Confluence
netAFDD	281	na	308	42	168
Date of maximum AFDD	3/1/2011	na	na§	1/7/2011	1/13/2011
A number of days with θ<32°F	7	na	22	1	2
Mean θ (°F)	29	na	30	38	32
Mean μ (°F)	47	na	38	58	49
Mean ψ (°F)	12	na	21	17	15

* Temperature data from Paoha Island were not available at the time of report writing.
** Temperature data are only available up to February 28, 2011.
§ Date of maximum AFDD for Lee Vining most likely had occurred on March 1, the same day as Cain Ranch.

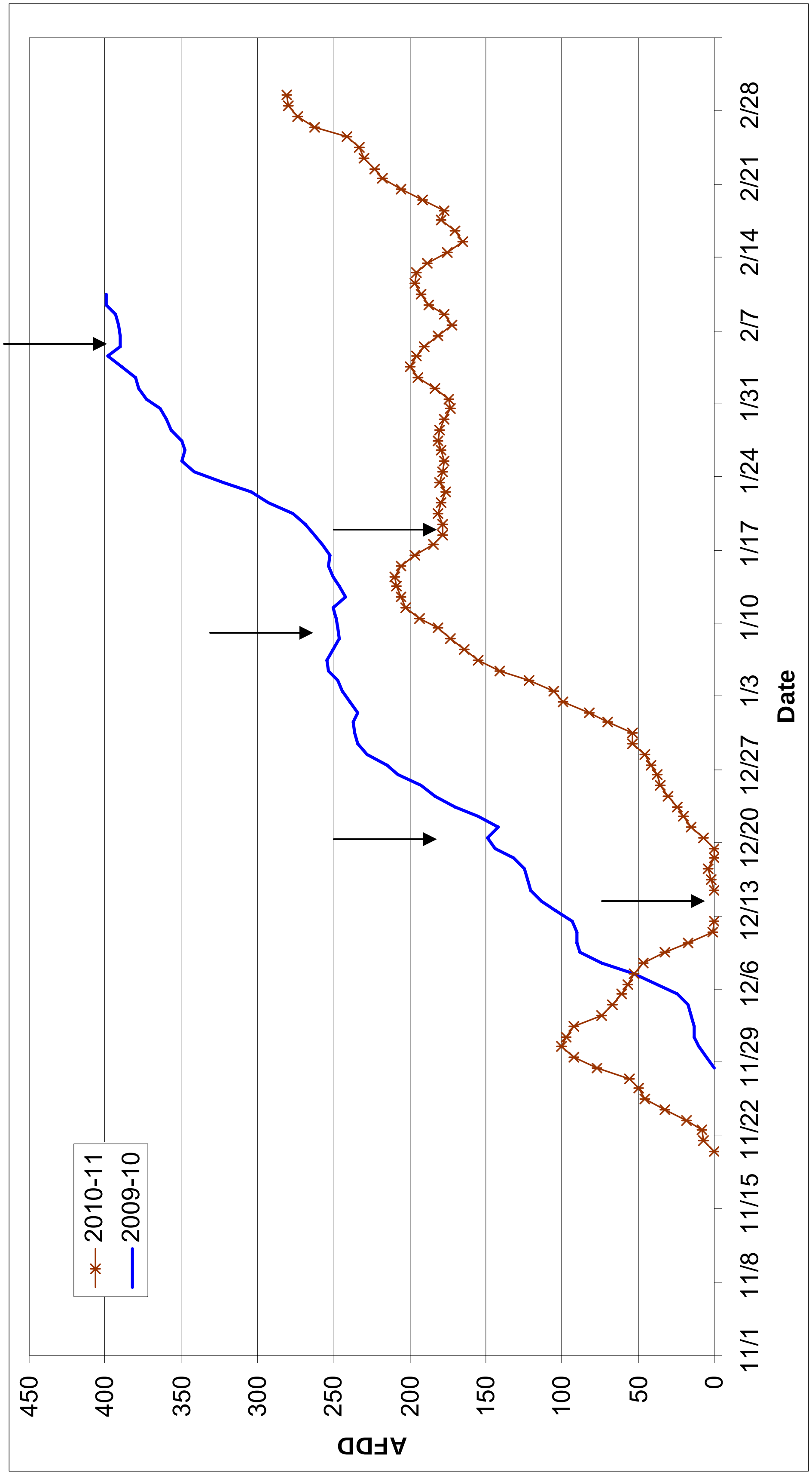
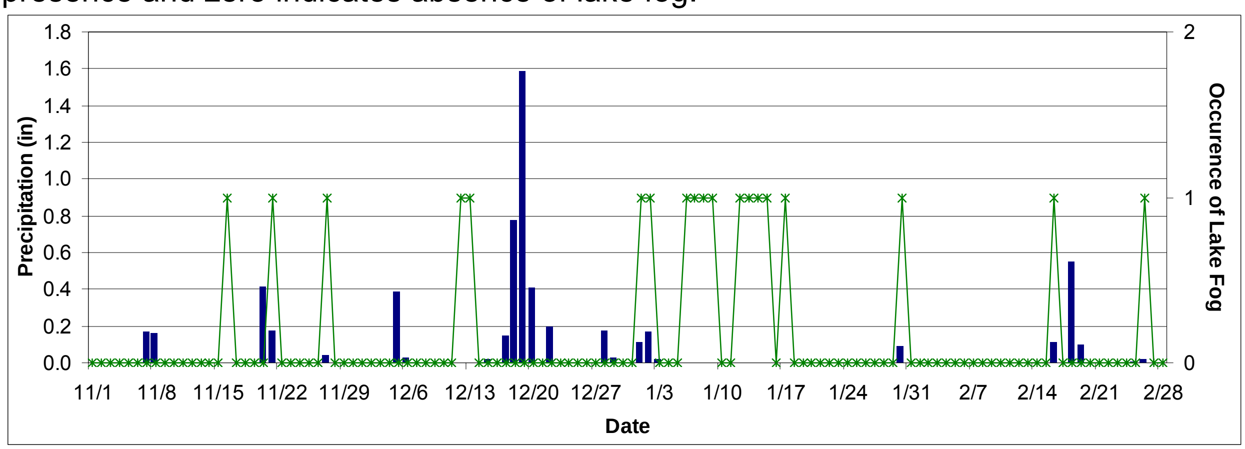


Figure 6. Comparison of AFDD at Cain Ranch between winters of 2009-10 and 2010-11. Down pointing arrows indicate reduction or disappearance of ice cover.

Comparisons of temperature readings among different stations for 2010-11 showed that similar readings were observed between Cain Ranch and Parker Creek Confluence, while the largest discrepancies were found between Cain Ranch and Section D (Table 3). Mean temperatures between Cain Ranch and Lee Vining were similar; however, θ and ψ were almost 8°F higher and lower respectively for Cain Ranch, indicating more stable daily temperature regimes in Lee Vining. The same trend was observed for Lee Vining and Paoha Island during the previous winter. However, temperature readings from Section D do not conform to this trend since Section D consistently showed higher daily mean air temperature (μ) and larger daily temperature fluctuations. Because of similarity between Paoha Island and Lee Vining in the winter of 2009-10 and also similarity of Lee Vining readings between 2009-10 and 2010-11, the temperature regime observed at Section D may not accurately represent the temperature regime of the area. Thus, the temperature readings from Lee Vining were used for Section D and F.

In late 2010, a series of large snow storms hit the Eastern Sierras which resulted in the wettest December recorded for Mammoth Mountain since 1968 (Figure 7). The wettest December was followed by one of the driest January with a total precipitation of 0.39in at Cain Ranch comparing to 2.93 in, the 20-year average of January's total precipitation. The December snow storms covered a large portion of the stream and effectively prevented anchor ice formation in the Tran-DR area even though the maximum daily air temperature (θ) remained below 32°F for almost two weeks. The same phenomenon was observed in the mid January during the winter of 2009-10. In addition to snow cover, lake fog also may have shielded the creek from the extreme temperature swing. The lake fog was present more notably during the second freeze-up periods particularly between January 6 and 9, 2011 during which lake fog lasted throughout the day (Figure 7). During the second freeze-up period, daily minimum air temperature (ψ) remained below 10°F at Cain Ranch but one day with the lowest ψ being -10°F. Meanwhile, at Lee Vining, ψ dropped below 10°F only twice during the same period with the lowest being 6°F.

Figure 7. Daily precipitation recorded at Cain Ranch and lake fog derived from Mono Lake WebCam from November 1, 2010, to March 6, 2011. For lake fog, one indicates presence and zero indicates absence of lake fog.



Water Temperature

Gradual decreases in water temperature in the downstream direction were observed in both Rush and Lee Vining creeks; however, the lowest water temperature in Lee Vining Creek occurred around B1 Channel branching point instead of Section D, and there was a slight warming below the Narrows for Rush Creek (Table 4). Lee Vining Creek had lower water temperatures than Rush Creek as the highest LV daily mean water temperature at Lee Vining Creek below Intake (except Section F) was more than one degree Fahrenheit lower than the lowest Rush Creek daily mean water temperature at County Road.

The coldest water temperatures were found below the point where B1 Channel branches out, and a number of days with daily mean water temperature below 32°F (super-cooling) was highest in that section, and higher in Upper Lee Vining Creek (above US Hwy 395) than in Section D (Table 4-a). Very similar longitudinal trends of water temperatures and a number of super-cooling days were found in the winter of 2010-11 to the previous winter (Table 4-b); however, the B1 Channel branching point had lower mean temperatures and far greater numbers of days with super-cooling than Section D, indicating the coldest section along Lee Vining Creek below Intake was between Hwy 395 and Section E. Mean water temperature warmed up almost 0.3°F in the distance of approximately 1 km, and most notably number of days with super-cooling decreased from 36 days to 0 days in the same distance, indicating discharge of warmer groundwater between B1 branching point and Section E. Between Section E and D, mean daily water temperatures remained almost constant while mean daily minimum temperature decreased and a number of super-cooling days increased to seven days. The differences between those two sections were much smaller than what was observed in the previous winter. For instance, the number of days with daily mean water temperature below 32 °F in Section D during the winter of 2009-10 were 28 days comparing to seven days during the winter of 2010-11. The number of days with super-cooling (daily minimum water temperature below 32°F) were also down by 22 days during the winter of 2010-11. Another notable difference between the winter of 2010-11 and previous winters was that the number of days with daily mean water temperature below 32°F in the upper sections were higher than those of Section D. Section B did not record daily mean water temperature below 32°F during the previous winter meanwhile 15 days of such temperature were recorded this winter, more than twice as much as those of Section D.

In Rush Creek, an overall cooling trend was present with a slight warming trend observed around P5-8 (Table 4-c). The daily temperature fluctuation which peaked at above Parker Creek Confluence was most likely due to the lowest flow usually occurring before flow augmentation by Parker and Walker creeks. Highest numbers of days with daily mean water temperatures below 32°F were, however, observed at the Narrows instead of above Parker Creek Confluence (40 vs. 14 days), suggesting that flow augmentation by Parker and Walker creeks would have resulted in net heat loss to Rush Creek. Frazil ice can form when water is super-cooled; however, above freezing daily minimum water temperature in most reaches of Rush Creek indicated that frazil ice was not continuously produced throughout the day and most likely daily dislodging of anchor ice with warming water temperature when anchor ice formed. Slight increases in temperatures around P5-8 may be attributable to Vestal Springs entering Rush Creek below the Narrows.

Table 4. Mean daily water temperature statistics and numbers of days with mean and maximum daily water temperatures below 32°F (super-cooling) at different stations for a) Lee Vining Creek 2010-11, b) Lee Vining Creek 2009-10 and c) Rush Creek 2010-2011. Mean temperatures were calculated by using temperature readings between November 19 and March 6 for the winter of 2010-11 and between November 17 and March 10 for the winter of 2009-10. Temperature readings from Lee Vining Creek County Road were excluded because temperature readings included readings as low as 23.1°F.

4-a) Lee Vining Creek during the winter of 2010-11

Section	Mean Daily Mean (°F)	Mean Daily Max (°F)	Mean Daily Min (°F)	Mean Range (°F)	Number of Days Mean below 32°F	Number of Days Min below 32°F
Below Conduit	34.3	35.9	33.1	2.9	0	27
Section B	34.1	35.8	32.9	2.9	15	49
Section C*	34.0	35.5	32.8	2.6	21	58
Below B1 Branching Point	33.6	34.7	32.7	2.0	36	65
Section E	33.9	35.6	32.9	2.7	0	38
Section D	33.9	36.2	32.7	3.5	7	47
Section F	36.0	41.0	33.7	7.3	0	0

* The temperature readings became very erratic after January 4 with the lowest temperature being 18.4°F, indicating that the sensor became exposed to air after January 4. Readings after January 4 were omitted. The daily statistics for the entire winter for Section C were extrapolated by regressing the temperature readings from Section B against those from Section C between November 19 and January 4. Estimates derived from this method should be reasonably close to actual readings because there were high correlations of temperature readings between Section C and B during the winter of 2009-10 (r = 0.95) and the period between November 19 and January 4 during the winter of 2010-11 (r = 0.99).

4-b) Lee Vining Creek during the winter of 2009-10

Section	Mean Daily Mean (°F)	Mean Daily Max (°F)	Mean Daily Min (°F)	Mean Range (°F)	Number of Days Mean below 32°F	Number of Days Min below 32°F
Below Conduit	34.4	35.9	33.1	2.8	0	15
Section B	34.2	35.8	32.8	3.0	0	8
Section C	33.9	35.2	32.8	2.4	6	38
Section E	33.8	35.7	32.6	3.2	0	10
Section D	33.6	36.2	32.3	3.9	28	69
Section F	34.2	38.0	32.5	5.6	0	33

4-c) Rush Creek during the winter of 2010-11

Section	Mean Daily Mean (°F)	Mean Daily Max (°F)	Mean Daily Min (°F)	Mean Range (°F)	Number of Days Mean below 32°F	Number of Days Min below 32°F
MGORD Top	38.7	38.9	38.5	0.35	0	0
MGORD Bottom	38.1	41.0	36.8	4.2	0	0
Old 395 Bridge	37.4	41.5	35.1	6.4	0	3
Above Parker	36.8	41.3	34.0	7.3	0	14
Narrows	35.7	39.6	33.3	6.3	1	40
P5-8	36.0	40.1	33.6	6.5	0	0
10 Channel	35.7	39.4	33.3	6.1	0	2
County Road	35.4	38.9	33.0	5.9	0	3

Ice Formation

Section D: During the winter of 2010-11, section D of Lee Vining Creek experienced very similar numbers of days with mean daily air temperature (μ) below 32°F to the previous winter (24 vs. 22 days), but the number of consecutive days with μ < 32°F was much shorter during the winter of 2010-11 (seven vs. 28 days) (Table 3). Water temperature parameters (daily mean, max, and min) in Section D were the lowest among the five original study sections, but higher than those from the B1 Channel branching point (Table 4-a).

In Tran_DR anchor ice formation was observed only during three visits on November 29, 2010, January 4, 2011 and February 22, 2011 with the largest extent of 71%, compared to 86% observed in the winter of 2009-10 (Figure 8). Extensive surface cover (>70%) was observed on November 29 and January 4 in the form of anchor ice and shelf ice. Extensive surface cover originated from anchor ice formation in the shallow left-bank side of the transect. The time lapse camera, placed downstream of Tran_DR, showed anchor ice in the shallow section caused to water to overflow and refreeze on the top of anchor ice, resulting in thick smooth ice sheet. Anchor ice underneath the ice sheet then melted, most likely due to increased water temperature, leaving shelf ice on the shallow section. The shelf ice persisted for three days in the end of November and for almost ten days in the early January. The longer persistence of the shelf ice in January was most likely due to heavy snowfall on January 1 and 2, which insulated shelf ice from short and long wave radiation.

During the winter of 2010-11, the extent of ice cover in general was much smaller in Tran_DR compared to the previous winter most likely due to less severe winter (netAFDD was higher in the previous winter by 100), but also due to change in channel geometry. A high gradient riffle existed downstream from Tran_DR, and this was where an ice dam was observed during the winter of 2009-10. The thalweg on the right side of the channel appeared to be deeper, resulted in deeper but less steep thalweg where most of the flow was being conveyed. Increase in the proportion of the water flowing through the thalweg also resulted in less water flowing over the high gradient riffle, which in turn would have reduced turbulence and anchor ice formation. During the winter of 2010-11, no ice dam formed to block the entire channel below Tran_DR (Figure 9).

Surface ice cover did not exceed 60% during weekly visits of the winter of 2010-11, suggesting that surface ice mostly remained along banks of the stream across Tran_DP (Figure 10); however the extent could have been larger because the weekly visits often did not coincided with low daily maximum air temperature (θ). Some accumulation of frazil slush underneath the surface ice cover toward the left bank was observed downstream of the transect in the shallower area on February 22, but frazil slush was not present around Tran_DP in the deeper area, leaving a pool space intact. Very little frazil accumulation may be attributable to lower frazil ice productions upstream of Tran_DP than Rush P5-8 and Rush P4-5. At least two ice dams between Tran_DR and DP were observed during freeze-ups of the previous winter; however, ice dams were absent in those two locations during freeze-ups of the winter of 2010-11.

Figure 8. Tran_DR percent ice cover (surface vs. subsurface cover), air temperature, water temperature, and AFDD (accumulated freezing degree day) between November 29 and March 7. Daily mean, maximum and minimum temperatures are shown as green, red and blue lines, respectively, for air and water temperatures. The air temperature data were obtained from Lee Vining. Water temperature was recorded at Tran_DP.

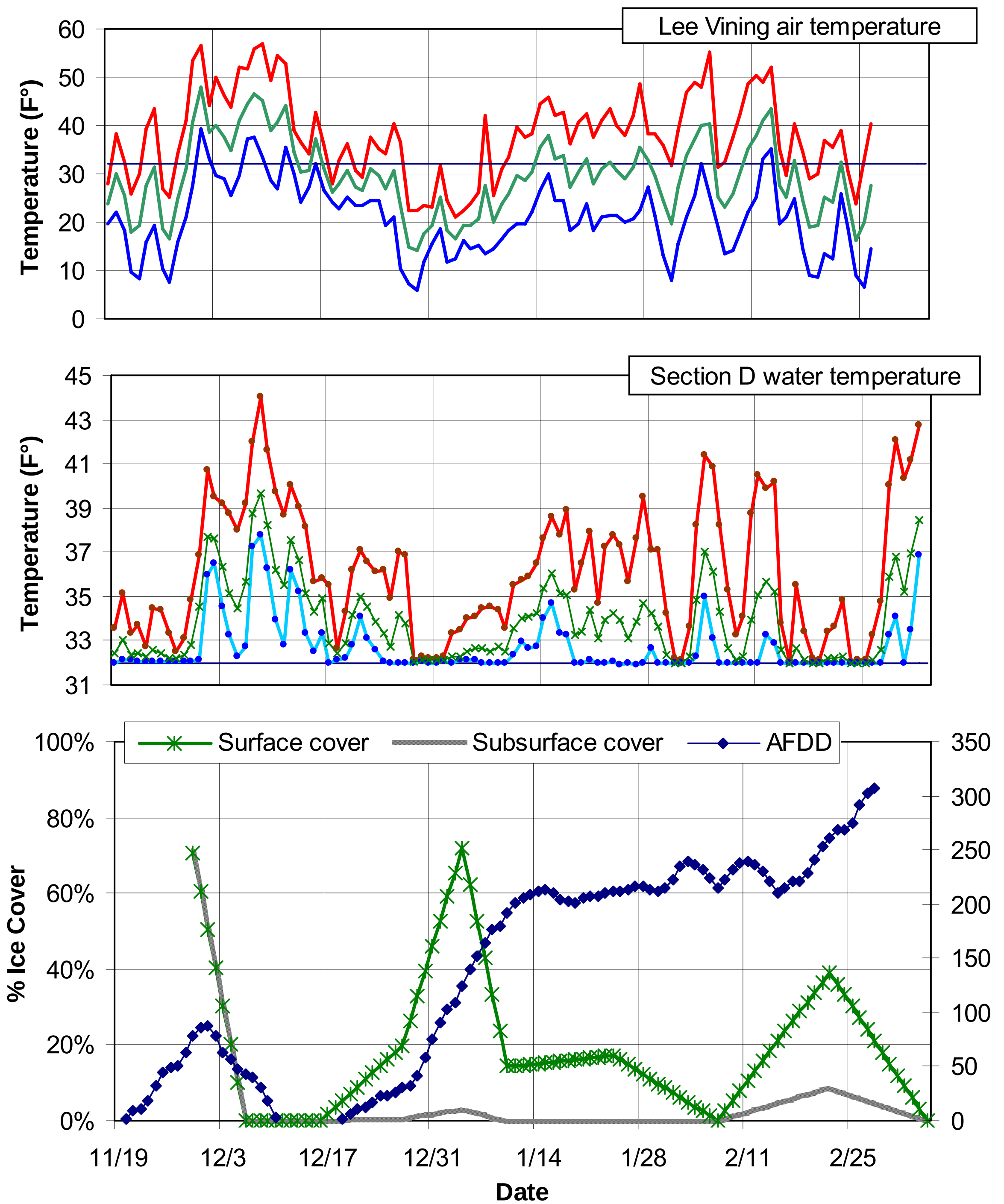


Figure 9. Comparison of an ice dam build up among different freeze-up periods at high gradient riffle between Tran_DR and Tran_DR, where an ice dam was observed several times during the winter of 2009-10. Pictures were taken, on a) December 9, 2009, b) November 29, 2010, and c) January 4, 2011. No ice dam was observed during the 2010-11 freeze-ups.

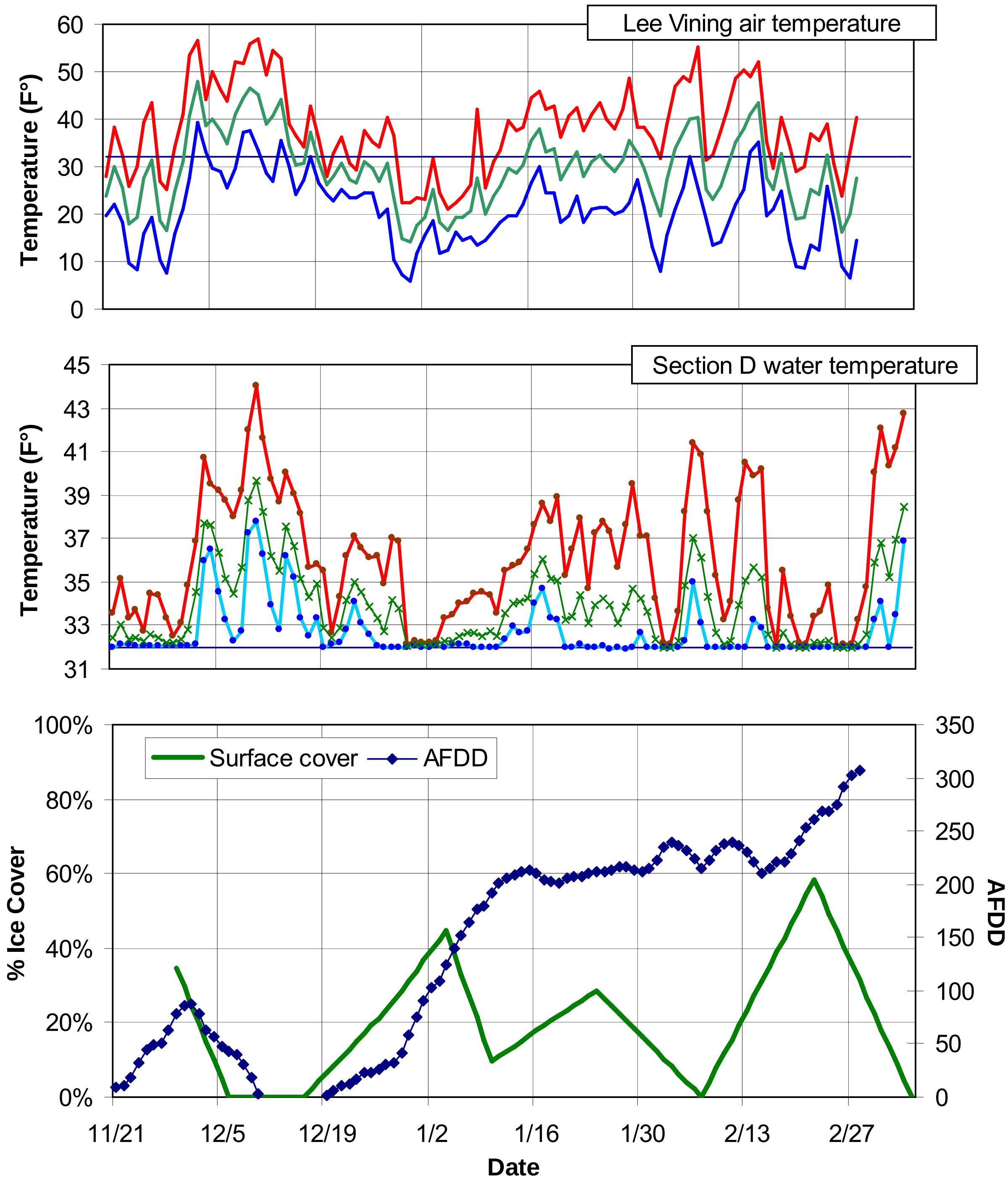
9-a) December 9, 2009

9-b) November 29, 2010

9-c) January 4, 2011

9-d) February 22, 2011

Figure 10. Tran_DP percent ice cover (surface vs. subsurface cover), air temperature, water temperature, and AFDD (accumulated freezing degree day) between November 29 and March 7. Daily mean, maximum and minimum temperatures are shown as green, red and blue lines, respectively, for air and water temperatures. The air temperature data were obtained from Lee Vining. Water temperature was recorded at Tran_DP.



Time Lapse Camera: A time lapse camera provided much more valuable information than initially planned. Occurrence and duration of anchor ice and evolution of anchor ice into shelf ice were clearly captured by the camera. Between November 18 and March 7 (total of 127 days), anchor ice formed on 43 days (Figure 11-a, Table 5). Of 43 days, anchor ice disappeared either in the morning (before noon) for 26 days or in the afternoon for 14 days. Anchor ice was found in 34% of the total days during the study (127days); however, anchor ice did not persist more than a day, and a majority of anchor ice disappeared in the morning or by early afternoon in the area downstream of Tran_DR in the winter of 2010-11. Fifteen of 43 days coincided with daily maximum air temperature (θ) below 32°F for Lee Vining; however, only three of those fifteen days showed persistence of anchor ice longer than one day. Very extensive anchor ice cover was found in 22 of 43 days, but anchor ice either disappeared or diminished to such that flow was no longer impeded by ice in 19 of those 22 days.

Occurrences of anchor ice were closely related to super-cooling of water as anchor ice formations were observed on the same days when daily minimum water temperatures were below 32°F (super-cooling) at (Figure 11-b). There were 46 days in total with super-cooling water found in Section D, and anchor ice was observed in 34 of 46 days. Some discrepancy could have arisen from snow accumulation (January 1 through 3), temporal malfunctioning of the camera (January 4), and lake fog (January 8 and 9). Extensive anchor ice was, however, observed only when daily mean water temperature remained below 32°F.

During three occasions (November 29 to 30, December 30 to 31, and February 25 to 26*), anchor ice was found to persist through out the day (Figure 11-a and 11-b). These three occasions coincided with at least two consecutive days with freezing daily maximum air temperatures (θ) at Lee Vining. On November 29, the extensive anchor ice formation was found in the morning, and remnants of anchor ice persist through out the day (Figure 12). It appears that extensive anchor ice formed at night, and water flowed over the ice and refroze forming the thick ice sheet. By the afternoon, however, the thick ice sheet was converted into shelf ice with water flowing underneath. This shelf ice is completely gone by December 1. The same process was observed on December 30 and 31 (Figure 13). Extensive anchor ice formations can break down in one day even during days with daily minimum water temperatures (ψ) and θ were below 32°F. For instance, those two conditions were met on February 2, the extensive anchor ice formation was found in the morning; however, the formation was broken down by the afternoon, and water was flowing through the section even though small islands of anchor ice mass remained at the end the day (Figure 14). An ice dam formed in the shallow section on February 3, but the dam disappeared by four o'clock in the afternoon.

*The camera was fogged up from 8:19am on February 25 until 7:24am on February 26. It was assumed anchor ice persisted through out February 25 based on the maximum air temperature at Lee Vining (30°F), the mean water temperature at Section D (31.98°F), and presence of the lake fog from Mono Lake WebCam.

Figure 11. Occurrence of subsurface ice in the riffle downstream from Tran_DR relating to a) air temperature and b) water temperature. Occurrence score of three indicates extensive subsurface cover which lasted for an entire day, two indicates extensive ice cover which disappeared during the same day of formation, one indicates anchor ice formation which disappeared either in the morning or afternoon of the day of formation, and zero indicates no anchor ice.

Figure 11-a. Relationships between occurrence of subsurface ice and air temperature.

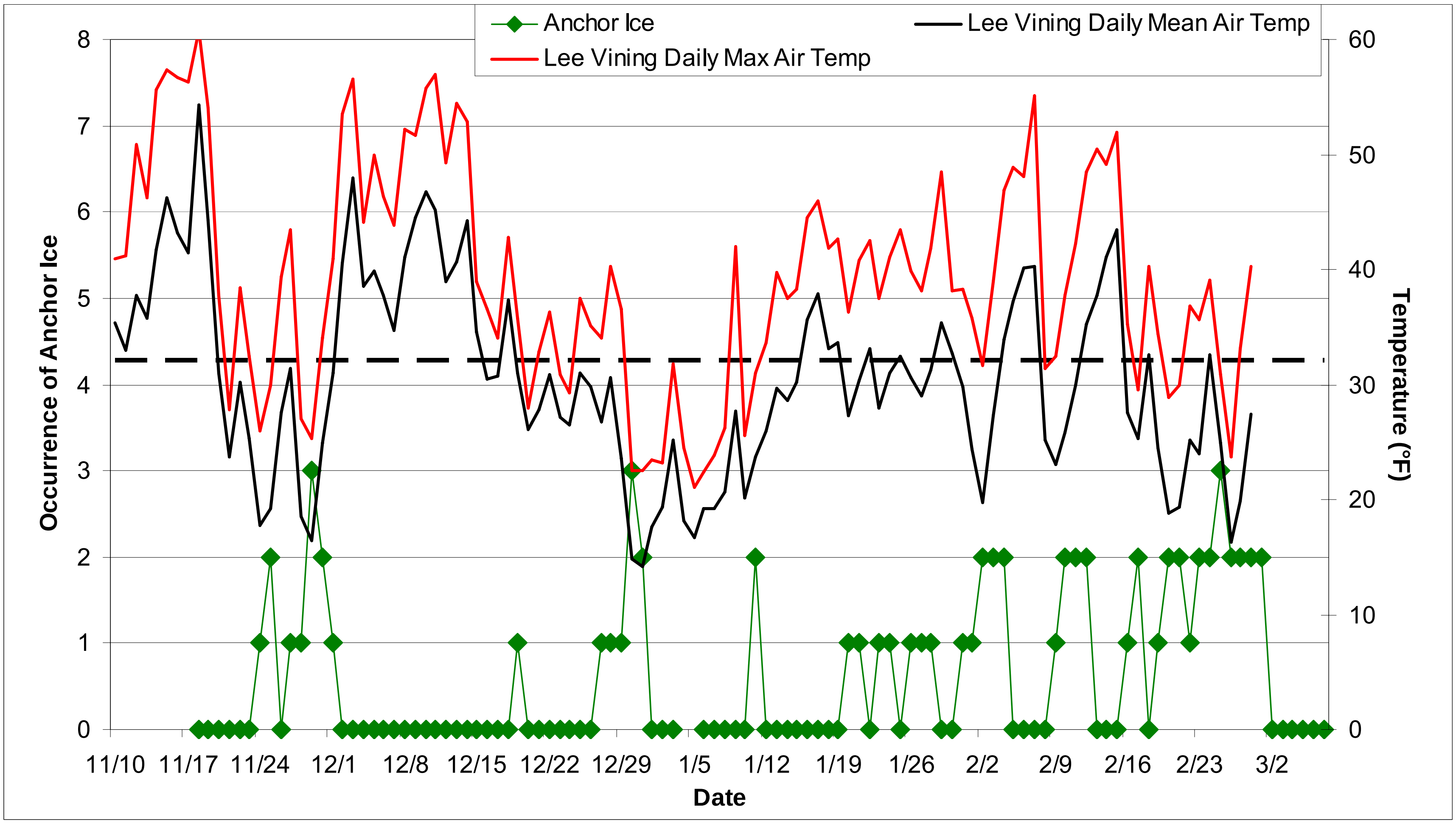


Figure 11-b. Relationships between occurrence of subsurface ice and water temperature.

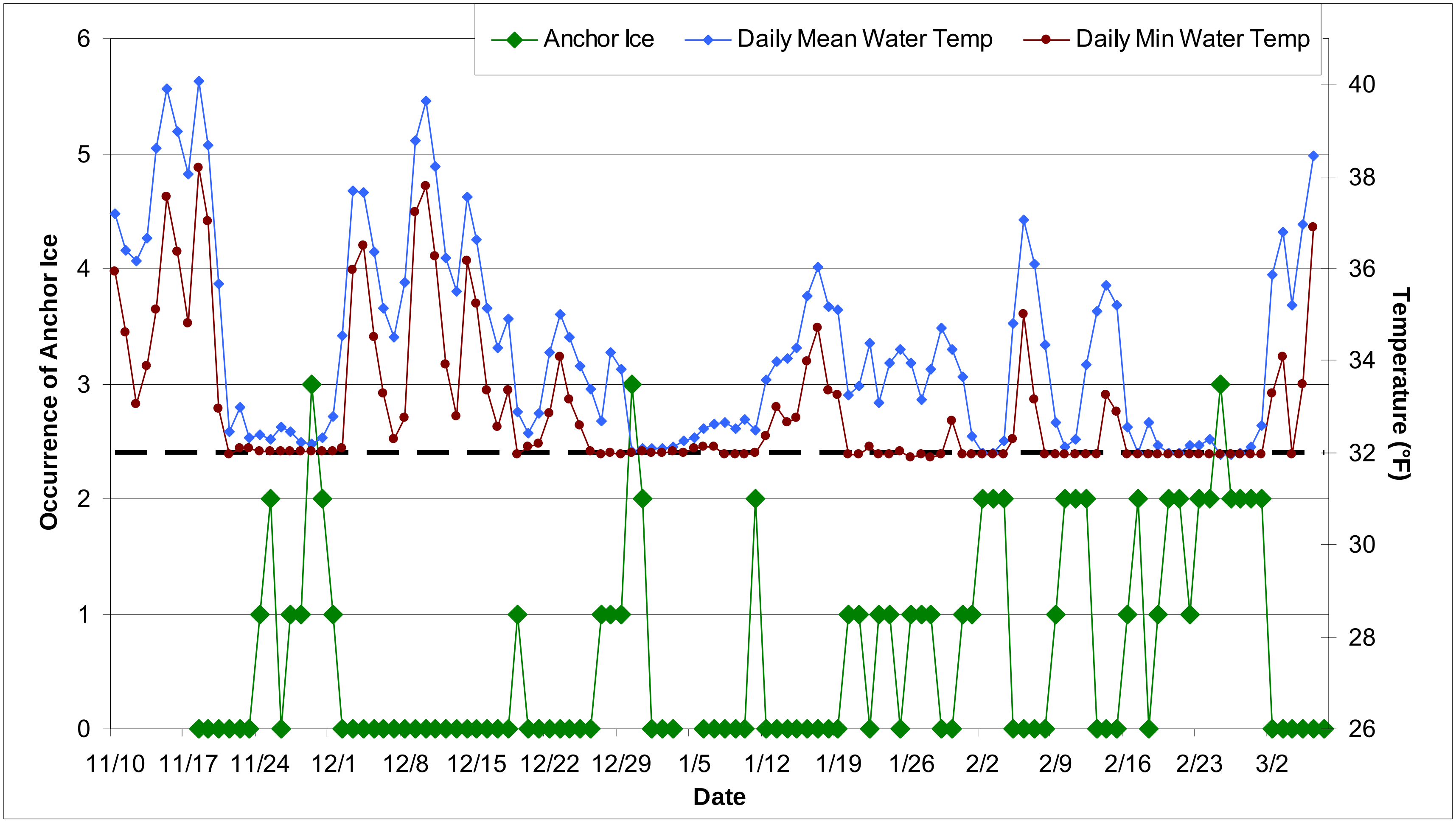


Table 5. Summary of anchor ice formation detected by the time lapse camera in the riffle downstream of Tran_DR between November 18, 2010, and March 7, 2011. Photos were missing on January 4 and 5 and February 25, 2011. An extensive cover was assigned for February 25 based on daily maximum air and daily mean water temperatures. θ indicates daily maximum air temperature at Lee Vining. θ indicates daily maximum air temperature.

	No.days	θ<32°F	Lasting more than one day
Anchor ice	21	0	0
Extensive anchor ice	22	15	3
2010-11 Ice survey	127		

Figure 12. Change of ice cover over time in the area downstream of Tran_DR. The picture starts at 6:44am, November 29, 2010, and ends at 4:49, November 30, 2010. Anchor ice formed on November 29 and persisted through out the day, and then converted into shelf ice on November 30, which eventually disappeared in the afternoon of November 30.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11/29/10 10:44 AM


BIRDCAM-01
11/29/10 11:44 AM


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Figure 13. Change of ice cover over time in the area downstream of Tran_DR. The picture starts at 7:33am, December 30, 2010, and ends at 4:39, November 30, 2010. Anchor ice formed on December 30 and persisted through out the day, and then converted into shelf ice on December 31, which persisted for more than a week due to snow fall on January 1.


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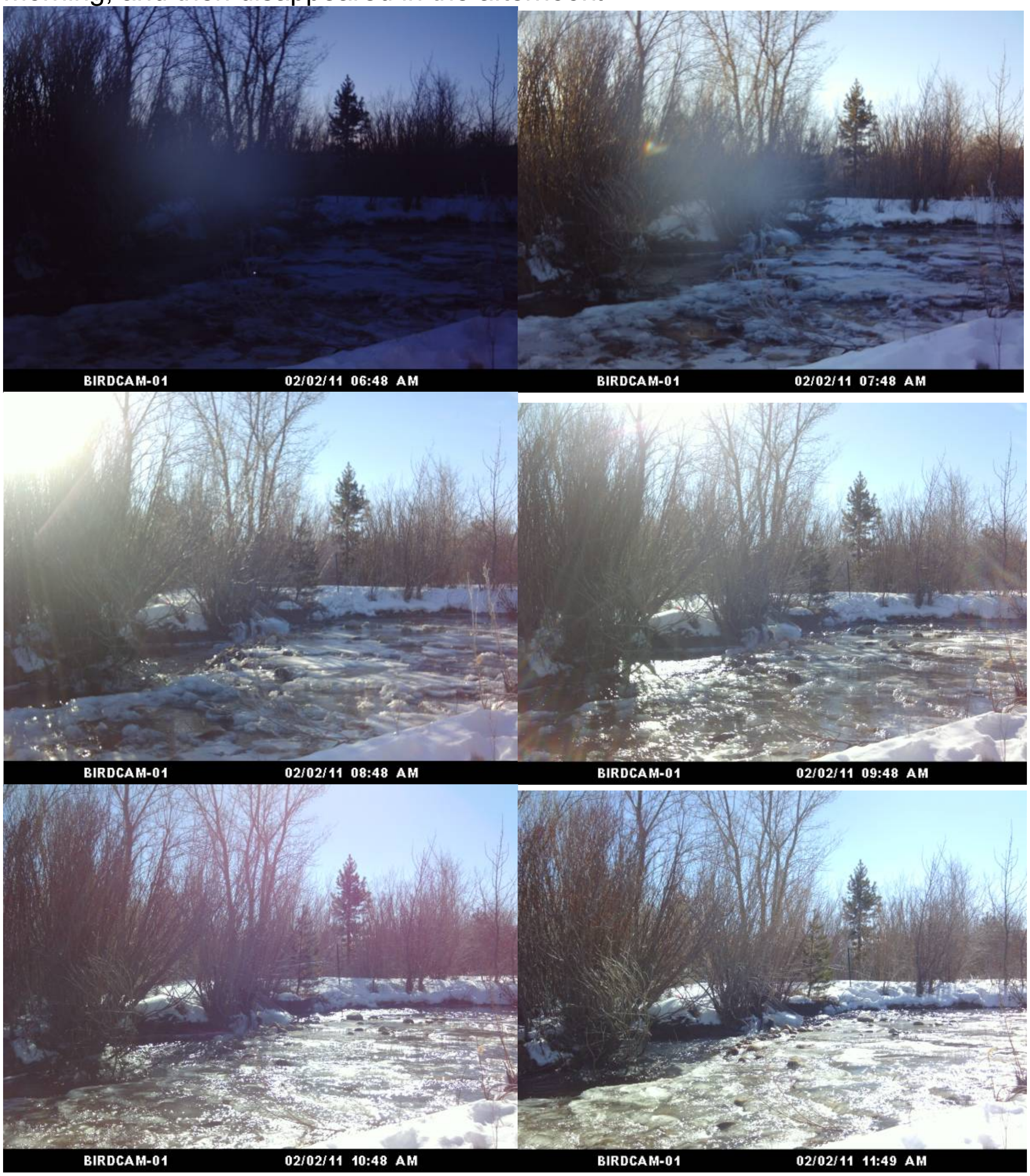
Figure 14. Change of ice cover over time in the area downstream of Tran_DR. The picture starts at 6:48am, February 2, 2011. Anchor ice formed night before or early morning, and then disappeared in the afternoon.

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Section F: Section F remained relatively ice free for the entire study period of the winter of 2010-11, and unlike the previous winter, the daily minimum water temperatures never dropped below 32°F (Figure 15 and 16, Table 4). During the winter of 2010-11, the highest mean daily water temperature was found in Section F again, but comparing to the previous winter mean daily water temperature was lower (Table 4a and b). The pool transect (Tran_FP) remained almost ice free (cover < 7%) except during the last freeze-up period in the end of February 2011 during which surface cover exceeded 30%. Across Tran_FR surface ice cover over 50% was occurred during each of three freeze-up events, and the transect was covered completely by surface cover uring the first freeze-up in the late November 2010. It appeared that the thalweg part of the transect (toward the right bank) downcut, which further restricted water flow over two-thirds of the transect toward the left bank. The average relative stream bed elevation along the left two-thirds was 0.6 ft higher than that of the right third, where the thalweg was located. Thus, Even with surface cover greater than 50%, the thalweg remained ice free during last two freeze-up events.

Figure 15. Tran_FP percent ice cover (surface vs. subsurface cover), air temperature, water temperature, and AFDD (accumulated freezing degree day) between November 29 and March 7. Daily mean, maximum and minimum temperatures are shown as green, red and blue lines, respectively, for air and water temperatures. The air temperature data were obtained from Lee Vining. Water temperature was recorded in B1 Channel between Tran_FR and Tran_FP.

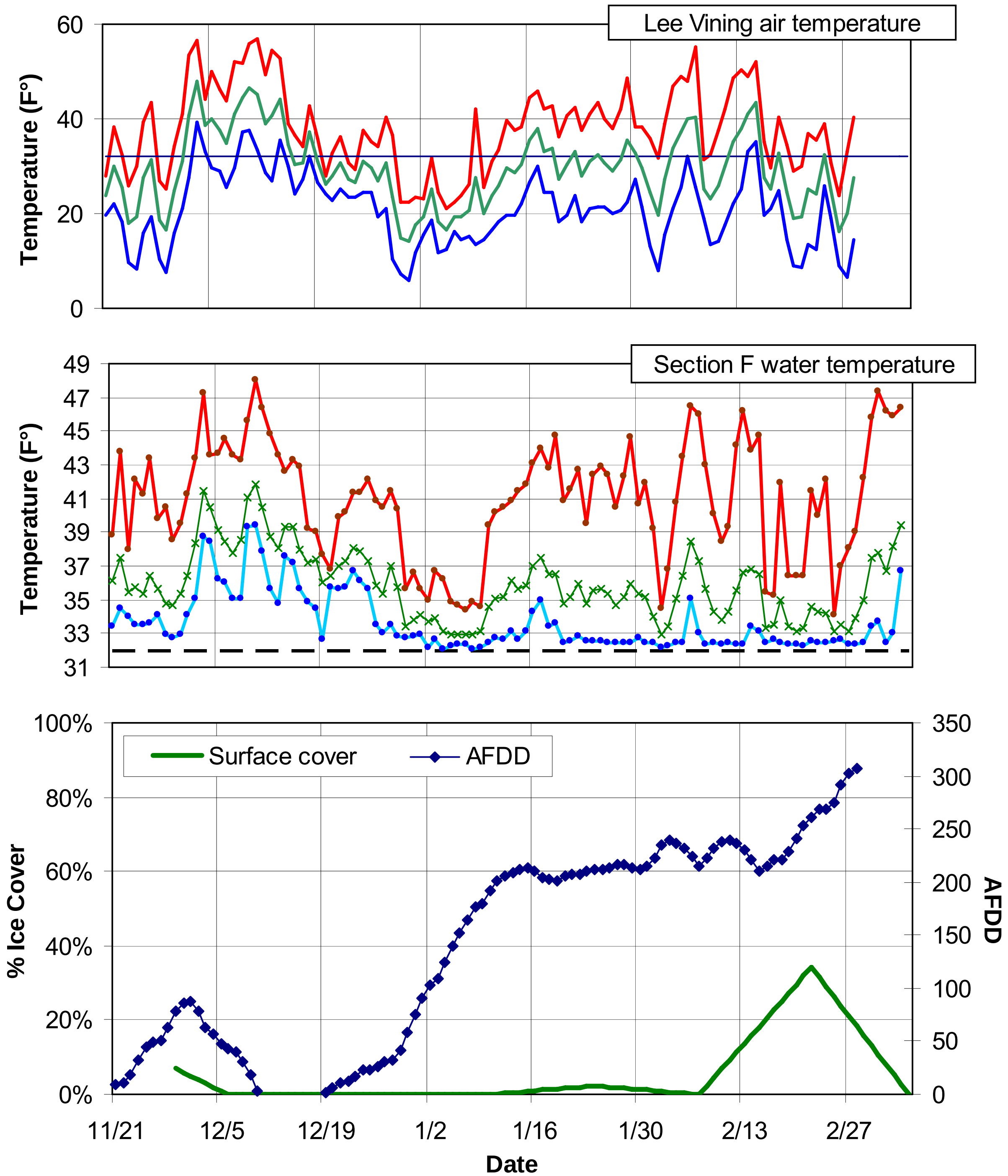
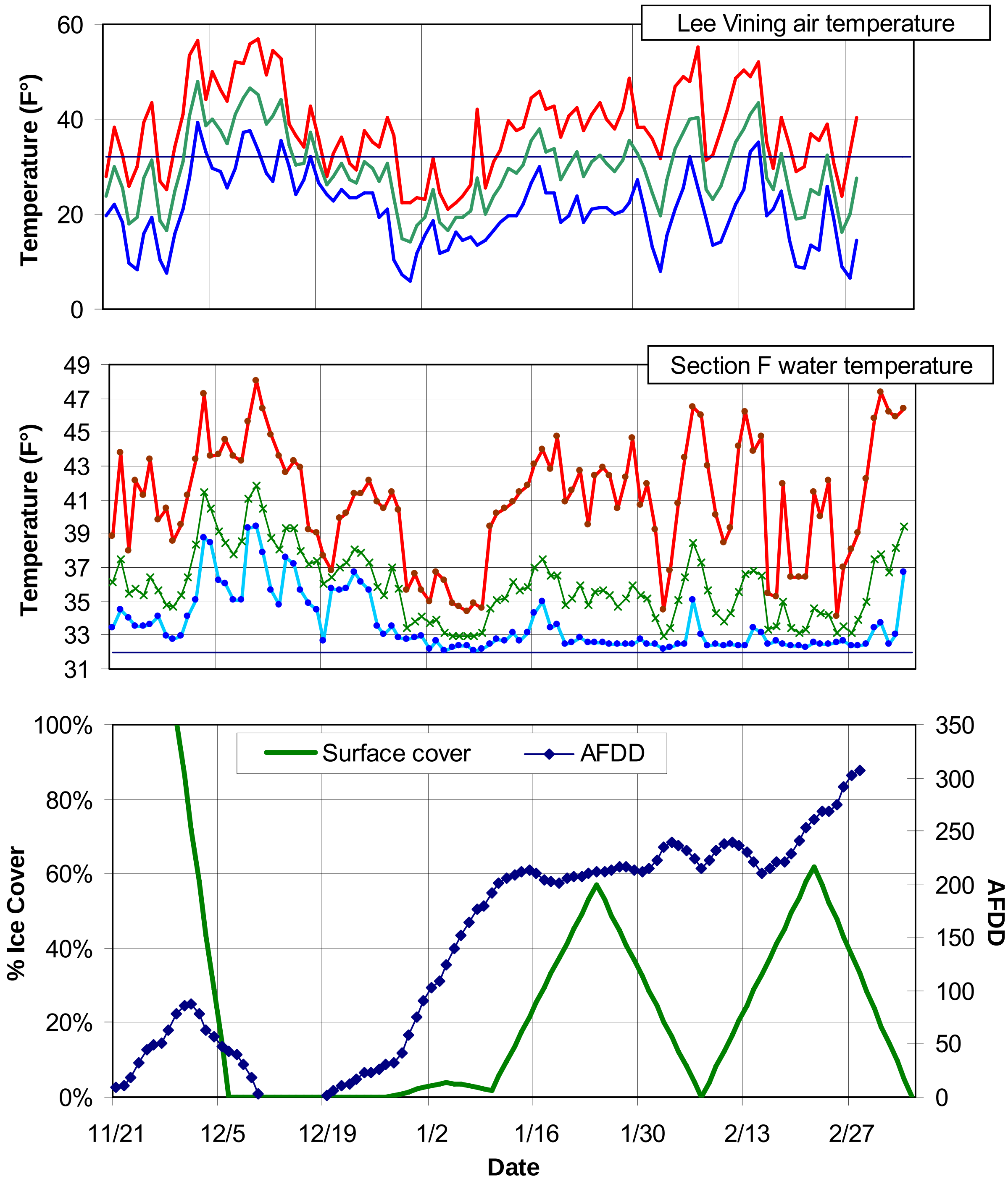


Figure 16. Tran_FR percent ice cover (surface vs. subsurface cover), air temperature, water temperature, and AFDD (accumulated freezing degree day) between November 29 and March 7. Daily mean, maximum and minimum temperatures are shown as green, red and blue lines, respectively, for air and water temperatures. The air temperature data were obtained from Lee Vining. Water temperature was recorded in B1 Channel between Tran_FR and Tran_FP.



Rush Creek Pool Transect (P5-8): The winter of 2010-11 was the first winter to study ice formations in Rush Creek Pool Transect (P5-8). P5-8 remained relatively ice free except during the three freeze-up events, and accumulation of frazil ice under surface ice cover was found in last two freeze-up events (Figure 17). Because the first visit on November 29, 2010 was made a day before the first peak of AFDD, it is possible the same degree of frazil accumulation would have occurred during the ascending limb of the first AFDD peak as AFDD steadily increased from zero to one hundred in ten days. During all three freeze-up periods, anchor ice was estimated to cover 23%, 31%, and 49% of the upstream section of the transect, and frazil ice slush was found accumulating underneath the surface ice and on the stream bed under the surface cover in the slow moving section of the pool and extending toward the wetted edge of the transect (Figure 18). In this study, these frazil ice slush masses on the streambed were classified as anchor ice and assumed to reach the wetted edge. Thickness of the surface ice plus frazil accumulation exceeded 1.6ft, across the transect, indicating reduced pool volume under the surface cover.

It should also be noted that during the last freeze-up event in February 2011 the daily minimum water and air temperatures never dropped below 32°F at the Rush Creek-Parker Creek Confluence even though sub-zero daily maximum temperatures were recorded at Cain Ranch on February 25 and 26 (30 and 27°F respectively). Occurrence of above freezing temperatures (both air and water) during the freeze-up period indicates daily dislodging of anchor ice. Between the right wetted edge (2.4 ft) and the staff gauge at 8ft, water velocities were constantly negative, creating a small eddy, and deposition of debris and fine sediments were found in that area. Dislodged anchor ice suggests that these anchor ice masses were weakly attached to the sediment; Type I anchor ice which attaches on top of substrata (Stickler and Alfredson 2009). Dislodged anchor ice slush would have been then transported downstream and accumulated in the P5-8. This may explain large accumulation of slush ice in the P5-8 during freeze-up events.

Increase in AFDD during the last freeze-up period at the end of February 2011 was much smaller than that observed during the second freeze-up (50 vs. 168), but the extent of ice cover observed on February 23 was greater than that observed on January 5 (49% vs. 36% for surface ice cover and 31% vs. 62% for subsurface ice cover). But AFDD based on Parker Creek Confluence showed a lower degree of AFDD increase during the third freeze-up even though Cain Ranch showed similar increase of AFDD during those two freeze-ups.

Figure 17. Rush Pool Transect (P5-8) percent ice cover (surface vs. subsurface cover), air temperature, water temperature, and AFDD (accumulated freezing degree day) between November 29 and March 7. Daily mean, maximum and minimum temperatures are shown as green, red and blue lines, respectively, for air and water temperatures. The air temperature data were obtained from Rush above Parker Confluence. Water temperature was recorded at P5-8.

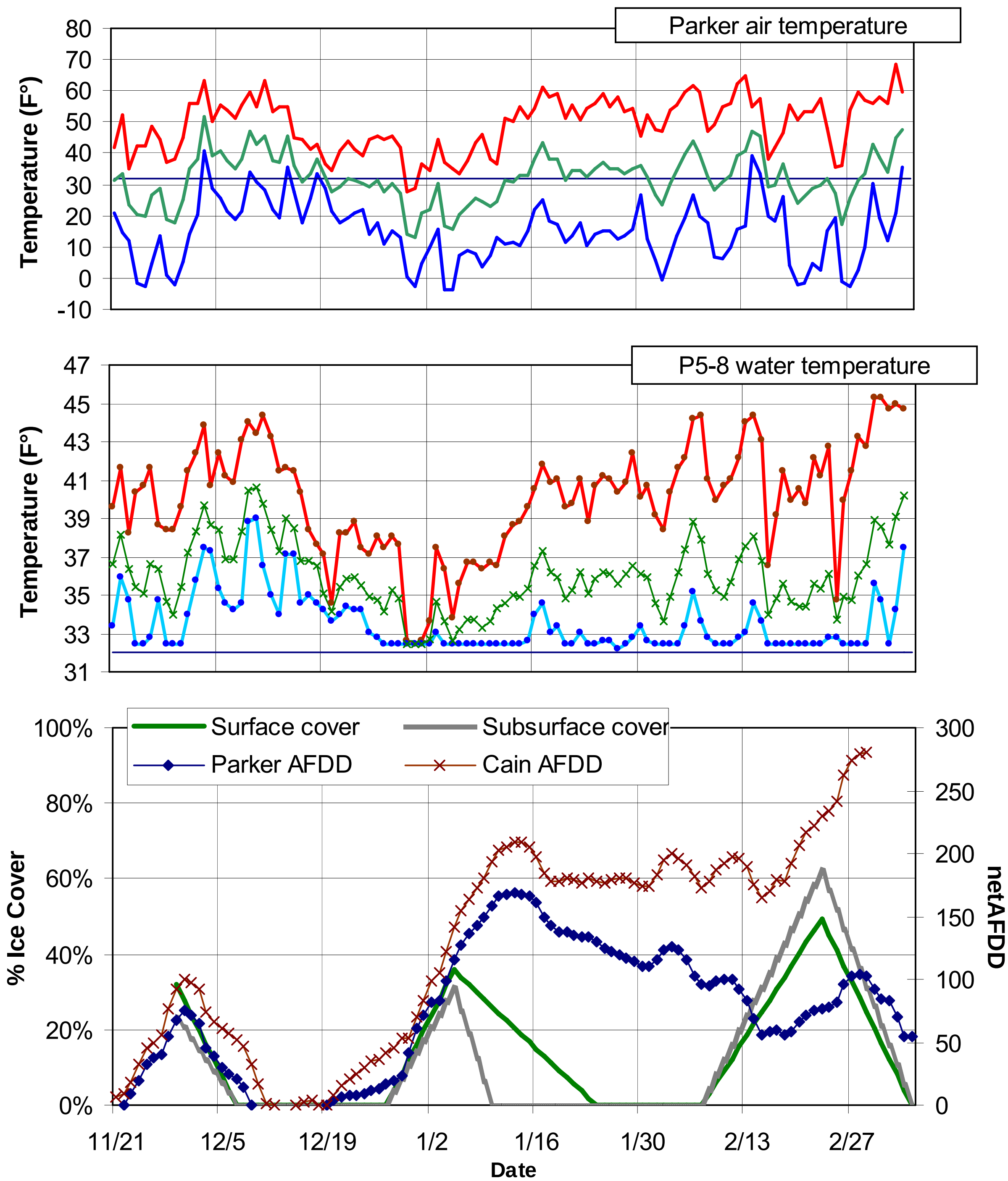
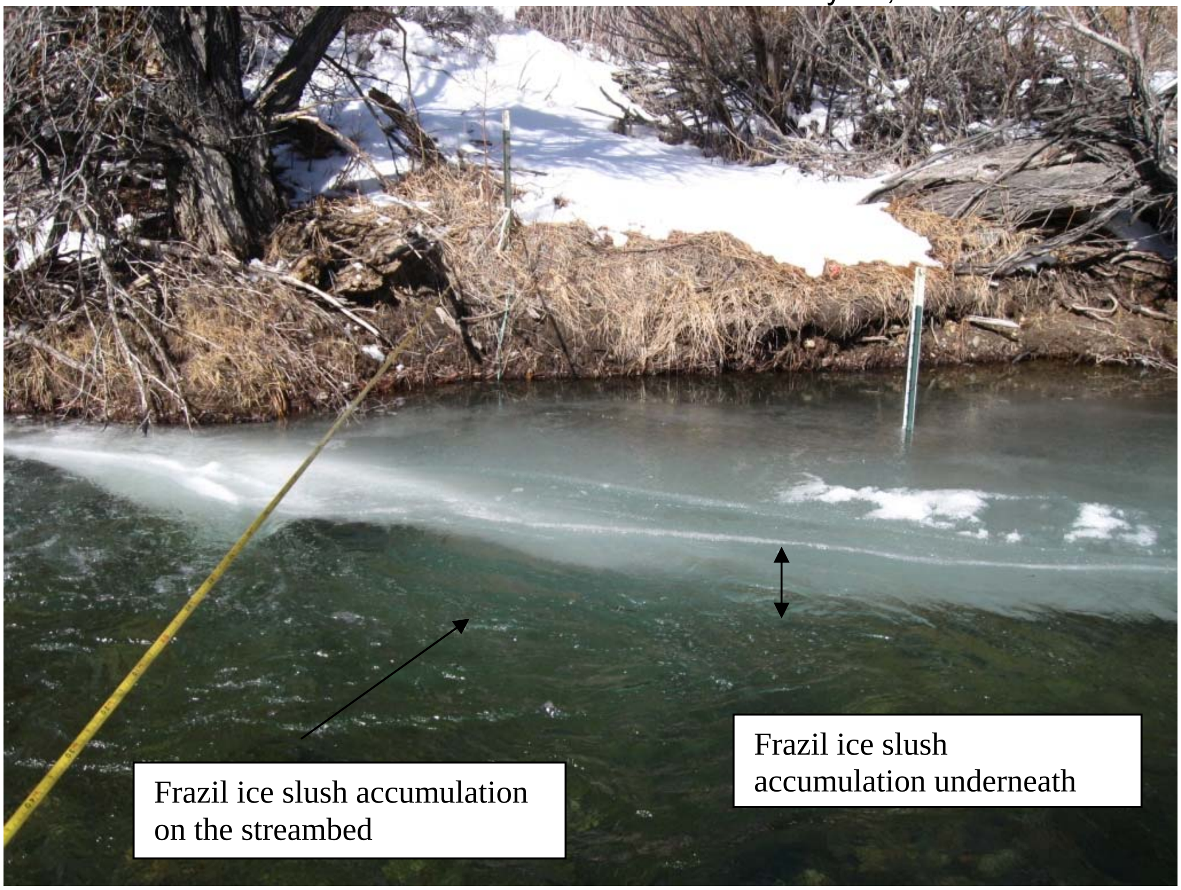


Figure 18. Frazil ice slush accumulation underneath the surface ice and on the streambed under the surface ice cover in P5-8 on February 23, 2011.

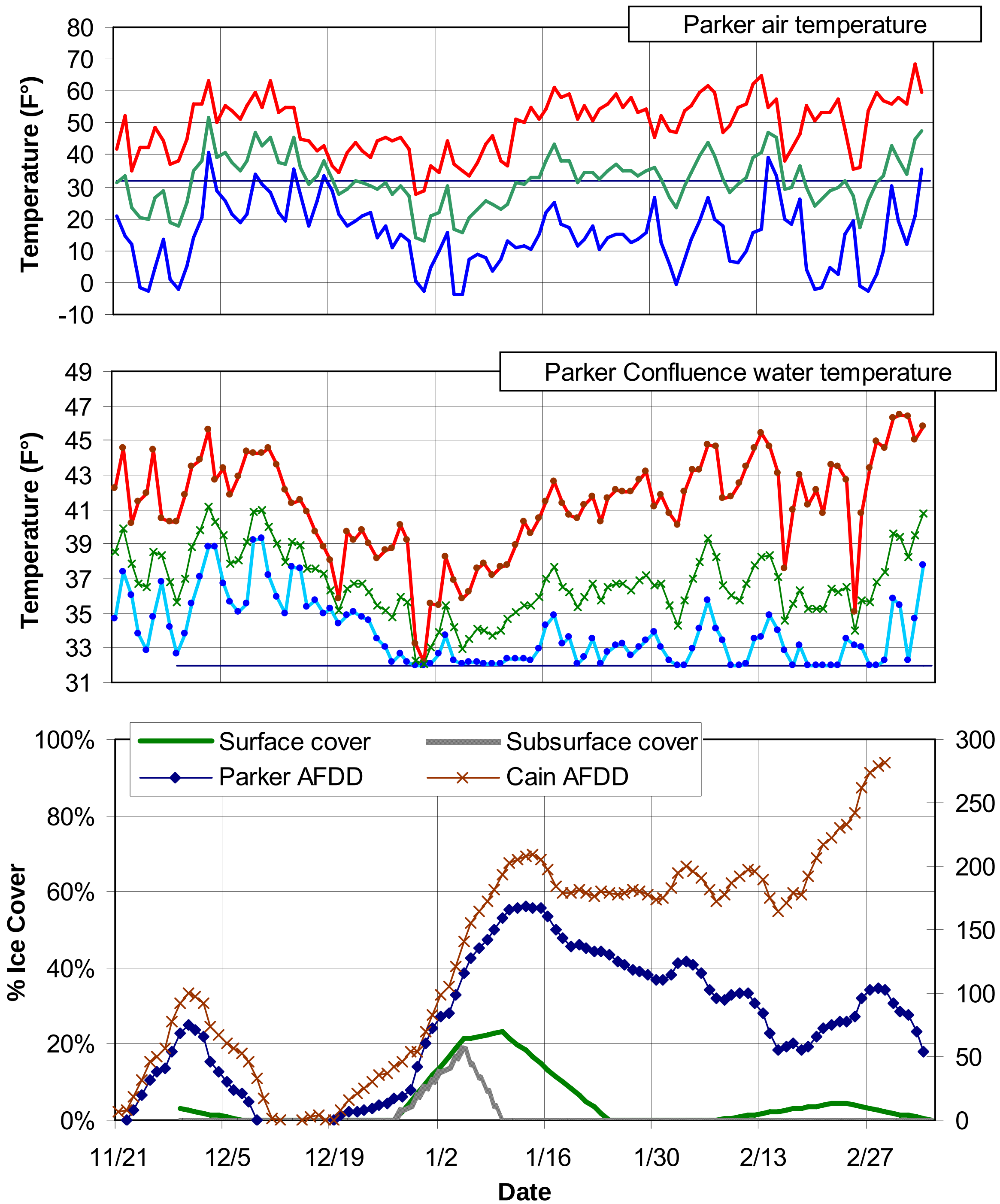


Rush Cree Riffle Transect (Tran_RR): According to air temperature readings from Cain Ranch and Lee Vining, there are three freeze-ups during the winter of 2010-11, but air temperature readings from Rush above Parker Creek Confluence showed only the second freeze-up period, which had an increase of >100 AFDD and maximum air temperature (θ) below 32°F (Figure 5, Table 3). During this period, the lowest mean water temperature was found around 32°F (slightly above the freezing point) on December 31. Anchor ice was only found during this freeze-up period in the area above Parker Creek Confluence; 20% across Rush Creek Riffle Transect and 30% estimate around P4-5.

Surface ice cover greater than 20% was found only during the second freeze-up along the edges of the stream across Tran_RR; thus the most of the stream remained ice cover free throughout the winter of 2010-11 (Figure 19). Anchor ice was found on January 5 during the second freeze-up. The anchor ice cover on that day could have been higher than what was recorded since some anchor ice might have been knocked loose while stretching the tape measure. Anchor ice estimates for upstream and downstream were 60% and 40% respectively; thus the extent of anchor ice could have been as high as 50%, but anchor ice appeared loosely attached to the top of substrates (Type I).

The same ice cover trend was found in P4-5. A pool transect for Rush Creek was moved from this area due to a concern regarding periodic breakage of ice downstream by synoptic flow measurements during the winter of 2010-11. A temporal transect was, however, set up to measure ice cover extent and photos were also taken during weekly visits. P4-5 consisted of a pool on the right side and glide on the left side with large substrates. P4-5 remained relatively ice free except during the second freeze-up events in the late December to early January. On January 5, anchor ice cover was estimated around 30% of the glide area even though there was no anchor ice along the transect. Surface ice cover was 35%; widths of 3.6ft and 3.2ft toward the left and right banks respectively. A thickness of the surface ice on the right side (slower moving water) was recorded as 1.6ft, indicating frazil slush accumulation underneath in the pool. Frazil ice accumulation was, however, limited to the area immediately upstream of the wing dam or rock structure below P4-5, leaving some area in the pool ice free. The surface covered remained as shelf ice for another week.

Figure 19. Rush Riffle Transect (RR) percent ice cover (surface vs. subsurface cover), air temperature, water temperature, and AFDD (accumulated freezing degree day) between November 29 and March 7. Daily mean, maximum and minimum temperatures are shown as green, red and blue lines, respectively, for air and water temperatures. The air temperature data were obtained from Rush above Parker Confluence. Water temperature was recorded at P5-8.



Spatial Extent of Subsurface Ice Formations in Lee Vining Delta

During the winter of 2010-11, eight locations with extensive anchor ice formations (>70% of the channel bed) and seven ice dams were found between Tran_DR and approximately 160m upstream of the County Road Ford Crossing (Figure 20). Extensive anchor ice and ice dam formations were found only during the November 29 survey, and anchor ice formations less than 40% were found in five of six marked anchor ice points (Up2, Anchor 2, 3, 4, and 6) on December 27 (Figure 21). On November 29, two extensive anchor ice formations and one ice dam were found upstream from County Road, and Anchor 8 (the most upstream extensive anchor ice formation) was found only 200 ft (60m) downstream of Tran_EP in Section E where no anchor ice was found during the previous winter. Even though no anchor ice or ice dam was found on January 4, three of the locations (Up2, Anchor5, and Up4) showed shelf ice surface raised almost a foot above the water surface at the time of the survey, indicating there might have been ice dam formations between December 30 and January 3 during which mean water temperatures were just above 32°F and daily maximum air temperature (θ) dropped below 32°F. Occurrence of extensive anchor ice and ice dam formations may not occur frequently, but spatial extent was wider than expected from the previous winter.

Figure 20. A map of locations of extensive anchor ice formation and ice dam in the Lee Vining Creek Delta Section. Up indicates an ice dam, and anchor indicates an extensive anchor ice formation (>70%).

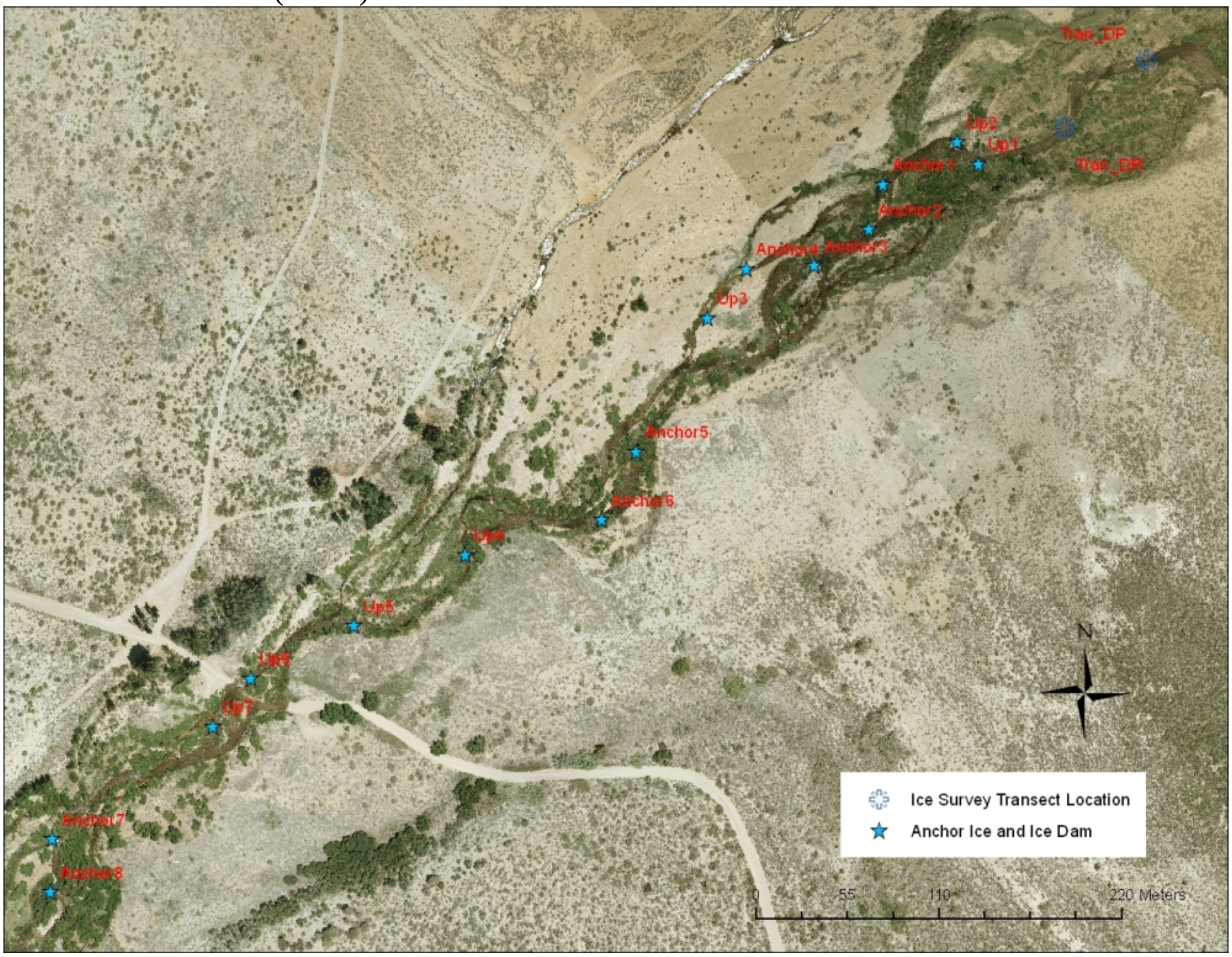


Figure 21. Pictures of ice dams and extensive anchor ice formations taken on November 29, 2010, and January 4, 2011. Pictures on the right were taken on November 29, and pictures on the left were taken on January 4.

21-a) Up 1

21-b) Up 2

21-c) Up 3

21-d) Up 4

21-e) Up 5

21-f) Up 6

21-g) Up 7

21-h) Anchor 1

21-i) Anchor 2 (November 29's picture shows upstream around the corner shown on the January 4's picture.)

21-j) Anchor 3

21-k) Anchor 4

21-l) Anchor 5

21-m) Anchor 6

21-n) Anchor 7

21-o) Anchor 8 (looking downstream on November 29 and upstream on January 4)

Historical Trend of Net Accumulated Freezing Degree Day (netAFDD)

Historical netAFDD values at Cain Ranch shows that netAFDD values and inter-annual variability were higher in the 1990's (Table 6). The highest netAFDD of 1,075 was recorded in the winter of 1992-93. For instance, during the winter of 2009-10, above 1,000 netAFDD values were found along the edges of the region strongly affected by Arctic air masses, such as Central Montana, Wyoming, Nebraska, Iowa, and Wisconsin; meanwhile high plain states (Eastern Montana, North Dakota and Northern Minnesota) and Rocky Mountain regions experienced netAFDD values over 2,000* (Figure 22). For the Mono Basin, the lowest netAFDD of 141 was found in the winter of 1999-2000, during which daily maximum air temperature (θ) never dropped below 32°F. The average netAFDD during the winters between 1991-92 and 1999-00 (1990's) was higher than those between 2000-01 and 2010-11 (2000's) (490 vs. 378 respectively). There were differences of eight days in mean days of θ and daily minimum air temperature (μ) below 32°F between the 1990's and 2000's; however, the number of days with θ<32°F was reduced by half (15 to 7 days) while the number of days with μ<32°F remained high (89 to 81 days). A number of consecutive days with θ<32°F only exceeded four days during the winters of 1991-92 and 1992-93, and since 2001 the average number of consecutive days for θ<32°F was two, indicating ambient temperature alone would have stopped frazil ice production and caused dislodgement of anchor ice.

Variability in netAFDD and number of days for θ<32°F and μ<32°F was much lower during the 2000's than during the 1990's. NetAFDD values ranged between 273 and 575 in the 2000's, and never exceeded 500 except during the winters of 2000-01 and 2004-5. The winter of 2007-08, when the meteorological data were not available, should have been similar to the 2009-10 winter in the terms of netAFDD and within the range in the 2000's because netAFDD values for the winters of 2007-08 and 2009-10 were very similar at Lee Vining (381 and 378 respectively). There is a trend based on the twenty years of data that values of netAFDD have shifted towards lower mean values with smaller variability during the 2000's than during the 1990's.

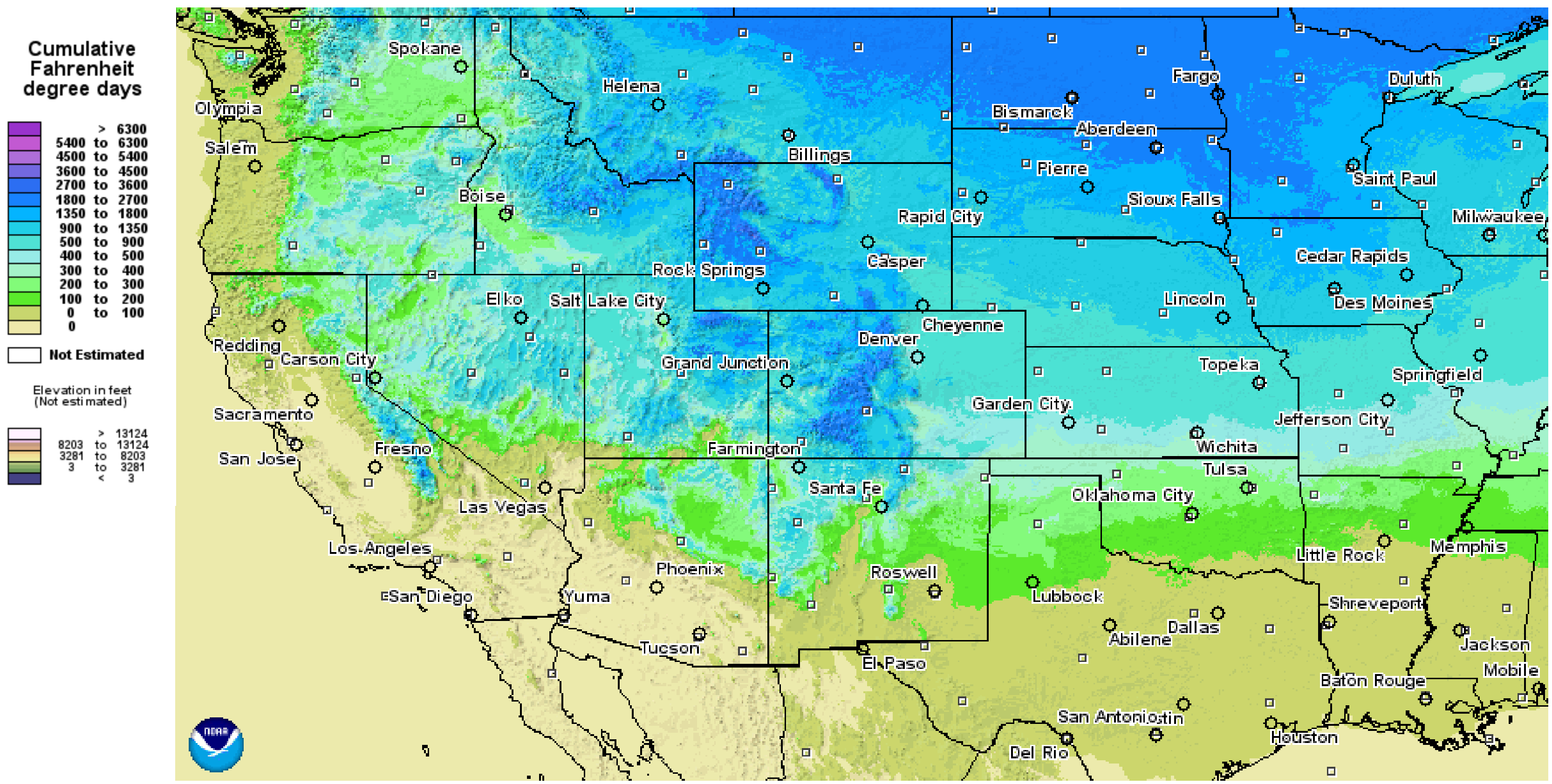
* During the same winter, netAFDD of Mono Basin was 400 based on Cain Ranch temperature data.

Table 6. Historical values of netAFDD and dates of maximum AFDD. The table also shows numbers days during which daily maximum and mean air temperatures were below 32°F. θ indicates daily maximum air temperature, and μ indicates daily mean air temperature. Weather data were not available during the winter of 2007-2008 due to a malfunctioning equipment.

Year	netAFDD	Date of maximum AFDD	No.days θ<0°F	No. consecutive days θ<0°F	No.days μ<0°F
1991-92	628	2/18/1992	18	8	78
1992-93	1075	3/12/1993	48	11	107
1993-94	464	2/2/1994	4	2	81
1994-95	537	2/17/1995	11	3	110
1995-96	201	3/6/1996	11	4	63
1996-97	258	2/28/1997	14	3	87
1997-98	783	3/11/1998	14	2	121
1998-99	323	2/15/1999	13	3	84
1999-00	141	1/6/2000	0	0	69
2000-01	575	3/5/2001	9	2	104
2001-02	414	2/5/2002	7	2	83
2002-03	364	2/12/2003	7	2	83
2003-04	411	3/4/2004	5	3	89
2004-05	506	2/19/2005	13	3	94
2005-06	324	3/22/2006	3	1	82
2006-07*	308	2/2/2007	5	3	56
2008-09	204	2/21/2009	3	1	68
2009-10	400	2/10/2010	7	3	88
2010-11	273	3/7/2011	7	2	61
Average					
Overall	431		10	3	85
1991/92-2000/01	490		15	4	89
2001/02-2010/11	378		7	2	81
Variability					
Overall	224		10	3	17
1991/92-2000/01	304		14	3	20
2001/02-2010/11	109		3	1	15

*Data are missing starting from February 23, 2007, so that numbers may be slightly higher for numbers of days with daily maximum and minimum air temperatures below 32°F.

Figure 22. NetAFDD during the winter of 2009-10 (October 1 through March 31) for Midwestern and Western parts of the United States. The image was downloaded from NOAA National Operational Hydrologic Remote Sensing Center website, http://www.nohrsc.nws.gov/interactive/html/map.html.



Discussion

River ice can adversely affect fish populations by flushing out fish from winter holding habitats in the forms of frazil slush accumulation underneath surface ice cover and by impeding fish movement in the forms of extensive anchor ice cover and ice dam formations (Cunjak 1996, Brown et al. 2000, Prowse 2001a). Both frazil slush accumulation and extensive subsurface ice build up were found in Lee Vining and Rush creeks, but their durations were very short during the winter of 2010-11. A strong episodicity of ice cover extent was observed although the range of ice cover fluctuation was not as great as that observed in the winter of 2009-10. Ice formation and break up in Mono Basin tributaries were much more dynamic than expected. Anchor ice was found to dislodge and reform on a daily basis even when daily maximum air temperature and daily mean water temperature were below 32°F. During freeze-up periods, frazil ice slush reduced pool volume by accumulating underneath the surface ice cover and on the streambed under surface cover. Spatial extent may not be known accurately, but duration as long as a week should have only occurred in P5-8 during the second freeze-up. Historical records at Cain Ranch showed less fluctuation and less severe winters in the first decade of the twenty-first century than in the last decade of the twentieth century. The highest netAFDD value of 1,075 in the past 20 years was routinely observed in the northern and/or mountain regiosn with well established brown trout populations, such as Montana and Wyoming. NetAFDD values during the past two winters were around the mean netAFDD of past 10 years, and netAFDD values observed in Mono Basin were relatively low comparing to those regions.

Ice will occur in Mono Basin tributaries because mean monthly air temperature falls below 32°F in December and January; however mean maximum monthly air temperature remain above 32°F in winter months. Thus, this raises the questions of 1) how extensive can ice cover be locally and within the framework of the study area (Lee Vining and Rush creeks below water diversion points) and 2) how long such an event will last? Extensive subsurface ice buildups were observed and their spatial extent could include many more high gradient riffles and high quality pools than observed in the study, but durations of such buildups were mostly as short as a few hours in the morning once the sun rose. Lake fog and precipitation appear to prevent anchor ice formation by shielding the area from extreme cold temperature and reducing the surface area available for heat exchange. In the past two winters, we identified the occurrence of freeze-ups three to four times per winter, during which maximum daily air temperature (θ) dropped below 32°F. Ice cover extents were higher during freeze-up periods than periods between freeze-up periods. Weekly visits, however, only provided us with snapshots in time which might (or not) have missed the peak extent of surface and subsurface ice covers and would have certainly missed the daily fluctuations of ice covers. The time lapse camera was an invaluable tool during the winter of 2010-11 because the time lapse photos taken at a one hour interval showed presence/absence and extent of surface and subsurface ice in a much finer scale. Ice cover extent was not quantifiable precisely, but surface and subsurface ice cover estimates were easily done in the shallow part of the Tran_DR area. It was also clear how much reduction of ice cover had occurred in the course of the day. Time lapse photos captured daily dislodgement of anchor ice during a majority of the winter days when anchor ice was observed in the early morning. Maximum daily air temperature (θ) is an important parameter for daily dislodging processes since ice starts to melt when ambient temperature rises above 32°F. However, anchor ice did not persist throughout the day even when θ < 32°F. It is more likely due to short wave radiation input into the streambed, which is more effective warming water and melt ice than convection between air and water. In the Mono Basin, the angle of solar incidence is higher than those found in higher latitudes, resulting in a larger component of solar radiation input as both short and long wave radiations. It was also determined that the number of consecutive days of θ<32°F was limited in the Mono Basin. Lee Vining showed five such days (longest among four temperature stations) in the winter of 2010-11, while Cain Ranch showed only two days.

Extensive anchor ice formations were found on 22 days, which covered the entire shallow part of the area leaving less than a third of the transect ice free, but only three of those 22 days showed anchor ice persisting for more than one day. This suggests frequent occurrences of formation and break up processes in a much shorter period than a week, and this daily break up process also applies to extensive anchor ice cover. Surface cover was found to persist for more than a week depending on precipitation and surface ice forming process. Water flowing over frazil ice cover was observed to form thick ice sheets; which, in turn, became shelf ice in the afternoon or following day. Shelf ice seems to persist longer than surface ice because it does not experience the mechanical force of flowing water and also air between water and ice is a poor conductor of heat. Lake fog could have reduced short wave radiation and also could have shielded the area from extreme cold temperature. The former effect was not very clearly shown by comparing presence/absence and duration of the lake fog from Mono Lake WebCam to those of subsurface ice formations, but the fog effect shielding the area from extreme cold temperature seemed present especially between January 6 and 9 during the second freeze-up period. During this period no or very little anchor ice was present even though maximum daily air temperature was mostly below 32°F. However, this period also followed a heavy snow fall which reduced the surface area of the creek available for heat exchange with air, suggesting decreased frazil ice production.

Occurrence and duration of anchor ice in the Tran_DR area may be applicable for extensive anchor ice and ice dam formations observed upstream during the qualitative survey. The qualitative survey was done on the same day as the survey in Section D, and occurrence and extent of anchor ice in the Tran_DR area appeared to coincide with that of upstream locations. A majority of anchor ice formation was not detected by the weekly visit in Section D, but the time lapse photos revealed 46 days when anchor ice formed. The upstream locations should have experienced similar occurrence of the subsurface ice formations because of proximity of Tran_DR to many upstream locations, concurrence of anchor ice between Tran_DR and those upstream locations, and also general cooling trend of water temperature below Section E.

Reductions of pool volume in P5-8 were observed during all three freeze-up periods with a varying degree of extent and in P4-5 during the second freeze-up period. This difference is interesting because P4-5 is located immediate downstream of a long, high gradient reach, below US Hwy 395, and the flow was eight to ten cfs lower in P4-5. A combination of this geomorphic feature and lower flow should lead to more extensive ice cover in P4-5. Before the ice survey of 2010-11, it was expected this high gradient reach would be the source of frazil ice, which would accumulate in P4-5; thus the only high quality pool in the reach would be most adversely affected by the winter baseflow. But P5-8, located approximately 0.5 mile (800m) downstream of P4-5, was more strongly affected by frazil ice accumulation than P4-5. However, water temperatures were higher at Rush above Parker Creek Confluence than at P5-8 and the Narrows (next upstream temperature station from P5-8). Rush Creek cools off gradually from MGORD to County Road. Warmer and more stable water releases from the bottom of Grant Lake Reservoir may have prevented frequent frazil ice production reaches between MGORD and Rush Creek above the Parker Creek Confluence in spite of lower stream flow and a higher gradient reach. It is also possible that addition of colder water from Walker and Parker creeks contribute to further net heat loss in Rush Creek. Therefore, general cooling of Rush Creek and augmentation of colder water may have resulted in more frequent frazil ice production, which was observed in the pools below the Narrows.

Spatial extent of frazil slush ice accumulation in high quality pools cannot be estimated from observations from the two pools; however, duration of pool volume reduction in P4-5 and P5-8 can be estimated based on air and water temperatures, the time lapse photos taken at Lee Vining Creek, and lake fog inferred from Mono Lake WebCam. Because frazil ice slush accumulation was found in the eddy section of the pool, melting or ice breaking process should be more likely caused by thermal deterioration rather than mechanical breakdown. Above 32ºF water and air temperature along with short wave radiation which would melt ice directly and also indirectly by heating stream banks greatly contributed to the thermal deterioration. In P4-5, daily fluctuations of water temperature greater than 8°F were observed in 12 out of 14 days during which daily minimum water temperatures were below 32°F. In P5-8, however, no super-cooling was recorded while similar large daily fluctuations of water temperature were recorded. During the first and third freeze-ups, daily maximum water temperatures in both pools exceeded 40°F almost at a daily basis. However, during the second freeze-up water remained super-cooled for two days on December 30 and 31 in P4-5 (above Parker Confluence), and daily maximum water temperature was at 32.5°F for three days from December 30 to January 1 in P5-8, suggesting high frazil ice production during the period and high frazil slush accumulation during or/and following the period. Lake fog was present on January 1 and 2 and may have reduced short wave radiation input, but lake fog may have receded earlier in those two reaches in Rush Creek that what observed from Mono Lake WebCam because the two reaches were located further inland than what being captured by Mono Lake WebCam. Daily maximum air temperature (θ) recorded at Parker Creek Confluence was 37°F and 34°F on those two days. Above freezing maximum water and air temperature indicated that the frazil slush accumulation would have been greatest on December 30 and 31, but started to decay shortly after. Dislodgement of frazil ice slush may have been replenished over night because of consistently low daily minimum air temperature at Cain Ranch and consistent occurrences of super-cooling in Parker Creek Confluence and the Narrows even after December 31. Frazil ice production may have occurred at night and in the early morning at a daily basis, and may have been enough to replenish the frazil ice slush to the pools. Large snow accumulation on January 1 would have covered the surface ice and shielded the pool from high air temperature on January 3. Therefore, reduction of pool volume by frazil ice slush accumulation could have lasted as long as a week in P4-5 and P5-8 even though the area affected by the accumulation in P4-5 was much smaller than in P5-8.

Frazil ice slush accumulation in P4-5 and P5-8 in Rush Creek was, however, found longitudinally variable within a pool, such that complete freeze-up of a pool was not observed. In P4-5, the accumulation found on January 5 2011 was limited to the area immediately upstream of the wing dam or rock structure below P4-5, leaving a large portion of the pool frazil ice accumulation free. In P5-8 surface cover and slush accumulation was found thickest between the transect and a staff gauge plate installed approximately 5 ft downstream, but was either reduced or disappeared upstream of the transect and downstream of the staff gauge plate during freeze-ups. The thickness of 3 ft was recorded just downstream of the transect on February 23, but upstream of the transect had very little frazil slush accumulation. Thus, fish could have adjusted their holding habitats within the pool.

Occurrence of subsurface ice buildups in the forms of extensive anchor ice and ice dam formations and frazil slush accumulation underneath surface ice were observed in the Mono Basin tributaries during the winter of 2010-11, and have occurred before and will occur again in future. How does lower winter baseflow contribute to such occurrences? How do such subsurface ice buildups affect fish population? It is not clear how lower winter baseflows could affect ice formation. The previous study in Lee Vining Creek was conducted under higher baseflows (CDFG 1993), but the winter temperature regime based on monthly mean temperatures were different among three winters their study was conducted. The flow was increased somewhat gradually from less than 10 cfs in December to more than 40 cfs in February in the winter of 1989-90, the first winter of CDFG study, Extensive anchor ice cover was noted only during February 1990. During the winter of 1990-91, Lee Vining Creek's flow was more stable around 15 cfs and very little or no anchor ice was found. These two findings lead to the conclusion that higher flow (>40cfs) resulted in more anchor ice formation while lower flows led to ice bridges which limited anchor ice formations. However, monthly air temperatures during those two winters revealed more climate driven processes. The mean monthly temperature of February 1990 was second coldest in 20 years, thus regardless of the flow regime extensive anchor ice would have formed. On the other hand, in the winter of 1990-91, the mean monthly temperature of December was fourth coldest in 20 years, which could have resulted in extensive anchor ice formations. This anchor ice in turn could have turned into shelf ice as captured by the time lapse camera during our study in the winter of 2010-11, and would have persisted throughout December. Therefore, the timing of freeze-ups does strongly affect type and extent of ice covers in Lee Vining Creek.

There was a difference of 6 cfs in Lee Vining Creek's winter baseflows between the winters of 2009-10 and 2010-11, and it can be argued that higher baseflows during the winter of 2010-11 would have resulted in higher water temperatures because most of the water temperature statistics were higher during the winter of 2010-11 than the winter of 2009-10. Those statistics, however, need a closer look. In the winter of 2010-11, the Upper Lee Vining Creek (below Intake, Section B, and Section C) shows longer periods of mean and minimum water temperature below 32°F meanwhile the opposite was true for the Lower Lee Vining (Sections D, E, and F). Colder water was released from Intake, but water was found much warmer downstream. This trend was opposite from the winter of 2009-10, during which progressive cooling was observed throughout the winter. A warming trend suggests water temperature regime was influenced by groundwater recharge and climate rather than stream discharge. However, the timing and duration of the freeze-ups were also different between the two winters, which also would have contributed reduced ice extent in the winter of 2010-11 from the winter of 2009-10. It is, thus, very difficult to compare extent of ice formations among winters even under very similar flow regimes.

Effects on fish populations by winter river ice were very difficult to interpret because of other confounding factors, such as the summer temperature regime especially for Rush Creek, and because fish populations were not directly observed during winter. Thus, an inference must be made based on ice conditions of their winter holding habitats and a degree of stream flow imepedement by subsurface ice buildups and frazil slush accumulation underneath surface ice. Brown et al. (2000) found fish being flushed out of the winter holding habitats due to hanging dam; however, during two winters of ice study hanging dam or complete freeze-up of a pool was not observed in Lee Vining and Rush creeks. Frazil ice slush accumulation was found in the pools located in one side of the stream along the bank. A faster moving water section conveyed a majority or all of the stream flow and remained ice free through out the winter of 2010-11. Thus, it is unlikely that fish were forced out the pool because of elimination of the pool by frazil ice accumulation and by increased water velocity through the ice free space in the pool. Fish could have adjusted their holding locations within the same pool. Because of highly transient nature of subsurface ice formations, it is unlikely that adverse effects on winter holding habitats for more than a week.

We do not know how much pool volume was reduced or if these reductions affected the holding locations preferred by over-wintering brown trout. Spatial extent of the frazil ice accumulations was not clear, but they only appear in certain reaches. P4-5 in Rush Creek did not experience the similar extent and frequency of the accumulations, and no such frazil slush accumulations were observed in Lee Vining Creek pools. P4-5 and Lee Vining Creek pools in the Delta Section were located directly downstream of high gradient reaches with sparse canopy cover, and those reaches could be a source of frazil ice. But at the same time high gradient riffles are also susceptible for subsurface ice buildups, which would have limited frazil ice transport downstream. For Rush Creek, frazil ice production and subsurface ice buildups may be limited downstream from US Hwy 395 due to relatively warmer temperature readings in upstream of US Hwy 395. The highest number of days with super-cooling was found immediately below the Narrows and numbers were very low at below 10-Channel Falls and County Road (2 and 3 days respectively). Forty eight high quality pools are located between the Narrows and County Road (3.5 river miles) along with 36 low quality pools (Class 3 or less) (Knudson et al. 2009). Considering a high density of pools and fewer days with super-cooling, it is very unlikely that all the 48 high quality pools become affected by frazil slush accumulation simultaneously.

Subsurface ice build ups which could impede fish movement in the forms of ice dam were frequently during the winters of 2009-10 and 2010-11. This is, however, based on the assumption that fish are moving or forced to move during winter. Fish can be actively feeding during winter (Jenkins et al. 1991, Heggenes et al. 1993), but fish normally remain in their holding habitats through out winter (Brown et al. 2001, Jakober et al. 1998, Muhlheld et al. 2001, Taylor et al. 2009b). Because there was a little evidence suggesting elimination of fish winter holding habitats in Lee Vining and Rush creeks during two winter of the study, it is unlikely that extensive subsurface ice formations in the riffles would have adversely affected fish populations in those two streams. Therefore, fish populations in the Mono Basin tributaries would have been affected very little by winter icing events.

The past 20 years of netAFDD and numbers of days with θ<32ºF (daily maximum air temperature) show a trend toward warmer and less variable winter temperature regimes. Three highest netAFDD were found in 1991-92, 1992-93, and 1997-98, but not in the first decade of the twenty-first century. The largest numbers of days with θ<32ºF and longest numbers of consecutive days with θ<32ºF were also found in the 1990's. The past five years in particular show netAFDD below the 20 year average. It does not necessarily indicate that this warming trend will persist in future and it is not clear where this trend would fit into the trend based on much longer time scale, such as Pacific Decadal Oscillation and El Niño/Southern Oscillation. Global warming predicts warmer winter temperatures in the Eastern Sierra, thus the trend observed in 2000's is most likely to remain in the future. Even if netAFDD values close to the three highest values in the 20 year record were to occur, the highest value of 1,075 is found routinely in the regions where well established brown trout populations are found, such as Montana (Table 7). Values of netAFDD in the mountain and foothill areas surrounding those cities in Montana should be toward the higher ends of the given ranges. Therefore it is less likely that winters in Mono Basin adversely affect trout population in a significant manner especially when taking into account an increased angle of insolation in the Mono Basin which would most likely further reduce subsurface ice cover extent and duration.

Table 7. Historical values of netAFDD for Mono Basin and four cities in Montana. Average values of netAFDD ranges given on the freezing degree day map from NOAA National Operational Hydrologic Remote Sensing Center website were presented in the table. Values of net AFDD for Mono Basin were calculated based on temperature readings at Cain Ranch.
A mean value of 675 represent the range between 450 and 900, 700 between 500 and 900, 1,124 between 900 and 1,350, and 1,575 between 1,350 and 1,800.

	Mono Basin	Bozeman	Butte	Missoula	Great Falls
Elevation (ft)	6,887	4,772	5,474	3,201	3,398
Latitude	37.88°	45.68°	46.01°	46.87°	47.49°
2003-04	411	1,125	1,575	675	675
2004-05	506	1,125	1,125	700	700
2005-06	324	1,125	1,125	700	700
2006-07*	308	1,125	1,125	700	700
2008-09	204	1,125	1,575	1,125	1,125
2009-10	400	1,125	1,575	700	1,125
2010-11	273	1,125	1,575	1,125	1,575

*Data are missing starting from February 23, 2007, so that numbers may be slightly higher for numbers of days with daily maximum and minimum air temperatures below 32°F.

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