# Juvenile Salmonid Monitoring in Battle Creek, California, November 2007 through June 2008

USFWS Report
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**Juvenile Salmonid Monitoring in Battle Creek, California,**
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**Abstract-** In late November 2007, the U.S. Fish and Wildlife Service continued an ongoing juvenile salmonid monitoring project on Battle Creek, California, using rotary screw traps; however, only one trap was operated to estimate passage during the current report period. Battle Creek, a tributary of the Sacramento River, is important to the conservation and recovery of federally listed anadromous salmonids in the Sacramento River watershed because of its unique hydrology, geology, and habitat suitability for several anadromous species. Information about juvenile salmonid abundance and migration in Battle Creek is necessary to guide efforts at maintaining and eventually restoring populations of threatened and endangered anadromous salmonids. From late-November 2007 through June 2008, three runs of Chinook salmon *Oncorhynchus tshawytscha*, rainbow trout/steelhead *Oncorhynchus mykiss*, and eight species of non-salmonids were captured in the Upper Battle Creek (UBC) rotary screw trap. To determine rotary screw-trap efficiency, we conducted 19 valid mark-recapture trials at UBC trap during the period January 8 through March 25, 2008. Weekly trap efficiencies using naturally produced fall Chinook salmon varied from 1.8 to 5.5% with a season average of 3.8%. In conjunction with our regular mark-recapture trials, we began a paired mark-recapture study at the UBC trap to determine whether hatchery produced Chinook salmon could be used as surrogates for naturally produced salmon. Trap efficiencies during the 19 paired trials were higher for naturally produced fish than for hatchery fish ($t$=-2.25; $P$=0.030). Only naturally produced Chinook salmon trap efficiencies were used to estimate passage of Chinook salmon and steelhead. Initially, Chinook salmon run designations were made using length-at-date criteria developed for the Sacramento River; however, spring and fall Chinook salmon catch data was combined prior to calculating spring Chinook salmon passage estimates. The brood year 2007 spring Chinook salmon passage estimate at the UBC trap was 74,823. Only three late-fall Chinook salmon were captured at the trap so a passage estimate was not calculated. The passage estimate for age 1+ rainbow trout/steelhead at the UBC trap was 371 and 1,150 for brood year 2008 young-of-the-year.

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## Introduction

In recent decades, California has experienced declines in several of its wild salmon and steelhead populations. These declines have been linked to a variety of factors, but the development of federal, state, municipal, and private water projects is likely a primary contributing factor (Jones and Stokes 2005). Because of the declines, two populations of Chinook salmon (*Oncorhynchus tshawytscha*) and one population of steelhead (*O. mykiss*) in the Sacramento River watershed were listed as threatened or endangered under the Endangered Species Act (ESA) or the California Endangered Species Act (CESA).

Battle Creek, a tributary of the Sacramento River, is important to the conservation and recovery of federally listed anadromous salmonids in the Sacramento River watershed because of its unique hydrology, geology, and habitat suitability for several anadromous species and historical land uses (Jones and Stokes 2005). Restoration actions and projects that are planned or have begun in Battle Creek focus on providing habitat for the endangered Sacramento River winter Chinook salmon, the threatened Central Valley spring Chinook salmon, and the threatened Central Valley steelhead. Currently the geographic range of the winter Chinook salmon Evolutionary Significant Unit is small and limited to the mainstem of the Sacramento River between Keswick Dam and the town of Red Bluff, California, where it may be susceptible to catastrophic loss. Establishing a second population in Battle Creek could reduce the likelihood of extinction. Battle Creek also has the potential to support significant, self-sustaining populations of spring Chinook salmon and steelhead.

Since the early 1900's, a hydroelectric project comprised of several dams, canals, and powerhouses has operated in the Battle Creek watershed. The hydroelectric project, currently owned by Pacific Gas and Electric Company (PG&E), has had severe impacts upon anadromous salmonids and their habitat (Ward and Kier 1999), including a reduction of instream flows, barriers to migration, loss of habitat, flow related temperature impacts, etc.

In 1992, the Central Valley Project Improvement Act (CVPIA), federally legislated efforts to double populations of Central Valley anadromous salmonids. The CVPIA Anadromous Fisheries Restoration Program outlined actions to restore Battle Creek, which included increasing flows past PG&E's hydroelectric power diversions to provide adequate holding, spawning, and rearing habitat for anadromous salmonids (USFWS 1997). Prior to 2001, PG&E was required under its Federal Energy Regulatory Commission (FERC) license to provide minimum instream flows of 0.08 $m^3/s$ (3 cfs) downstream of diversions on North Fork Battle Creek and 0.14 $m^3/s$ (5 cfs) downstream of diversions on South Fork Battle Creek. However, from 1995 to 2001, the CVPIA Water Acquisition Program contracted with PG&E to increase minimum stream flow in the lower reaches of the north and south forks of Battle Creek. This initial flow augmentation provided flows between 0.71 and 0.99 $m^3/s$ (25 and 35 cfs) below Eagle Canyon Dam on the north fork and below Coleman Diversion Dam on the south fork.

In 1999, PG&E, California Department of Fish and Game (CDFG), U.S. Fish and Wildlife Service (USFWS), U.S. Bureau of Reclamation (USBR), and National Marine Fisheries Service (NMFS) signed a Memorandum of Understanding (MOU) to formalize the agreement regarding the Battle Creek Chinook Salmon and Steelhead Restoration Project (Restoration Project). The planning, designing, and permitting phases of the Restoration Project have taken longer than originally anticipated; therefore, funds for increased minimum flows in North and South Fork Battle Creek from the CVPIA Water Acquisition Program ran out in 2001. However, the federal and State of California interagency program known as the CALFED Bay-Delta Program (CALFED) funded the Battle Creek Interim Flow Project beginning in 2001 and will continue to until the Restoration Project begins. The intent of the Interim Flow Project (IFP) is to provide immediate habitat improvement in the lower reaches of Battle Creek to sustain current natural populations while implementation of the more comprehensive Restoration Project moves forward. Under the IFP, PG&E would maintain minimum instream flows at 0.85 $m^3/s$ (30 cfs) by reducing their hydroelectric power diversions from May to October. In 2001, funding for the IFP was provided for the north fork, but not the south fork. In 2002, some of the north fork IFP flows were reallocated to the south fork under an agreement which allows for changing flows on either of the forks based on environmental conditions (i.e., water temperatures, numbers and locations of live Chinook salmon and redds). Beginning in late 2002, the IFP began providing the full minimum flow of 0.85 $m^3/s$ (30 cfs) on both forks. In 2001, increased flows were provided only on the north fork in part based on observations of higher Chinook salmon spawning on the north fork than on the south fork. Redd counts from 1995 to 1998 indicated that 39% of spawning occurred in the north fork versus 23% in the south fork (J. M. Newton, USFWS, RBFWO, unpublished data).

The U.S. Fish and Wildlife Services' Red Bluff Fish and Wildlife Office (RBFWO) began using rotary screw traps to monitor downstream passage of juvenile salmonids on Battle Creek, Shasta and Tehama Counties, California, in September 1998 (Whitton et al. 2006). During the current report period, the RBFWO only operated the Upper Battle Creek trap to estimate downstream passage; however, the Lower Battle Creek trap was used to capture fall Chinook salmon for mark-recapture trials. In conjunction with our standard mark-recapture trials, we conducted a paired mark-recapture study using hatchery-produced fall Chinook salmon to determine whether they could be used as surrogates for the naturally produced Chinook salmon used in our regular trials. The purpose of this report is to summarize rotary screw trap data collected during the period November 28, 2007 through June 30, 2008. This ongoing monitoring project has three primary objectives: (1) determine an annual juvenile passage index (JPI) for Chinook salmon (salmon) and rainbow trout/steelhead (trout), for inter-year comparisons; (2) obtain juvenile salmonid life history information including size, condition, emergence, emigration timing, and potential factors limiting survival at various life stages, and (3) collect tissue samples for genetic analyses.

## Study Area

Battle Creek and its tributaries drain the western volcanic slopes of Mount Lassen in the southern Cascade Range. The creek has two primary tributaries, North Fork Battle Creek, which originates near Mt. Huckleberry and South Fork Battle Creek, which originates in Battle Creek Meadows south of the town of Mineral, California. North Fork Battle Creek is approximately 47.5 km (29.5 miles) long from the headwaters to the confluence and has a natural barrier waterfall located 21.7 km (rm 13.5) from the confluence (Jones and Stokes 2004). South Fork Battle Creek is approximately 45 km (28 miles) long and has a natural barrier waterfall (Angel Falls) located 30.4 km (rm 18.9) from the confluence (Jones and Stokes 2004). The mainstem portion of Battle Creek flows approximately 27.3 km (17 miles) west from the confluence of the two forks to the Sacramento River east of Cottonwood, California. The entire watershed encompasses an area of approximately 93,200 ha (360 $miles^2$; Jones and Stokes 2004). The current 39 km (24.4 miles) of anadromous fishery in Battle Creek encompasses that portion of the creek from the Eagle Canyon Dam on North Fork Battle Creek and Coleman Dam on South Fork Battle Creek to its confluence with the Sacramento River (Figure 1). Historically, the anadromous fishery exceeded 85 km (53 miles).

Battle Creek has the highest base flows of any of the Sacramento River tributaries between Keswick Dam and the Feather River, and flows are influenced by both precipitation and spring flow from basalt formations (Jones and Stokes 2005). The average flow in Battle Creek is approximately 14.1 $m^3/s$ (500 cfs; Jones and Stokes 2004). South Fork Battle Creek is more influenced by precipitation and likely experiences higher peak flows, whereas North Fork Battle Creek receives more of its water from snow melt and spring-fed tributaries. Maximum discharge usually occurs from November to April as a result of heavy precipitation. Average annual precipitation in the watershed ranges from about 64 cm (25 inches) at the Coleman Powerhouse to more than 127 cm (50 inches) at the headwaters, with most precipitation occurring between November and April (Ward and Kier 1999). Ambient air temperatures range from about 0ºC (32ºF) in the winter to summer highs in excess of 46ºC (115ºF).

Land ownership in the Battle Creek watershed is a combination of state, federal, and private including the CDFG, Bureau of Land Management (BLM), and USFWS. Most of the land within the restoration area is private and zoned for agriculture, including grazing. Currently, much of the lower Battle Creek watershed is undeveloped, with scattered private residences, ranching enterprises, and local entities.

The RBFWO installed and operated two rotary screw traps on Battle Creek in 1998, the first site was located 4.5 km (rm 2.8) upstream of the confluence with the Sacramento River, and the second site was located 9.5 km (rm 5.9) upstream of the confluence (Figure 1). A third rotary screw trap was operated during the 2005 to 2006 sample period, and was located 12.0 km (rm 7.5) upstream of the confluence, and 2.5 km (rm 1.6) upstream of the upper trap (Figure 1). The lower trap site was designated Lower Battle Creek (LBC), the upper trap site was designated Upper Battle Creek (UBC), and the third site was designated Powerhouse Battle Creek (PHBC). The UBC trap was the only trap operated continuously during the current report period. The stream substrate at these locations is primarily composed of gravel and cobble, and the riparian zone vegetation is dominated by California sycamore (*Plantanus racemosa*), alder (Alnus spp.), Valley oak (*Quercus lobata*), Himalayan blackberry (*Rubus discolor)*, California wild grape (*Vitis Californica*) and other native and non-native species.

## Methods

### *Rotary Screw Trap Operation*

In November 2007, the Red Bluff Fish and Wildlife Office continued the operation of two rotary screw traps on Battle Creek. The rotary screw traps, manufactured by E.G. Solutions® in Corvallis, Oregon, consist of a 1.5-m diameter cone covered with 3-mm diameter perforated stainless steel screen. The cone, which acts as a sieve separating fish and debris from the water flowing through the trap, rotates in an auger-type action passing water, fish, and debris to the rear of the trap and directly into an aluminum live box. The live box retains fish and debris, and passes water through screens located in the back, sides, and bottom. The cone and live box are supported between two pontoons. Two 30 to 46-cm diameter trees on opposite banks of the creek were used as anchor points for securing each trap in the creek, and a system of cables, ropes and pulleys was used to position the traps in the thalweg. In prior years, modifications were made to the traps to reduce potential impacts to captured fish and to improve our efficiency. Modifications to traps included increasing the size of the live boxes and flotation pontoons, and adding baffles to the live boxes. However, during the current report period, the baffles were removed from the live box because of concerns they may increase mortality during periods of high debris. The debris appeared to build up behind the first set of baffles, reducing the ability of fish to swim towards the back of the trap box.

During the current report period, the Upper Battle Creek trap (UBC) was operated from November 28, 2007 through June 30, 2008. The Lower Battle Creek trap (LBC), which was only used to capture naturally produced fall Chinook salmon for use in mark-recapture trials to estimate trap efficiency at the Upper Battle Creek Trap (UBC), was operated for 1 or 2 d prior to marking. The UBC trap installation date was determined using water temperatures and spawning dates to estimate the time of emergence. Redd observations during our snorkel surveys were used to determine spawning dates. We attempted to operate the UBC trap 24 h per day; 7 d each week, but at times high flows and trap repair limited our ability to operate the trap continuously (Appendix 1). The trap was not operated when stream flows exceeded certain levels in order to prevent fish mortality, damage to equipment, and to ensure crew safety. For the periods November 27 to December 15, 2007 and February 4 to June 30, 2008 the trap was checked once per day unless high flows, heavy debris loads, or high fish densities required multiple trap checks to avoid mortality of captured fish or damage to equipment. From December 16, 2007 to February 3, 2008, the trap was checked at least twice a day to reduce the potential for mortality of threatened spring Chinook salmon. High flows, debris loads, and fish densities are possible during this time. When flows allowed, the crews were able to access the trap by wading from the stream bank; however, during high flows access to the trap required that the crews use the cable and pulley system to pull the trap into shallow water. After or during sampling and maintenance, the trap was repositioned in the thalweg.

To reduce the potential mortality of fish captured in the trap, the UBC trap was operated with the half-cone modification from November 28, 2007 through February 16, 2008 and February 21 to April 8, 2008. The half-cone modification allows half of the fish and debris to be discharged from the cone back into the creek, effectively reducing our catch of fish and debris by half (Whitton 2007c). The trap was operated at full-cone for the remainder of the reporting period. The LBC trap was always operated at full cone to ensure sufficient numbers of fall Chinook salmon were available for mark-recapture trials.

Each time the UBC trap was sampled, crews would sample fish present in the live box, and remove debris from the cone and live box. During the primary daytime clearing, the crew would also collect environmental and trap data, and complete any necessary trap repairs. Data collected at the trap included, dates and times of trap operation, water depth at the trap site, cone fishing depth, number of cone rotations during the sample period, cone rotation time, amount and type of debris removed from the live box, basic weather conditions, water temperature, water velocity entering the cone, and turbidity. Water depths were measured to the nearest 0.03 m (0.1 feet) using a graduated staff. The cone fishing depth was measured with a gauge permanently mounted to the trap frame in front of the cone. The number of rotations of the RST cone was measured with a mechanical stroke counter (Reddington Counters, Inc., Windsor, CT) that was mounted to the trap railing adjacent to the cone. The amount of debris in the live box was volumetrically measured using a 44.0 liter (10-gallon) plastic tub. Water temperatures were measured every 30 min with an instream Onset Optic Stow Away® temperature data logger. Water velocity was measured as the average velocity from a grab-sample using an Oceanic® Model 2030 flowmeter (General Oceanics, Inc., Miami, Florida). The average velocity was measured for a minimum of 5 min while the live box was being cleared of debris. Water turbidity was measured from a grab-sample with a Hach® Model 2100 turbidity meter (Hach Company, Ames, Iowa). In addition, daily stream discharge data collected by the U.S. Geological Survey at the Coleman Hatchery gauging station (#11376550) was also used for trap operations and to allow comparisons of discharge and downstream migration patterns. The gauge site is located below the Coleman Fish Hatchery barrier weir and approximately 0.2 km downstream of the UBC trap (Figure 1).

*Biological Sampling*

Juvenile sampling at the UBC trap was conducted using standardized techniques that were generally consistent with the CVPIA's Comprehensive Assessment and Monitoring Program (CAMP) standard protocol (CVPIA 1997). Dip nets were used to transfer fish and debris from the live box to a sorting table for examination. Each day the trap was sampled, all fish were counted and then depending on the species, either fork length (FL) or total length (TL) was measured from a minimum number of each species. Mortalities were also counted and measured. Live fish to be measured were placed in a 3.8-L (1-gallon) plastic tub and anesthetized with a tricaine methanesulfonate (MS-222; Argent Chemical Laboratories, Inc. Redmond, Washington) solution at a concentration of 60 to 80 mg/L. After being measured, fish were placed in a 37.8-L (10-gallon) plastic tub filled with fresh water to allow for recovery before being released back into the creek. Water in the tubs was replaced as necessary to maintain adequate temperature and oxygen levels. All live fish captured in the trap were released downstream of the trap. When the trap was checked more than once a day, fish were only measured during the primary daytime sample, otherwise only the number (all species) and lifestage (salmonids) were recorded. Catch data for all fish taxa were typically summarized as either weekly totals for salmonids or season totals for non-salmonids. Different criteria were used to sample salmon, trout, and non-salmonid species.

*Chinook salmon.*—When less than approximately 250 salmon were captured in the trap, all salmon were counted and FL was measured to the nearest 1 mm. When more than 250 juvenile salmon are captured, subsampling occurs as described in Whitton et al. (2007a); however, during the current reporting period no subsampling occurred because the total catch for any daytime trap check did not exceed 250 fish. All measured juvenile salmon were assigned a life-stage classification of yolk-sac fry (C0), fry (C1), parr (C2), silvery parr (C3), or smolt (C4), and a run designation of fall, spring, late-fall, or winter. Life-stage classification was based on morphological features and run designations were based on length-at-date criteria developed by Greene (1992). To obtain information on condition factor, Chinook salmon >50 mm were weighed to the nearest 0.1 g. Condition factor data will be summarized in a later report. If the trap was checked multiple times in addition to the primary daytime check, only numbers and lifestage were recorded for Chinook salmon.

The length-at-date criteria used to assign a run designation was developed for the Sacramento River, and we have determined that it cannot be directly applied to juvenile Chinook salmon captured in the UBC trap. Management of adult passage allows for passage of spring Chinook salmon, and unclipped late-fall Chinook salmon and steelhead above the hatchery's barrier weir, but excludes passage of fall Chinook salmon. Juvenile Chinook salmon assigned either a spring or fall Chinook salmon run designation were considered to be spring Chinook salmon at the UBC trap; therefore, data were combined for these two run designations prior to analyses and summarization. All other Chinook salmon runs were individually summarized by brood year if sufficient numbers were captured. Length data for all Chinook salmon runs were combined for graphical purposes.

Genetic samples were collected from a select number of Chinook salmon throughout the sample period to use as an alternative method for determining run designation. A 2-$mm^2$ tissue sample removed from the upper or the lower lobe of the caudal fin was divided into three equal parts and placed in 2-ml triplicate vials containing 0.5 ml of ethanol as a preservative. The triplicate samples were collected for: 1) USFWS archive, 2) CDFG archive, and 3) analysis by a genetics laboratory.

*Rainbow trout/steelhead*.—Due to the smaller numbers encountered, all rainbow trout/steelhead captured in the trap were counted and FL measured to the nearest 1 mm. Life stages of juvenile trout were classified similarly as salmon {i.e., yolk-sac fry (R1), fry (R2), parr (R3), silvery parr (R4), and smolt (R5)} as requested by the Interagency Ecological Program (IEP) Steelhead Project Work Team. All live rainbow trout/steelhead > 50 mm were weighed to the nearest 0.1 g for CDFG's Stream Evaluation Program. If the trap was checked multiple times in addition to the primary daytime check, only numbers and lifestage were recorded for rainbow trout/steelhead.

*Non-salmonid taxa*.—All non-salmonid taxa that were captured were counted, but we only measured approximately 20 randomly selected individuals of each taxa. Total length was measured for lamprey *Lampetra spp.*, sculpin *Cottus spp.*, and western mosquitofish (*Gambusia affinis*); otherwise, FL was measured for all other non-salmonid taxa. Non-salmonids were not the focus of this monitoring project; therefore, only total catch by species is provided in this report but length data is available for the measured subsample of those captured in the trap.

*Trap Efficiency and Juvenile Salmonid Passage*

One of the goals of our monitoring project was to estimate the number of juvenile salmonids passing downstream in a given unit of time, usually a week and brood year. We defined this estimate as the juvenile passage index (JPI). Since each trap only captures fish from a small portion of the stream cross section, we use trap efficiencies, which are determined using mark-recapture methods, and the weekly catch to estimate weekly and annual JPI's. For days when the trap was not fishing, daily catch was estimated by averaging an equal number of days before and after the days not fished. For example, if the trap did not fish for 2 d, the daily catch for those days was estimated by averaging catch from 2 d before and 2 d after the period the trap did not fish. However, if one of the days before or after was also a missed day, it was usually not used to estimate other missed days. For example, if the trap did not fish for 3 d, but one of the 3 d before was also a missed day, then catch from the 2 d before and 3 d after the missed period were used to estimate catch. If partial catch data was available for a missed sample day, the information was only used when the daily catch estimated using the methods described above resulted in a smaller daily catch.

*Mark-recapture trials.*—Mark-recapture trials were conducted to estimate trap efficiency. Ideally, separate mark-recapture trials should be conducted for each species, run, and life-stage to estimate species and age-specific trap efficiencies. However, catch rates for steelhead, spring, and late-fall Chinook salmon were too low to conduct separate trials; therefore, all species and life-stage passage estimates were estimated using fall Chinook salmon fry trap efficiencies. Outmigration at the UBC trap typically begins in mid to late November and continues through mid to late June. Mark-recapture trials are usually conducted from early January through mid to late April when sufficient numbers of Chinook salmon are available in the LBC trap. Although sufficient numbers of fish may be available in December, it is possible that a higher proportion of spring Chinook salmon are present; therefore to reduce any potential impacts we do not conduct trials at this time.

*Paired mark-recapture study*.—During the 2007-2008 season, we conducted a paired mark-recapture study to determine whether hatchery produced fall Chinook salmon could be used as surrogates for estimating trap efficiency of naturally produced Chinook salmon. Coleman National Fish Hatchery provided hatchery fall Chinook salmon, and naturally produced fall Chinook salmon were captured using the LBC trap. To reduce the potential for size related differences in trap efficiency, we selected hatchery fish that were of similar size to our naturally produced Chinook salmon. We conducted two trials each week during the period December 30, 2007 through April 7, 2008; however, during a few weeks high flow events or fish availability limited us to one trial. During this period, seven unpaired hatchery trials were conducted when insufficient numbers of naturally produced fish were available for marking.

In preparation for marking, the LBC trap was set 1 to 2 d prior to marking to ensure sufficient numbers of naturally produced Chinook salmon were available. Hatchery fish were removed from the raceway on the day of marking. Two marks were used for most trials; however, during one trial naturally produced fish only had one mark applied to allow for visual differentiation of hatchery and naturally produced fish underwater. To apply the first mark, juvenile salmon were anesthetized with an MS-222 solution at a concentration of 60 to 80 mg/L. Once anesthetized, a small portion of the caudal fin was removed with a scalpel. With the exception of one trial, an upper caudal fin-clip was applied to naturally produced Chinook salmon and a lower caudal fin-clip was applied to hatchery fish. During one trial, the clip location was reversed to determine whether clip location affected trap efficiency. The switch was made during a period of stable flows. After the fin-clipped salmon had recovered in fresh water, they were placed in a live-car and immersed in Bismark brown-Y stain (J. T. Baker Chemical Company, Phillipsburg, New Jersey) for 50 min at a concentration of 8 g/380 L of water (211 mg/L). During the primary marking phase (fin-clips), we measured approximately 30 to 70 fish to allow for length comparisons between hatchery and naturally produced fish. To determine any potential 24-hour mortality, marked salmon were generally held overnight and released the next day. Hatchery and naturally produced fish were held in separate live-cars in the trapbox to allow for ease in counting, but were mixed prior to release. Mortalities and injured fish were removed and the remaining fish were counted and released. All salmon marked for UBC trials were released at the Coleman National Fish Hatchery's Intake 3 located 1.6 km (1.0 mi) upstream of the trap (Figure 1). To allow for even mixing with unmarked fish, the marked fish were released in small groups from the river-right bank. With the exception on one trial, marked fish were released at dusk or after dark to reduce the potential for unnaturally high predation on salmon that may be temporarily disorientated during transportation, and to simulate natural populations of outmigrating Chinook salmon which move downstream primarily at night (Healey 1998; J. T. Earley, USFWS, RBFWO, unpublished data). Marked Chinook salmon that were recaptured in the trap were counted, measured, and subsequently released downstream of the trap to prevent them from being recaptured again.

During one trial, we conducted an underwater observation experiment to determine whether hatchery and naturally produced Chinook salmon exhibited observable differences in behavior upon release. Released fish were comprised of three groups: hatchery, naturally produced, and a mixed group. The individual groups were dual marked as described above; however, naturally produced fish in the mixed group were only marked with a fin-clip to allow for differentiation from hatchery fish underwater. Three observers dressed in dry suits, masks, and snorkels were located across the channel while a fourth individual released approximately one third of each group upstream of each observer. Observers were not told which of the individual groups was being released to reduce any potential influence on observations. The three observers watched their group of fish as long as possible. Flow conditions were variable at the three release sites.

*Trap efficiency.*—Trap efficiency was estimated using a stratified Bailey's estimator, which is a modification of the standard Lincoln-Peterson estimator (Bailey 1951; Steinhorst et al. 2004). The Bailey's estimator was used as it performs better with small sample sizes and is not undefined when there are zero recaptures (Carlson et al. 1998; Steinhorst et al. 2004). In addition, Steinhorst et al. (2004) found it to be the least biased of three estimators. Trap efficiency was estimated by

$$\hat{E}_h = \frac{(r_h + 1)}{(m_h + 1)}, \tag{1}$$

where $m_h$ is the number of marked fish released in week $h$ and $r_h$ is the number of marked fish recaptured in week $h$. Although trap efficiency was calculated for all mark-recapture trials, only those naturally produced Chinook salmon trials with at least seven recaptures were used to estimate passage as suggested by Steinhorst et al. (2004; Table 2). If two mark-recapture trials were conducted during the same week, the results were combined to calculate the average weekly trap efficiency. Juvenile Chinook salmon downstream passage at the UBC trap was not estimated using trap efficiencies for hatchery fish.

The goal of our paired mark-recapture study was to determine whether hatchery fish could be used as surrogates for naturally produced fish; therefore, we included the results from all valid trials in our statistical comparison, whether or not there were seven recaptures. Trap efficiencies for hatchery and naturally produced fish were compared using a two-sample t-test. The influence of fork length and flow on trap efficiency was briefly explored.

*Juvenile passage index(JPI).*—Weekly JPI estimates for Chinook salmon and rainbow trout/steelhead were calculated using weekly catch totals and either the weekly trap efficiency, pooled trap efficiency, or average season trap efficiency. The average season trap efficiency for all half-cone trials was doubled to estimate passage during weeks when the trap was operated at full cone (April 9 to June 30, 2008). The results from our hatchery trials were not used to estimate passage of Chinook salmon at the UBC trap. A juvenile Chinook salmon JPI was only calculated for brood year 2007 spring Chinook salmon at UBC trap because there were insufficient numbers of late-fall Chinook salmon captured in the trap. All life stages of fall and spring Chinook salmon were combined. A juvenile passage index was calculated for rainbow trout/ steelhead and summarized as either young-of-the-year (yoy) or age 1+, which included individuals from all other age classes The fork length distribution (fork length by date) of rainbow trout/steelhead captured in the trap was used to determine weekly catch of young-of-the-year and age 1+. With few exceptions, graphical display of fork length distribution indicated a distinct separation of the two groups. In addition, age 1+ and young-of-the-year rainbow trout/steelhead captured during the same week could usually be distinguished by their life-stage classification.

The season was stratified by week because as Steinhorst et al. (2004) found, combining the data where there are likely changes in trap efficiency throughout the season leads to biased estimates. Using methods described by Carlson et al. (1998) and Steinhorst et al. (2004), the weekly JPI's were estimated by

$$\hat{N}_h = \frac{U_h}{\hat{E}_h}, \tag{2}$$

where $U_h$ is the unmarked catch during week *h.* The total JPI for the year is then estimated by

$$\hat{N} = \sum_{h=1}^{L} \hat{N}_h \tag{3}$$

where $L$ is the total number of weeks. Variance and the 90 and 95% confidence intervals for $\hat{N}_h$ each week were determined by the percentile bootstrap method with 1,000 iterations (Efron and Tibshirani 1986; Buckland and Garthwaite 1991; Thedinga et al. 1994; Steinhorst et al. 2004). Using simulated data with known numbers of migrants, and trap efficiencies, Steinhorst et al. (2004) determined the percentile bootstrap method for developing confidence intervals performed the best, as it had the best coverage of a 95% confidence interval. Each bootstrap iteration involved first drawing 1,000 $r*_{hj}$ (j=1, 2…, 1000; asterisk indicates bootstrap simulated values) from the binomial distribution ($m_h$, $\hat{E}_h$)(Carlson et al. 1998) and then calculating 1,000 $\hat{N}*_{hj}$ using equations (1) and (2), replacing $r_h$ with $r*_{hj}$. The 1,000 bootstrap iterations of the total JPI ($\hat{N}*_j$) were calculated as

$$\hat{N}*_j = \sum_{h=1}^{L} \hat{N}*_{hj} \ . \qquad (4)$$

As described by Steinhorst et al. (2004), the 95% confidence intervals for the weekly and total JPI's were found by ordering the 1,000 $\hat{N}*_{hj}$ or $\hat{N}*_j$ and locating the 25$^{th}$ and 975$^{th}$ values. Similarly, the 90% confidence intervals for the weekly and total JPI's were found by locating the 50$^{th}$ and 950$^{th}$ values of the ordered iterations. Ordering was not performed until after the $\hat{N}*_j$ were derived. The variances for $\hat{N}_h$ and $\hat{N}$ were calculated as the standard sample variances of the 1,000 $\hat{N}*_{hj}$ and $\hat{N}*_j$, respectively (Buckland and Garthwaite 1991).

## Results

*Rotary Screw Trap Operation*

During the current report period, the UBC trap was operated continuously from November 28, 2007 to June 30, 2008, except during high flows and periods of trap repair (Appendix 1). The trap was not operated from July 1 to November 27, 2007 because sampling from previous years has shown that little or no salmonid outmigration occurs during that time (Whitton et al. 2006, Whitton et al. 2007a). In addition, analyses of temperature data and spring Chinook salmon spawning dates predicted that juvenile emergence would begin in early December. Of the 366 d available, the trap was operated approximately 208 d. The period of little or no salmonid catch, July 1 to November 27, 2007 accounted for 150 of 158 missed sample days (95%) and high flows and trap repairs accounted for the remaining 8 d (5%). The monthly sampling effort varied from a low of about 1% in November 2007 to a high of 100% for several months (Figure 2, Appendix 1).

Mean daily water temperatures at the UBC trap varied from a low of 5.0ºC (41.0ºF) on January 21, 2008 to a high of 24.0ºC (75.1ºF) on July 7, 2008 (Figure 3). Mean daily flow measured by the U.S. Geological Survey at the Coleman Hatchery gauging station (#11376550) varied from a low of 6.8 $m^3/s$ (241 cfs) in early to late November 2007 to a high of 42.9 $m^3/s$ (1,514 cfs) on January 4, 2008 (Figure 4). During the period of trap operation, there were only 3 d when flows exceeded 42.5 $m^3/s$ (1,500 cfs) with a peak flow of 50.1 $m^3/s$ (3,190 cfs) occurring on January 4, 2008 (Figure 5). Turbidity at the UBC trap varied from a low of 1.04 NTU's on December 14, 2007 to a high of 9.6 NTU's on February 23, 2008 (Figure 5). In general, turbidity increased with increasing flows, but increases in turbidity did not always accompany similar increases in flow. However, turbidity was only measured when the trap was operating; therefore, it is likely that turbidity was higher during high flow events.

*Biological Sampling*

*Upper Battle Creek (UBC) salmonids*.—According to the length-at-date criteria, 56 spring and 2,910 fall Chinook salmon were captured in the UBC trap; however, based on adult management at the barrier weirs, fall-run were considered to be spring Chinook salmon; therefore, they were combined for analyses. Brood year 2007 (BY07) spring Chinook salmon were first captured at the UBC trap the week of December 2, 2007 with a peak weekly catch of 1,123 the week of January 6, 2008 (Figure 6). The last BY07 spring Chinook salmon was captured June 22, 2008. The total catch of BY07 juvenile spring Chinook salmon at the UBC trap was 2,966. However, after adjusting the total catch for days the trap was not operated, the adjusted total catch was 2,446. Only three brood year 2008 (BY08) late-fall Chinook salmon were captured in the UBC trap, and according to the length-at-date criteria, no winter Chinook salmon were captured; therefore, no additional information will be provided for these runs.

Fork lengths of spring Chinook salmon sampled at the UBC trap varied from 31 to 128 mm with a mean fork length of 40 mm (N=1,768; Figure 7 and 8). Length frequency data for all runs were combined because fall and spring-run were already combined, and only three late-fall were captured in the trap. Approximately 90% of all Chinook salmon captured in the UBC trap had fork lengths ≤40 mm (Figure 8). The life-stage composition of spring Chinook salmon captured at the UBC trap was 0.1% yolk-sac fry, 90% fry, 0.7% parr, 2.5% silvery parr, and 6.7% smolt (Table 1 and Figure 9).

During the reporting period, 19-age 1+ and 83 young-of-the-year (yoy) rainbow trout/steelhead were captured in the UBC trap. They were first captured the week of December 7, 2007 with a peak weekly capture of 27 occurring the week of May 18, 2008 (Figure 10). The actual rainbow trout catch at the UBC trap was 102; however, after adjusting the total catch for days the trap was not operated, the adjusted total catch was 96. No young-of-the-year were captured at the trap until March 25, 2008, with most being captured after April 29 (Figure 10). Fork lengths of rainbow trout/steelhead ranged 23 to 270 mm with a median fork length of 65mm (N=96; Figure 11 and 12). Young-of-the-year rainbow trout/steelhead were 87.5% of all trout captured at the trap and had fork lengths <120 mm (Figure 12). The life-stage composition of all rainbow trout/steelhead was 8.4% fry, 75.8% parr, 12.6% silvery parr, and 3.2% smolt (Table 1 and Figure 13).

*Upper Battle Creek (UBC) non salmonids.*—From November 28, 2007 through June 30, 2008, eight native non-salmonid species were captured in the UBC trap, including California Roach, Hesperoleucus symmetricus (N=5), hardhead, *Mylopharodon conocephalus* (N=334), Pacific lamprey, Lampetra tridentata (N=69), riffle sculpin, *Cottus gulosus* (N=119), Sacramento pikeminnow, *Ptychocheilus grandis* (N=30), Sacramento sucker, *Catostomus occidentalis* (N=805), tule perch, *Hysterocarpus traski* (N=3), threespine stickleback, *Gasterosteus aculeatus* (N=3), and Western Brook lamprey, *Lampetra richardsoni (*N=3) (Appendix 2 and 3). No introduced species were captured in the UBC trap. Cottid, cyprinid, centrarchid, and lamprey fry that could not be identified to species were also captured at the trap. Besides Chinook salmon, Sacramento suckers and hardhead were the next most abundant species captured in the UBC trap.

*Trap Efficiency and Juvenile Salmonid Passage*

*Upper Battle Creek trap efficiency (UBC).*—During the current report period, twenty-two mark-recapture trials, using naturally produced Chinook salmon, were conducted at the UBC trap from January 8 to March 25, 2008 (Table 2). The results of three trials were not used to estimate passage. One trial was incomplete because the trap was pulled early during a storm event, during the second trial fish were released during daylight hours; therefore, the trial can not be directly compared to other trials, and finally the third trial was conducted at full-cone and the results were again not directly comparable to other trials. Of the 19 trials used to estimate passage, 14 had at least seven recaptures as recommended by Steinhorst et al. (2004; Table 2). The five trials with less than seven recaptures were pooled either with other trials conducted during the same week or with trials conducted during an adjacent week (March 25, 2008). During nine of the twelve weeks that trials were conducted, two separate mark-recapture trials were conducted each week, the results of which were pooled prior to calculating a weekly trap efficiency or passage. Weekly trap efficiencies for the valid pooled and unpooled trials varied from 0.018 to 0.056, with a season average trap efficiency of 0.038. During the report period, the season average trap efficiency for all half-cone trials was used to estimate passage for 5 weeks when the trap was operating with the half cone modification (December 2, 2007 to January 5, 2008). The half-cone season average was doubled and used to estimate passage for 13 weeks when the trap was operated at full-cone (April 6 to June 30, 2008).

*Paired mark-recapture study*.—Twenty-two paired mark-recapture trials were conducted at the UBC trap, and of those, 19 were included in the analyses (Table 3). We also conducted seven additional unpaired hatchery trials, two of which occurred prior to any paired trials and the remaining five occurred at or near the end of the study (Table 3 and Figure 14). Trap efficiencies for hatchery fish varied from 0.013 to 0.070 with a median of 0.025 for paired trials and 0.028 for all trials. Naturally produced Chinook salmon trap efficiencies varied from 0.013 to 0.069 with a median trap efficiency of 0.040. Trap efficiencies of naturally produced Chinook salmon were significantly higher than trap efficiencies of hatchery fish ($t$=-2.25; $P$=0.030). Of the 19 paired trials included in the analyses, trap efficiency for naturally produced fish was higher in 14 trials (Table 3 and Figure 14).

Flow is often correlated with trap efficiency; however, during our study, there did not appear to be any relationship between flow at the time of release and naturally produced Chinook salmon trap efficiencies (Figure 14). In contrast, trap efficiencies for hatchery fish closely tracked flow at the time of release until February 8, 2008, but a similar relationship was not apparent in later trials.

Median fork length for hatchery produced Chinook salmon during paired trials varied from 36 to 47 mm with a median fork length of 39mm. Median fork length for naturally produced Chinook salmon varied from 35 to 38mm with a median fork length of 37mm. During 15 of the 19 paired trials, the median fork length of hatchery fish was higher than the median fork length of naturally produced fish, but the difference between the two groups was ≤2 mm for 10 trials (Figure 15). However, during the last three paired trials the difference in median fork length increased, with there being a difference of 12 mm during the last paired trial. During two of these trials, trap efficiencies for hatchery fish were higher than for naturally produced fish. When these three trials were removed from the analyses, the differences in trap efficiencies between hatchery and naturally produced Chinook salmon increased (t=-3.29: P=0.0025).

Our underwater observation experiment suggests that hatchery and naturally produced fish may exhibit different behavior at the time of release. When the separate groups of hatchery and naturally produced fish were released, all three observers saw similar behavior. Hatchery fish quickly dropped to the bottom of the water column where they stayed close to the substrate and were oriented headfirst into the current. In contrast, naturally produced fish quickly moved headfirst downstream just below the water surface. Behavior within the mixed group was more difficult to characterize. In the high velocity area, no separation of the two groups was observed before the group either swam or was swept downstream by the current. However, one observer was able to detect naturally produced fish separating from the hatchery fish and subsequently moving downstream.

*Upper Battle Creek juvenile salmonid passage (UBC).—*Passage estimates for spring and fall Chinook salmon were combined because of the overlap in fork length. Juvenile passage indexes were not calculated for late fall and winter Chinook salmon because only three late-fall and no winter Chinook salmon were captured in the trap. Passage estimates were also calculated for rainbow trout/steelhead.

The annual JPI for BY07 spring Chinook salmon was 74,823, and the 90 and 95% confidence intervals were 62,508 to 93,490 and 60,655 to 101,861, respectively (Table 4). The weekly JPI's for spring Chinook salmon increased rapidly to a peak of 36,086 the week of January 6, 2008, and then decreased until late-March when passage began increasing slowly to a second peak of 613 the week of April 20, 2008. Only three late fall Chinook salmon were captured in the UBC trap; therefore a JPI was not calculated. The annual JPI for yoy rainbow trout/steelhead passing the UBC trap between November 28, 2007 and June 30, 2008 was 1,150 whereas passage for age1+ fish was 371 (Table 5). The 90 and 95% confidence intervals for the yoy annual JPI estimate were 1,040 to 1,284 and 1,018 to 1,311, and the 90 and 95% confidence intervals for the annual JPI for age 1+ fish were 271 to 402 and 262 to 426, respectively. Most age 1+ fish migrated during December through mid-May, whereas yoy were not captured in the trap until late March with a peak weekly passage of 352 the week of May 18, 2008.

## Discussion

### *Trap Operation*

During the current report period, we were able to operate the trap 96% (208 d) of the season (216 d). With the exception of the 2004-2005 report period, the UBC trap was operated fewer days during the juvenile Chinook salmon and rainbow trout/steelhead migration period (November through June) in all other years. Between November 28, 2007 to June 30, 2008 there were about 8 d (185 hours) when the trap was not operated due to high flows and trap repair; however, the 8 d the trap did not fish includes 5 d (120 hours) when the trap did not operate at all and 6 d (≈65 hours) when the trap only fished for part of a day. In other words, there were 11 d where passage estimates were calculated using the estimated catch or partial catch depending on which was larger. During the 2004-2005 season, the UBC trap was also not operated for about 8 d, which includes 6 d the trap did not operate at all and 5 d (49.5 hours) when the trap was only operated for part of a day. Similar to the current report period, there were 11 d where passage estimates were calculated using an estimated catch; however, passage estimates may have been more accurate during the 2004-2005 season because five of the days the trap was not operated at all or was operated for a partial day were in May, which is after the peak outmigration period; therefore the affect of estimating daily catch likely had less impact on the overall annual passage estimate.

Our ability to operate the trap during most of the peak outmigration period likely led to improved passage estimates for Chinook salmon and rainbow trout/steelhead relative to previous years. However, estimating catch on days the trap was not operated may have affected our weekly and annual JPI's, but the magnitude of the affect likely varied with the time of the year, catch, and number of consecutive days estimated. Two high flow events occurred in early and late January, which is during the period of peak outmigration for fall and spring Chinook salmon fry; therefore, we may have underestimated catch during these periods because fry often disperse downstream during or following high flow events (Healey 1991). Although the storm event on January 4, 2008 only lasted about one day, the trap was damaged which resulted in a loss of three additional days while the trap was repaired. Daily catch had begun to increase prior to the storm event, and was even higher after the trap was repaired; therefore, it is possible that we underestimated daily catch. Although the trap was not operated in July through late November during the current report period, this likely had limited impact on Chinook salmon and rainbow trout/steelhead passage estimates because previous sampling has shown that few or no salmonids are captured during this period (Whitton et al. 2006; Whitton et al. 2007a; Whitton et al. 2007b). It likely reduced the accuracy of our annual catch totals for non-salmonids, but they are not the focus of this monitoring project.

Determining whether there are better methods for estimating catch for days the trap is not operational may improve the accuracy of our passage estimates. Currently, average catch for an equal number of days before and after a period of missed sampling is used to estimate catch when the trap is not operated. The accuracy of this method as well as others such as catch per unit volume (CPUV) or effort (CPUE) should be tested to determine whether there is a particular method that is more accurate at estimating catch during high-flow periods and other days the trap is not operated. The CPUE methodology has been used in a few other rotary screw trap studies to estimate passage during periods when traps were not operated (Griffith et al. 2001 and Volkhardt et al. 2005), but comparisons with other methods did not occur.

> ***Recommendation:*** *Investigate the use of CPUV, CPUE, or other methods to estimate catch for days the trap is not operated.*

*Biological Sampling*

To effectively estimate passage and describe the biological characteristics of all runs of Chinook salmon on Battle Creek, the sampling methods used at the traps must be tested to ensure their applicability and accuracy. In previous years, length-at-date criteria for determining run designation (Greene1992) have been used on Battle Creek to differentiate runs of juvenile Chinook salmon captured in the traps. However, these criteria were developed for the mainstem Sacramento River, and we have determined that they are not accurate for tributary runs of Chinook salmon. Considering the overlap between runs, genetic sampling is likely the most accurate method for assigning a run designation. However, it is expensive and will likely only be done on a portion of the total catch, which then requires the results to be extrapolated to the total catch. In addition, current genetic techniques for run identification of Central Valley Chinook may need to be verified or refined for application specifically to Battle Creek populations.

> ***Recommendation****: Develop or utilize methods such as genetics for determining the run designation of Chinook salmon captured in the UBC trap.*

*Trap Efficiency and Juvenile Salmonid Passage*

*Trap efficiency.*—During the current report period we began a paired mark-recapture study to determine whether hatchery produced fall Chinook salmon could be used as surrogates for naturally produced fall Chinook to conduct mark-recapture trials at the UBC trap. There are insufficient numbers of fish captured in the UBC trap to conduct trials; therefore, we use fall Chinook salmon captured in the LBC trap to estimate trap efficiency. However, there are two periods during the migration period when we typically do not conduct mark-recapture trials. First, we do not conduct trials in late November through December to reduce any potential impacts on threatened spring Chinook salmon. In late November through December the potential for capturing spring Chinook salmon in the LBC trap is higher than after early January; therefore we made the decision not to conduct mark recapture trials until after January 1. We also do not conduct trials in May and June because warm water and air temperatures increase the potential for mortality of marked fish. If hatchery fish could be used as surrogates during these two periods, we would not need to use the season average trap efficiency and the accuracy of our passage estimates could increase. December is part of the period of peak outmigration for fry and May is a period of peak out migration for parr, silvery parr, and smolt; therefore, accurate passage estimates during these periods are important.

In order to use hatchery fish as surrogates we had to determine whether trap efficiencies for hatchery fish were similar to naturally produced fall Chinook salmon. The results of our paired mark-recapture study suggest we may not be able to use hatchery fish as surrogates for naturally produced Chinook salmon. Trap efficiencies of hatchery fish were lower in 74% of our 19 valid trials. In addition, hatchery fish were not available until December 28, which was only 10 d earlier than naturally produced fish. Although the first group of hatchery fish was released into the raceway December 17, 2007, they were not sufficiently "buttoned-up" to mark on December 20. Water temperatures play an important role in the rate of development; therefore, with warmer water temperatures hatchery fish may be available earlier in other years.

The differences observed between hatchery and naturally produced trap efficiencies are likely explained by a variety of biological and environmental variables. Our study indicated that the variables influencing trap efficiency may be different for the two groups. Early in the study trap efficiencies of hatchery fish were highly correlated with flow at the time of release; however, this relationship was not maintained throughout the study (Figure 14). Flows at time of release did not appear to be correlated to naturally produced Chinook salmon trap efficiencies at any time during the study; however, the range of release flows (8.4 to 20.6 $m^3/s$ {298 to727 cfs}) over which the study was conducted was limited by low flow conditions in the drainage. Of the 19 valid paired trials, 11 were conducted at flows <11.3 $m^3/s$ (400 cfs), and only three trials were conducted at flows >14.2 $m^3/s$ (500 cfs). It is possible that trap efficiencies for naturally produced fish would show a correlation with flow over a wider range. Increasing fork length may have also influenced trap efficiencies of hatchery fish; however, there were only a few trials where hatchery fish were >2mm larger than naturally produced fish. During these trials trap efficiencies were higher than the average trap efficiency for hatchery fish.

The hatchery environment may also influence trap efficiencies because velocities in the raceways are much lower than those experienced during our mark-recapture trials. The results of our underwater observation experiment appear to support this idea. Hatchery fish quickly dropped into the substrate following release, which suggests they may have been seeking cover. If hatchery fish are attempting to avoid high velocities, it is possible that they migrate towards areas of lower velocity such as stream edges or the stream substrate. Both of these locations would make them less likely to be captured in the rotary screw trap, which is positioned in the thalweg of the creek. Another alternative is that being raised in a hatchery environment influences migratory behavior. Hatchery fish may not all migrate downstream immediately following release. Fork length may also influence release behavior, because larger fish would likely be able to handle higher velocities than smaller fish. Determining what variables influence trap efficiency of naturally produced fish may allow us to develop a statistical relationship to estimate daily trap efficiencies.

> ***Recommendation**: Continue the paired mark-recapture study to explore relationships between trap efficiency and biological and environmental variables, quantify differences in trap efficiency related to differences in fork length, and verify the results from the current report period.*

*Juvenile salmonid passage.*—During the current report period, catch data for spring and fall Chinook salmon were combined to estimate passage because the length-at-date criteria used to assign run designations is not accurate in Battle Creek. Stream temperatures play a critical role in emergence timing; therefore, variation in stream temperatures between years will influence fry emergence timing. According to the length-at-date criteria there were only 56 juvenile spring Chinook salmon captured in the UBC trap during the current report period, whereas there were 2,910 fall Chinook salmon. During the adult Chinook salmon monitoring season at the hatchery's barrier weir, flows were relatively low leading to very accurate counts of adult passage into the upper watershed. The combined passage estimate for the trap and video periods was 291 potential adult spring Chinook salmon; however, an unusually large pulse of fish (N=16) passed the video monitoring site on July 18, 2007 during an unusual summer storm event. These fish may have been early returning fall Chinook salmon, but it is unlikely that these 16 adult Chinook salmon which account for 5.5% of the adult passage can explain the fact that 98% of the juveniles captured at the UBC were assigned a fall Chinook salmon run designation. The length-at-date criteria were based on Sacramento River emergence timing, which will likely differ if water temperatures in the Sacramento River are warmer than temperatures in Battle Creek.

The combined spring and fall Chinook salmon juvenile passage estimate for the current report period is higher than the combined spring and fall passage estimates for BY01, BY02, and BY04, but lower than combined passage estimates for BY98, BY99, and BY03 (Table 6). Adult escapement in 2007 was the highest (n=291) since monitoring began at the hatchery's barrier weir; however, juvenile passage was lower than observed in 1998, 1999, and 2003. Several factors may explain why juvenile passage did not reflect the high adult escapement, including inaccurate juvenile passage estimates, adult mortality, underestimated adult passage in previous years, and low survival to emergence. Peak juvenile passage at the UBC trap typically occurs in late December to early January. During the current report period, the UBC trap was not operated for 4 d in early January because of high flows and trap damage; therefore, it is possible that weekly passage estimates made during that time underestimated the actual passage. A second storm occurred in late-January, and although it was not the period of peak passage, there were still large numbers of juvenile Chinook salmon being captured in the trap.

Adult mortality or reduced fertility prior to spawning may have made a minor contribution to the lower juvenile passage estimates observed at the UBC Trap. One hundred thirty two redds were observed during snorkel surveys, which is 13 less than we would predicted if there was a 1:1 sex ratio, 100% survival to spawning, and all females spawned. In contrast, in 2002 there were 222 adult Chinook salmon passed upstream of the barrier weir; however, only 78 redds were observed during snorkel surveys. There appears to have been high adult mortality in 2002, which may explain the low juvenile passage observed at the UBC trap. Furthermore, over all years, the number of redds per adult female (assuming a 1:1 sex ratio) is strongly correlated with increased flow and decreased water temperature during the summer months (Newton et al. 2008). Increased flow increases the area of holding habitat, reduces stressfully high water temperatures, and likely improves predator (otter) avoidance behavior for adult Chinook salmon. In 2007, mean monthly flows from June through September were lower than in 1998, 1999, and 2003 possibly explaining why juvenile production was lower in 2007 than these other three years.

The higher juvenile passage estimates in 1998, 1999, and 2003 may also be the result of both unobserved and observed passage of adult fall Chinook salmon. In 1998 and 1999, high flows likely allowed fall Chinook salmon to jump over the barrier weir because only 178 and 73 adults spring Chinook salmon were passed through the barrier weir trap, respectively (Figure 16). July and August flows in these two years were the highest observed since monitoring began; therefore, it is likely that fall Chinook salmon jumped the weir unobserved (Figure 16). In 2003, 221 adult Chinook salmon were passed through the barrier weir trap; however, 48% (n=106) passed after August 1, 2003. Brown and Alston (2007) concluded that these fish were likely fall Chinook. Because these fish arrived in August, they were not exposed to the high water temperatures that earlier spring Chinook salmon experience, and likely had higher survival to spawning (Figure 17). A similar pulse (18.9%; n=42) was observed in 2002. These late pulses of fish led to the barrier weir trap and ladder being closed August 1 in years after 2003.

Survival to emergence is another factor that may contribute to lower juvenile passage estimates. Water temperatures ≤ 13.3ºC (56 ºF) are considered optimal for Chinook salmon egg incubation (Ward and Kier 1999; Figure 17). Temperature analyses conducted by Newton et al. (2008) indicated that during the incubation period the average percent of days where temperatures were classified as excellent (≤ 13.3 º C) was 99.4% for all redds. The analyses used a best-case scenario which assumes that incubation began the day prior to the snorkel survey in which the redd was first observed. Redd incubation temperatures during the current report period do not appear to have been higher than temperatures observed in 2004 to 2006, with the exception of a few brief periods in late October and November; however, temperatures were within the range considered optimal for incubation. In 2004 to 2006, the average percent of days during which temperatures were classified as excellent for all redds was ranged from 95.7 to 99.6% (Alston et al. 2007; Newton et al. 2007a; Newton et al. 2007b). High flow events that cause scour can also contribute to reduced survival to emergence; however during the current report period there were only 3 d when flows exceeded 42.5 $m^3$/s (1,500 cfs) and the peak flow was 50.1 $m^3$/s (3,190cfs). These flows are unlikely to cause significant scour of substrate that would lead to reduced survival to emergence.

Late-fall Chinook salmon juvenile passage at the UBC trap continued to decline. According to the length-at-date criteria, only three late-fall Chinook salmon were captured at the UBC trap during the current report period. Prior to 2001, CNFH did not pass late-fall Chinook salmon upstream of the barrier weir; therefore, only those that were able to jump the weir during high flows or passed through the fish ladder at the end of the immigration period (after early March) escaped upstream of the UBC trap. This likely resulted in the low juvenile production estimates in 1999 and 2000. The CNFH began passing natural-origin (i.e., unclipped) adult late-fall Chinook salmon upstream of the barrier weir in 2001. In 2002, late-fall Chinook salmon juvenile passage was the highest on record, corresponding to the highest adult escapement estimate (n=249). However, since 2002, both adult escapement and juvenile passage have steadily declined. From October 2007 through February 2008, the hatchery only passed 19 adult late-fall Chinook salmon above the barrier weir. Genetic samples collected from adult Chinook salmon passed at the barrier weir trap in 2008 have not been analyzed; therefore, it is possible some additional late-fall Chinook salmon were passed upstream after March 1, 2008. Typically, juvenile late-fall Chinook salmon begin to show up in the UBC in late March to early April, but that did not occur during the current report period. Two late-fall fry were captured in the trap in late-May.

In 2008, rainbow trout/steelhead juvenile passage at the UBC trap was lower than all previous years when passage estimates were made (Table 6). Only three rainbow trout/steelhead fry were captured in the UBC trap in March. Preliminary adult data indicates that passage in fall 2007 through July 2008 was the second lowest, which may explain the decline observed in juvenile passage (J. Newton, USFWS, personal communication). Rainbow trout/ steelhead fry typically begin to show up in the UBC trap in late February through March. In most years, fry <35 mm were not observed in the UBC trap after mid-May; however, in 2008, fry <30 mm were captured in the trap in June. Whether this indicates a shift in emergence timing is unknown at this time. Rainbow trout/steelhead fry were observed in the LBC trap in March, which is similar to previous years. High flow events during the incubation period were limited; therefore it is unlikely that scouring of redds occurred.

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**Tables**

Table 1. Life-stage summary of fall, late-fall, spring and winter Chinook salmon and rainbow trout/ steelhead captured at the Upper Battle Creek rotary screw trap from November 28, 2007 through June 30, 2008.

| | Spring Chinook | | Late-Fall Chinook | | Winter Chinook | | Rainbow | |
|---|---|---|---|---|---|---|---|---|
| Life Stage | # | % | # | % | # | % | # | % |
| Yolk Sac Fry | 2 | 0.1 | 2 | 66.7 | 0 | 0 | 0 | 0 |
| Fry | 1,570 | 90.0 | 1 | 33.3 | 0 | 0 | 8 | 8.4 |
| Parr | 13 | 0.7 | 0 | 0 | 0 | 0 | 72 | 75.8 |
| Silvery Parr | 44 | 2.5 | 0 | 0 | 0 | 0 | 12 | 12.6 |
| Smolt | 116 | 6.7 | 0 | 0 | 0 | 0 | 3 | 3.2 |
| ***Totals*** | *1,745* | *100* | *3* | *100* | *0* | *0* | *95* | *100* |

Table 2. Summary of the mark-recapture trials conducted at the Upper Battle Creek (UBC) rotary screw trap from November 28, 2007 through June 30, 2008. Shaded rows indicate weeks where mark-recapture data were pooled to calculate the weekly trap efficiency. Trials highlighted with **bold text** were not used. All valid mark-recapture trials were conducted while the trap was operated with the half-cone modification.

| Release Date | Time of Release | Number Released | Recaptures | Efficiency[a] | Pooled /Season Avg. Efficiency | Weekly Mean Flow, $m^3/s$ (cfs) |
|---|---|---|---|---|---|---|
| 01/09/08 | 02:05 | 481 | 14 | 0.031 | --- | 13.6 (482) |
| 01/12/08 | 19:37 | 303 | 12 | 0.043 | 0.054 | 9.3 (328) |
| 01/15/08 | 20:19 | 305 | 20 | 0.069 | 0.054 | 9.3 (328) |
| 01/19/08 | 20:36 | 335 | 19 | 0.060 | 0.055 | 16.0 (564) |
| 01/23/08 | 19:15 | 286 | 14 | 0.052 | 0.055 | 16.0 (564) |
| **01/27/08[b]** | **21:30** | **266** | **2** | **---** | **---** | **16.6 (585)** |
| 01/29/08 | 19:40 | 303 | 16 | 0.056 | --- | 16.6 (585) |
| **02/03/08[c]** | **8:40** | **308** | **4** | **---** | **---** | **11.2 (395)** |
| 02/05/08 | 20:30 | 303 | 9 | 0.033 | --- | 11.2 (395) |
| 02/09/08 | 19:35 | 299 | 9 | 0.033 | 0.035 | 9.3 (327) |
| 02/12/08 | 19:36 | 302 | 11 | 0.040 | 0.035 | 9.3 (327) |
| **02/16/08[d]** | **19:00** | **302** | **49** | **0.165** | --- | 11.4 (404) |
| 02/20/08 | 19:00 | 296 | 11 | 0.040 | 0.038 | 11.4 (404) |
| 02/22/08 | 19:00 | 301 | 11 | 0.040 | 0.038 | 11.4 (404) |
| 02/26/08 | 18:50 | 296 | 12 | 0.044 | --- | 14.2 (503) |
| 03/01/08 | 19:12 | 309 | 14 | 0.048 | 0.045 | 10.8 (382) |
| 03/04/08 | 19:35 | 70 | 2 | 0.042 | 0.045 | 10.8 (382) |
| 03/08/08 | 19:02 | 306 | 6 | 0.023 | 0.018 | 11.1 (391) |
| 03/11/08 | 20:30 | 299 | 4 | 0.017 | 0.018 | 11.1 (391) |
| 03/15/08 | 19:55 | 304 | 3 | 0.013 | 0.028 | 11.4 (401) |
| 03/18/08 | 18:45 | 523 | 20 | 0.040 | 0.028 | 11.4 (401) |
| 03/25/08 | 20:30 | 148 | 3 | 0.027 | 0.028 | 10.7 (378) |

[a] Bailey's Efficiency was calculated by: $\hat{E} = \frac{r+1}{m+1}$, where r = recaptures and m = number of marked fish released.

[b] This trial was not used because there was significant mortality prior to release and the trap was pulled the day after marked fish were released.

[c] This trial was not used because marked fish were released during the daylight.

[d] This trial was not used because the trap was temporarily switched to full-cone.

Table 3. Comparison of naturally produced and hatchery fall Chinook salmon mark-recapture trials conducted at the Upper Battle Creek rotary screw trap in 2008. Shading indicates which group had the highest trap efficiency during a single trial, and bold text indicates paired trials that were not used in the analyses.

| Release Date | Naturally Produced | | | Hatchery | | |
|---|---|---|---|---|---|---|
| | Marked | Recaptured | Trap Efficiency | Marked | Recaptured | Trap Efficiency |
| 12/29/07[a] | --- | --- | --- | 249 | 6 | 0.028 |
| 01/01/08[a] | --- | --- | --- | 254 | 4 | 0.020 |
| 01/09/08 | 481 | 14 | 0.031 | 503 | 19 | 0.040 |
| 01/12/08 | 303 | 12 | 0.043 | 291 | 9 | 0.034 |
| 01/15/08 | 305 | 20 | 0.069 | 301 | 5 | 0.020 |
| 01/19/08 | 335 | 19 | 0.060 | 304 | 5 | 0.020 |
| 01/23/08 | 286 | 14 | 0.052 | 299 | 9 | 0.033 |
| **01/27/08[b]** | **266** | **2** | **---** | **182** | **2** | **---** |
| 01/29/08 | 303 | 16 | 0.056 | 299 | 20 | 0.070 |
| **02/03/08[c]** | **308** | **4** | **0.016** | **308** | **4** | **0.016** |
| 02/05/08 | 303 | 9 | 0.033 | 301 | 7 | 0.027 |
| 02/09/08 | 299 | 9 | 0.033 | 302 | 5 | 0.020 |
| 02/12/08 | 302 | 11 | 0.040 | 305 | 6 | 0.023 |
| **02/16/08[d]** | **302** | **49** | **0.165** | **300** | **26** | **0.090** |
| 02/20/08 | 296 | 11 | 0.040 | 301 | 3 | 0.013 |
| 02/22/08 | 301 | 11 | 0.040 | 306 | 4 | 0.016 |
| 02/26/08 | 296 | 12 | 0.044 | 307 | 3 | 0.013 |
| 03/01/08 | 309 | 14 | 0.048 | 309 | 6 | 0.023 |
| 03/04/08 | 70 | 2 | 0.042 | 303 | 5 | 0.020 |
| 03/08/08 | 306 | 6 | 0.023 | 302 | 8 | 0.030 |
| 03/11/08 | 299 | 4 | 0.017 | 309 | 3 | 0.013 |
| 03/15/08 | 304 | 3 | 0.013 | 303 | 14 | 0.049 |
| 03/18/08 | 523 | 20 | 0.040 | 562 | 19 | 0.036 |
| 03/22/08 | --- | --- | --- | 306 | 9 | 0.033 |
| 03/25/08 | 148 | 3 | 0.027 | 304 | 14 | 0.049 |
| 03/29/08[a] | --- | --- | --- | 302 | 10 | 0.036 |
| 04/01/08[a] | --- | --- | --- | 300 | 10 | 0.037 |
| 04/05/08[a] | --- | --- | --- | 307 | 10 | 0.036 |
| **04/08/08[d]** | **---** | **---** | **---** | **309** | **33** | **0.110** |

[a] Naturally produced Chinook salmon were not available during this trial.
[b] The results of this trial were not used because the trap was pulled early due to high flows.
[c] The results of this trial were not used because marked fish were released during daylight hours.
[d] The results of this trial were not used because the trap was at full-cone and the results are not directly comparable to trials conducted at half-cone.

Table 4. Weekly summary of brood year 2007 juvenile spring Chinook salmon passage estimates for the Upper Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI). Shaded rows indicate adjacent weeks where the results of mark-recapture trials were pooled to calculate passage. Only weeks in which spring Chinook salmon were captured are included.

| Week | Efficiency (E) | Catch[b] | Estimated Passage (N) | SE[c] | 90% Confidence Interval[c] | | 95% Confidence Interval[c] | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower CI | Upper CI | Lower CI | Upper CI |
| 12/02/07 | 0.038[a] | 12 | 313 | 71 | 221 | 442 | 214 | 473 |
| 12/09/07 | 0.038[a] | 12 | 313 | 72 | 221 | 442 | 214 | 473 |
| 12/16/07 | 0.038[a] | 82 | 2,138 | 495 | 1,509 | 3,018 | 1,490 | 3,233 |
| 12/23/07 | 0.038[a] | 91 | 2,373 | 571 | 1,674 | 3,588 | 1,570 | 3,864 |
| 12/30/07 | 0.038[a] | 431 | 11,239 | 2,580 | 7,930 | 15,861 | 7,675 | 16,994 |
| 01/06/08 | 0.031 | 1,123 | 36,086 | 9,574 | 24,604 | 54,129 | 23,534 | 60,413 |
| 01/13/08 | 0.054 | 584 | 10,777 | 1,955 | 8,271 | 14,226 | 7,903 | 15,463 |
| 01/20/08 | 0.054 | 197 | 3,604 | 627 | 2,785 | 4,713 | 2,664 | 5,106 |
| 01/27/08 | 0.055 | 209 | 3,737 | 933 | 2,647 | 5,295 | 2,444 | 6,354 |
| 02/03/08 | 0.032 | 25 | 760 | 275 | 475 | 1,267 | 447 | 1,520 |
| 02/10/08 | 0.034 | 6 | 172 | 41 | 125 | 258 | 117 | 278 |
| 02/17/08 | 0.038 | 20 | 520 | 111 | 386 | 748 | 362 | 797 |
| 02/24/08 | 0.043 | 6 | 137 | 42 | 94 | 223 | 85 | 255 |
| 03/02/08 | 0.044 | 2 | 45 | 11 | 32 | 63 | 29 | 69 |
| 03/09/08 | 0.018 | 3 | 165 | 55 | 107 | 260 | 101 | 303 |
| 03/16/08 | 0.027 | 8 | 289 | 60 | 217 | 411 | 205 | 434 |
| 03/23/08 | 0.027 | 3 | 108 | 22 | 81 | 146 | 77 | 163 |
| 03/30/08 | 0.038[a] | 6 | 156 | 35 | 114 | 221 | 107 | 237 |
| 04/06/08 | 0.077[d] | 16 | 209 | 33 | 167 | 268 | 158 | 285 |
| 04/13/08 | 0.077[d] | 22 | 287 | 47 | 229 | 368 | 221 | 392 |
| 04/20/08 | 0.077[d] | 47 | 613 | 101 | 480 | 811 | 463 | 837 |
| 04/27/08 | 0.077[d] | 21 | 274 | 42 | 219 | 351 | 207 | 374 |
| 05/04/08 | 0.077[d] | 17 | 222 | 34 | 173 | 284 | 168 | 303 |
| 05/11/08 | 0.077[d] | 13 | 169 | 25 | 135 | 217 | 130 | 224 |
| 05/18/08 | 0.077[d] | 7 | 91 | 14 | 72 | 117 | 70 | 125 |

Table 4. (Continued)

| Week | Efficiency (E) | Catch[b] | Estimated Passage (N) | SE[c] | 90% Confidence Interval[c] | | 95% Confidence Interval[c] | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower CI | Upper CI | Lower CI | Upper CI |
| 06/01/08 | 0.077[d] | 1 | 13 | 2 | 10 | 17 | 10 | 17 |
| 06/22/08 | 0.077[d] | 1 | 13 | 2 | 10 | 17 | 10 | 17 |
| ***Totals*** | **---** | ***2,965*** | ***74,823*** | ***9,993*** | ***62,508*** | ***93,490*** | ***60,655*** | ***101,861*** |

[a] Half-cone season average efficiency was calculated using all valid un-pooled and pooled trials conducted January 8 to March 25, 2008. The half-cone season average was applied during weeks when no mark-recapture trials were conducted, and the trap was operating at half-cone.
[b] Daily catch was estimated for days the trap was not fishing.
[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.
[d] Full-cone season average trap efficiency was calculated by doubling the half-cone season average. The full-cone season average was applied during weeks when no mark-recapture trials were conducted, and the trap was operating at full-cone.

Table 5. Weekly summary of rainbow trout/steelhead passage estimates for the Upper Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI). Weekly estimates listed above the dotted line are for trout from previous brood years (age 1+). Weekly estimates below the line are for brood year 2008 trout captured during the reporting period. Shaded rows indicate adjacent weeks where the results of mark-recapture trials were pooled to calculate passage. Weeks with no catch are not included.

| Week | Efficiency (E) | Catch[b] | Estimated Passage (N) | SE[c] | 90% Confidence Interval[c] Lower CI | 90% Confidence Interval[c] Upper CI | 95% Confidence Interval[c] Lower CI | 95% Confidence Interval[c] Upper CI |
|---|---|---|---|---|---|---|---|---|
| **Previous Brood Years (Age 1+)** | | | | | | | | |
| 12/02/07 | 0.038 | 1 | 26 | 6 | 19 | 37 | 18 | 39 |
| 01/06/08 | 0.031[a] | 1 | 32 | 8 | 22 | 48 | 20 | 54 |
| 01/13/08 | 0.054 | 1 | 18 | 3 | 14 | 24 | 13 | 26 |
| 01/27/08 | 0.055 | 9 | 161 | 39 | 109 | 228 | 105 | 249 |
| 02/17/08 | 0.038 | 1 | 26 | 5 | 19 | 35 | 18 | 37 |
| 02/24/08 | 0.043 | 1 | 69 | 7 | 15 | 33 | 14 | 37 |
| 04/13/08 | 0.076 | 1 | 13 | 2 | 10 | 17 | 10 | 18 |
| 05/11/08 | 0.076 | 2 | 26 | 4 | 20 | 33 | 20 | 36 |
| ***Totals*** | --- | ***17*** | ***371*** | ***74*** | ***271*** | ***402*** | ***262*** | ***426*** |
| **Brood Year 2008 (YOY)** | | | | | | | | |
| 03/23/08 | 0.027 | 3 | 108 | 22 | 79 | 146 | 75 | 154 |
| 04/27/08 | 0.076 | 1 | 13 | 2 | 10 | 17 | 10 | 18 |
| 05/04/08 | 0.076 | 4 | 52 | 8 | 41 | 69 | 39 | 74 |
| 05/11/08 | 0.076 | 8 | 104 | 16 | 82 | 134 | 79 | 138 |
| 05/18/08 | 0.076 | 27 | 352 | 52 | 281 | 452 | 271 | 481 |
| 05/25/08 | 0.076 | 22 | 287 | 45 | 225 | 368 | 217 | 392 |
| 06/01/08 | 0.076 | 9 | 117 | 18 | 92 | 146 | 89 | 155 |
| 06/08/08 | 0.076 | 5 | 65 | 10 | 51 | 81 | 49 | 89 |
| 06/22/08 | 0.076 | 2 | 26 | 4 | 20 | 33 | 20 | 36 |
| 06/29/08 | 0.076 | 2 | 26 | 4 | 21 | 33 | 20 | 35 |
| ***Totals*** | --- | ***83*** | ***1,150*** | ***181*** | ***1,040*** | ***1,284*** | ***1,018*** | ***1,311*** |

[a] Half-cone season average efficiency (0.038) was calculated using all valid un-pooled and pooled trials conducted January 8 to March 25, 2008. The full-cone season average (0.076) was calculated by doubling the half-cone average since only one invalid full-cone trial was conducted with naturally produced fish during the season. A full or half-cone season average was applied during weeks when no mark-recapture trials were conducted.
[b] Daily catch was estimated for days the trap was not fishing.
[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.

Table 6. Summary of fall, late-fall, and spring Chinook salmon and rainbow trout/steelhead juvenile passage estimates at the Upper Battle Creek rotary screw trap including run designation, brood year, original CAMP estimate, current estimate (N), and the 90 and/or 95% confidence intervals for the current annual estimates. Shaded rows indicated estimates for the current reporting period.

| Run | Brood Year | Original CAMP Estimate[c] | Current Estimate | 90% Confidence Interval Lower CI | 90% Confidence Interval Upper CI | 95% Confidence Interval Lower CI | 95% Confidence Interval Upper CI |
|---|---|---|---|---|---|---|---|
| Spring | 1998 | 4,589 | 4,791 | --- | --- | 3,949 | 6,204 |
| | 1999 | 10,061 | 6,233 | --- | --- | 5,225 | 7,678 |
| | 2000 | --- | --- | --- | --- | --- | --- |
| | 2001 | --- | 482 | 389 | 615 | 377 | 644 |
| | 2002 | --- | 926 | 810 | 1,070 | 798 | 1,102 |
| | 2003 | --- | 11,264 | 9,251 | 14,026 | 8,973 | 14,709 |
| | 2004 | --- | 3,253 | 2,803 | 3,835 | 2,748 | 3,996 |
| | 2005[e] | --- | N/A | N/A | N/A | N/A | N/A |
| | 2006[g] | --- | | N/A | N/A | N/A | N/A |
| | 2007 | --- | 74,823 | 62,508 | 93,490 | 60,655 | 101,861 |
| Fall[i] | 1998 | 1,466,274 | 1,193,916 | --- | --- | 996,588 | 1,546,430 |
| | 1999 | 211,662 | 239,152 | --- | --- | 202,274 | 291,194 |
| | 2000-partial[a] | --- | 43,850 | --- | --- | 37,476 | 54,567 |
| | 2001 | --- | 20,920 | 18,642 | 24,337 | 18,195 | 25,143 |
| | 2002 | --- | 17,754 | 15,883 | 19,731 | 15,648 | 20,244 |
| | 2003 | --- | 141,393 | 128,557 | 155,900 | 127,193 | 160,251 |
| | 2004 | --- | 26,763 | 22,614 | 32,162 | 22,131 | 33,695 |
| | 2005[f] | -- | N/A | N/A | N/A | N/A | N/A |
| | 2006[g] | | N/A | N/A | N/A | N/A | N/A |
| | 2007[h] | --- | N/A | N/A | N/A | N/A | N/A |
| Late-Fall | 1999 | --- | 212 | 177 | 261 | 170 | 273 |
| | 2000 | --- | 50 | 36 | 70 | 35 | 78 |
| | 2001 | --- | N/A | N/A | N/A | N/A | N/A |
| | 2002 | --- | 7,628 | 5,950 | 9,969 | 5,753 | 10,604 |
| | 2003 | --- | 6,673 | 5,835 | 7,409 | 5,679 | 7,631 |
| | 2004 | --- | 1,145 | 809 | 1,732 | 768 | 1,968 |
| | 2005 | --- | 147 | 112 | 198 | 109 | 213 |

| | 2006[f] | -- | N/A | N/A | N/A | N/A | N/A |
|---|---|---|---|---|---|---|---|

Table 6 (Cont.)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2007 | | N/A | N/A | N/A | N/A | N/A |
| | 2008 | | N/A | N/A | N/A | N/A | N/A |
| RBT/Steelhead | 1999 (1+)[b] | --- | 1,011 | 832 | 1,272 | 813 | 1,333 |
| | 1999 (YOY)[b] | --- | 9,379 | 8,001 | 11,139 | 7,870 | 11,747 |
| | 2000 (1+)[b] | --- | 2,780 | 2,268 | 3,569 | 2,213 | 3,723 |
| | 2000 (YOY)[b] | | 23,019 | 19,513 | 27,001 | 18,957 | 28,343 |
| | 2001[d] | --- | N/A | N/A | N/A | N/A | N/A |
| | 2002 (1+)[e] | --- | 1,348 | 1,201 | 1,607 | 1,170 | 1,666 |
| | 2002 (YOY) | --- | 24,740 | 21,034 | 29,565 | 20,454 | 31,426 |
| | 2003 (1+)[e] | --- | 592 | 522 | 671 | 511 | 698 |
| | 2003 (YOY) | --- | 7,087 | 6,441 | 7,769 | 6,349 | 7,978 |
| | 2004 (1+)[e] | --- | 826 | 753 | 903 | 741 | 917 |
| | 2004 (YOY) | --- | 2,770 | 2,512 | 3,057 | 2,455 | 3,142 |
| | 2005 (1+)[e] | --- | 485 | 421 | 573 | 411 | 610 |
| | 2005 (YOY) | --- | 5,490 | 4,355 | 7,074 | 4,231 | 7,431 |
| | 2006 (1+ )[f] | --- | N/A | N/A | N/A | N/A | N/A |
| | 2006 (YOY)[f] | --- | N/A | N/A | N/A | N/A | N/A |
| | 2007 (1+)[g] | | N/A | N/A | N/A | N/A | N/A |
| | 2007(YOY)[g] | | N/A | N/A | N/A | N/A | N/A |
| | 2008 (1+) | | 371 | 271 | 402 | 262 | 426 |
| | 2008 (YOY) | | 1,150 | 1,040 | 1,284 | 1,018 | 1,311 |

[a] This passage estimate is not a complete brood year as the trap was not fished past February 9, 2001.
[b] These estimates are not brood years, rather two periods are summarized: October 9, 1998 to December 26, 1999 and December 27, 1999 to February 9, 2001.
[c] The original CAMP estimates cover the period January 1 through December 31; therefore, they may not include the entire brood year, and late-fall estimates may include fish from two brood years.
[d] No estimate was made during 2001 because the trap was not operated during the primary migration period. All age 1+ fish were included in the 2000 estimate.
[e] Passage estimates for age 1+ fish are not for the current brood year, but rather a mixture of previous year-classes captured during the reporting period.
[f] No passage estimates were made for the period October 1, 2005 to September 30, 2006 because high flows severely limited our ability to operate the traps.
[g] No passage estimates were made in 2007 because the trap was only operated 4 d each week and was not operated after February 15, 2007.
[h] Chinook salmon assigned a fall or spring run designation were considered to be spring Chinook; therefore the combined catch data was used to estimate spring Chinook salmon passage.
[i] Fall Chinook salmon in most years are likely spring-run Chinook salmon assigned a fall-run designation according to the length-at-date criteria.

**Figures**

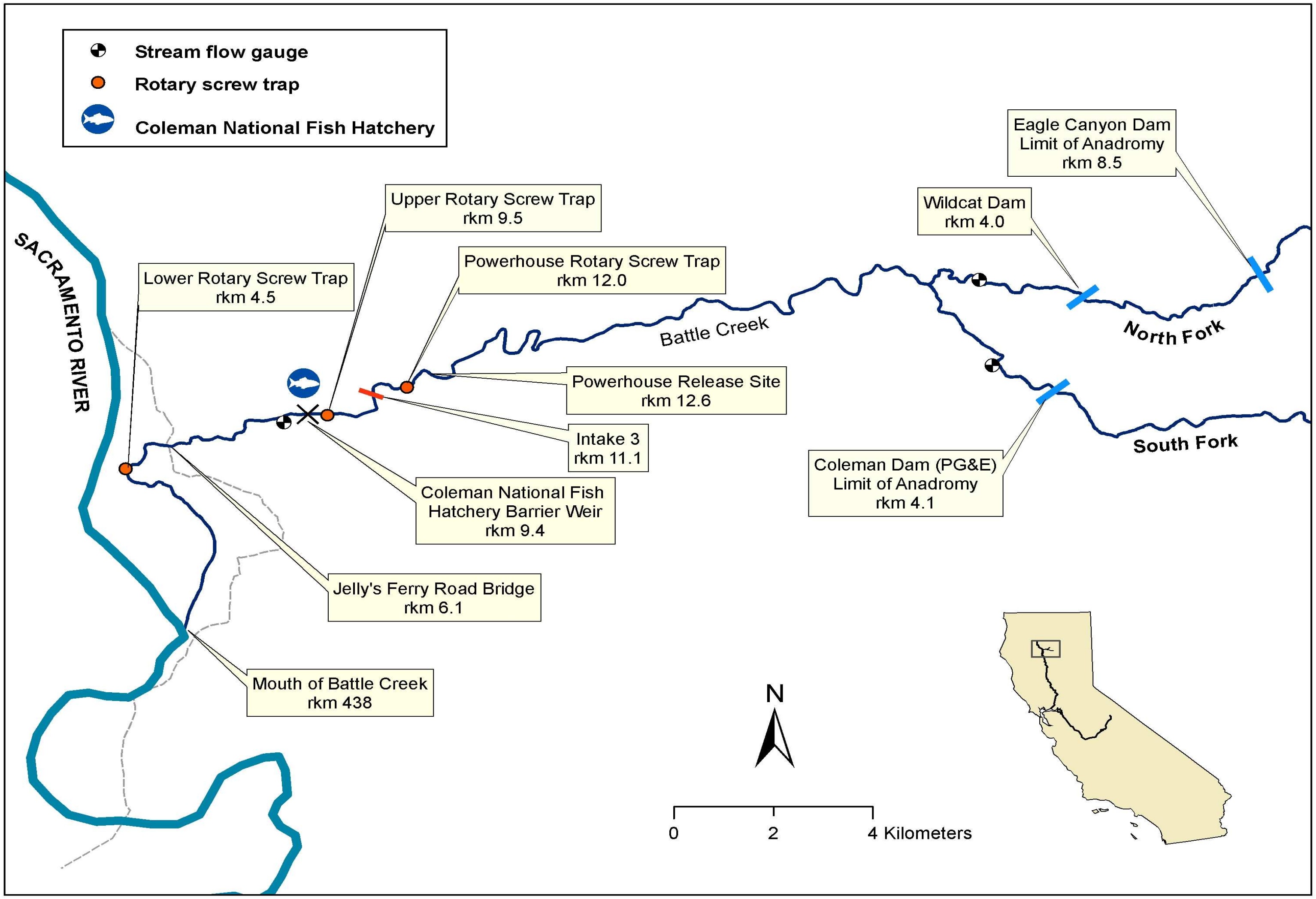


Figure 1. Map of Battle Creek depicting the location of USFWS' rotary screw traps and other important features.

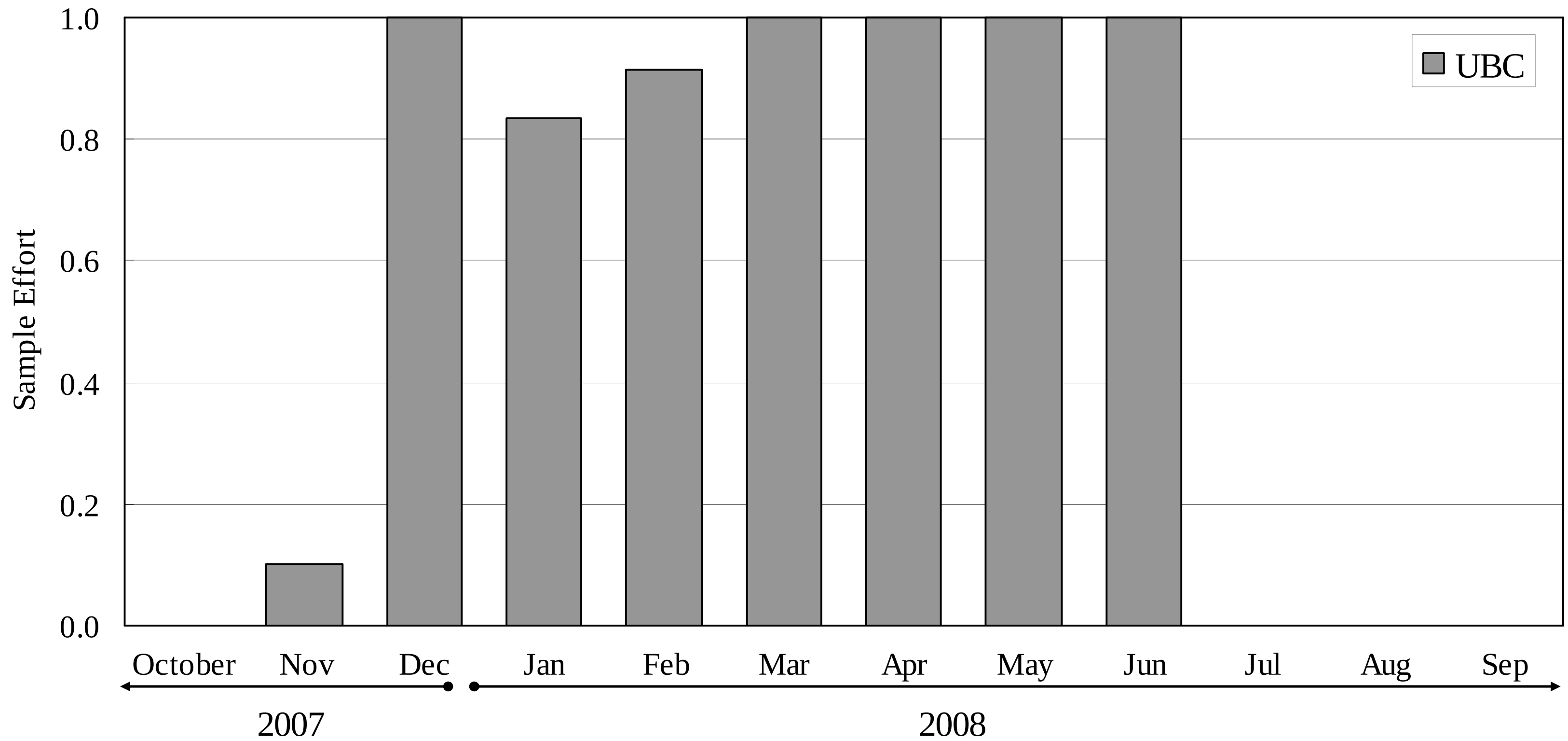


Figure 2. Sampling effort summarized as the proportion (range: 0 to 1) of days fished each month at the Upper Battle Creek rotary screw trap (UBC) from October 1, 2007 to September 30, 2008. Dates of trap operation were November 28, 2007 through June 30, 2008.

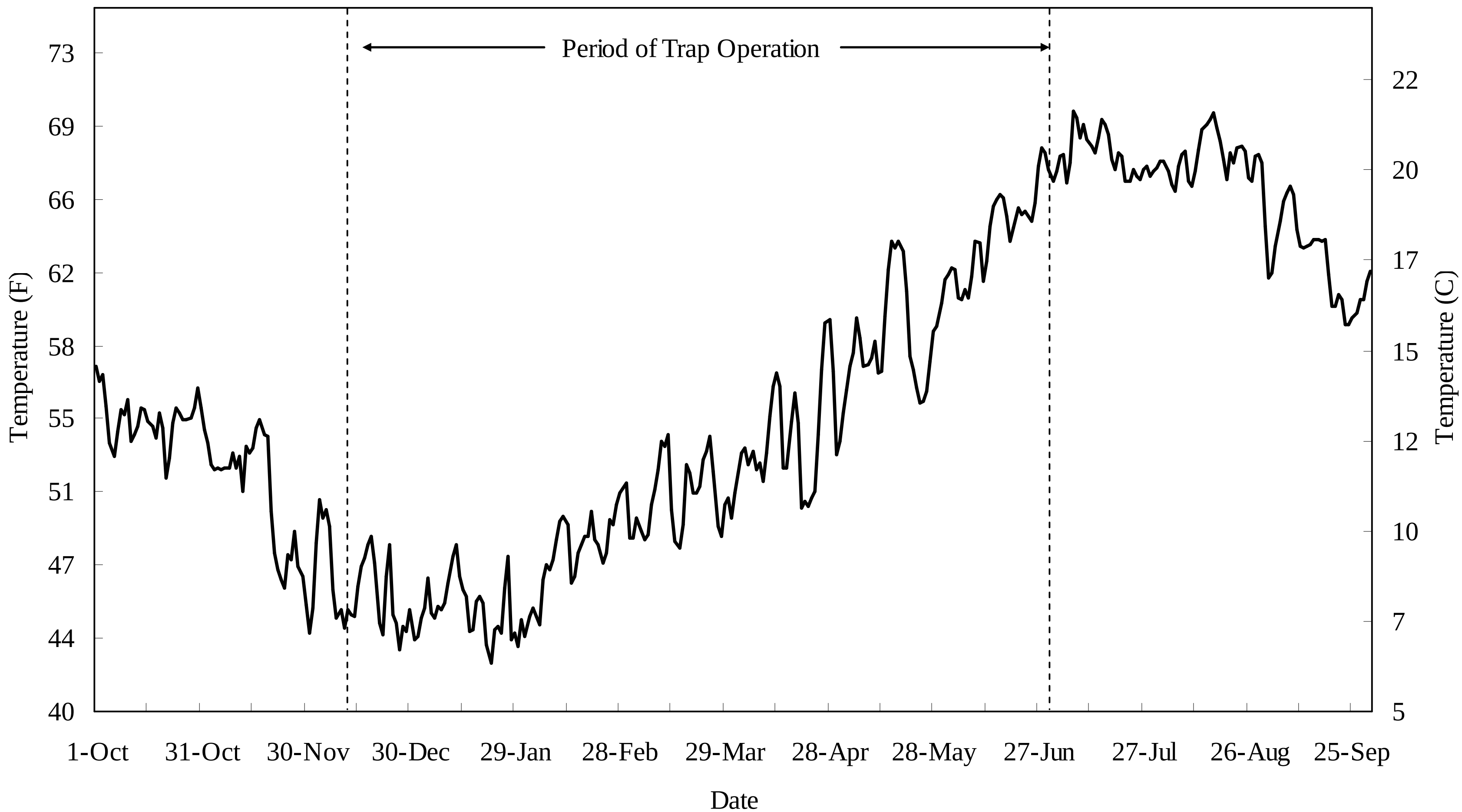


Figure 3. Mean daily water temperatures (ºC and ºF), at the Upper Battle Creek rotary screw trap from October 1, 2007 through September 30, 2008.

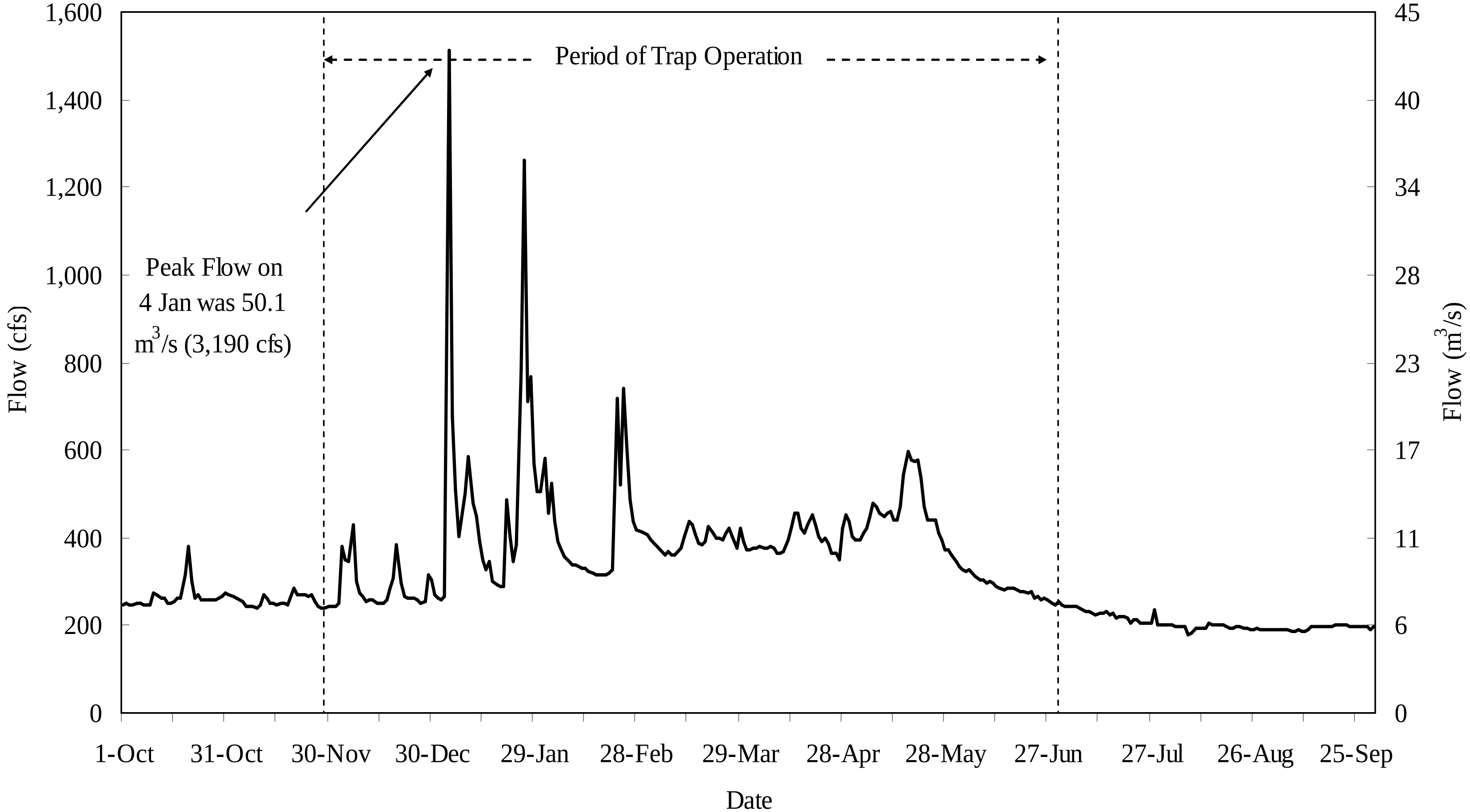


Figure 4. Mean daily flows ($m^3$/s and cfs) collected by the U.S. Geological Survey at the Coleman Hatchery gauging station (BAT #11376550) from October 1, 2007 through September 30, 2008. The gauge site is located below the Coleman National Fish Hatchery barrier weir and approximately 0.2 km downstream of the Upper Battle Creek rotary screw trap

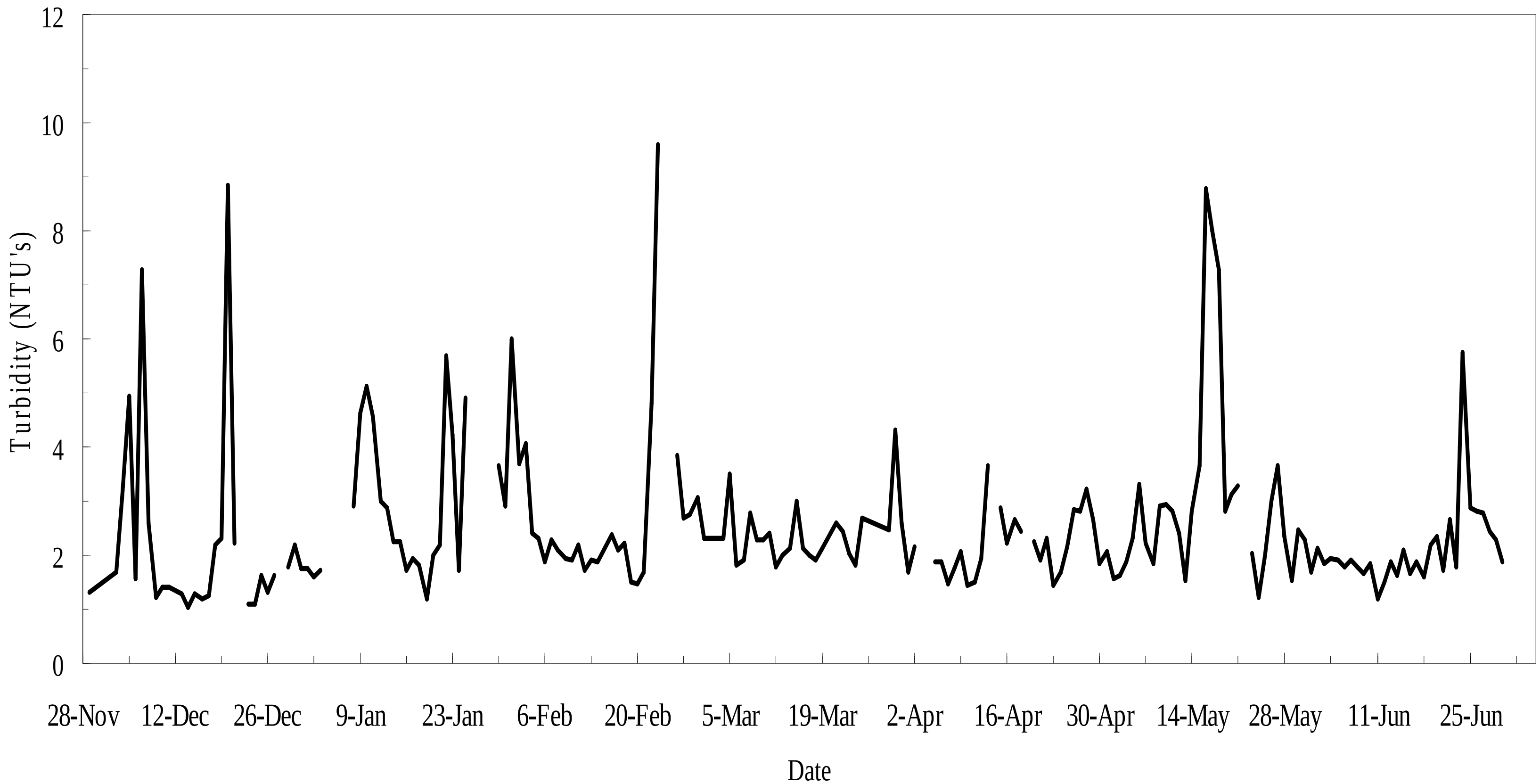


Figure 5. Turbidity (NTU) measured at the Upper Battle Creek rotary screw trap during trap operation (November 28, 2007 to June 30, 2008).

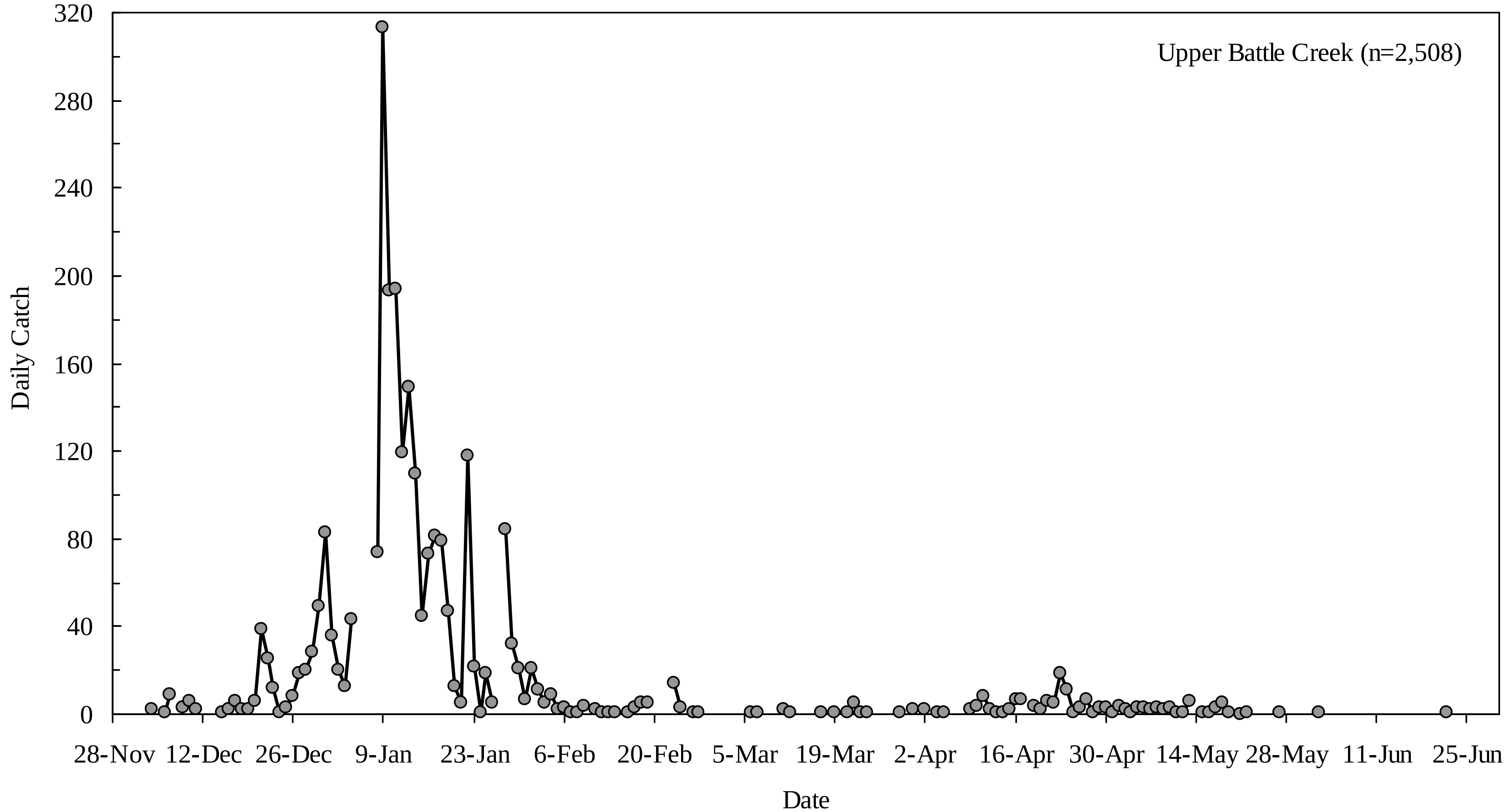


Figure 6. Daily catch of spring Chinook salmon captured at the Upper Battle Creek rotary screw trap from November 28, 2007 through June 30, 2008. Daily catch totals may be partial if the trap was not operated on all days of a week.

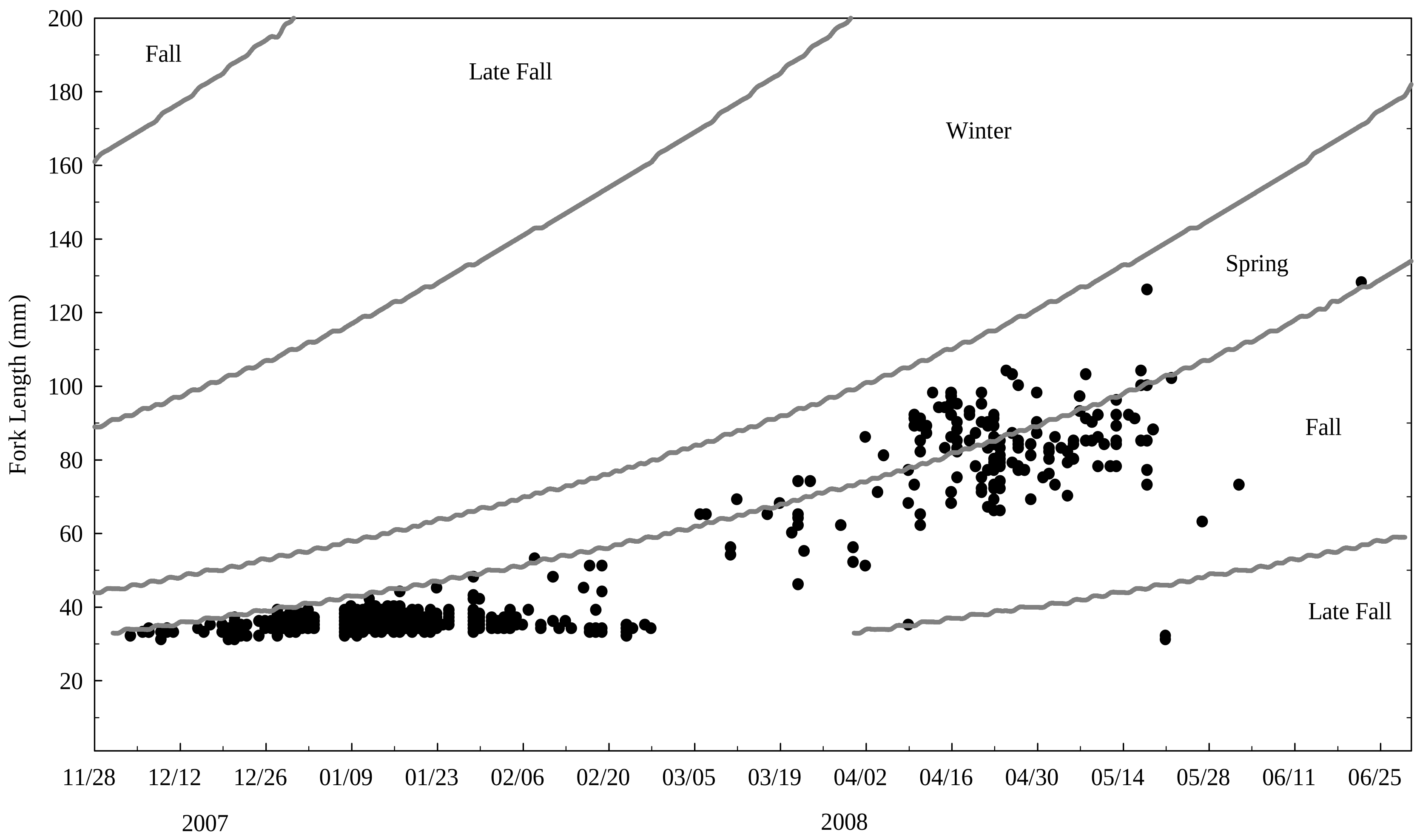


Figure 7. Fork length (mm) distribution by date and run for Chinook salmon captured at the Upper Battle Creek rotary screw trap from November 28, 2007 to June 30, 2008. Spline curves represent the maximum fork lengths expected for each run by date, based on criteria developed by the California Department of Water Resources (Greene 1992). Trap not operated after June 30, 2008.

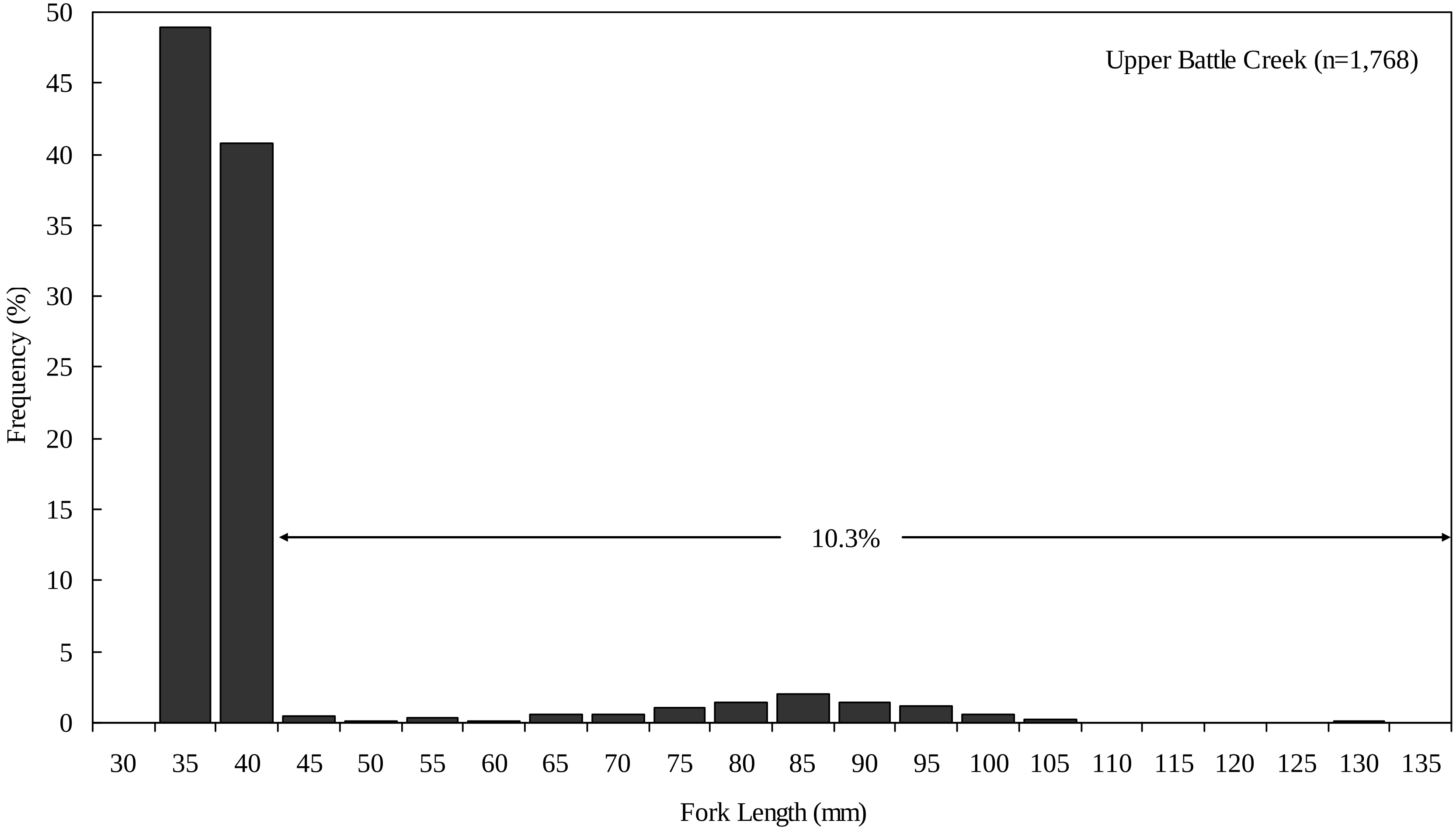


Figure 8. Length frequency (%) for all runs of Chinook salmon measured at the Upper Battle Creek rotary screw trap (UBC) during November 28, 2007 through June 30, 2008. Fork length axis labels indicate the upper limit of a 5-mm length range.

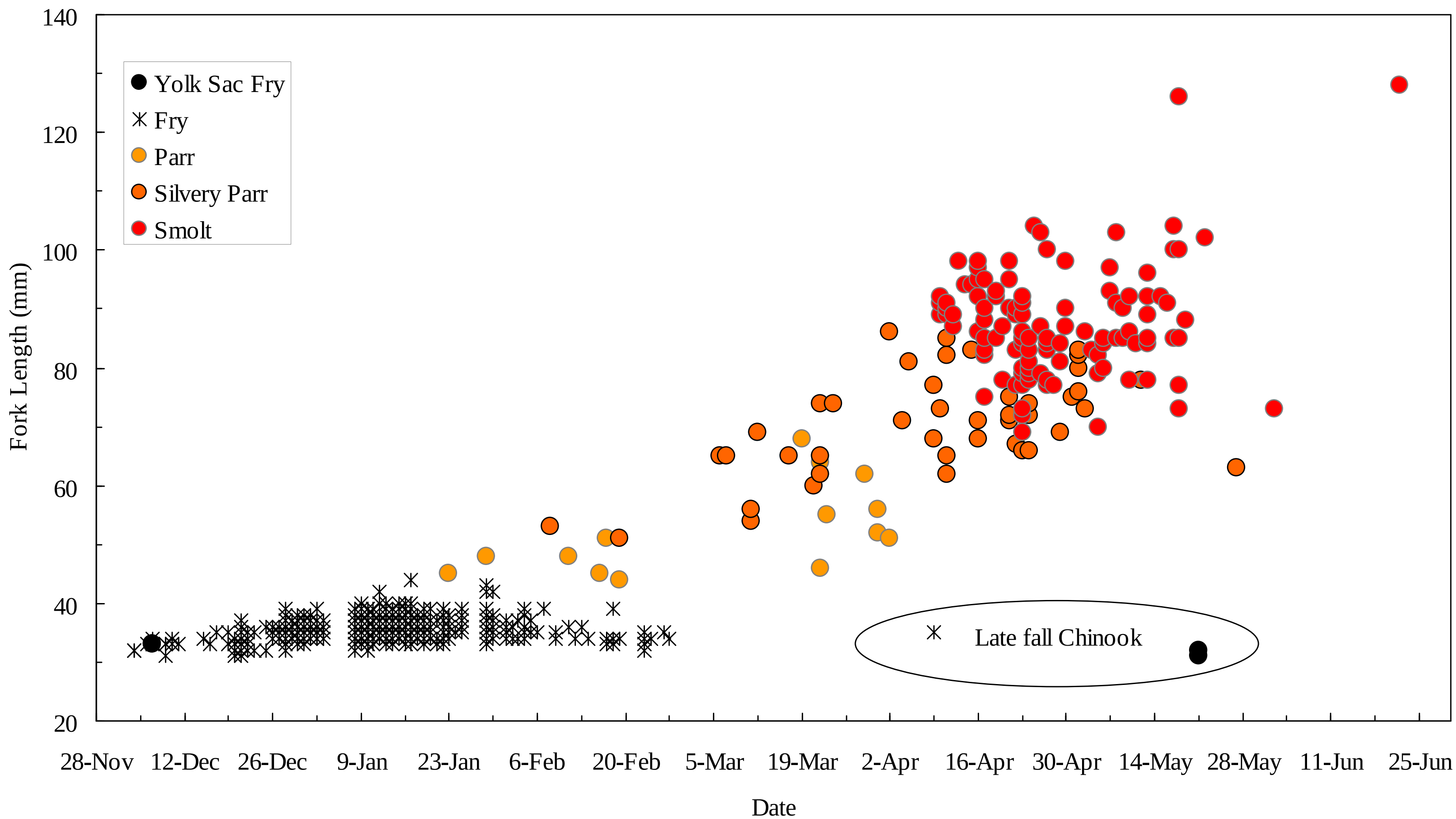


Figure 9. Life stage distribution for all runs of Chinook salmon measured at the Upper Battle Creek rotary screw trap during November 28, 2007 through June 30, 2008.

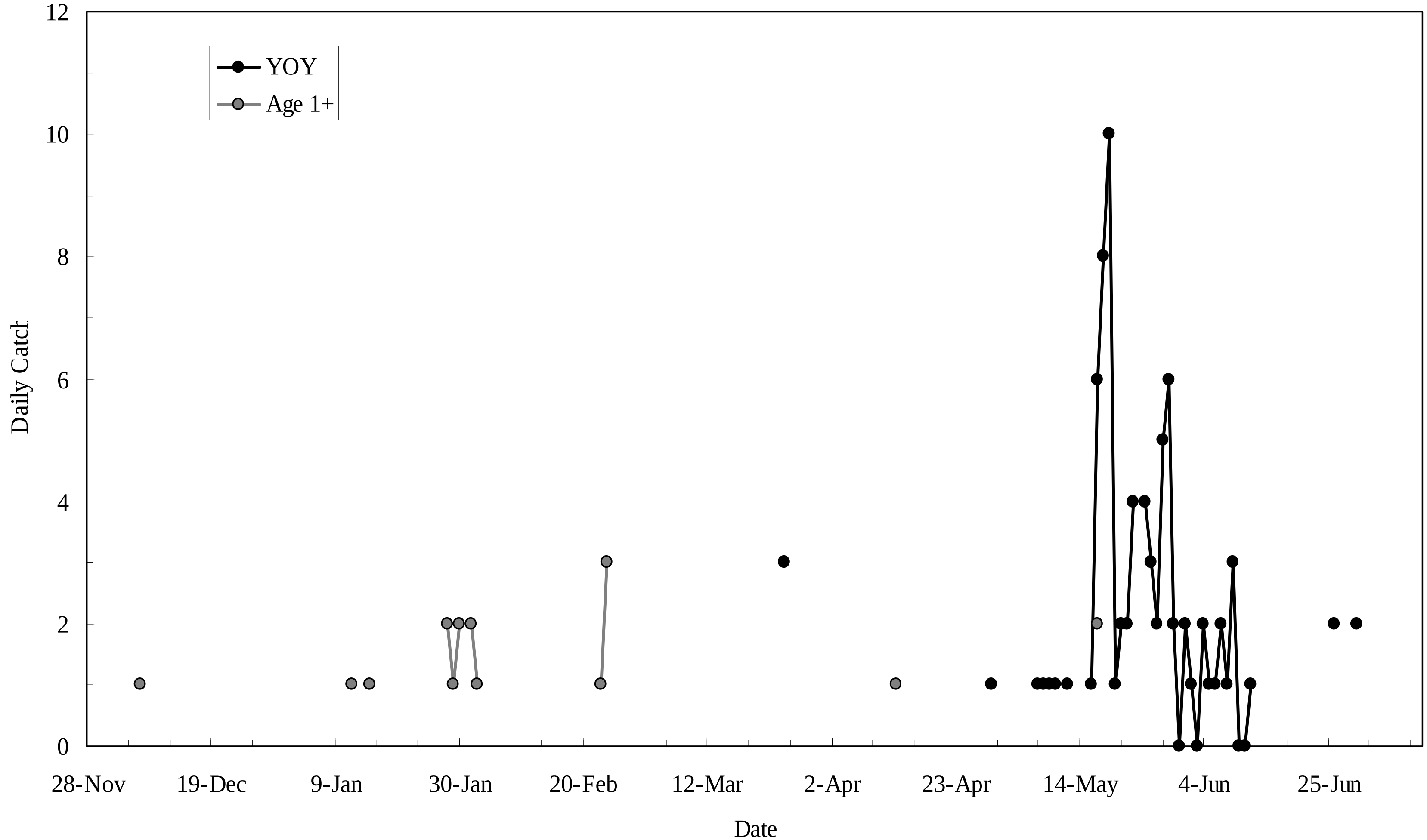


Figure 10. Daily catch of young-of-the-year (YOY) and age 1+ (Age1+) rainbow trout/steelhead captured at the Upper Battle Creek rotary screw trap from November 28, 2007 through June 30, 2008. Daily catch totals may be partial if the trap was not operated on all days of a week.

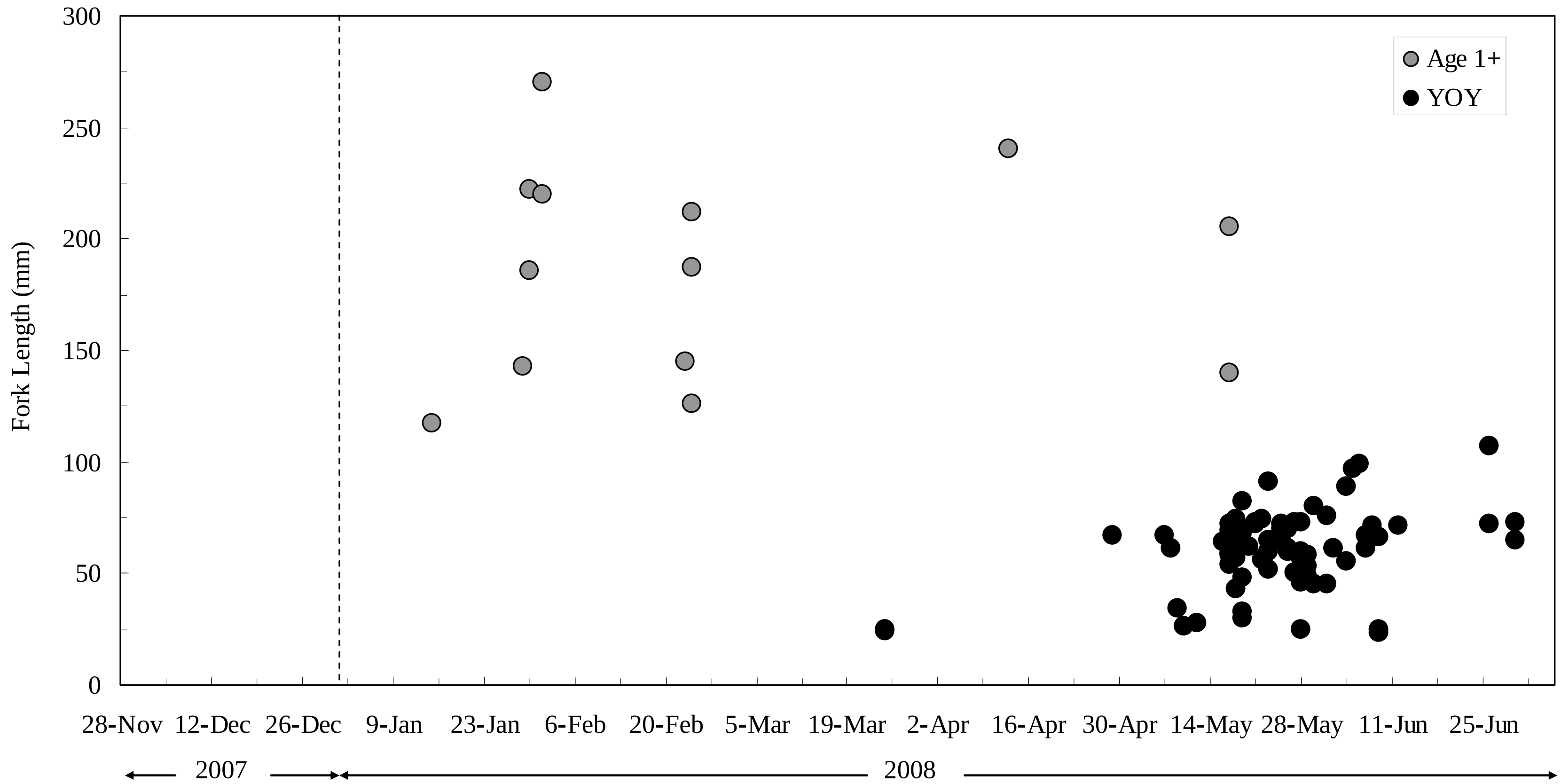


Figure 11. Fork length (mm) distribution by date for age 1+ and young-of-the-year rainbow trout/steelhead measured at the Upper Battle Creek rotary screw trap during November 28, 2007 through June 30, 2008. Age 1+ fish may include individuals from more than one year class.

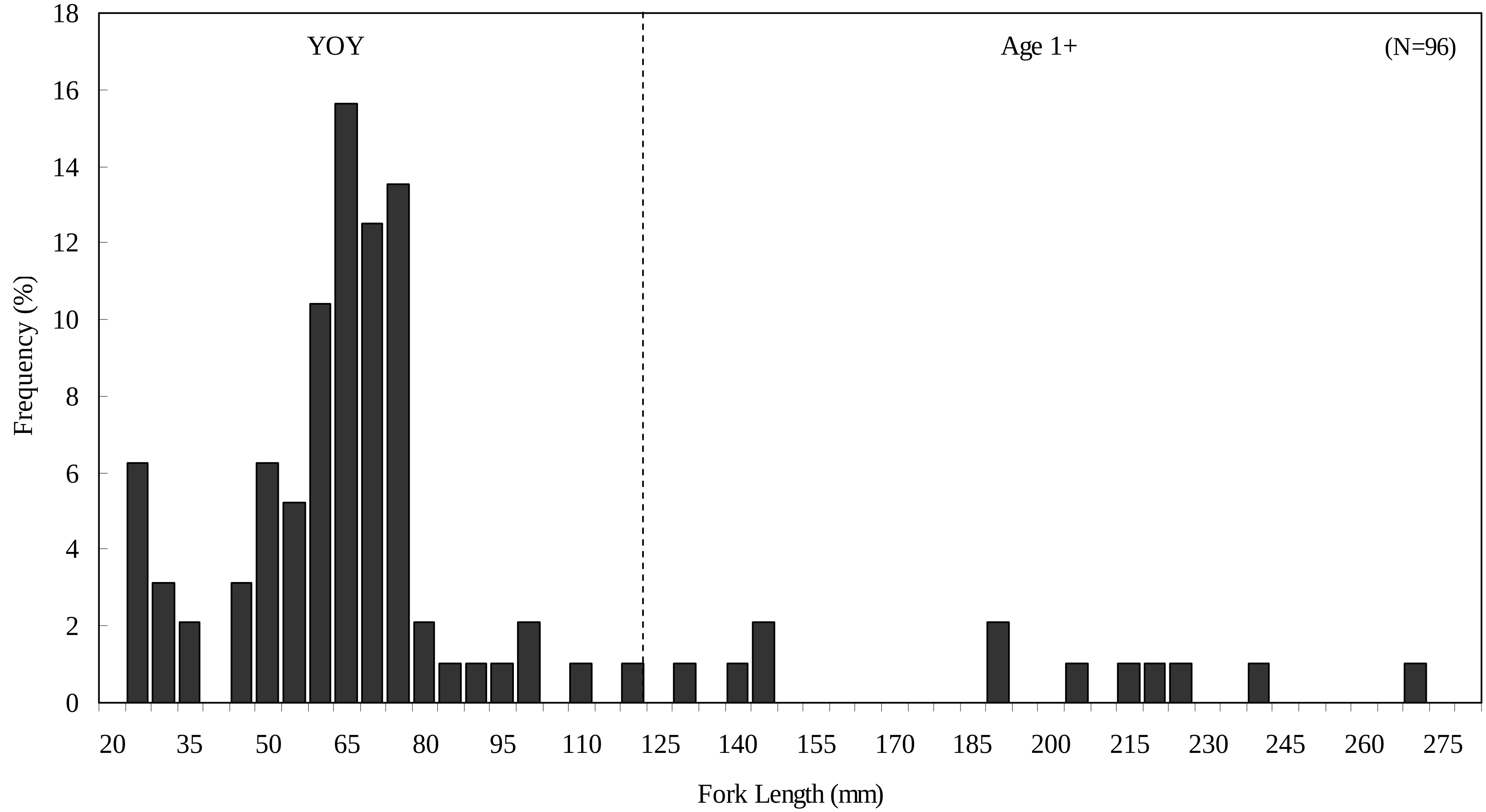


Figure 12. Fork length frequency (%) for rainbow trout/steelhead sampled at the Upper Battle Creek rotary screw trap during November 28, 2007 through June 30, 2008. Fork length axis labels indicate the upper limit of a 5-mm length range.

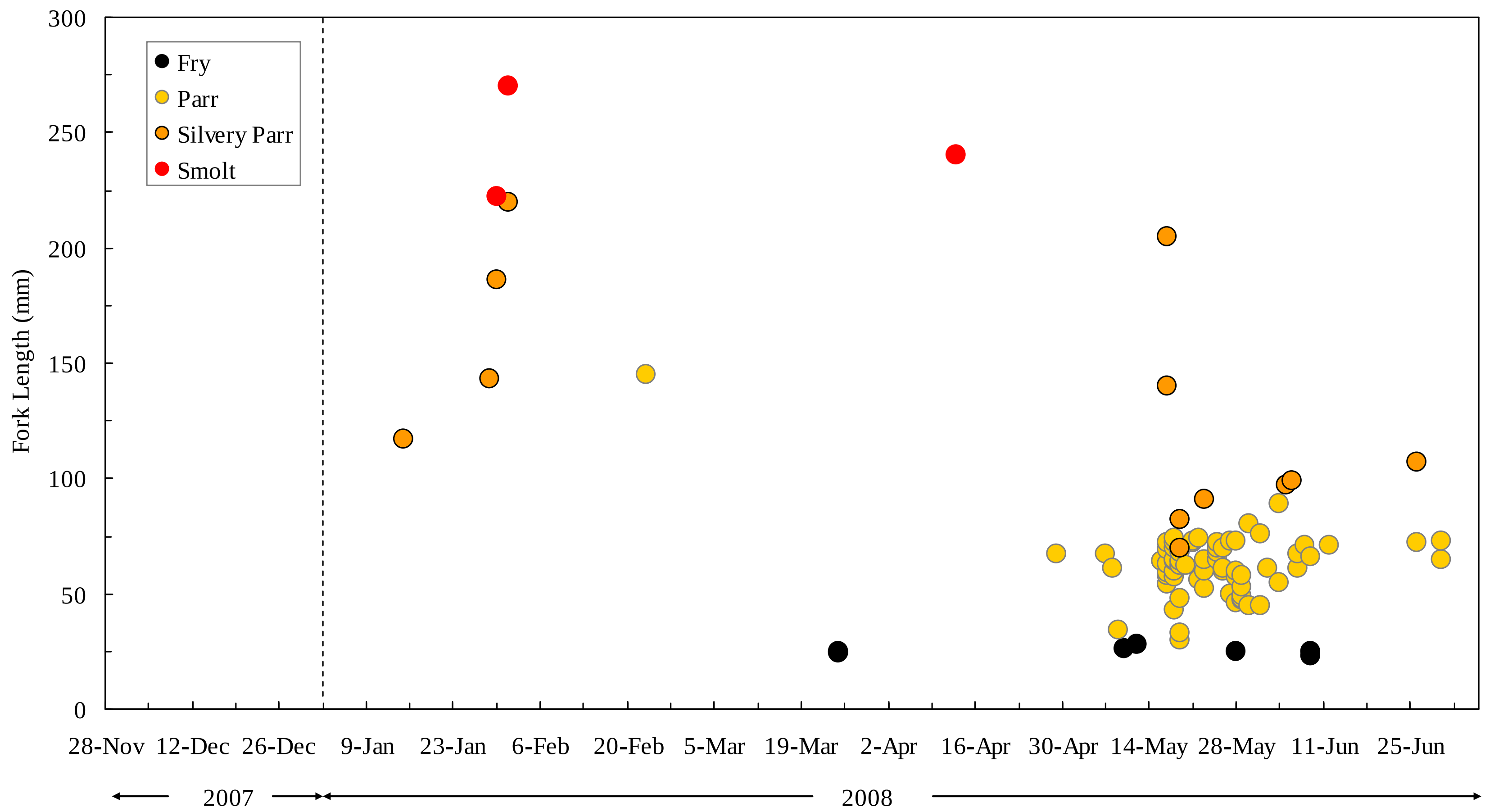


Figure 13. Rainbow trout/steelhead life-stage distribution at the Upper Battle Creek rotary screw trap during November 28, 2007 through June 30, 2008.

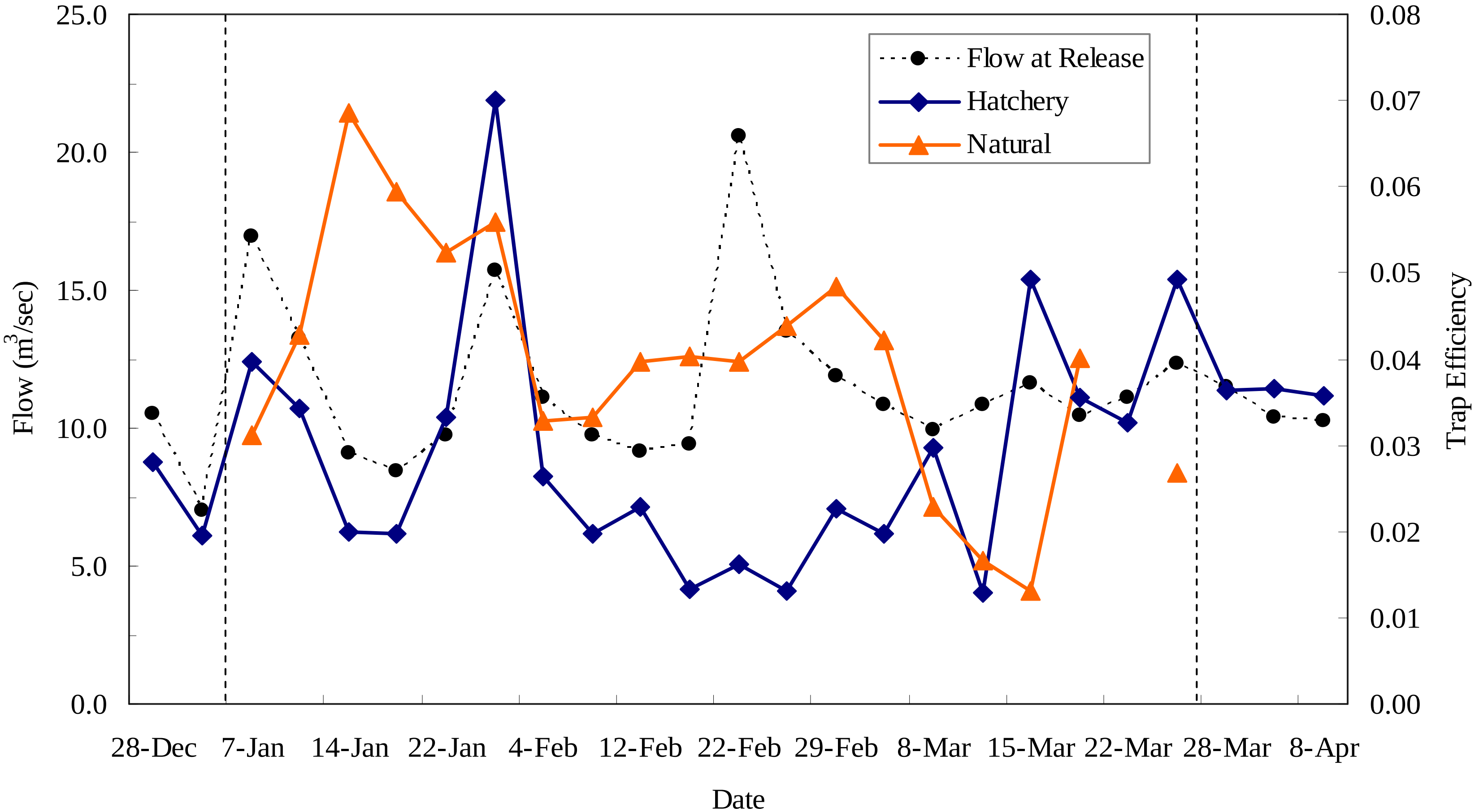


Figure 14. Trap efficiency and flow at the time of release for mark-recapture trials conducted at the Upper Battle Creek rotary screw trap using hatchery and naturally produced fall Chinook salmon, 2008. The dotted lines encompass all paired trials.

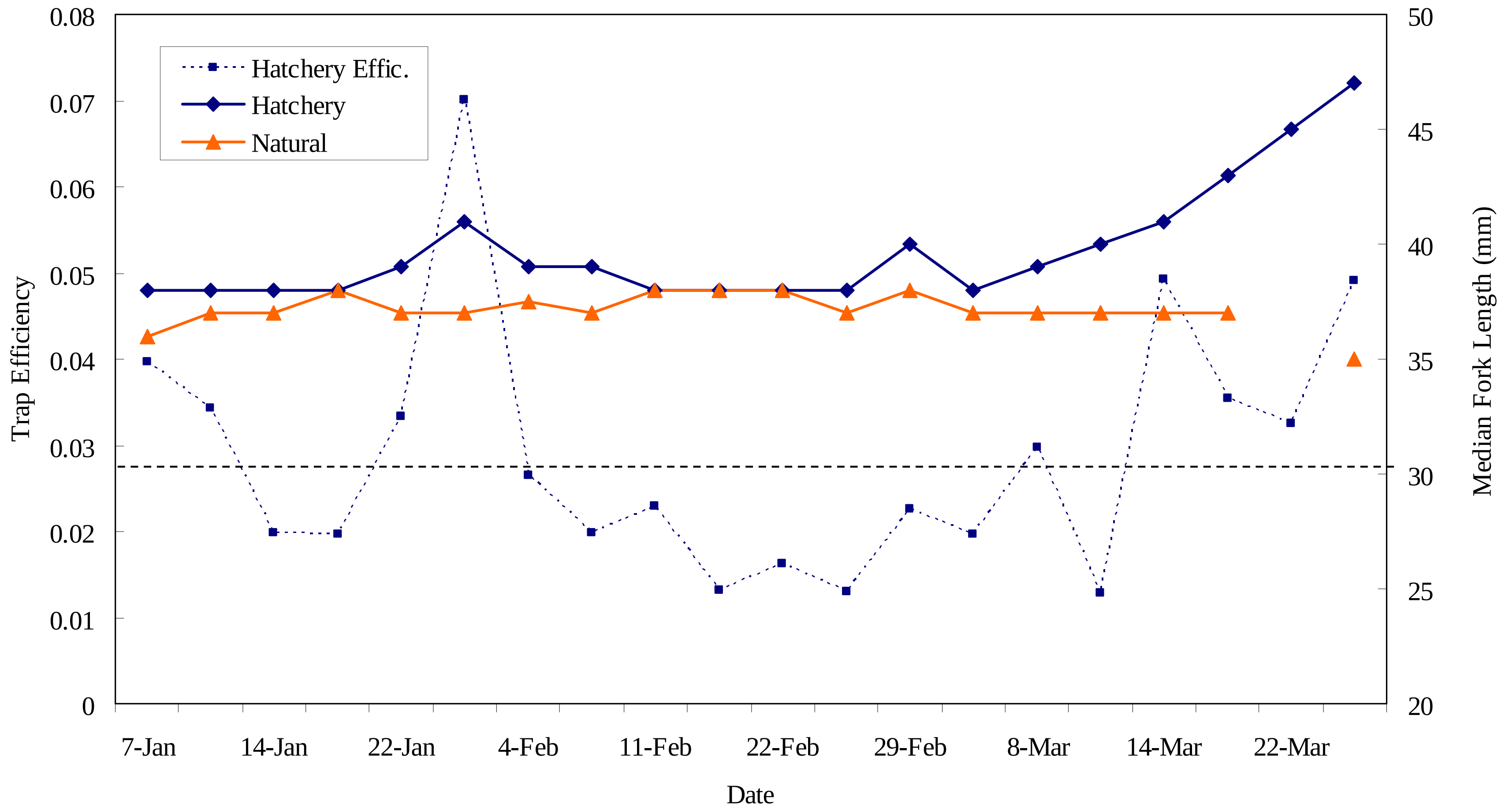


Figure 15. Median fork length of hatchery and naturally produced Chinook salmon used for mark-recapture trials conducted at the Upper Battle Creek rotary screw trap, 2008..

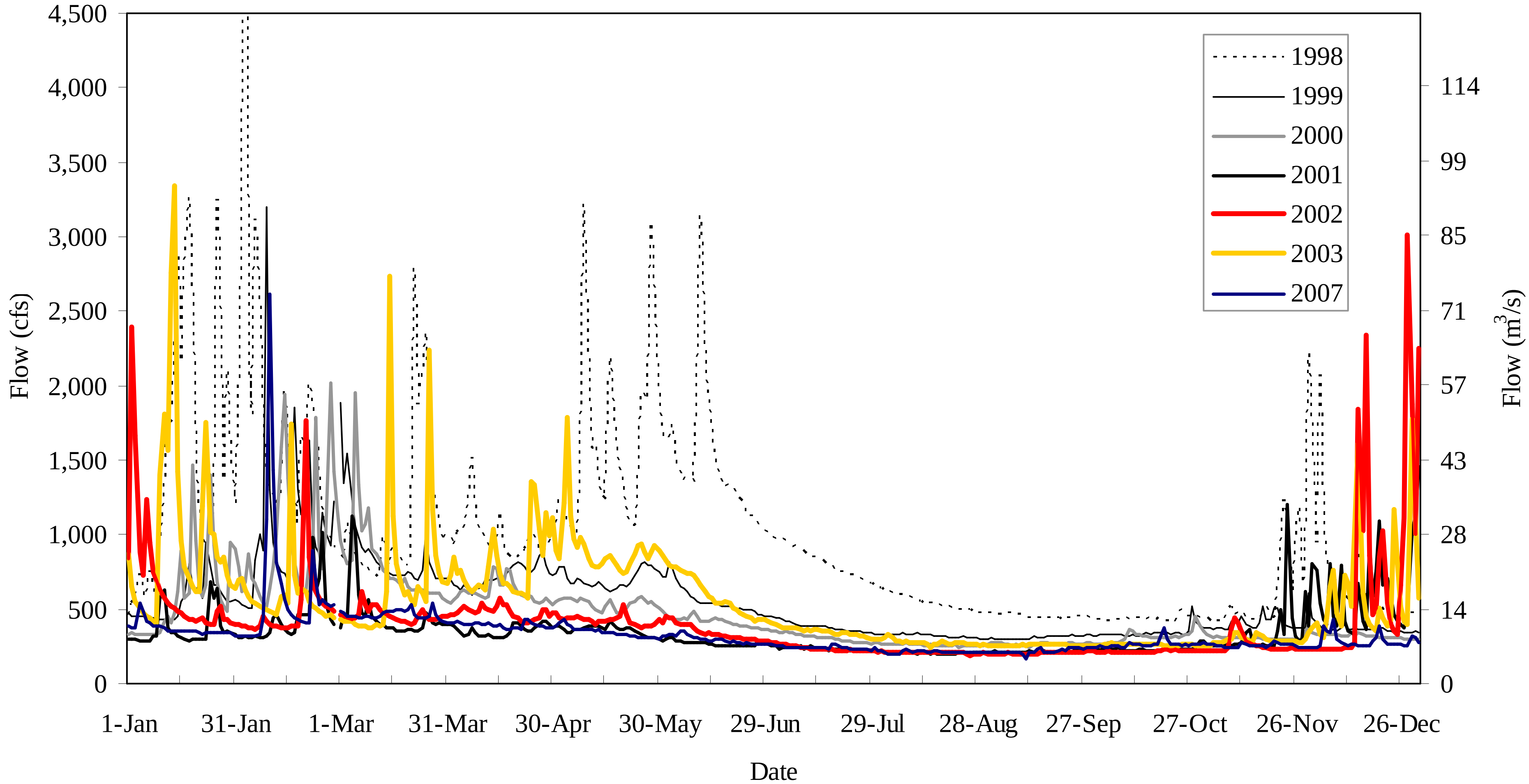


Figure 16. Mean daily flows ($m^3$/s and cfs) recorded at the U. S. Geological Survey gauging station (BAT-#11376550) located below the Coleman National Fish Hatchery barrier weir. Flows are for the period January 1 to December 31 for the years, 1998 to 2003 and 2007.

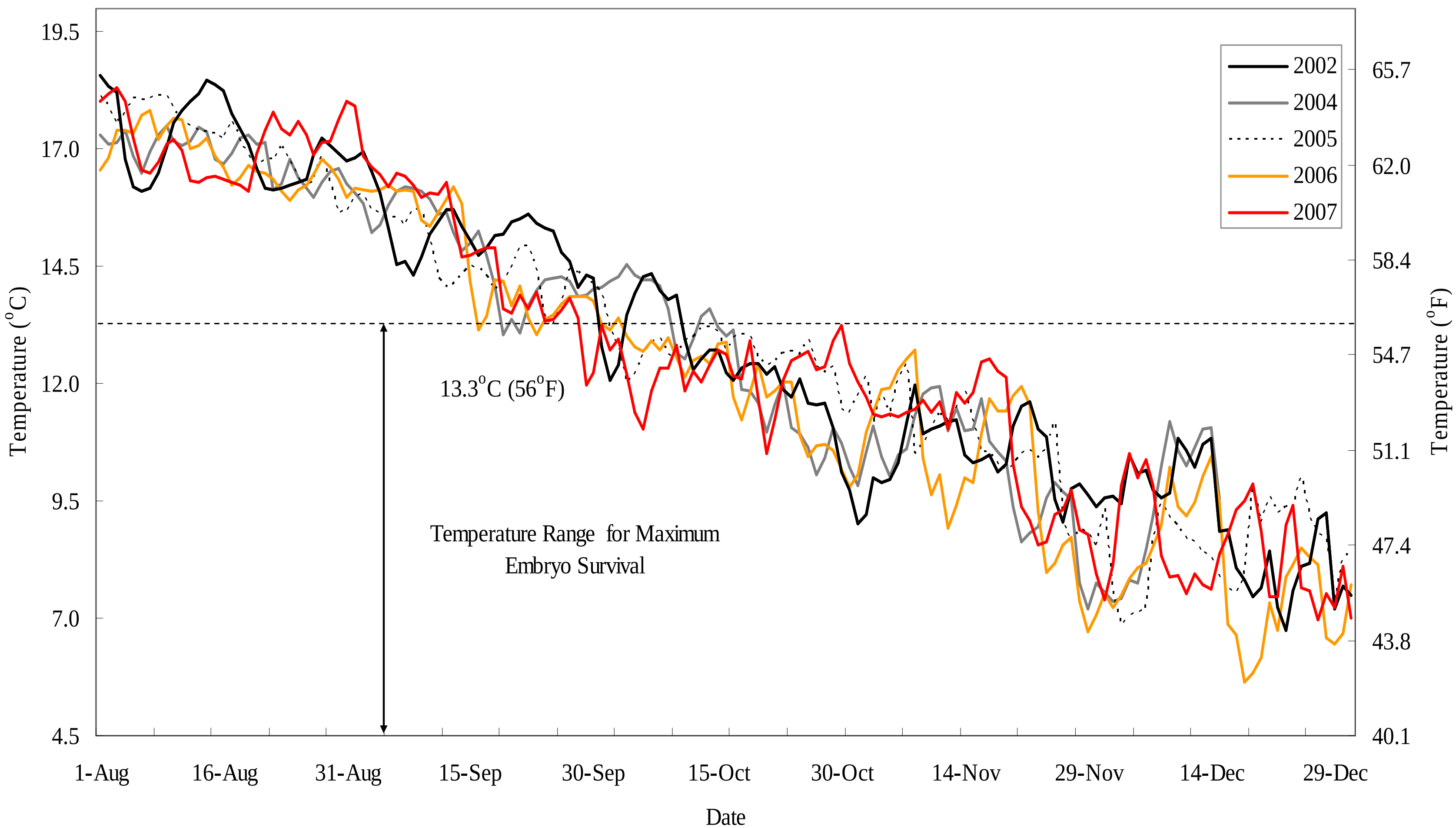


Figure 17. Mean daily water temperatures during the Spring Chinook salmon incubation period for the years 2002 and 2004 through 2007. Temperature data for 2002 through 2006 were included to allow for comparisons with 2007. Mean daily stream temperatures were calculated from temperature data collected by the CDEC gauge at the Wildcat Road Bridge for the years 2002 and 2004 through 2007. The temperature range for optimum Chinook salmon embryo survival is included.

**Appendix**

Appendix 1. Summary of days the Upper Battle Creek rotary screw trap did not fish during the report period (November 28, 2007 to June 30, 2008), including sample dates, hours fished, and reason for not fishing.

| Sample Dates | Hours Fished (approx) | Reason |
|---|---|---|
| | **2008** | |
| January 4 | 19 | High Flows-Trap Sank |
| January 5-7 | 0 | Trap Repair |
| January 26 | 10 | High Flows |
| January 27 | 0 | High Flows |
| January 28 | 11.3 | High Flows |
| January 31[a] | 10 (?) | Trap not rotating at am check |
| February 23 | 11.5 | High Flows |
| February 24 | 17.5 | High Flows |
| February 25 | 0 | High Flows |

[a] Actual fishing time is unknown, but likely 10 hours. The trap was checked at about 7:00 pm and since the trap was stuck on river right, we assume it did not fish after this time. The number of cone rotations appears to support this assumption.

Appendix 2. Summary of non-salmonid species captured by the Upper Battle Creek rotary screw trap from November 28, 2007 through June 30, 2008.

| Species | Month | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Total |
| CAR | 0 | 0 | 3 | 0 | 0 | 2 | 0 | 0 | 5 |
| CENFRY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| COTFRY | 0 | 1 | 0 | 0 | 0 | 0 | 4 | 27 | 32 |
| CYPFRY | 0 | 6 | 9 | 1 | 0 | 2 | 22 | 120 | 160 |
| HH | 0 | 59 | 49 | 22 | 4 | 20 | 166 | 2 | 322 |
| LFRY | 0 | 2 | 6 | 1 | 2 | 18 | 22 | 5 | 56 |
| PL | 0 | 18 | 7 | 11 | 0 | 9 | 18 | 6 | 69 |
| RFS | 0 | 2 | 2 | 3 | 32 | 25 | 30 | 25 | 119 |
| SPM | 0 | 15 | 6 | 4 | 0 | 3 | 2 | 0 | 30 |
| SASU | 0 | 14 | 7 | 4 | 0 | 1 | 51 | 728 | 805 |
| TP | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| TSS | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 3 |
| WBL | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 3 |

Appendix 3. Species key for non-salmonid fish taxa captured at the Upper Battle Creek trap from November 28, 2007 through June 30, 2008.

| Abbreviation | Common Name | Scientific Name |
|---|---|---|
| CAR | California roach | *Hesperoleucus symmetricus* |
| CENFRY | unknown centrarchidae | *Centrarchidae spp.* |
| COTFRY | cottus fry | *Cottus spp.* |
| CYPFRY | unknown cyprinidae | *Cyprinidae spp.* |
| HH | hardhead | *Mylopharodon conocephalus* |
| LFRY | unknown lampetra | *Lampetra spp.* |
| PL | Pacific lamprey | *Lampetra tridentata* |
| RFS | riffle sculpin | *Cottus gulosus* |
| SPM | Sacramento pikeminnow | *Ptychocheilus grandis* |
| SASU | Sacramento sucker | *Catostomus occidentalis* |
| TP | tule perch | *Hysterocarpus traski* |
| TSS | threespine stickleback | *Gasterosteus aculeatus* |
| WBL | western brook lamprey | *Lampetra richardsoni* |