Juvenile Salmonid Monitoring in Battle Creek, California, November 2008 through June 2009

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Juvenile Salmonid Monitoring in Battle Creek, California, November 2008 through June 2009

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Abstract- In November 2008, the U.S. Fish and Wildlife Service continued an ongoing juvenile salmonid monitoring project on Battle Creek, California, using rotary screw traps. 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 November 12, 2008 through July 2, 2009, spring and late-fall run Chinook salmon *Oncorhynchus tshawytscha*, rainbow trout/steelhead *Oncorhynchus mykiss,* and 10 species of non-salmonids were captured in the Upper Battle Creek (UBC) rotary screw trap. During the period January 24 through March 21, 2009, we conducted nine valid mark-recapture trials at the UBC trap to determine rotary screw-trap efficiency. Trap efficiencies using naturally produced fall Chinook salmon varied from 3.1 to 8.9 with a season average of 6.0%. We continued the paired mark-recapture study initiated in 2008, to determine whether hatchery produced Chinook salmon could be used as surrogates for naturally produced salmon; however, we added one additional component to the study to explore potential differences in trap efficiency related to median fork length. A third group of large hatchery fish was included in the mark-recapture trials. Trap efficiencies during the 10 paired trials were not different for naturally and hatchery produced fish of similar size (t=-1.45; P=0.182), and trap efficiencies during the 17 paired hatchery trials were not different for small and large hatchery fish (t=-1.26; P=0.228). Only naturally produced Chinook salmon trap efficiencies were used to estimate passage of Chinook salmon and steelhead at the UBC trap. 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. In addition, several Chinook salmon classified as fall-run were reclassified as late-fall run based on data collected during spawning surveys and adult passage data collected by Coleman National Fish Hatchery. The brood year 2008 spring Chinook salmon passage estimate at the UBC trap was 11,757, and the brood year 2009 late-fall Chinook salmon passage estimate was 1,562. The passage estimates for age 1+ rainbow trout/steelhead and brood year 2009 young-of-the-year at the UBC trap were 2,215 and 2,190 respectively.

Table of Contents

List of Tables

List of Figures

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 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 maintains 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 46% of spawning occurred in the north fork versus 26% in the south fork (Newton et al. 2008).

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 12, 2008 through July 2, 2009. 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 2008, 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, in 2007 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 12, 2008 through July 2, 2009. 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 for spring Chinook salmon. 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 limited our ability to operate the trap continuously (Appendix 1). In late May through June, the trap was fished 5 d/week due to funding and staff shortages. 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 12 to December 6, 2008 and February 1 to July 2, 2009 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 7, 2008 to January 31, 2009, 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.

Juvenile spring Chinook salmon passage was expected to be low due to low adult escapement and redd counts; therefore the trap was operated at full cone to increase our catch in order to estimate passage. Due to high leaf loads and low flows, the trap was operated with the half-cone modification for a short period of time (November 15-30, 2009), but no Chinook salmon were captured during this time. 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 StowAway® 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 National Fish Hatchery barrier weir and approximately

0.2 km downstream of the UBC trap (Figure 1). All environmental and biological data were entered into a Panasonic Toughbook® at the trap site. The Toughbooks allowed field staff to enter sample and catch data directly into our existing database, which increased our efficiency by reducing the time necessary for data entry and proofing.

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 were captured, subsampling occurred 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 a modification of the 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. During the current report period, the length-at-date criteria was modified to assign a run designation to late-fall Chinook salmon. At the beginning of the late-fall run outmigration, overlap with Chinook salmon classified as fall-run occurs; however, graphical display of fork length distributions indicated a distinct separation of the two groups. Redd data from snorkel surveys, incubation timing, and late-fall Chinook salmon passage data from Coleman National Fish hatchery were used to determine whether the length-at-date criteria should be modified. 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 during the daytime sample 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 that were captured during the daytime sample 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 calculated using fall Chinook salmon fry trap efficiencies. Outmigration of anadromous salmonids 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 threatened 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 2008-2009 season, we continued a paired mark-recapture study initiated during the 2007-2008 season. The primary goal of the study was to determine whether hatchery produced fall Chinook salmon could be used as surrogates for naturally produced Chinook salmon when estimating trap efficiency; however, during the current season we explored one additional objective. Results from the 2007-2008 season suggested that fish size might influence trap efficiency (Whitton et al. 2008); therefore, in addition to marking similar size hatchery and naturally produced fish, we also marked large hatchery fish to determine whether trap efficiency of large hatchery fish was different from small hatchery fish. 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 between our small hatchery and naturally produced fish, we selected hatchery fish that were of similar size to the naturally produced Chinook salmon. The large-hatchery fish were selected based on availability, but we waited approximately one month to ensure that fish were about 10 mm larger than the small hatchery fish. Paired trials did not begin until January 24, 2009 because sufficient numbers of naturally produced fall Chinook salmon were not available in the LBC trap. We conducted two trials each week during the period December 28, 2008 through April 7, 2009; however, during a few weeks high flow events, fish availability, or reduced staff limited us to one trial a week. During this period, seven unpaired hatchery trials were conducted when insufficient numbers of naturally produced fish were available for marking. We also conducted eight paired trials with just small and large hatchery fish. One unpaired naturally produced trial was also conducted.

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 applied to all fish for all trials. Large hatchery and naturally produced fish were given the same mark but were differentiated based on size. We made sure there was no size overlap by checking the fork-lengths of fish that may overlap. Upper size limits for naturally produced fish and lower size limits for large hatchery fish were determined from the subsample of fish measured for both groups. Any fish with overlapping fork lengths were removed and not included in the trial.

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, we used a scalpel to remove a small portion of the upper or lower caudal fin. To determine whether fin-clip location influenced trap efficiency, we alternated upper and lower fin-clips between trials, but during any one trial, large hatchery and naturally produced Chinook salmon always had the same clip. 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 50 fish to allow for length comparisons between hatchery and naturally produced fish, and between small and large hatchery 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. 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 shortly 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). To explore the relationship of trap efficiency to biological and environmental variables we collected the following information at the time of release: flow at release, temperature at release, turbidity at release, moon fraction, weather, cloud cover, etc. 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.

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

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

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 estimate a single 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 and whether there were differences in trap efficiency for small and large hatchery fish; therefore, we included the results from all valid trials in our statistical comparisons, whether or not there were seven recaptures. Trap efficiencies for hatchery and naturally produced fish and small and large hatchery fish were compared using a paired two-sample t-test.

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 results from our hatchery trials were not used to estimate passage of Chinook salmon at the UBC trap. A juvenile Chinook salmon JPI was calculated for brood year 2008 spring Chinook salmon and brood year 2009 late-fall Chinook salmon at UBC 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

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

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 25th and 975th values. Similarly, the 90% confidence intervals for the weekly and total JPI's were found by locating the 50th and 950th 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, we attempted to operate the UBC trap continuously from November 12, 2008 to July 2, 2009, except during high flows and periods of reduced sampling (Figure 2 and Appendix 1). The trap was not operated after July 2 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). Of the 365 d available, the trap was operated approximately 211 d. The period of little or no salmonid catch, July 3 to November 11, 2009 accounted for 132 of 154 missed sample days (86%), reduced sampling accounted for 12 d (8%), and high flows accounted for the remaining 10 d (6%). The monthly sampling effort varied from a low of about 6% in July 2009 to a high of 100% in December, January, and April (Figure 2).

Mean daily water temperatures at the UBC trap varied from a low of 5.3ºC (41.5ºF) on December 18, 2008 to a high of 22.4ºC (72.3ºF) on July 29, 2009 (Figure 3). Mean daily flow measured by the U.S. Geological Survey at the Coleman Hatchery gauging station (#11376550) varied from a low of 5.1 m^3/s (181 cfs) in late August 2009 to a high of 74.7 m^3/s (2,638 cfs) on March 2, 2009 (Figure 4). During the period of trap operation, there were only 2 d when flows exceeded 42.5 m^3/s (1,500 cfs) with a peak flow of 106.5 m^3/s (3,760 cfs) occurring on March 2, 2009 (Figure 5). Turbidity at the UBC trap varied from a low of 1.06 NTU's on January 8, 2009 to a high of 31.5 NTU's on February 9, 2009 (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, 16 spring and 883 fall Chinook salmon were captured in the UBC trap; however, based on adult management at the barrier weirs, juvenile fall-run were considered to be spring Chinook salmon; therefore, they were combined for analyses. In addition, redd data collected during the snorkel surveys, incubation timing, and CNFH adult late-fall passage data indicated that 30 of the Chinook salmon captured in late March to early April which were classified as fall-run according to the length-at-date criteria were likely late-fall Chinook salmon and were reclassified as such. Brood year 2008 (BY08) spring Chinook salmon were first captured at the UBC trap the week of December 14, 2008 with a peak weekly catch of 238 the week of January 25, 2009 (Figure 6). The last BY08 spring Chinook salmon was captured May 26, 2009. The total catch of BY08 juvenile spring Chinook salmon at the UBC trap was 868. However, after adjusting the total catch for days the trap was not operated, the adjusted total catch was 911 spring Chinook salmon. The total catch of BY09 late-fall Chinook salmon was 91, with a peak catch of 29 the week of April 19, 2009 (Figure 6). No additional late-fall Chinook salmon were added as a result of adjusting for the days the trap was not operated. According to the length-at-date criteria, no winter Chinook salmon were captured; therefore, no additional information will be provided for this run.

Fork lengths of spring Chinook salmon sampled at the UBC trap varied from 32 to 108 mm with a mean fork length of 41 mm and a median of 35 mm (N=534; Figure 7 and 8). Fork lengths of late-fall Chinook salmon varied from 30 to 38 mm with a mean and median fork length of 35 mm (N=91). Length frequency data for all runs were combined. Approximately 85% 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 0.2% yolk-sac fry, 82.0% fry, 2.1% parr, 9.0% silvery parr, and 6.7% smolt (Table 1 and Figure 9). The life-stage composition of late-fall Chinook salmon was 25.4% yolk-sac fry, 83.5% fry, and 1.1% parr.

During the reporting period, 111 (77 measured) age 1+ and 111 young-of-the-year (yoy) rainbow trout/steelhead were captured in the UBC trap. Age 1+ rainbow trout/steelhead were first captured the week of December 21, 2008 with a peak weekly capture of 52 occurring the week of January 25, 2009 (Figure 10). The actual rainbow trout catch at the UBC trap was 222; however, after adjusting the total catch for days the trap was not operated, the adjusted total catch was 261. No young-of-the-year were captured at the trap until March 1, 2009, with most being captured after April 12 (Figure 10). Fork lengths of rainbow trout/steelhead ranged from 22 to 253 mm with a mean fork length of 85 mm and a median of 42 mm (N=188; Figure 11 and 12). Fifty percent of the rainbow trout/steelhead captured in the trap were young-of-the-year which had fork lengths ≤85 mm (Figure 12). The life-stage composition of all rainbow trout/steelhead was 2.2% yolk-sac fry, 41.4% fry, 23.9% parr, 29.3% silvery parr, and 3.1% smolt (Table 1 and Figure 13).

Upper Battle Creek (UBC) non salmonids.—From November 12, 2008 through July 2, 2009, ten native non-salmonid species were captured in the UBC trap, including California roach, *Hesperoleucus symmetricus* (N=13), speckled dace, *Rhinichthys osculus* (N=1), hardhead, *Mylopharodon conocephalus* (N=399), Pacific lamprey, *Lampetra tridentata* (N=1,186), riffle sculpin, *Cottus gulosus* (N=51), Sacramento sucker, *Catostomus occidentalis* (N=505), Sacramento pikeminnow, *Ptychocheilus grandis* (N=38), tule perch, *Hysterocarpus traski* (N=8), threespine stickleback, *Gasterosteus aculeatus* (N=11), and Western brook lamprey, *Lampetra richardsoni* (N=1) (Appendix 2 and 3). No introduced species were captured in the UBC trap during the 2008-2009 field season. Cottid, cyprinid, centrarchid, and lamprey fry that could not be identified to species were also captured at the trap. Besides Chinook salmon, Pacific lamprey and Sacramento suckers 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, eleven mark-recapture trials, using naturally produced Chinook salmon, were conducted at the UBC trap from January 24 to March 21, 2009 (Table 2). Of the 11 trials used to estimate passage, 9 had at least seven recaptures as recommended by Steinhorst et al. (2004; Table 2). The two 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 21, 2009). During three of the eight 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 0.031 to 0.089, with a season average trap efficiency of 0.060. During the report period, the season average trap efficiency for all trials was used to estimate passage for 16 weeks.

Paired mark-recapture study.—Ten paired mark-recapture trials using naturally and small hatchery produced fall Chinook salmon were conducted at the UBC trap, and the results of all 10 were included in the analyses. In addition, 17 paired trials using small and large hatchery produced Chinook salmon were conducted at the UBC trap, and of those 16 were used in the analyses (Table 3 and Appendix 3). We also conducted seven unpaired hatchery trials using small hatchery fish, and one unpaired trial using naturally produced Chinook salmon. All seven unpaired hatchery trials were conducted during the period December 28, 2008 to January 20, 2009 (Table 3 and Figure 14). Trap efficiencies for small hatchery fish varied from 0.014 to 0.085 with a median of 0.034 for all trials. Trap efficiencies for large hatchery fish varied from 0.021 to 0.058 with a median of 0.046 for all trials. Trap efficiencies for naturally produced Chinook salmon varied from 0.014 to 0.090 with a median of 0.056 for all trials. The median trap efficiencies for the 10-paired trials using small hatchery and naturally produced fall Chinook salmon was 0.037 and 0.053, respectively. The median trap efficiencies for the 16-paired trials using small and large hatchery produced fall Chinook salmon was 0.035 and 0.046, respectively. Although the trap efficiencies of naturally produced fall Chinook salmon were higher in 8 of the 10 paired trials, they were not statistically different than the trap efficiencies of small hatchery fish (t=-1.45; P=0.182; Figure 14). In addition, although the trap efficiencies of large hatchery produced fall Chinook salmon were higher in 13 of the 17 paired trials, they were not statistically different than the trap efficiencies of small hatchery fish (t=-1.26; P=0.228; Figure 15).

Median fork length for naturally produced fall Chinook salmon varied from 35.5 to 38 mm, whereas median fork length for small hatchery fish varied from 36 to 55 and from 47 to 74 mm for large hatchery fish (Figure 16 and Appendix 3). With the exception of the last two trials, the median fork length of small hatchery fish was never more than 3 mm longer than the median fork length of naturally produced fall Chinook salmon. The difference in median fork length between small and large hatchery fish varied from 9 to 19 mm

Upper Battle Creek juvenile salmonid passage (UBC).—Juvenile passage indexes were calculated for spring and late-fall Chinook salmon and rainbow trout/steelhead. No winter Chinook salmon were captured in the UBC trap. The annual JPI for BY08 spring Chinook salmon was 15,591, and the 90 and 95% confidence intervals were 12,217 to 20,101 and 11,757 to 21,225, respectively (Table 4). The weekly JPI's for spring Chinook salmon increased rapidly to a peak of 4,259 the week of January 25, 2009, and then decreased until late March when passage began increasing slowly to a second peak of 266 the week of April 26, 2009. The annual JPI for BY09 late-fall Chinook salmon was 1,562, and the 90 and 95% confidence intervals were 1,372 to 1,775 and 1,352 to 1,816, respectively (Table 5). Late-fall Chinook salmon passage peaked at 483 the week of April 19, 2009. The annual JPI for yoy rainbow trout/steelhead passing the UBC trap between November 12, 2008 and July 2, 2009 was 2,190 whereas passage for age 1+ fish was 2,215 (Table 6). The 90 and 95% confidence intervals for the yoy annual JPI estimate were 1,666 to 2,890 and 1,596 to 3,072, and the 90 and 95% confidence intervals for the annual JPI for age 1+ fish were 1,701 to 2,914 and 1,633 to 3,123, respectively. Most age 1+ fish migrated during December through mid-May, whereas yoy were not captured in the trap until early March with a peak weekly passage of 349 the week of April 19, 2009.

Discussion

Trap Operation

During the current report period, we were able to operate the trap 91% (211 d) of the season (233 d). Of the 22 d the trap was not operated, 10 d (240 hours) were due to high flows and 12 days were due to reduced sampling. The 10 d (240 hours) the trap did not fish due to high flows, includes 8 d when the trap was not operated at all and 5 d (≈48 hours) when the trap only fished for part of the day (2-16 hours). In other words, there were 13 d during the primary outmigration period for spring Chinook salmon fry that passage estimates were calculated using estimated daily catches. Peak outmigration at the UBC trap typically occurs in January, and outmigration during the current report period appears to have also peaked in January because weekly catch had declined to <20 Chinook salmon per week from a high of 238 in late January; therefore, the affect of lost sampling days due to high flows on our overall passage estimate was likely minimal. The remaining 12 d the trap was not operated occurred in late May when Chinook salmon outmigration was also low (<10 per week); however, outmigration of juvenile rainbow trout/steelhead does occur at this time; therefore, reduced sampling may have influenced our trout passage estimates. Although the trap was not operated in July through mid-November during the current report period, this likely had little influence 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.

Trap Efficiency and Juvenile Salmonid Passage

*Trap efficiency.—*During the current report period we continued the paired mark-recapture study initiated in 2008 to determine whether hatchery produced fall Chinook salmon could be used as surrogates for naturally produced fall Chinook salmon to conduct mark-recapture trials at the UBC trap. In contrast to the previous season, we found no significant difference between the trap efficiencies of small hatchery and naturally produced fish (t=-1.44; P=0.182); however, due to shortages in naturally produced fish, only 10-paired trials were conducted this season compared to 19 last year. Although not statistically significant, trap efficiency of naturally produced fish was higher in eight of the 10 trials.

During the period 1990 to 2007, the return of fall Chinook salmon to Battle Creek has ranged from approximately 12,708 to 463,296 with a median estimate of 80,351. The 2008 preliminary estimate of adult escapement into Battle Creek was about 15,000 fall Chinook salmon, of which approximately 10,600 were taken into Coleman NFH for use as brood stock; therefore, the number of fall Chinook salmon that spawned in Battle Creek may have been <5,000. The low number of adults spawning in lower Battle Creek likely explains the limited number of naturally produced fish. Seven trials were conducted with small hatchery fish prior to the first paired trial on January 24, 2009, which was 16 days later than during the 2007-2008 season.

When the trap efficiency data for the two seasons were combined, the difference observed between hatchery and naturally produced fall Chinook salmon was even more significant (t=-2.56; P=0.016) than observed for the 19 paired trials conducted during the 2007-2008 season (t=-2.16; P=0.044). It seems likely there was a difference in trap efficiency between small hatchery and naturally produced Chinook salmon; however, we conducted too few trials this season to detect a difference. During one trial, the trap efficiency for small hatchery fish was 0.085 and during a second trial, the trap efficiency for naturally produced fish was 0.014. The trap efficiency for small hatchery fish was much higher than expected and the trap efficiency for naturally produced fish was much lower than expected; as a result, these two observations likely have a lot of influence. When these two trials were not included in the analysis, the difference between the two groups was highly significant (t=-3.22 P=0.015). Currently, the range of natural variation in trap efficiency is unknown for either group, but this information would be useful in determining whether unusually high or low trap efficiencies may be outliers.

In addition to our regular paired trials with small hatchery and naturally produced fall Chinook salmon, we added a third group of large hatchery fish to explore the relationship between median fork length and trap efficiency as recommended in the 2007-2008 Report. Although trap efficiencies for large hatchery fish were higher in 13 of 17 trials, they were not significantly different from small hatchery fish (t=-12.6; P=0.228); however, when the trial in which the small hatchery fish had an unusually high trap efficiency (0.085) is removed, trap efficiencies for the two groups are significantly different (t=-2.19; P=0.046). As mentioned previously, we do not know whether the unusually high trap efficiency is within the natural range of variability for small hatchery fish, and we do not have any additional information that would indicate that the trial was not valid. It seems unlikely that the trap efficiency of Chinook salmon would be the same at all fork lengths. Thomas et al. (1969) found the swimming ability of yolk sac fry increased with a reduction in yolk sac; but he also observed a decrease in swimming ability just before complete yolk-sac absorption. As Chinook salmon fry grow, their swimming ability increases, therefore they are more likely to be in faster water (Lister and Genoe 1970), which may account for the higher trap efficiencies. Larger fish would also have increased ability to avoid the trap, but maybe they were unable to at the sizes used in our trials. The hatchery environment may have reduced the ability of large hatchery fish to avoid the trap because velocities in the raceways are lower than Battle Creek velocities during our mark-recapture trials.

> ***Recommendation**: Continue the paired mark-recapture study to explore relationships between trap efficiency and biological and environmental variables and determine the natural range of variation in trap efficiency for hatchery and naturally produced fish.*

Juvenile Salmonid Passage.— The combined spring and fall Chinook salmon juvenile passage index (JPI) for the current report period is the lowest estimate since monitoring began in 1998. Several factors may explain why this estimate was the lowest on record, including low adult escapement, adult mortality or reduced fertility due to high summer water temperatures during the holding period, and redd scour due to high flows. Adult escapement in 2008 (n=105) was below the previous 10-year average of 158, which partially explains the low JPI; however, in years with similar escapement (i.e., 2001 and 2004), we observed higher JPI’s, which suggests that something in addition to low adult escapement was driving the low passage estimates we observed.

Some adult mortality may have occurred as only 40 redds were observed during snorkel surveys, which is 13 less than we would have predicted if there was a 1:1 sex ratio, 100% survival to spawning, and all females had spawned. Similarly, in 2002 there were 222 adult Chinook salmon passed upstream of the barrier weir; but only 78 redds were observed during snorkel surveys, which likely explains the low juvenile passage observed that year. Newton et al. (2008) found that the number of redds per adult female (assuming a 1:1 sex ratio) is positively correlated with increasing flows and decreasing water temperatures during the summer months. Higher flow increases the area of holding habitat, reduces stress caused by high water temperatures, and likely improves predator (otter) avoidance behavior for adult Chinook salmon. In 2008, mean monthly flows from June through September (225 cfs) were the lowest since 1998, and mean monthly temperatures were the highest (65.5°F) since 2001. According to Stafford et al. (2010) overall water temperatures in 2008 were adequate for spring Chinook salmon production, but likely at a reduced number due to high water temperatures during the holding period. Seventy-two percent of mean daily water temperatures during the holding period were categorized as fair or poor in the most utilized holding pool, which likely led to some reduced fertility and adult mortality.

During the egg incubation period, mean daily water temperatures at redd locations were categorized as excellent for 88.8 to 96.3% of the days, suggesting there may have been a minimal level of reduced egg survival due to high water temperatures during incubation. Redd scour in some years may negatively influence production but was likely not a factor for BY08 spring Chinook salmon because there were no large storm events during the spawning and incubation periods.

Brood year 2009 (BY09) late-fall Chinook salmon juvenile passage at the UBC trap increased significantly from the previous year. Adult escapement above CNFH (n=32) was almost twice that of 2008 (n=19), and the JPI for BY09 (n=1,562) increased substantially from BY08 (n=39). 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 barrier weir. Coleman National Fish Hatchery 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 of 249. Since 2002, both adult escapement and juvenile passage have steadily declined until this year when we had the third highest JPI recorded at the UBC rotary screw trap. In 2008 adult escapement and the JPI were lower than 2009. In fact, when all years are included, passage of adults by CNFH and the late-fall Chinook salmon JPI appears to be positively correlated (R^2=0.69, Figure 19).

In 2009, rainbow trout/steelhead juvenile passage at the UBC trap was low relative to most years since 1999, when monitoring began. It is likely that the low passage estimate was primarily a result of low adult escapement. As observed with late-fall Chinook salmon, passage of adult rainbow trout/steelhead above the barrier weir by CNFH has a strong positive correlation with the JPI for young-of-the year rainbow trout/steelhead (R^2=0.79, Figure 19). A relatively low JPI was somewhat expected because CNFH ceased passing hatchery-origin adult steelhead in 2005, thereby reducing the spawning population in the short term. 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 and 2009 fry <30 mm were captured in the trap in early June in 2008 and through late June in 2009 indicating that there might be a shift in emergence timing from the previous years.

Stream temperatures, likely did not impact late-fall Chinook salmon and rainbow trout/steelhead production because mean monthly water temperatures during spawning and incubation are well below the lethal range. In 2009, high flow events during the incubation period were limited; however, there was one high flow event on March 3, 2009 when flows peaked at 3,449 cfs on the south fork, 721 cfs on the north fork, and 3,760 on the mainstem which may have contributed to some scour of rainbow trout/steelhead and late-fall Chinook redds.

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Tables

Table 1. Life-stage summary of spring, late-fall and winter Chinook salmon and rainbow trout/ steelhead captured at the Upper Battle Creek rotary screw trap from November 12, 2008 through July 2, 2009.

	Spring Chinook		Late-Fall Chinook		Winter Chinook		Rainbow	
Life Stage	#	%	#	%	#	%	#	%
Yolk Sac Fry	1	0.2	14	15.4	0	0	5	2.2
Fry	430	82.0	76	83.5	0	0	92	41.4
Parr	11	2.1	1	1.1	0	0	53	23.9
Silvery Parr	47	9.0	0	0	0	0	65	29.3
Smolt	35	6.7	0	0	0	0	7	3.1
Totals	*524*	*100*	*91*	*100*	*0*	*0*	*222*	*100*

Table 2. Summary of the mark-recapture trials conducted at the Upper Battle Creek rotary screw trap from November 12, 2008 through July 2, 2009 using naturally produced fall Chinook salmon. Shaded rows indicate weeks where mark-recapture data were pooled to calculate the weekly trap efficiency. Trials highlighted with **bold text** were not used. Trials in italicized font were pooled between two weeks.

Release Date	Time of Release	Number Released	Recaptures	Efficiency[a]	Pooled Efficiency	Weekly Mean Flow, m^3/s (cfs)
01/24/09	17:30	512	21	0.043	0.056	10.6 (374)
01/27/09	17:45	507	35	0.071	0.056	10.6 (374)
01/31/09	17:33	418	36	0.088	0.085	7.8 (275)
02/03/09	18:45	514	42	0.083	0.085	7.8 (275)
02/07/09	22:16	503	24	0.050	0.031	10.7 (377)
02/10/09	18:15	512	6	0.014	0.031	10.7 (377)
02/19/09	18:30	502	44	0.089	---	20.4 (720)
02/25/09	18:45	325	24	0.077	---	23.7 (837)
03/10/09	19:11	236	9	0.042	---	14.4 (509)
03/17/09	*19:37*	*197*	*10*	*0.056*	*0.047*	*13.2 (467)*
03/21/09	*19:40*	*123*	*4*	*0.040*	*0.047*	*12.5 (441)*

---

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

Table 3. Comparison of naturally produced and hatchery fall Chinook salmon mark-recapture trials conducted at the Upper Battle Creek rotary screw trap in 2009. Shading indicates trials that were used for statistical comparison, and bold text indicates invalid trials.

	Naturally Produced			Small Hatchery Fish			Large Hatchery Fish		
Release Date	Marked	Recaptured	Efficiency	Marked	Recaptured	Efficiency	Marked	Recaptured	Efficiency
12/28/08[a]	---	---	---	506	12	0.0256	---	---	---
01/03/09[a]	---	---	---	508	16	0.0333	---	---	---
01/06/09[a]	---	---	---	504	10	0.0218	---	---	---
01/10/09[a]	---	---	---	503	26	0.0536	---	---	---
01/13/09[a]	---	---	---	503	22	0.0456	---	---	---
01/17/09[a]	---	---	---	502	16	0.0338	---	---	---
01/20/09[a]	---	---	---	510	6	0.0137	---	---	---
01/24/09	512	21	0.0429	510	17	0.0352	472	9	0.0211
01/27/09	507	35	0.0709	489	13	0.0286	---	---	---
01/31/09	418	36	0.0883	482	9	0.0207	495	11	0.0242
02/03/09	514	42	0.0835	505	20	0.0415	508	22	0.0452
02/07/09	503	24	0.0496	505	42	0.0850	511	27	0.0547
02/10/09	512	6	0.0136	555	25	0.0468	528	12	0.0246
02/18/09[b]	---	---	---	**501**	**4**	**0.0100**	**500**	**6**	**0.0140**
02/19/09	502	44	0.0895	---	---	---	---	---	---
02/25/09	325	24	0.0767	510	19	0.0391	483	27	0.0578
03/07/09[a]	---	---	---	495	15	0.0323	523	18	0.0363
03/10/09	236	9	0.0422	505	19	0.0395	493	22	0.0466
03/14/09[a]	---	---	---	509	17	0.0353	493	23	0.0486
03/17/09	197	10	0.0556	513	23	0.0467	512	28	0.0565
03/21/09	123	4	0.0403	496	16	0.0342	493	20	0.0425
03/24/09[a]	---	---	---	507	14	0.0295	501	27	0.0558
03/28/09[a]	---	---	---	505	16	0.0336	506	28	0.0572
03/31/09[a]	---	---	---	499	10	0.0220	501	11	0.0239
04/04/09[a]	---	---	---	504	19	0.0396	500	23	0.0479
04/07/09[a]	---	---	---	495	6	0.0141	500	14	0.0299

[a] Naturally produced Chinook salmon were not available during this trial.

[b] This trial was not used in analyses because the trap was not fishing in the correct location during the first night of the release.

Table 4. Weekly summary of brood year 2008 juvenile spring Chinook salmon passage estimates for the Upper Battle Creek rotary screw trap, including week, Bailey's 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
12/14/08	0.060[a]	2	33	6	25	44	24	48
12/21/08	0.060[a]	85	1,414	235	1,101	1,823	1,057	1,888
12/28/08	0.060[a]	72	1,198	188	933	1,544	896	1,659
01/04/09	0.060[a]	74	1,231	207	939	1,587	921	1,705
01/11/09	0.060[a]	209	3,478	559	2,708	4,483	2,600	4,815
01/18/09	0.060[a]	85	1,414	227	1,101	1,823	1,037	1,958
01/25/09	0.056	238	4,259	563	3,468	5,395	3,372	5,517
02/01/09	0.085	7	83	9	69	97	68	102
02/08/09	0.031	13	426	76	322	550	307	629
02/15/09	0.089	14	156	22	124	196	121	201
02/22/09	0.077	12	156	31	115	206	112	230
03/01/09	0.060[a]	18	300	50	228	386	220	415
03/08/09	0.042	10	237	86	148	395	132	395
03/15/09	0.047	1	21	6	15	32	13	36
03/22/09	0.047	1	21	6	15	32	14	36
03/29/09	0.060[a]	5	83	14	65	111	62	115
04/05/09	0.060[a]	4	67	10	52	86	50	89
04/12/09	0.060[a]	7	116	19	93	156	87	161
04/19/09	0.060[a]	8	133	22	102	178	98	184
04/26/09	0.060[a]	16	266	43	207	343	199	369
05/03/09	0.060[a]	10	166	26	127	214	122	222
05/10/09	0.060[a]	12	200	32	156	249	146	267
05/17/09	0.060[a]	5	83	14	65	107	62	115
05/24/09	0.060[a]	3	50	9	39	64	37	69

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
Totals	**---**	***911***	***15,591***	***2,460***	***12,217***	***20,101***	***11,757***	***21,225***

[a] The season average trap efficiency (0.060) was applied to weeks when mark-recapture trials were not 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 5. Weekly summary of late-fall Chinook salmon passage estimates for the Upper Battle Creek rotary screw trap, including week, Bailey's 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 late-fall 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
03/22/09	0.047[a]	10	214	57	146	321	134	357
03/29/09	0.060[a]	23	383	64	292	493	281	530
04/05/09	0.060[a]	3	50	8	38	64	37	69
04/12/09	0.060[a]	11	183	31	140	244	132	263
04/19/09	0.060[a]	29	483	80	376	622	361	644
04/26/09	0.060[a]	6	100	16	78	129	75	138
05/10/09	0.060[a]	7	116	20	89	150	87	161
05/17/09	0.060[a]	2	33	5	26	43	25	46
Totals	**---**	***91***	***1,562***	***125***	***1,372***	***1,775***	***1,352***	***1,816***

Table 6. Weekly summary of rainbow trout/steelhead passage estimates for the Upper Battle Creek rotary screw trap, including week, Bailey’s 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 2009 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[a]	Estimated Passage (N)	SE[c]	90% Confidence Interval[b]		95% Confidence Interval[b]	
					Lower CI	Upper CI	Lower CI	Upper CI
Previous Brood Years (Age 1+)								
12/21/09	0.060	5	83	13	65	107	61	111
12/28/08	0.060	1	17	3	13	21	12	22
01/25/09	0.056	52	931	124	758	1,153	727	1,205
02/01/09	0.085	2	24	2	20	28	19	29
02/08/09	0.031	1	33	6	24	44	24	46
02/15/09	0.089	6	67	10	53	84	51	89
02/22/09	0.077	28	365	78	261	507	254	537
03/01/09	0.060	18	300	49	233	386	224	415
03/08/09	0.089	8	190	64	119	316	112	379
03/22/09	0.047	1	21	6	15	32	13	36
04/19/09	0.060	1	17	3	13	21	12	23
05/03/09	0.060	9	150	25	114	193	112	207
05/17/09	0.060	1	17	3	13	22	12	24
Totals	---	***133***	***2,215***	***386***	***1,701***	***2,914***	***1,633***	***3,123***
Brood Year 2009 (YOY)								
03/01/09	0.060	2	33	5	25	43	24	44
03/08/09	0.042	1	24	9	15	40	14	40
03/15/09	0.047	4	86	23	58	128	56	143
03/22/09	0.047	7	150	42	98	225	94	250
03/29/09	0.060	9	150	24	117	193	112	207

Table 6 Continued.

04/12/09	0.060	14	233	37	181	300	171	323
04/19/09	0.060	21	349	54	272	435	261	467
04/26/09	0.060	6	100	16	76	129	75	138
05/03/09	0.060	10	166	28	127	214	122	230
05/10/09	0.060	10	166	26	130	214	124	222
05/17/09	0.060	7	116	19	91	156	87	161
05/24/09	0.060	4	67	10	52	86	50	89
05/31/09	0.060	1	17	3	13	21	12	23
06/07/09	0.060	7	116	19	93	156	87	161
06/14/09	0.060	18	300	50	228	400	220	415
06/21/09	0.060	4	67	11	52	86	50	92
06/28/09	0.060	3	50	8	38	64	37	67
Totals	**---**	***128***	***2,190***	***384***	***1,666***	***2,890***	***1,596***	***3,072***

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[a] Daily catch was estimated for days the trap was not fishing.

[b] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.

Table 7. 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 (CI) 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		95% Confidence Interval	
				Lower CI	Upper CI	Lower CI	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[f]	---	N/A	N/A	N/A	N/A	N/A
	2006[g]	---	107,014	N/A	N/A	N/A	N/A
	2007	---	74,823	62,508	93,490	60,655	101,861
	2008	---	15,591	12,217	20,101	11,757	21,225
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,h]		N/A	N/A	N/A	N/A	N/A
	2007[h]	---	N/A	N/A	N/A	N/A	N/A
	2008 [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

Table 7 Continued.

	2005	---	147	112	198	109	213
	2006[f]	---	N/A	N/A	N/A	N/A	N/A
	2007	---	N/A	N/A	N/A	N/A	N/A
	2008[j]	---	39	N/A	N/A	N/A	N/A
	2009	---	1,562	1,372	1,775	1,352	1,816
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
	2009 (1+)	---	2,215	1,701	2,914	1,633	3,123
	2009 (YOY)	---	2,190	1,666	2,890	1,596	3,072

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[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] Methods used to calculate the BY06 passage estimate are described in an internal file memo. 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.

[j] CIs were not calculated because the passage estimate was based on a total of only three captured late-fall Chinook.

Figures

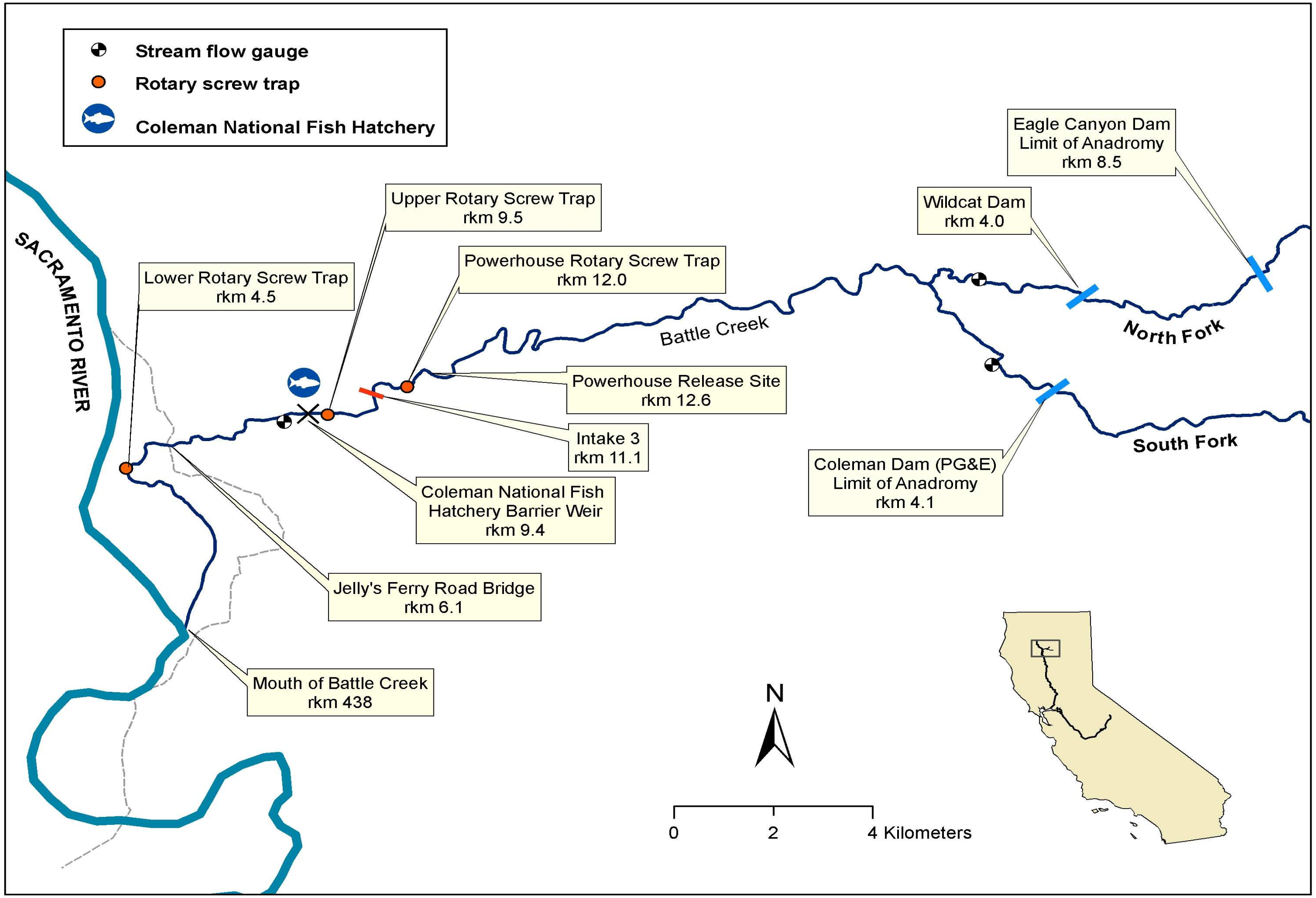

Figure 1. Map of Battle Creek depicting the location of USFWS' rotary screw traps and other important features.

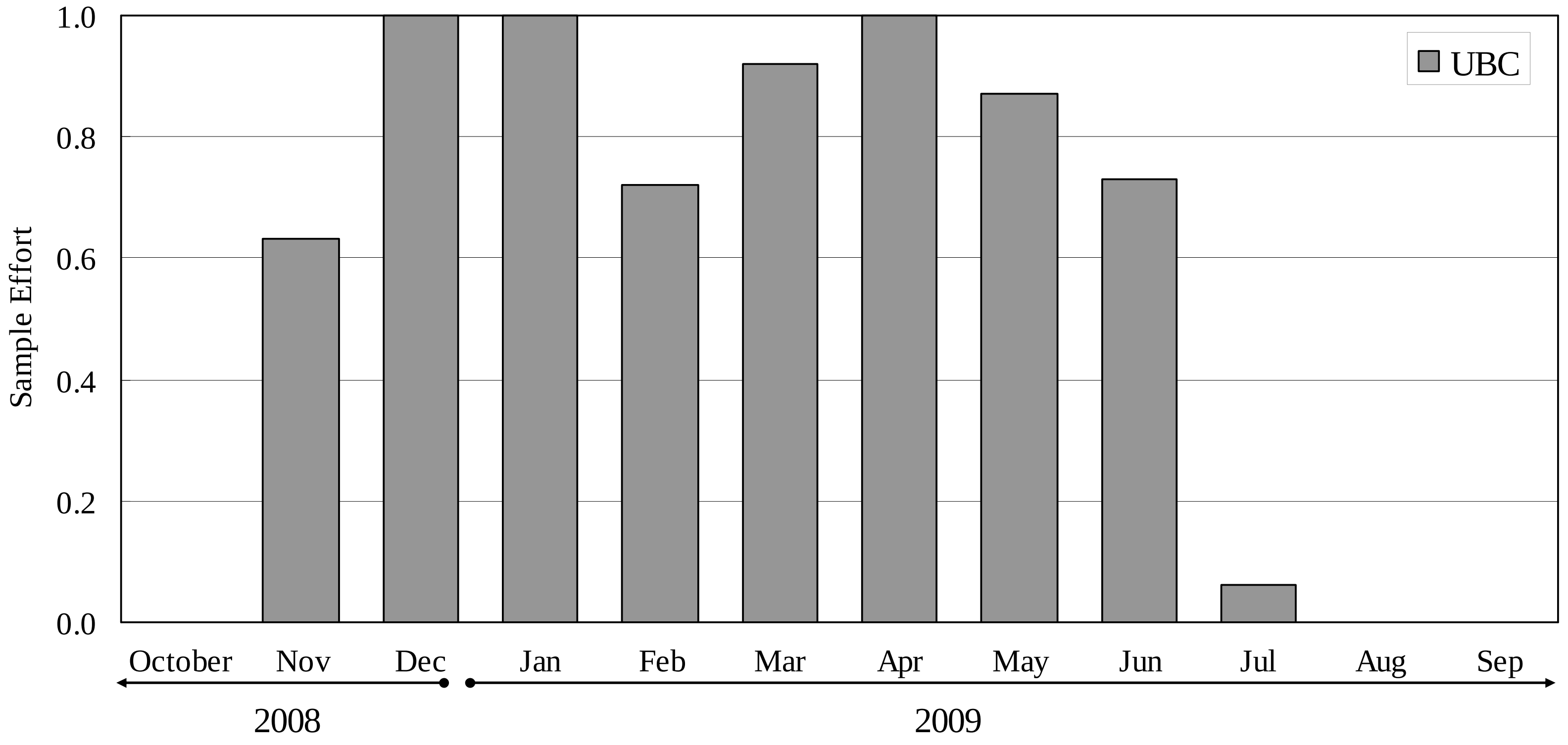

Figure 2. Sampling effort summarized as the proportion (range: 0 to 1) of days fished each month at the Upper Battle Creek rotary screw trap (UBC) from October 1, 2008 to September 30, 2009. Dates of trap operation were November 12, 2008 through July 2, 2009. Sample effort in May and June declined due to a reduced sampling schedule of 5d/week.

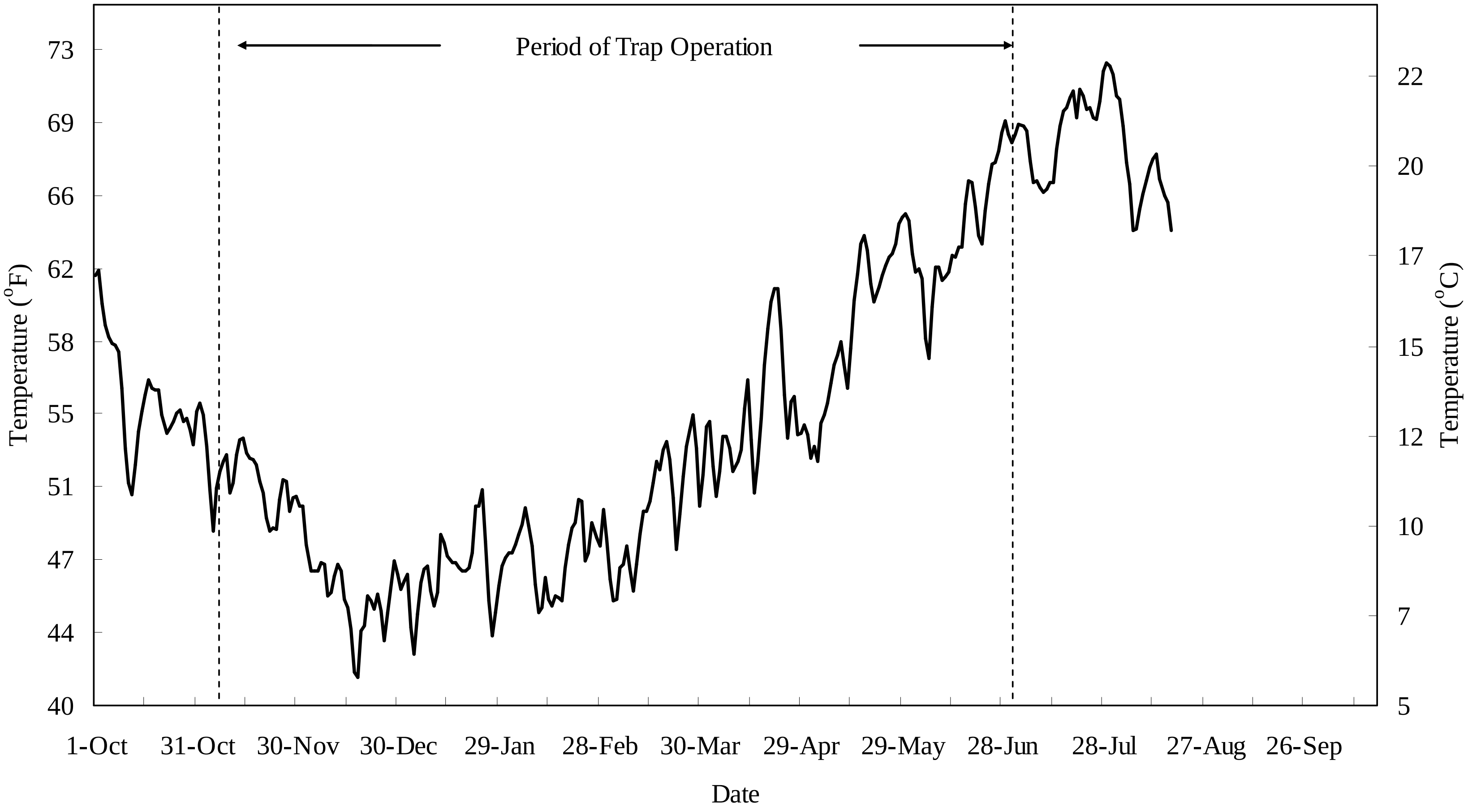

Figure 3. Mean daily water temperatures (ºF and ºC), at the Upper Battle Creek rotary screw trap from October 1, 2008 through August 17, 2009.

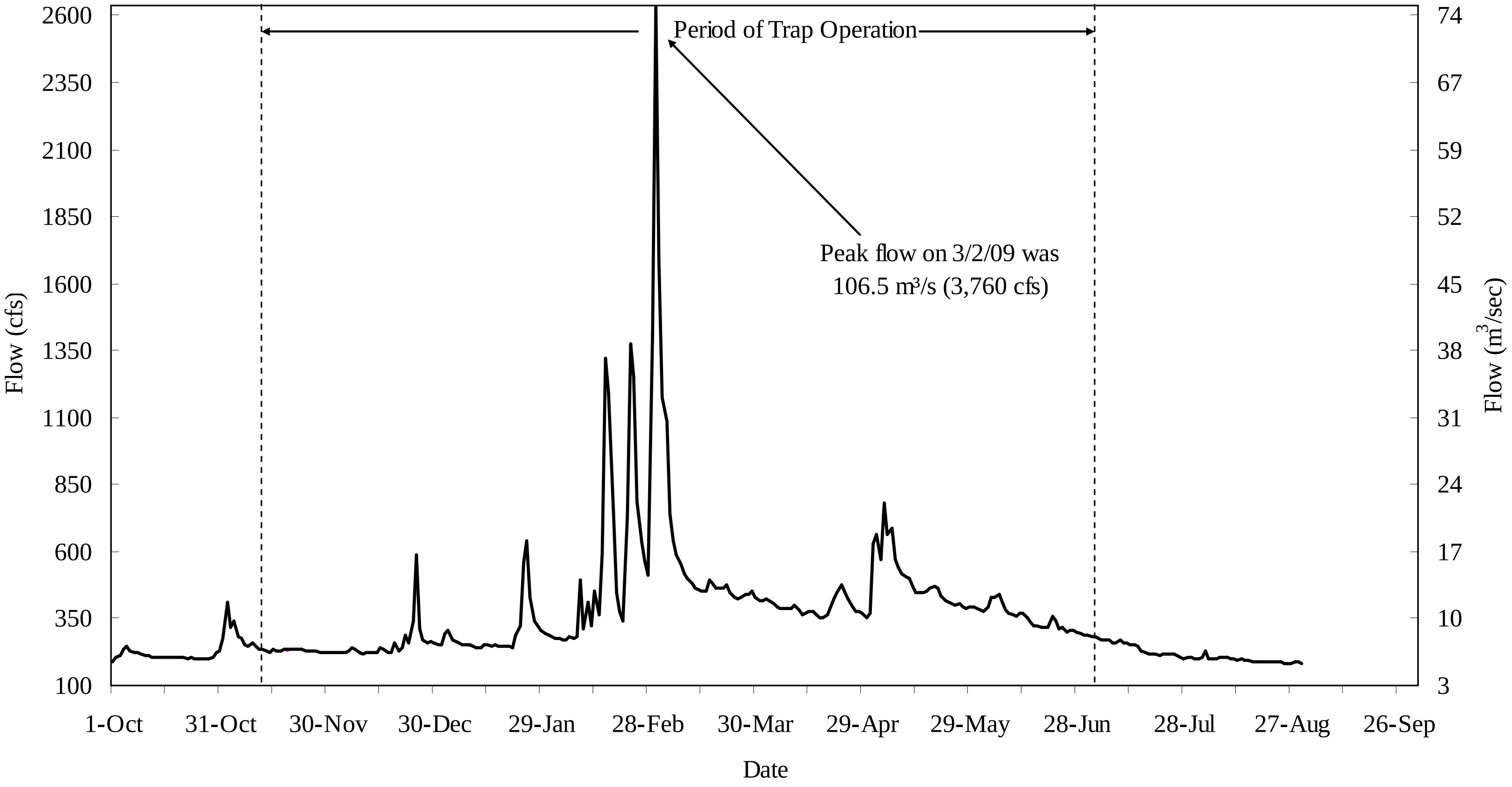

Figure 4. Mean daily flows (cfs and m^3/s) collected by the U.S. Geological Survey at the Coleman Hatchery gauging station (BAT #11376550) from October 1, 2008 through August 30, 2009. The gauge site is located below the Coleman National Fish Hatchery barrier weir and approximately 0.2 km downstream of the Upper Battle Creek rotary screw trap.

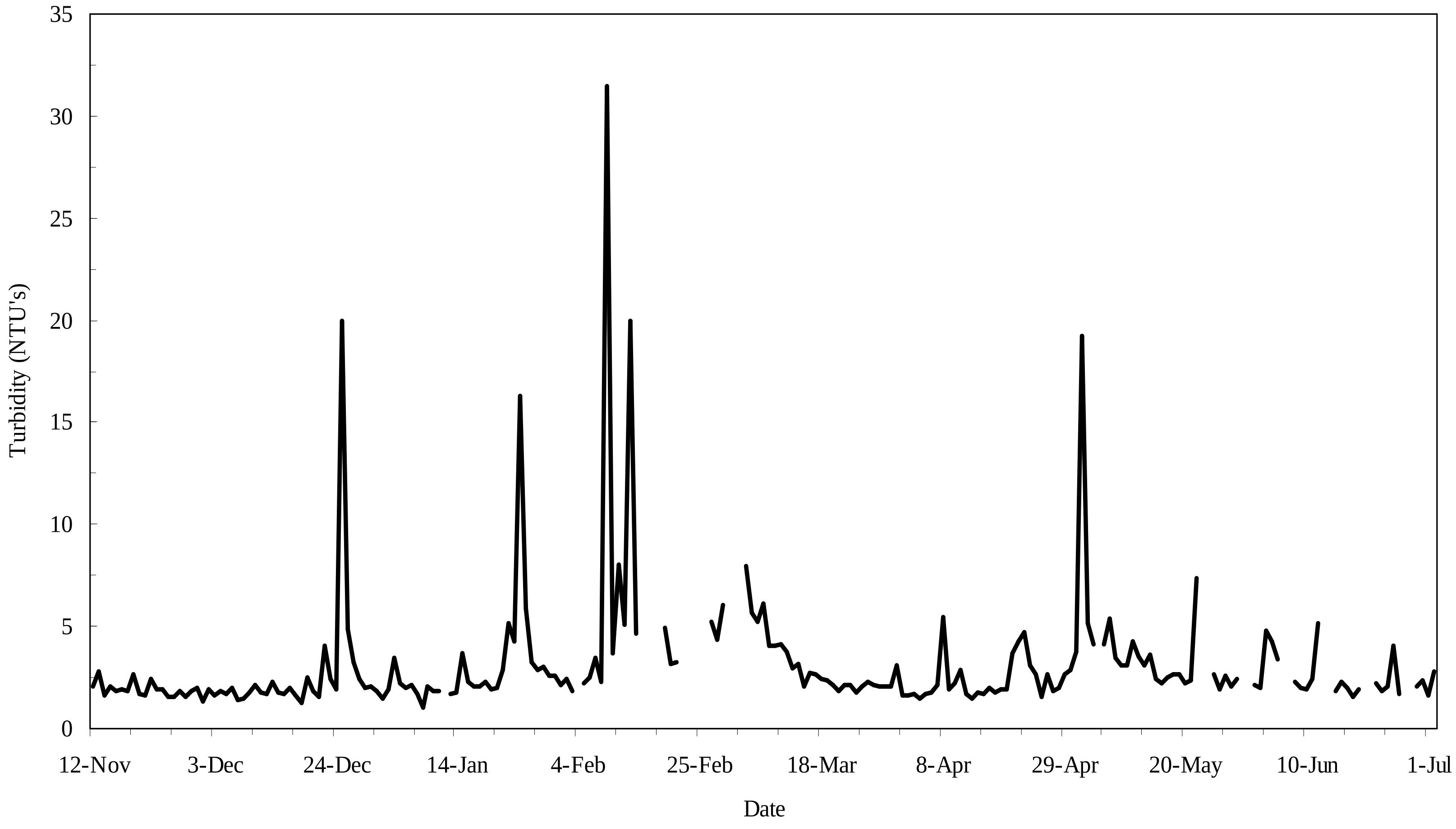

Figure 5. Turbidity (NTU) measured at the Upper Battle Creek rotary screw trap during trap operation (November 12, 2008 to July 2, 2009).

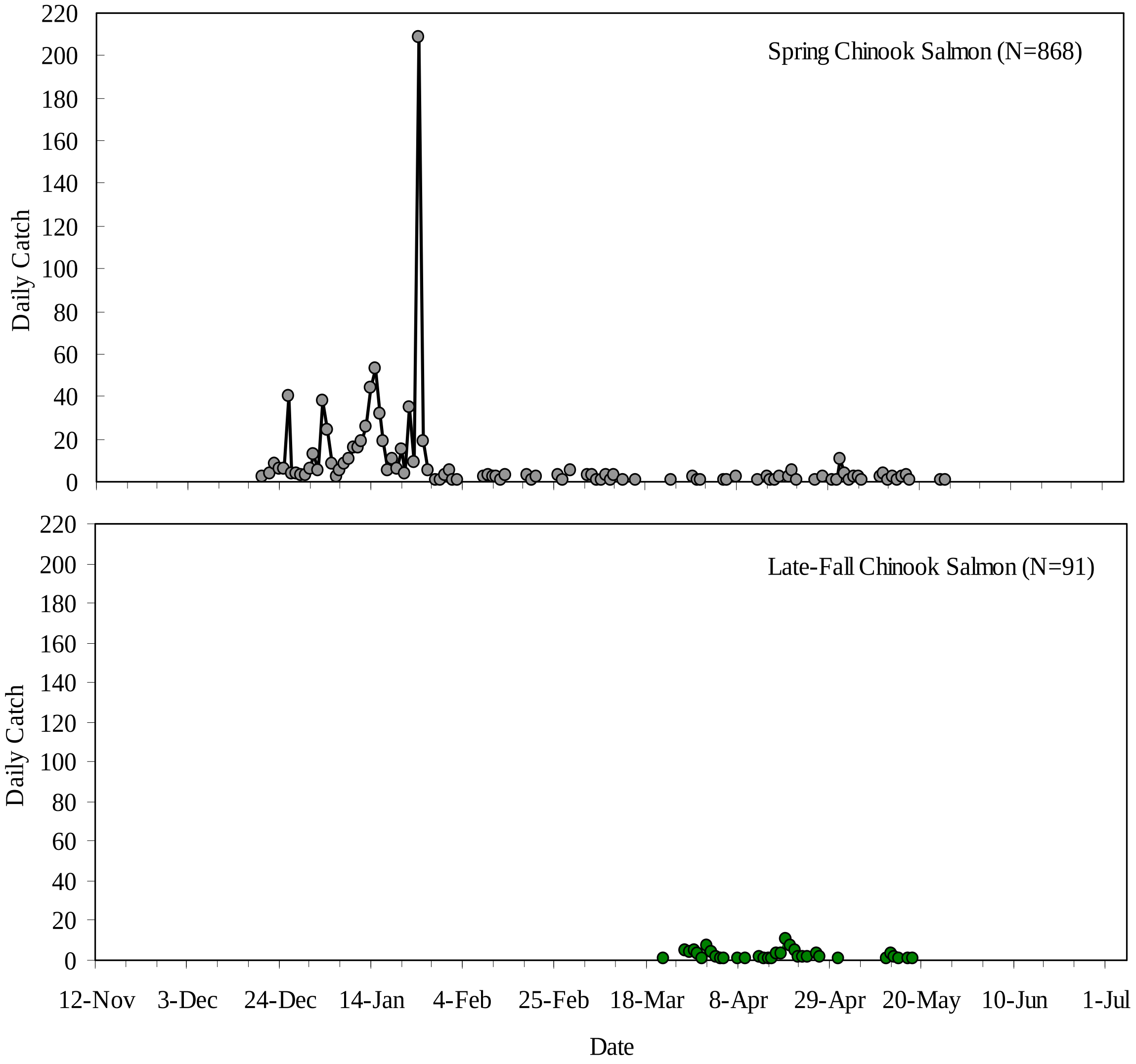

Figure 6. Daily catch of spring and late-fall Chinook salmon captured at the Upper Battle Creek rotary screw trap from November 12, 2008 through July 2, 2009. Daily catch totals may be partial if the trap was not operated on all days of a week. This figure does not included days with zero catch.

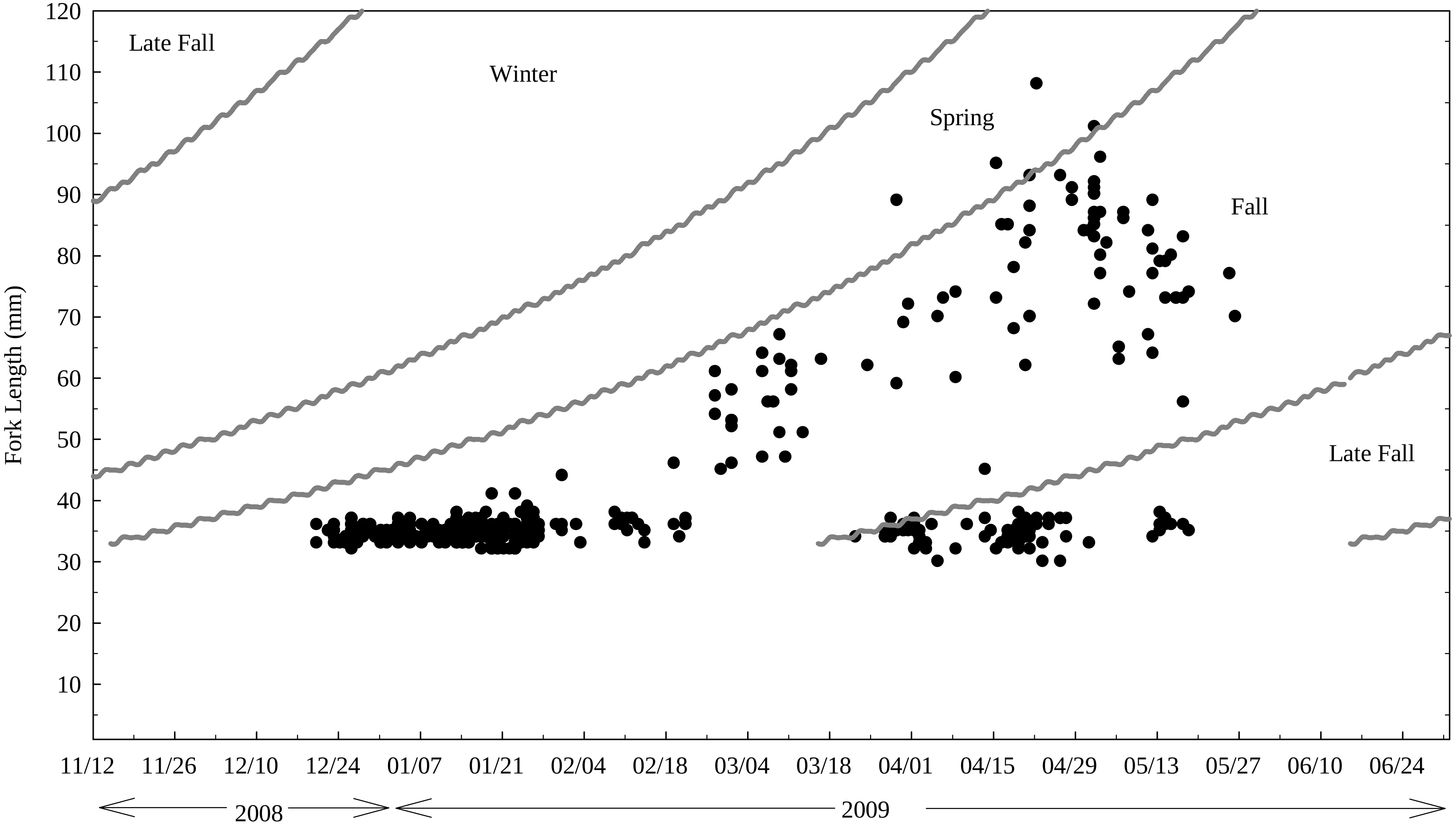

Figure 7. Fork length (mm) distribution by date and run for Chinook salmon captured at the Upper Battle Creek rotary screw trap from November 12, 2008 to July 2, 2009. Spline curves represent the maximum fork lengths expected for each run by date, based on criteria developed by the California Department of Water Resources (Greene 1992). Trap not operated after July 2, 2009.

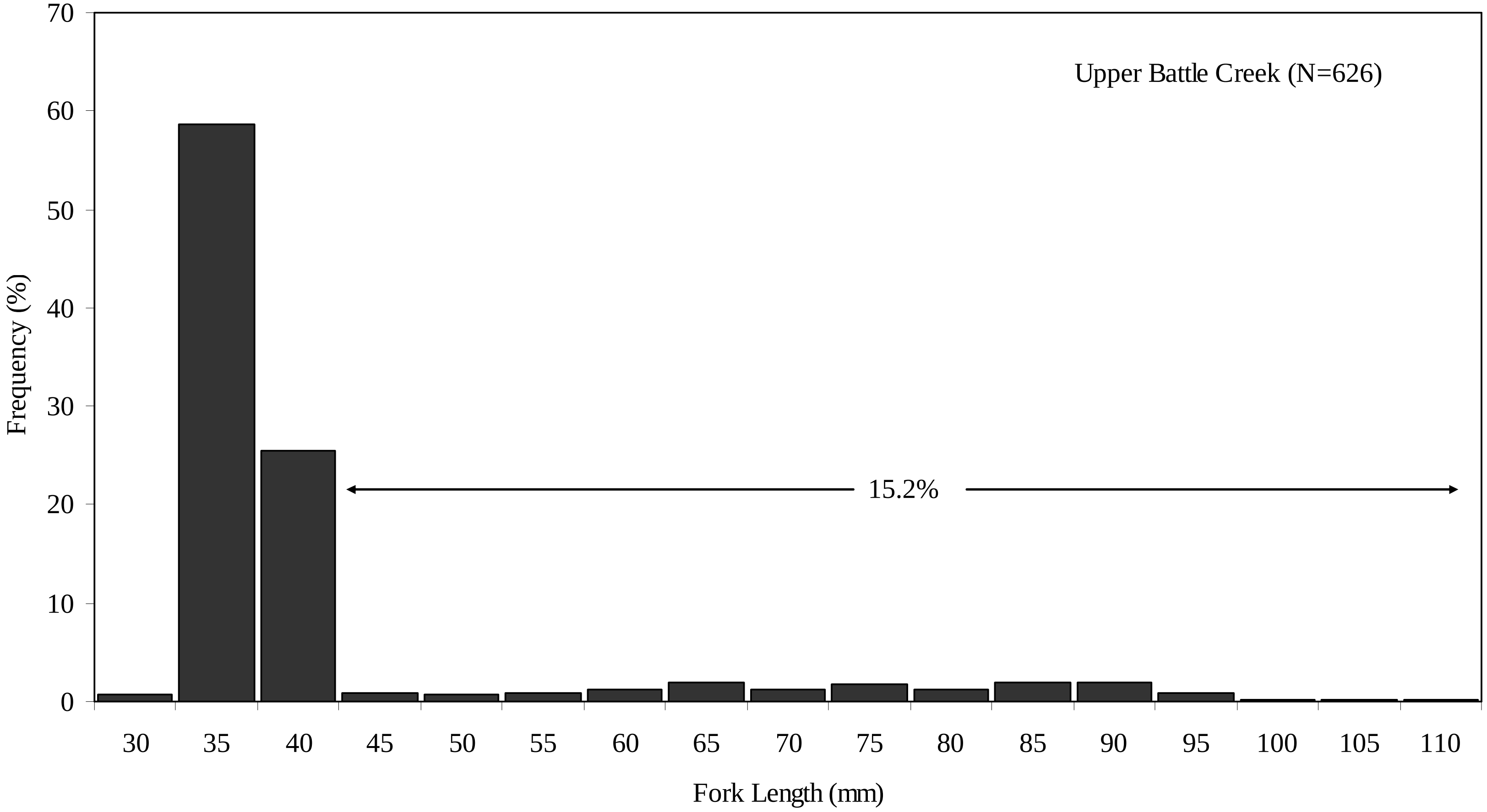

Figure 8. Length frequency (%) for all runs of Chinook salmon measured at the Upper Battle Creek rotary screw trap during November 12, 2008 through July 2, 2009. Fork length axis labels indicate the upper limit of a 5-mm length range.

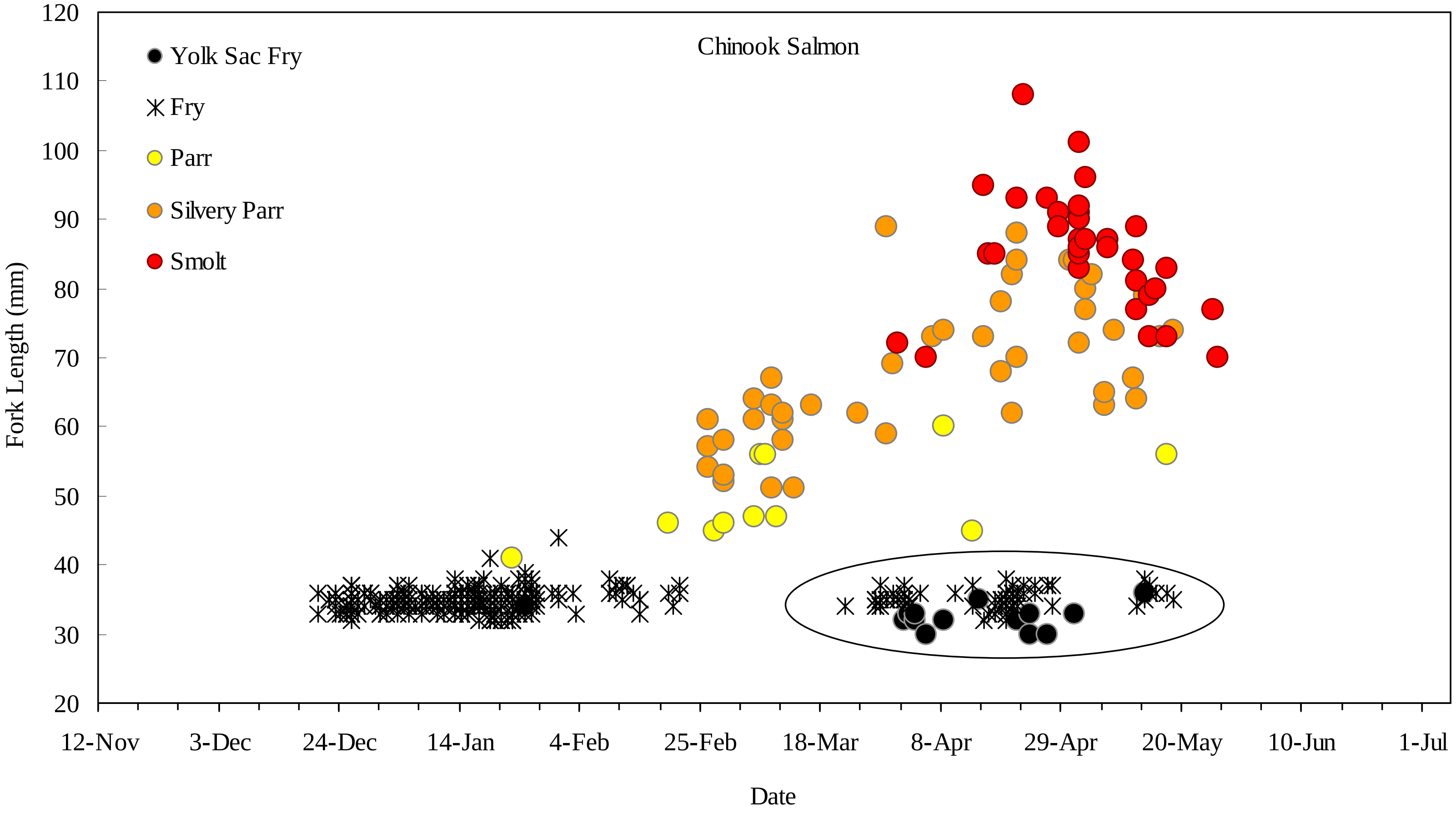

Figure 9. Life stage distribution for all runs of Chinook salmon measured at the Upper Battle Creek rotary screw trap during November 12, 2008 through July 2, 2009. Late-fall Chinook salmon captured in the trap are indicated by the oval.

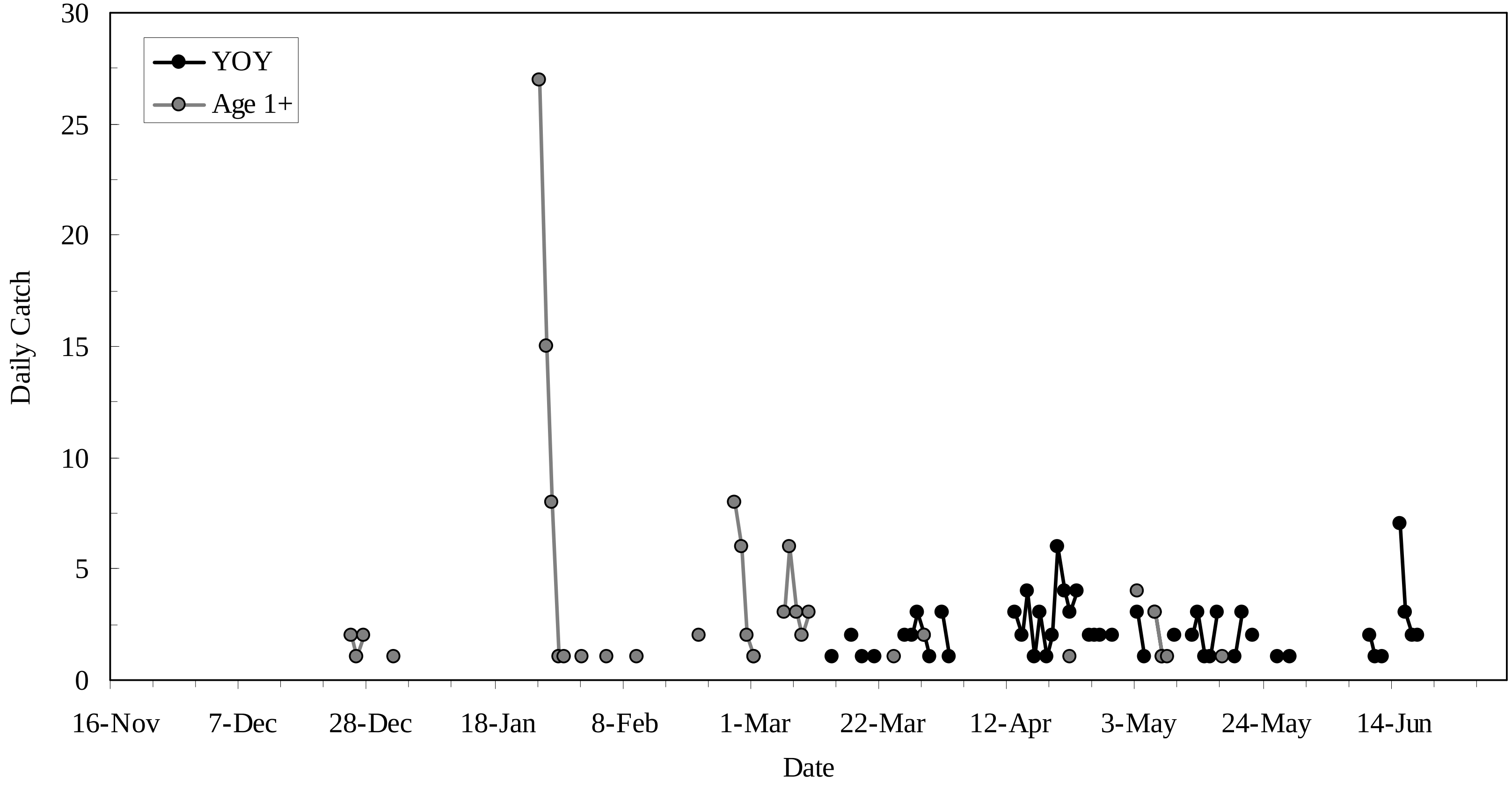

Figure 10. Daily catch of young-of-the-year (YOY) and age 1+ (Age1+) rainbow trout/steelhead captured at the Upper Battle Creek rotary screw trap from November 12, 2008 through July 2, 2009. Daily catch totals may be partial if the trap was not operated on all days of a week. This figure does not included days with zero catch.

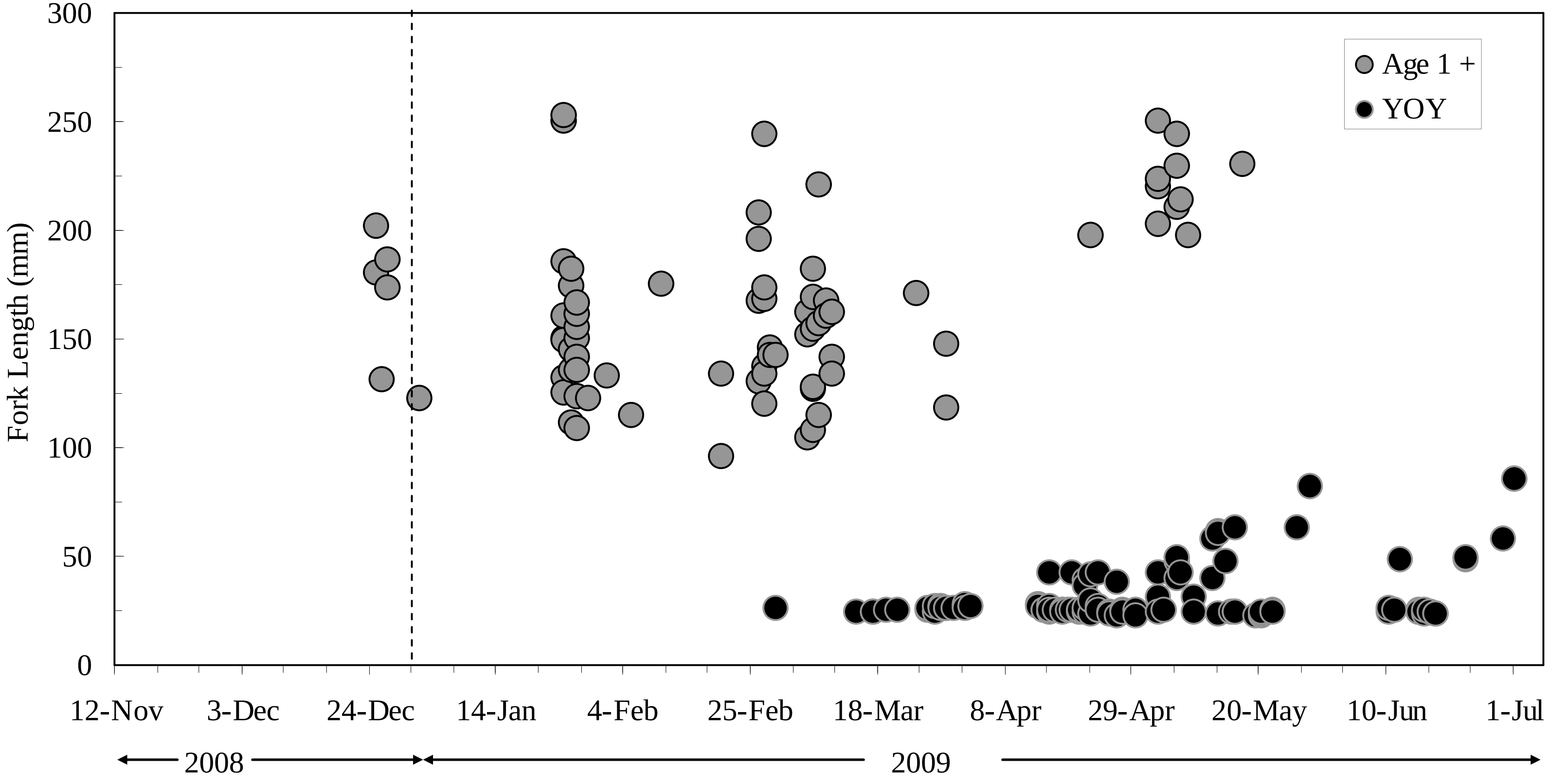

Figure 11. Fork length (mm) distribution by date for young-of-the-year (YOY) and age 1+ (Age1+) rainbow trout/steelhead measured at the Upper Battle Creek rotary screw trap during November 12, 2008 through July 2, 2009. Age 1+ fish may include individuals from multiple brood years.

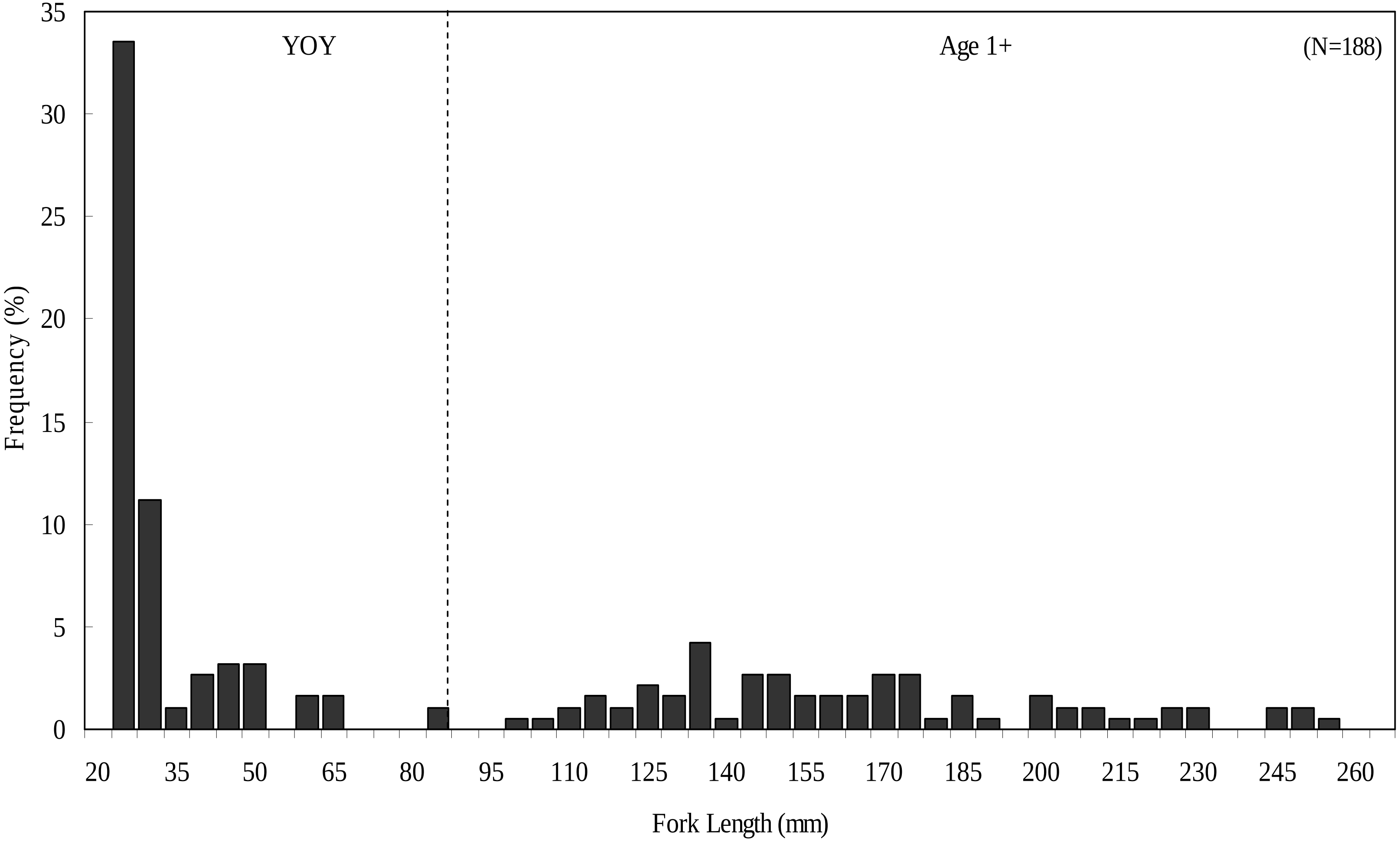

Figure 12. Fork length frequency (%) for rainbow trout/steelhead sampled at the Upper Battle Creek rotary screw trap during November 12, 2008 through July 2, 2009. Fork length axis labels indicate the upper limit of a 5-mm length range.

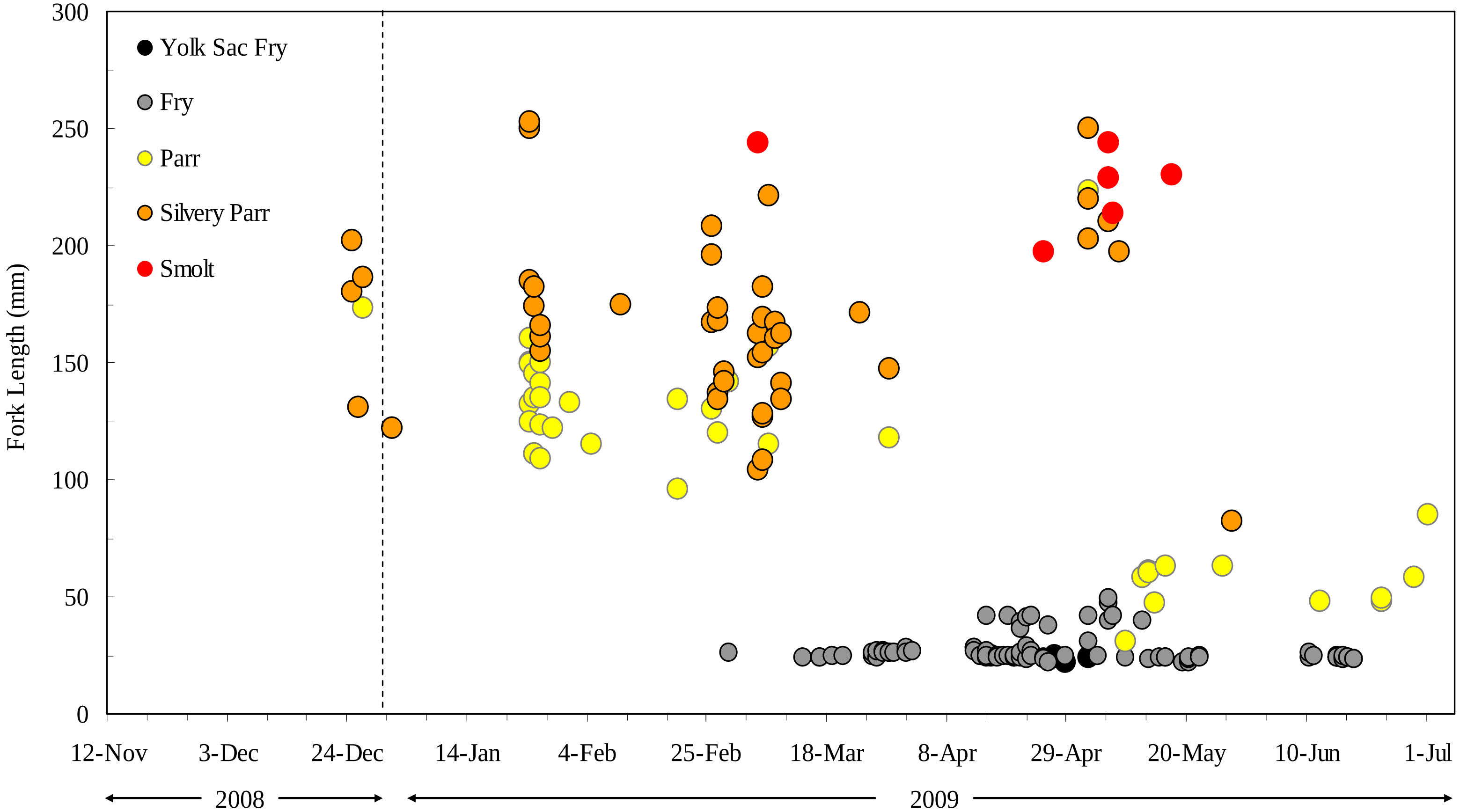

Figure 13. Rainbow trout/steelhead life-stage distribution at the Upper Battle Creek rotary screw trap during November 12, 2008 through July 2, 2009.

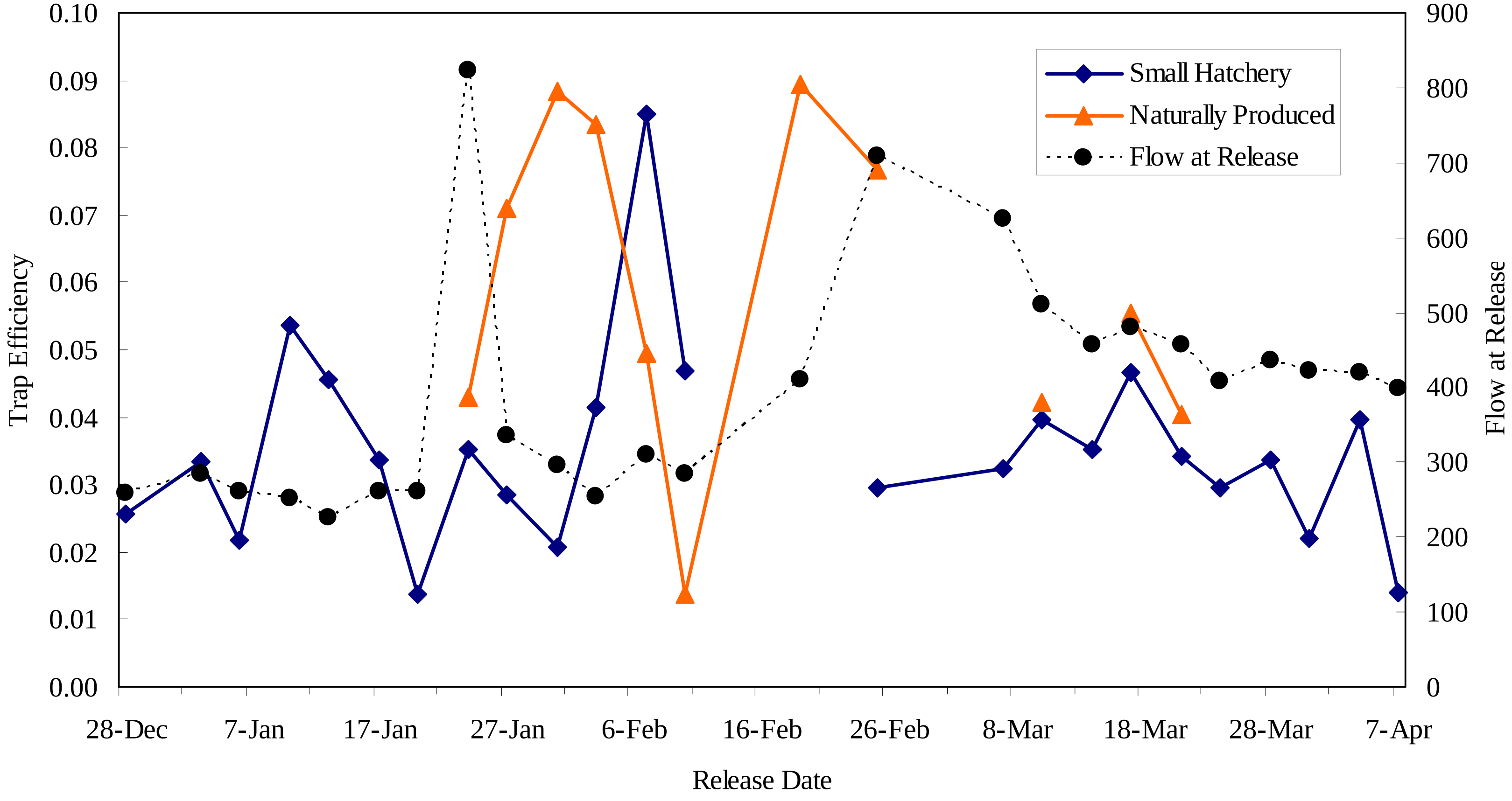

Figure 14. Trap efficiency and flow at the time of release for mark-recapture trials conducted at the Upper Battle Creek rotary screw trap using small hatchery and naturally produced fall Chinook salmon, 2009.

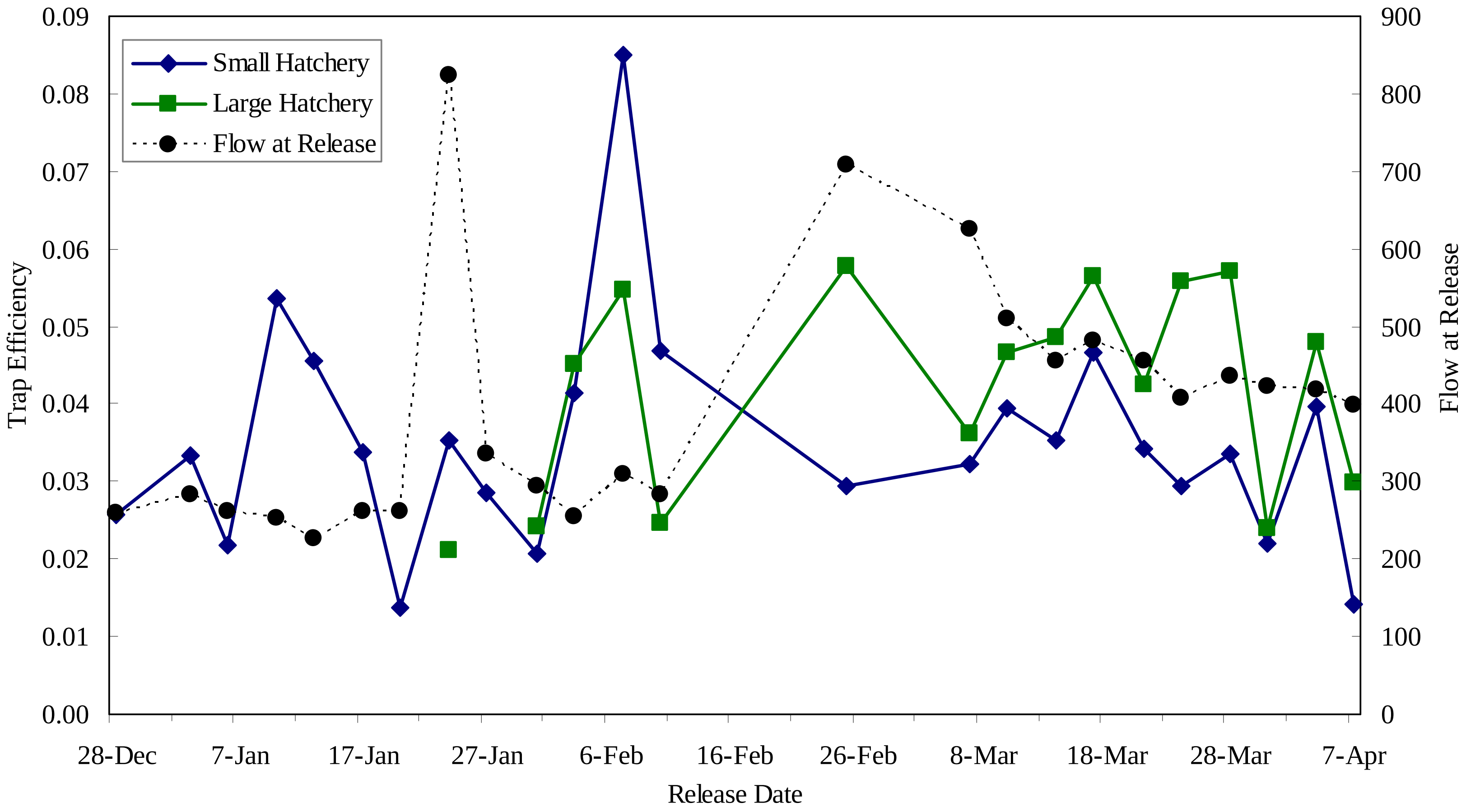

Figure 15. Trap efficiency and flow at the time of release for mark-recapture trials conducted at the Upper Battle Creek rotary screw trap using small and large hatchery produced fall Chinook salmon, 2009.

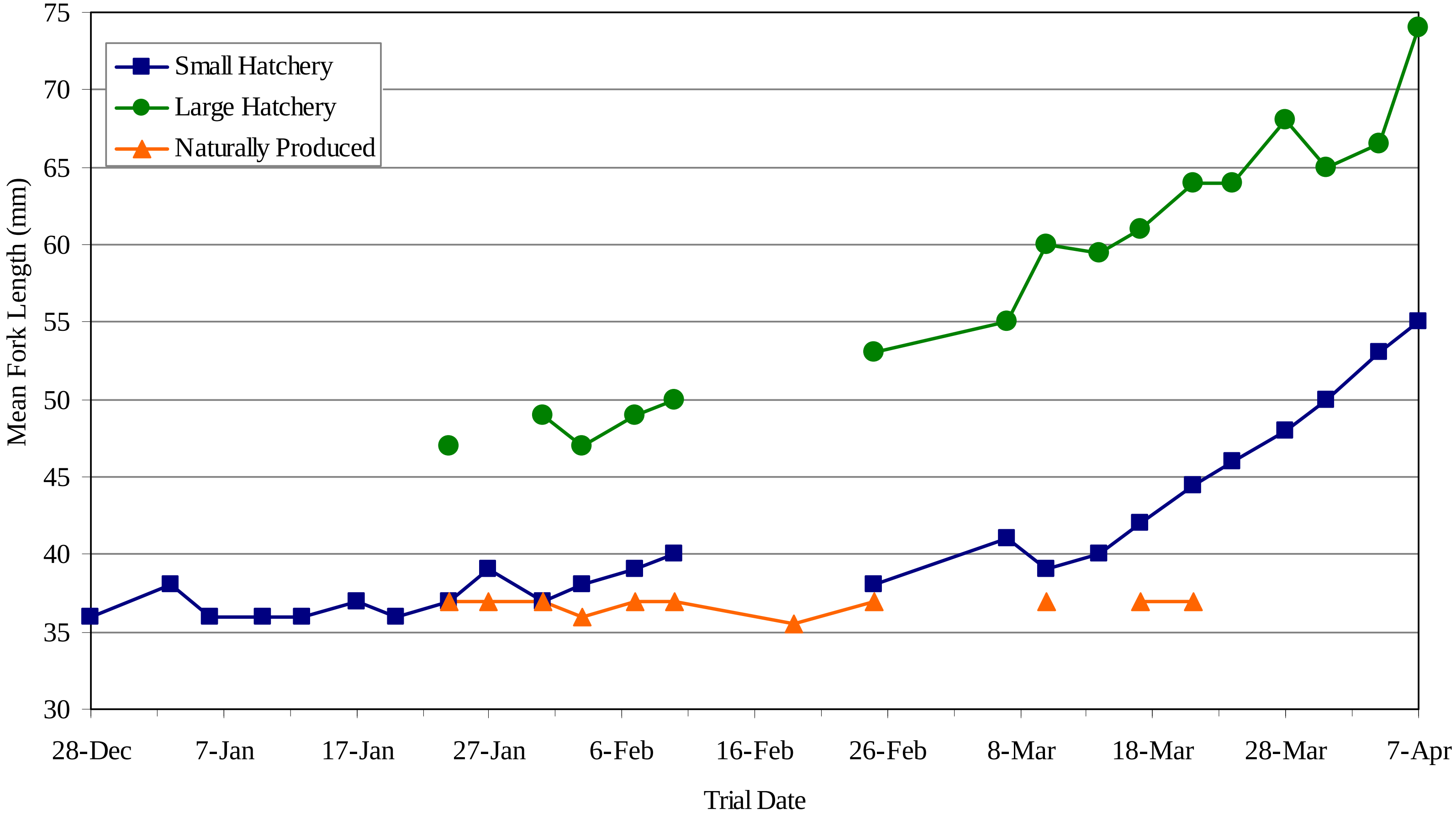

Figure 16. Median fork length of hatchery and naturally produced Chinook salmon used for mark-recapture trials conducted at the Upper Battle Creek rotary screw trap, 2009.

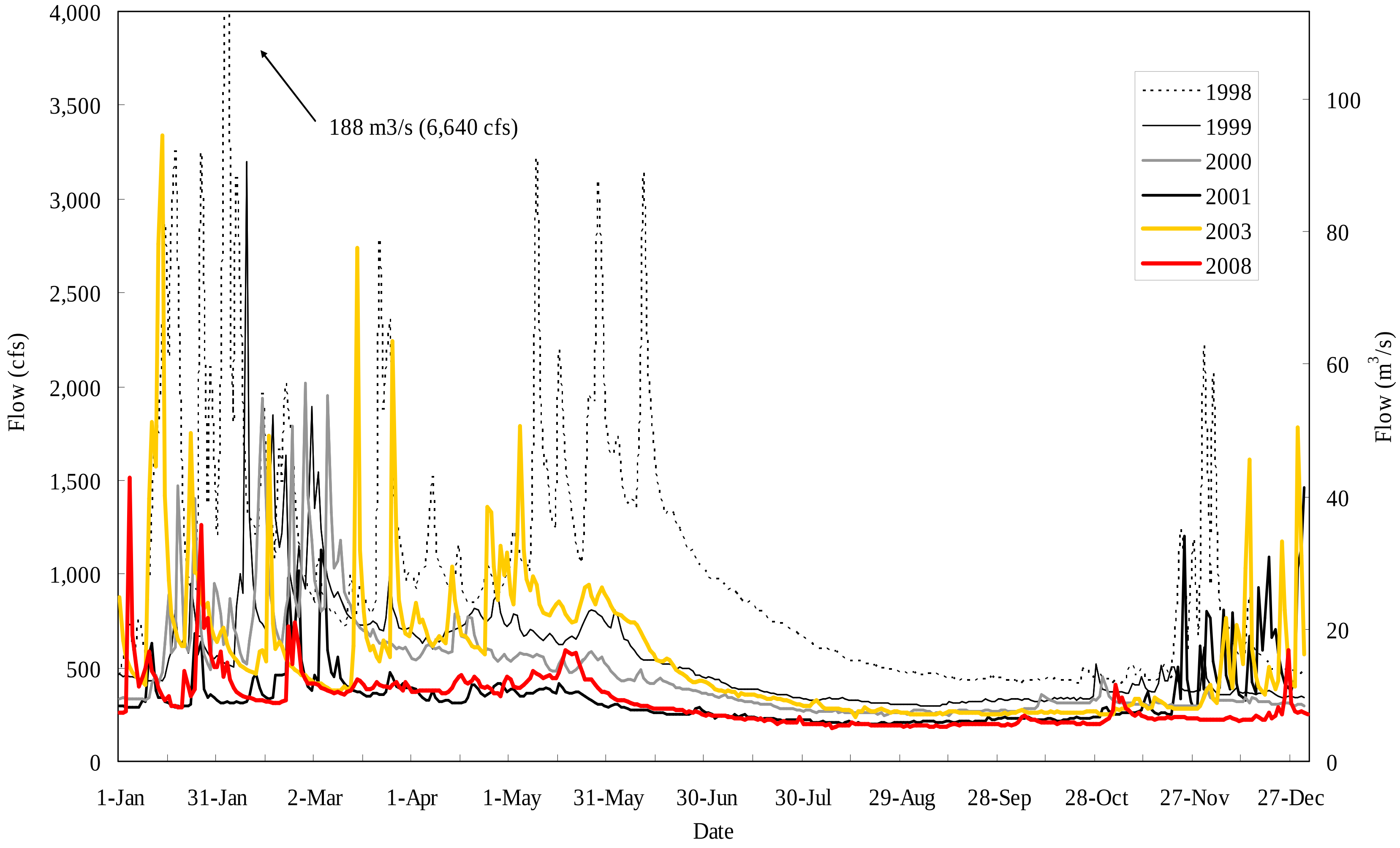

Figure 17. Mean daily flows (m^3/s and cfs) recorded at the U. S. Geological Survey gauging station (BAT-#11376550) located below the Coleman National Fish Hatchery barrier weir. Flows are for the period January 1 to December 31 for the years, 1998 to 2001, 2003 and 2008.

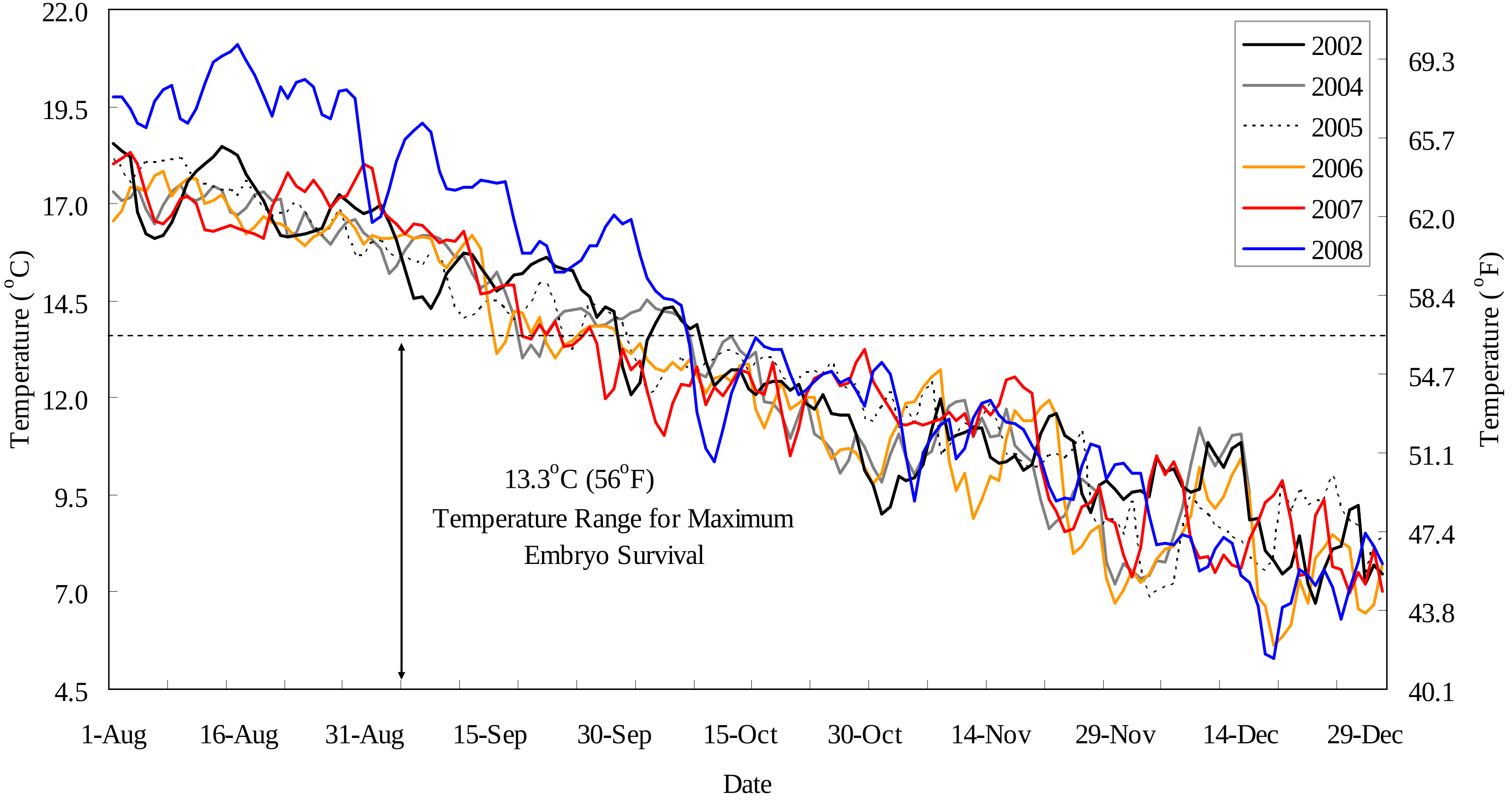

Figure 18. Mean daily water temperatures during the spring Chinook salmon incubation period for the years 2002 and 2004 through 2008. Temperature data for 2002 and 2004 through 2007 were included to allow for comparisons with 2008. Mean daily stream temperatures were calculated from temperature data collected by the CDEC gauge at the Wildcat Road Bridge on the North Fork Battle Creek. The temperature range for optimum Chinook salmon embryo survival is included.

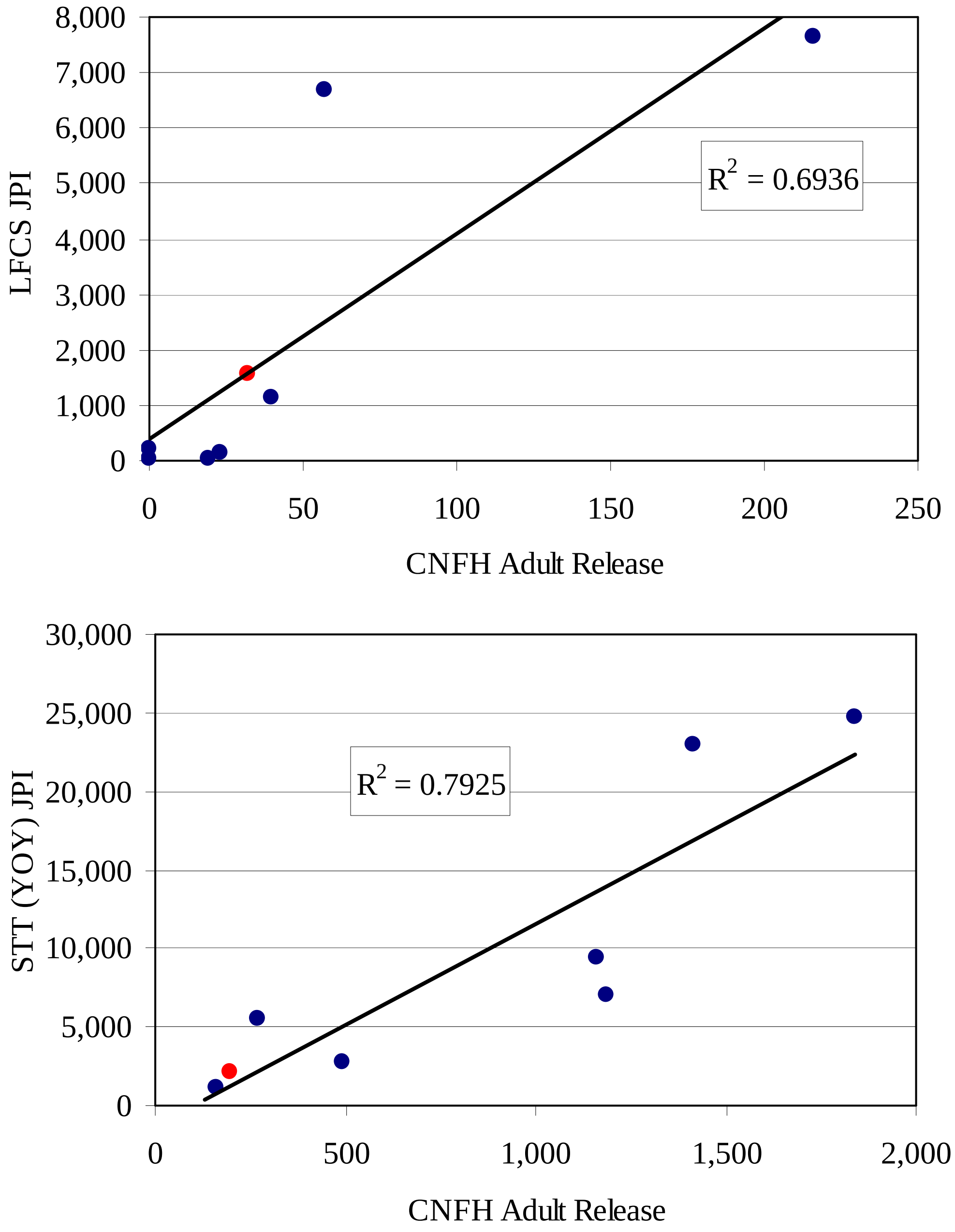

Figure 19. Relationship between Coleman National Fish Hatchery (CNFH) releases of naturally produced adult late-fall Chinook salmon (LFCS; upper) and rainbow trout/steelhead (STT, lower) above the hatchery's barrier weir with the juvenile passage indices for juvenile late-fall Chinook salmon and young of the year (YOY) rainbow trout/steelhead captured at the UBC trap from 1999 to 2009. The red points are for the current report period.

Appendix

Appendix 1. Summary of days the Upper Battle Creek rotary screw trap did not fish during the report period (November 12, 2008 to July 2, 2009), including sample dates, hours fished, and reason for not fishing.

Sample Dates	Hours Fished (approx)	Reason
	2009	
February 16	0	High Flows
February 17	0	High Flows
February 18	6	High Flows
February 22	8	High Flows
February 23	0	High Flows
February 24	0	High Flows
February 25	0	High Flows
February 26	13.5	High Flows
March 2-4	0	High Flows
March 5	16	High Flows
May 23, 24, 30, and 31	0	Reduced Sampling
June 6, 7, 13, 14, 20, 21, 27, and 28	0	Reduced Sampling

Appendix 2. Monthly catch of non-salmonid species in the Upper Battle Creek rotary screw trap from November 12, 2008 through July 2, 2009.

	Month									
Species	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Total
CAR	0	4	6	0	2	0	1	0	0	13
CENFRY	0	0	0	0	0	0	0	1	0	1
COTFRY	0	1	0	1	0	0	0	16	0	18
CYPFRY	0	3	6	6	9	7	230	200	110	571
HH	1	68	27	45	35	41	175	7	0	399
LFRY	0	0	0	2	9	4	6	7	0	28
PL	1	116	1,052	7	5	0	5	0	0	1,186
RFS	0	0	2	12	11	8	5	9	4	51
SASU	0	6	4	2	2	1	17	460	13	505
SPM	1	2	2	8	6	0	18	1	0	38
TP	0	2	0	0	0	1	1	4	0	8
TSS	0	2	2	0	1	0	1	5	0	11
WBL	0	0	1	0	0	0	0	0	0	1

Appendix 3. Species key for non-salmonid fish taxa captured at the Upper Battle Creek trap from November 16, 2008 through July 2, 2009.

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*

Appendix 4. Partial summary of information collected during mark-recapture trials conducted at the Upper Battle Creek rotary screw trap, including release date, release time, flow at release, turbidity at release, release group (SH=small hatchery, SL=large hatchery, and NP=naturally produced), median fork length for marked fish and median fork length for recaptured fish.

Release Date	Release Time	Flow @ Release	Turbidity @ Release	Release Group	Median Fork Length (Marked)	Median Fork Length (Recaps)
12/28/08	17:00	259	2.33	SH	36	36
01/03/09	16:45	284	2.85	SH	38	38
01/06/09	17:15	262	2.23	SH	36	36
01/10/09	17:01	252	1.86	SH	36	36.5
01/13/09	17:10	227	2.69	SH	36	36
01/17/09	19:15	262	4.1	SH	37	37
01/20/09	17:30	262	2.25	SH	36	36
01/24/09	17:30	823	36.4	SH	37	38
01/24/09	17:30	823	36.4	LH	47	48
01/24/09	17:30	823	36.4	NP	37	38
01/27/09	17:45	336	3.1	SH	39	38
01/27/09	17:45	336	3.1	NP	37	37
01/31/09	17:33	295	2.53	SH	37	37
01/31/09	17:33	295	2.53	LH	49	51
01/31/09	17:33	295	2.53	NP	37	37
02/03/09	18:45	255	2.8	SH	38	38
02/03/09	18:45	255	2.8	LH	47	46
02/03/09	18:45	255	2.8	NP	38	38
02/07/09	22:16	309	3.07	SH	39	39
02/07/09	22:16	309	3.07	LH	49	49
02/07/09	22:16	309	3.07	NP	37	37
02/10/09	18:15	284	3.38	SH	40	40
02/10/09	18:15	284	3.38	LH	50	49
02/10/09	18:15	284	3.38	NP	37	36.5
02/18/09	17:48	556	7.49	SH	39	39.5
02/18/09	17:48	556	7.49	LH	50	48.5
02/19/09	18:30	411	4.52	NP	35.5	37
02/25/09	18:45	709	7.63	SH	38	38
02/25/09	18:45	709	7.63	LH	53	52
02/25/09	18:45	709	7.63	NP	37	38
03/07/09	18:50	625	5.27	SH	41	41
03/07/09	18:50	625	5.27	LH	55	55
03/10/09	19:11	510	4.09	SH	39	39
03/10/09	19:11	510	4.09	LH	60	61
03/10/09	19:11	510	4.09	NP	37	41
03/14/09	19:10	456	2.99	SH	40	41
03/14/09	19:10	456	2.99	LH	59.5	58

Appendix 4 Continued.

03/21/09	19:40	456	2.25	SH	44.5	45
03/21/09	19:40	456	2.25	LH	64	63.5
03/21/09	19:40	456	2.25	NP	37	36.5
03/24/09	19:32	407	2.07	SH	46	46
03/24/09	19:32	407	2.07	LH	64	64
03/28/09	20:45	435	2.23	SH	48	47
03/28/09	20:45	435	2.23	LH	68	69
03/31/09	20:12	423	2.05	SH	50	51.5
03/31/09	20:12	423	2.05	LH	65	66
04/04/09	19:45	419	2.12	SH	53	53
04/04/09	19:45	419	2.12	LH	66.5	68
04/07/09	19:54	399	2.27	SH	55	57.5
04/07/09	19:54	399	2.27	LH	74	71.5