

**Juvenile Salmonid Monitoring in Battle Creek, California,
November 2009 through July 2010**

USFWS Draft Report

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February 2011



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The suggested citation for this report is:

Whitton, K. S., D. J. Colby, J. M. Newton, and M. R. Brown. 2011. Juvenile salmonid monitoring in Battle Creek, California, November 2009 through July 2010. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

**Juvenile Salmonid Monitoring in Battle Creek, California,
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Abstract- In late-November 2009, 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 24, 2009 through July 16, 2010, spring and late-fall run Chinook salmon *Oncorhynchus tshawytscha*, rainbow trout/steelhead *Oncorhynchus mykiss*, and 9 species of non-salmonids were captured in the Upper Battle Creek (UBC) rotary screw trap. During the period January 11 through February 22, 2009, we conducted five valid mark-recapture trials at the UBC trap to determine rotary screw-trap efficiency. Trap efficiencies using naturally produced fall Chinook salmon varied from 4.2 to 13.8% with a season average of 9.1%. Only naturally produced Chinook salmon trap efficiencies are 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 2009 spring Chinook salmon passage estimate at the UBC trap was 96,555, and the brood year 2010 late-fall Chinook salmon passage estimate was 770. The passage estimates for age 1+ rainbow trout/steelhead and brood year 2010 young-of-the-year at the UBC trap were 1,760 and 3,352 respectively.

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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 m³/s (3 cfs) downstream of diversions on North Fork Battle Creek and 0.14 m³/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 m³/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 m³/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 m³/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. The purpose of this report is to summarize rotary screw trap data collected during the period November 24, 2009 through July 16, 2010. 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 (13.5 miles) 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 (18.9 miles) 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 miles²; 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 m³/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 0°C (32°F) in the winter to summer highs in excess of 46°C (115°F).

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 2009, 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 24, 2009 through July 16, 2010. 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 estimate 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). 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. In early July, the trap was fished 4 d/week because catch was limited to small numbers of rainbow trout and non-salmonids. In contrast to recent years, the trap was only checked once per day in December through January, unless high flows were expected. Reduced staffing prevented us from scheduling a regular night shift. 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.

Similar to the 2008-2009 season, the trap was primarily operated at full cone to improve our passage estimate by increasing catch. Due to high leaf loads and low flows, the trap was operated with the half-cone modification for a short period of time (November 23 to December 19, 2009). 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 measured volumetrically using a 44.0 liter (10-gallon) plastic tub. Water temperatures were measured every 30 min with an instream HOBO® Pro v2 temperature logger. Water velocity was measured as the average velocity from a grab-sample using an Oceanic® Model 2030 mechanical 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 (BAT #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). 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 were 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 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-mm² 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. If the trap was checked multiple times in addition to the primary daytime check, only numbers and life stage were recorded for rainbow trout/steelhead. 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. During the current report period, approximately 50 rainbow trout/steelhead were sacrificed for otolith microchemistry analysis, to determine the maternal origin of trout captured in the trap. Trout collected included individuals from one of three groups including, age 1+, young-of-the-year < 50 mm and young-of-the-year ≥ 50 mm.

Non-salmonid taxa.—All non-salmonid taxa that were captured were identified and 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. In contrast to previous seasons, lamprey were recorded by life stage (ammocoetes, macrophthalmia or transformer, and adult). In addition, lamprey ammocoetes were identified to genus using pigment patterns in the caudal fin and caudal ridge as described by Whitton et al. 2010. 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 a 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. During the 2009-2010 season, we had intended to conduct a series of hatchery and naturally produced trials with multiple release groups to quantify the variability in trap efficiency under similar release conditions; however, the number of planned trials was scaled back due to reduced staffing and the limited availability of naturally produced fish. Coleman National Fish Hatchery provided hatchery fall Chinook salmon, and naturally produced fall Chinook salmon were captured using the LBC trap.

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. If two groups of fish were used for a trial, two marks were applied to each group. The primary mark was either an upper or lower caudal fin clip, and the secondary mark was Bismark brown. If three groups of fish were used for a trial, two marks were applied to two groups (upper or lower caudal fin clip), but the third group was only marked with Bismark brown. 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. 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 groups.

To determine any potential 24-hour mortality, marked salmon were generally held in live-cars in the trapbox overnight and released the next day. 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). During each trial, groups containing fish with multiple marks were released as one group, which may have altered the intent of the study. To allow for even mixing with unmarked fish, the marked fish were released in small groups from the river-right bank. 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, RBFWS, 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

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

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). When multiple groups were released at one time, the results were combined to estimate a weekly trap efficiency. Juvenile Chinook salmon downstream passage at the UBC trap was not estimated using trap efficiencies for hatchery fish.

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 result from our hatchery trial was not used to estimate passage of Chinook salmon at the UBC trap. A juvenile Chinook salmon JPI was calculated for brood year 2009 spring Chinook salmon and brood year 2010 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

$$\hat{N}_h = \frac{U_h}{\hat{E}_h}, \quad (2)$$

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

$$\hat{N} = \sum_{h=1}^L \hat{N}_h \quad (3)$$

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} ($j=1, 2, \dots, 1000$; 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

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

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 24, 2009 to July 16, 2010, except during high flows and periods of reduced sampling (Figure 2 and Appendix 1). Typically the trap is not operated after June 30, but higher than expected numbers of rainbow trout/steelhead were being captured in the trap; therefore the trap was operated until numbers had declined. The trap was not operated after July 16 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 235 d available during the sample period, the trap was operated approximately 204 full days and 13 partial days. In addition, there were 18 d (432 hours) the trap was not operated at all, of which 11 d were due to reduced sampling when there were few or no fish and the remaining 7 d were due to high flows or predicted storm events. The monthly sampling effort varied from a low of about 13% in November 2009 to a high of 100% in May and June (Figure 2).

The mean daily water temperatures at the UBC trap varied from a low of 4.3°C (39.8°F) on December 9, 2009 to a high of 20.4°C (68.9°F) on July 16, 2010 (Figure 3). Mean daily water temperatures increased to a peak of 20.9°C (69.6°F) 2 d after the trap was no longer fishing. Mean daily flow measured by the U.S. Geological Survey at the Coleman Hatchery gauging station (#11376550) varied from a low of 5.7 m³/s (201 cfs) in mid-December 2009 to a high of 50.4 m³/s (1,780 cfs) on January 19, 2010 (Figure 4). During the period of trap operation, there were 7 d when flows exceeded 42.5 m³/s (1,500 cfs) with a peak flow of 116.4 m³/s (4,110 cfs) occurring on January 19, 2010 (Figure 4). Turbidity at the UBC trap varied from a low of 1.0 NTU's on November 30, 2009 and January 11, 2010 to a high of 35.4 NTU's on December 22, 2009 (Figure 4). In general, turbidity increased with increasing flows, but the increases in turbidity relative to flow appeared to decrease over time. Turbidity was only measured when the trap was operating; therefore, it is possible that turbidity may have been higher when the trap was not fishing during high flow events.

Biological Sampling

Upper Battle Creek (UBC) salmonids.—Of the 4,597 Chinook salmon measured at the UBC trap, the length-at-date criteria indicated that 4,303 were fall-run, 3 were late fall-run, 290 were spring-run and 1 was a winter-run. However, based on adult management which does not allow passage of adult fall Chinook salmon above the CNFH barrier weir, juvenile fall-run were

considered to be spring Chinook salmon and combined for analyses. In addition, redd data collected during the snorkel surveys, incubation timing, and CNFH adult late-fall passage data suggests that 65 of the Chinook salmon captured in early March to mid-April that 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 2009 (BY09) spring Chinook salmon were first captured at the UBC trap the week of December 13, 2009 with a peak weekly catch of 3,222 the week of January 10, 2010 (Figure 5). The last BY09 spring Chinook salmon was captured June 19, 2010. The total catch of BY09 juvenile spring Chinook salmon at the UBC trap was 7,493. However, after adjusting the total catch for days the trap was not operated, the adjusted total catch was 8,218 spring Chinook salmon. The total catch of BY10 late-fall Chinook salmon was 70, with a peak catch of 30 the week of April 19, 2010 (Figure 5). Only two of the 70 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, one winter Chinook salmon was captured, but it was more likely a spring-run as the length was only 2 mm larger than a spring-run would be on that date.

Fork lengths of spring Chinook salmon sampled at the UBC trap varied from 31 to 117 mm with a mean fork length of 42 mm and a median of 36 mm (N=4,226; Figure 6 and 7). Fork lengths of late-fall Chinook salmon varied from 31 to 42 mm with a mean and median fork length of 37 mm (N=67). Length frequency data for all runs were combined. Approximately 87% of all Chinook salmon captured in the UBC trap had fork lengths ≤ 40 mm (Figure 7). The life-stage composition of spring Chinook salmon captured at the UBC trap was <0.1% yolk-sac fry, 86.9% fry, 1.2% parr, 2.6% silvery parr, and 9.2% smolt (Table 1 and Figure 8). The life-stage composition of late-fall Chinook salmon was 4.5% yolk-sac fry, 92.5% fry, and 3.0% parr.

During the current reporting period, 418 rainbow trout/steelhead were captured in the UBC trap, of which 394 were measured (107 age 1+ and 287 young-of-the-year). Age 1+ rainbow trout/steelhead were first captured the week of December 13, 2009 with a peak weekly capture of 30 occurring the week of January 24, 2010 (Figure 9). Young-of-the-year rainbow trout/steelhead were first captured at the trap on March 21, 2010 with a peak weekly capture of 68 the week of May 30, 2010. Although the actual rainbow trout catch at the UBC trap was 418, after adjusting the total catch for days the trap was not operated, the adjusted total catch was 460. During the current reporting period, 50% of all rainbow trout/steelhead were captured after June 9, 2010.

Fork lengths for age 1+ rainbow trout/steelhead ranged from 86 to 350 mm with a mean fork length of 176 mm and a median of 170 mm (N=107; Figure 10 and 11), and young-of-the-year ranged from 24 to 105 mm with a mean and median of 63 mm (N=287). Seventy three percent of the rainbow trout/steelhead captured in the trap were young-of-the-year. The life-stage composition of all rainbow trout/steelhead was 0% yolk-sac fry, 9.6% fry, 76.6% parr, 10.2% silvery parr, and 3.6% smolt (Table 1 and Figure 12).

Upper Battle Creek (UBC) non salmonids.—From November 23, 2009 through July 16, 2010, ten native non-salmonid species were captured in the UBC trap, including California roach, *Hesperoleucus symmetricus* (N=10), hardhead, *Mylopharodon conocephalus* (N=760), Pacific lamprey macrophthalmia, *Lampetra tridentata* (N=1,022), riffle sculpin, *Cottus gulosus* (N=66), Sacramento sucker, *Catostomus occidentalis* (N=240), Sacramento pikeminnow, *Ptychocheilus grandis* (N=84), tule perch, *Hysterothorax traski* (N=11), threespine stickleback, *Gasterosteus aculeatus* (N=12), and adult Western brook lamprey, *Lampetra richardsoni* (N=5) (Appendix 2 and 3). No introduced species were captured in the UBC trap during the 2009-2010 field season. Cottid, cyprinid, and centrarchid fry, and lamprey ammocoetes that could not be identified to species were also captured at the trap. In contrast to previous seasons, lamprey ammocoetes were identified to genus, and we captured 119 *Entosphenus* spp., 16 *Lampetra* spp.,

and 2 unidentified ammocoetes. Besides Chinook salmon, Pacific lamprey macrophthalmia, hardhead, and rainbow trout 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, six mark-recapture trials, using naturally produced Chinook salmon, were conducted at the UBC trap from January 11 to February 22, 2010 (Table 2). Of the six trials, only five were used to estimate passage as one trial was considered invalid because the trap was not in the thalweg for a period of time shortly after the fish were released. Weekly trap efficiencies for the valid pooled and unpooled trials varied from 4.1 to 13.8%, with a season average trap efficiency of 9.1%. During the report period, the season average trap efficiency estimated from all valid trials was used to estimate passage for 27 weeks. During three of the six trials we used two or three different marks to identify groups within a release (Table 2). The maximum differences in trap efficiency between groups within a trial varied from 0.13 to 2.6%; however, as the fish were released together, the groups may not have been independent. In addition to the trials using naturally produced Chinook salmon, one trial with three release groups was conducted using hatchery produced fall Chinook salmon from Coleman National Fish Hatchery. Trap efficiency for the three groups varied from 4.8 to 5.4% with a maximum difference of 0.6%, but again the groups may not have been independent

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 BY09 spring Chinook salmon was 96,176, and the 90 and 95% confidence intervals were 87,733 to 105,748 and 86,669 to 108,586, respectively (Table 3). The weekly JPI's for spring Chinook salmon increased rapidly to a peak of 34,704 the week of January 10, 2010 and then in general decreased until late March when passage began increasing to a second peak of 1,330 the week of April 18, 2010. The annual JPI for BY10 late-fall Chinook salmon was 770, and the 90 and 95% confidence intervals were 712 to 844 and 698 to 860, respectively (Table 4). Late-fall Chinook salmon passage peaked at 330 the week of March 21, 2010. The annual JPI for yoy rainbow trout/steelhead passing the UBC trap between November 24, 2009 and July 16, 2010 was 3,352 whereas passage for age 1+ fish was 1,760 (Table 5). The 90 and 95% confidence intervals for the yoy annual JPI estimate were 3,134 to 3,592 and 3,099 to 3,650, and the 90 and 95% confidence intervals for the annual JPI for age 1+ fish were 1,654 to 1,899 and 1,627 to 1,942, respectively. Most age 1+ fish migrated during December through mid-April, whereas yoy were not captured in the trap until late March with a peak weekly passage of 747 the week of May 30, 2010.

Discussion

Trap Operation

During the 2009-2010 season, we operated the UBC trap 89% of the season, or 204 full days (4,896 hours) and 13 partial days (136 hours). In addition, there were 18 d (432 hours) the trap was not operated at all, of which 11 d were due to reduced sampling when passage was minimal and the remaining 7 d were due to high flows or predicted storm events. Of the 31 d the trap was not fishing or only fished a partial day, catch was estimated for spring Chinook salmon

passage on 15 d, late-fall Chinook salmon on 2 d, and rainbow trout/steelhead on 6 d. Partial catch data was used on 4 d when the trap did not operate 24 hours, because it was either more than the estimated catch, or because the trap was operated most of the 24 hour sample period and the time the trap was not operated occurred during daylight hours when catch is typically very low. During the current season, the UBC trap was not fished for 31 full or partial days, which are more days than during the two previous seasons, but several of those days, occurred during periods when there were few or no fish. In fact, 6 d occurred in July, which is after the trap is typically pulled in most years.

The impact on the annual passage estimates appears to have been minimal on most days; however, the 5 d the trap did not operate in late-January may have impacted the spring Chinook salmon estimate because in most years, peak passage occurs in January. During the current report period, the peak daily catch of spring Chinook salmon appears to have occurred on January 13 (N=1,780); however, a secondary peak occurred the week of January 17, but the trap was not fishing for 3d during the week; therefore, it is possible that a higher peak may have occurred while the trap was not fishing. The combined catch for those 2 weeks was 57% of the total annual catch of spring Chinook salmon. In fact, 70% of the estimated total annual catch of spring Chinook salmon occurred between January 3 and January 23, 2010. The trap was not operated in mid-July through mid-November during the current report period, but this likely had little influence on Chinook salmon passage estimates as none were captured after June 19 and previous sampling has shown that few salmon are captured during this period; however, because of the delayed migration timing for rainbow trout/steelhead, it is possible that we underestimated the passage of this species, but as daily catch was declining at the time trapping was discontinued, it was likely only slightly underestimated (Whitton et al. 2006; Whitton et al. 2007a; Whitton et al. 2007b).

Biological Sampling

During the current report period, 50% of the young-of-the-year rainbow trout/steelhead were captured in the UBC trap after June 9, 2010, which is later than in all other years the trap was operated from January to July (Figure 13). A similar catch distribution was observed in 1999, but in most years, 50% of the annual catch occurs prior to mid-May. In contrast, in 2000 50% of all YOY trout were captured prior to March 22, 2000. Reasons for the differences in migration timing are unknown, but flow may influence migration patterns as fry typically concentrate in shallow water along stream edges where velocities are lower, but move into faster water as they grow (Moyle 2002). Very few fish <50 mm (13.9%) were captured in the UBC trap during the 2009-2010 season, and flows were higher than observed in the two previous seasons. In addition, there were three storm events between January 19 and February 7, 2010 that produced flows from 95.1 to 116.4 m³/sec (3,360 to 4,110 cfs), which may have scoured redds produced prior to or during those dates. In some years YOY trout were captured in the trap as early as late February to early March, whereas only one was captured before April 1 during the current season.

Zimmerman and Reeves (1999) found that only a small portion of resident rainbow trout spawning on the Deschutes River in Oregon occurred when steelhead spawned, and resident trout typically spawned later. In fact, using otolith microchemistry and information collected during spawning surveys, they were able to determine that steelhead and resident trout are reproductively isolated in the Deschutes River. If resident rainbow trout spawn later in Battle Creek, the capture distribution observed during the current report period suggests there may be more resident rainbow trout spawning in Battle Creek than steelhead, but this cannot be

confirmed. It is also possible that steelhead fry are choosing to spend time rearing in Battle Creek before migrating downstream, which may explain the large numbers of YOY trout >50 mm observed in the trap in April and May. Otolith microchemistry is currently being used to determine the maternal origins of trout captured in the UBC trap. This data would provide information allowing us to determine the ratio of resident to anadromous *O. mykiss* captured in the Upper Battle Creek rotary screw trap.

Trap Efficiency and Juvenile Salmonid Passage

Trap efficiency.—During the 2009-2010 season we had intended to conduct a series of mark-recapture trials where three groups of fish with different marks were released at the same time to determine the natural variability in trap efficiency under the same release conditions. Staffing shortages and limited availability of naturally produced fish prevented us from completing this study. Information on the variability in trap efficiencies is important for determining whether trial results are reasonable, and to determine what biological and environmental variables influence trap efficiency. Occasionally trap efficiency will appear to be unusually low or high compared to trials conducted under similar conditions, with no obvious reason. Understanding the normal range of variability will allow us to better evaluate our mark-recapture data which directly influences the accuracy of our passage estimates. During the current season, we were able to conduct five valid trials using naturally produced fish one of which had three groups of uniquely marked fish and two of which had two groups of fish. The maximum differences in trap efficiency between the groups varied from 0.1 to 2.6%; however, releasing all of the fish as if they were a single group may have influenced the results. Rather than testing for variability in trap efficiency, we ended up testing whether mark location or type influenced trap efficiency. Roberts (1996) reported that group size influences animal behavior, including a reduction in individual vigilance, which may influence their capture probability. The influence of group size should be considered during future releases as well as release methods to prevent one group from influencing the behavior of other groups. In addition to the three trials using naturally produced fish, one trial was conducted using hatchery produced fish. The maximum difference in trap efficiency between the three groups was 0.6%. The results from our multiple group releases, likely provide limited information as too few trials were conducted to determine if mark location influenced trap efficiency.

During the period 1990 to 2007, the return of adult fall Chinook salmon to Battle Creek has ranged from approximately 12,708 to 463,296 with a median estimate of 80,351. The 2009 preliminary estimate of adult escapement into Battle Creek was about 8,268 (not including jacks), of which 6,227 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 <2,500. The low number of adults spawning in lower Battle Creek likely explains the limited number of naturally produced fish available for mark-recapture trials.

We only conducted six mark-recapture trials during the season, one of which was considered invalid because the trap was out of the thalweg for approximately 45 minutes shortly after release. Trap efficiencies for that trial were lower than expected, and based on observations made during the 2007-2008 season, fish released at Intake 3 may arrive at the trap in less than 30 minutes. A season average trap efficiency of 9.1% was used to estimate trap efficiency for most of the season (27 weeks). It is not possible to know how the use of the season average trap efficiency influenced our annual passage estimate because it depends on how different the season average trap efficiency was from the actual trap efficiency for each week. Trap efficiencies for the trials conducted ranged from 4.1 to 12.5%.

Recommendation: Continue the paired mark-recapture study using hatchery and naturally produced fish 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. Modify release methods to ensure that different groups are independent.

Juvenile Salmonid Passage.— The combined spring and fall Chinook salmon juvenile passage index (JPI) for the current report period is the fifth highest since monitoring began in 1998; however, three of the brood years with higher juvenile passage (1998, 1999, and 2003) were known to have had adult fall Chinook salmon escape above the barrier weir. The only other year with a higher passage estimate was BY2006, but the passage estimate was based on a partial year of sampling; therefore, the accuracy of the estimate is unknown. The BY2009 spring Chinook salmon passage estimate is based on a full season of data so the estimate is likely better; however, since the season average trap efficiency was used to estimate passage for 27 weeks, there is still uncertainty associated with this year's estimate.

Similar to the 2008-2009 season, the UBC trap was operated in the full-cone configuration for most of the season; however, the season average trap efficiency for the 2008-2009 season was 6.0% , and was estimated using seven weekly trap efficiencies (11 trials). The current season average trap efficiency is based on the results of five weekly trap efficiencies (5 trials) which varied from 4.1 to 12.5%. During both years, no trials were conducted in December or early January, which are often periods of peak passage for spring Chinook salmon. During the current report period, the season average trap efficiency was used to expand 54% of all spring Chinook salmon caught in the trap. If trials could have been conducted for the month of January, then 74% of the catch would have been used to estimate passage. Ideally, if we were able to estimate trap efficiency and get good catch data for the period mid-December through January, the accuracy of our passage estimates would be greatly improved as during the current year 88% of all spring Chinook salmon were captured during that time.

Several factors may explain why this year's passage estimate was one of the highest, including high adult escapement, low adult mortality, or high survival to emergence. Adult escapement in 2009 (n=194) was the fifth highest since 1995. In addition, adult mortality appears to have been fairly low as 88 redds were observed, despite the limited number of surveys conducted (n=2). The observed number of redds was only 9 less than we would have predicted (n=97) if there was a 1:1 sex ratio, 100% survival to spawning, and all females had spawned. When compared to 2007 which had higher adult escapement (n=291) but a similar adult survival (91% of predicted redds), BY2009 appears to have had a much higher survival to emergence because juvenile passage was higher although there were 44 fewer redds than in 2007. An alternative explanation is that there were additional redds that were not accounted for due to the limited number of snorkel surveys (n=2) in 2009; however, the number of predicted redds in 2009 assuming 100% survival was still 35 fewer than the number observed in 2007.

During the egg incubation period, temperatures are typically warmest from September 15 to October 31. High temperatures during this time can lead to reduced egg survival. On the North Fork, mean daily temperatures during this period were rated as good or excellent 70% of the time at the most downstream location to 100% at Eagle Canyon Dam (Newton et al 2010). On the South Fork (reach 3), mean daily temperatures were rated as good or excellent 70-74% of the time. On the mainstem, mean daily temperatures in Reach 4 were rated as good to excellent 70% of the time, and 17 of the 23 redds observed in the mainstem were in this reach. Only six

redds were observed in reaches 5 and 6 where temperatures were rated as good to excellent only 22-30% of the time. The high juvenile passage observed at the UBC trap suggests that suboptimal incubation temperatures during the spawning period had limited impact on survival to emergence. Although unobserved redds may have been present, survival to emergence still appears to have been high.

During the BY2007 season, the UBC trap was operated using the half-cone configuration, and twice during the season a mark-recapture trial was conducted with the trap in the full-cone configuration. This testing was done during a period when trap efficiencies were fairly consistent and flows were not changing. We had unexpected results which suggested that catch rates in the half-cone configuration may not be 50% of catch rates in the full-cone configuration. The trap efficiency for naturally produced fish released on February 12, 2007 was 4.0%. When the cone configuration was switched to full-cone on February 16, the trap efficiency increased to 16.5%. When the trial was completed, the cone-configuration was returned to half-cone on February 20, and the trap efficiency returned to 4.0%. A similar increase was observed with hatchery fish. The trap efficiency started at 2.3%, increased to 9.0%, and returned to 1.3%. During this time, flows at the time of release ranged from 324 to 332 cfs. In April, a second test was done with hatchery fish, and the trap efficiency increased from 3.6% to 11.0%. Fish were not available for a follow-up trial, but the results of these tests suggest that testing trap efficiency at different cone configurations is necessary. During the current season (BY2009), the trap was operated in the full-cone configuration, and whether the differences in juvenile passage observed between 2007 and 2009 may be partly related to differences in catch rates at different cone configurations, is unknown. Testing needs to be done as our ability to make valid comparisons between years depends on the accuracy of our estimates. In addition, our ability to make comparisons with other years when the trap was operated in the full-cone configuration and which had high juvenile passage is confounded with the known presence of fall Chinook salmon or as in 2006, where the juvenile passage estimate was made using partial catch data and trap efficiency data for other years.

Recommendation: Use hatchery or naturally produced fish to determine catch rates (trap efficiency) when the rotary screw trap is operated in the half-cone and full-cone configurations.

Brood year 2010 (BY09) late-fall Chinook salmon juvenile passage at the UBC trap was about half of the passage observed in 2009. The decrease observed in juvenile passage is likely the result of both reduced adult passage and scouring caused during high flow events. Adult escapement in 2010 (n=27) was only slightly lower than observed in 2009 (n=32); and therefore, cannot explain the almost 50% drop observed in juvenile passage. However, there were three storm events between January 19 and February 7, 2010 that produced flows of 95.1 to 116.4 m³/sec (3,360 to 4,110 cfs), which may have scoured redds produced prior to or during those dates. 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 a portion of the natural-origin (i.e., unclipped) adult late-fall Chinook salmon upstream of the barrier weir in 2001. Some unmarked late-fall are spawned each year. Despite this change in policy, adult late-fall escapement upstream of the barrier weir remains low.

In 2010, rainbow trout/steelhead juvenile passage at the UBC trap was the second highest since CNFH stopped passing hatchery-origin adult steelhead upstream of the barrier weir in

2005. Passage of age 1+ trout was lower in 2010 than 2009, but YOY passage (n=3,352) was more than 50% higher (n=2,190). With the exception of 1999 and 2008, YOY trout migration began later than all other years and continued later than all other years. 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. A similar trend was observed in 2010, with a 24 mm trout fry captured on July 9. Otolith microchemistry is being conducted on previous steelhead/rainbow trout samples to determine the maternal origin of trout captured in the UBC trap. Otolith samples were collected during the current season, and analysis may confirm whether a shift to more resident rainbow trout is occurring in Battle Creek. Coleman National Fish Hatchery passed 265 steelhead trout prior to March 1, and an additional 160 trout were passed through the barrier weir fish ladder, for a total of 425, which is the second highest since 2005. It is also 74 more than were passed in 2009, which may account for the increased passage of YOY trout at the UBC trap.

Acknowledgements

We would like to thank the Red Bluff Fish and Wildlife Office staff who worked on this project: Mark Belter, RJ Bottaro, Casey Collins, Jim Earley, Sierra Franks, Sarah Giovannetti, Jacie Knight, Hayley Potter, Jason Rhoten, Laurie Stafford, Andy Trent, and Julie Warden. We thank the Coleman National Fish Hatchery staff, especially Scott Hamelberg and Mike Keeler, for accommodating our program at the Coleman National Fish Hatchery, and Kurt Brown for coordinating the selection of hatchery fish for our paired mark-recapture study. Funding for this project was primarily provided by the Anadromous Fish Restoration Program of the CVPIA and secondarily by the CALFED Ecosystem Restoration Program. CALFED funds originated from Proposition 50 and were administered by the California Department of Fish and Game under grant number P0685505.

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Tables

Table 1. Life-stage summary of spring, late-fall and winter Chinook salmon and rainbow trout/ steelhead measured at the Upper Battle Creek rotary screw trap from November 24, 2009 through July 16, 2010.

Life Stage	Spring Chinook		Late-Fall Chinook		Winter Chinook		Rainbow	
	#	%	#	%	#	%	#	%
Yolk Sac Fry	3	<1%	3	4.5	0	0	0	0.0
Fry	3672	86.9	62	92.5	0	0	38	9.6
Parr	49	1.2	2	3.0	0	0	302	76.6
Silvery Parr	110	2.6	0	0	0	0	40	10.2
Smolt	391	9.2	0	0	0	0	14	3.6
Totals	4225	100	67	100	0	0	394	100

Table 2. Summary of the mark-recapture trials conducted at the Upper Battle Creek rotary screw trap from November 24, 2009 through July 16, 2010 using naturally produced fall Chinook salmon. Shaded rows indicate trials where multiple groups were released and the results were pooled to calculate a weekly trap efficiency. Trials highlighted with **bold text** were not used.

Release Date	Time of Release	Number Released	Recaptures	Efficiency ^a	Pooled Efficiency	Weekly Mean Flow, m ³ /s (cfs)
01/12/10	17:10	516	47	0.093		11.8 (417)
01/23/10	17:20	505	47	0.095		25.1 (885)
02/01/10	18:25	488	19	0.041	0.041	20.0 (706)
02/01/10	18:25	520	21	0.042	0.041	20.0 (706)
02/09/10^b	18:45	422	10	0.026	0.032	16.9 (597)
02/09/10^b	18:45	424	16	0.040	0.032	16.9 (597)
02/14/10	18:15	512	47	0.094	0.099	11.9 (421)
02/14/10	18:15	500	52	0.106	0.099	11.9 (421)
02/22/10	18:20	508	56	0.112	0.125	17.8 (629)
02/22/10	18:20	497	64	0.131	0.125	17.8 (629)
02/22/10	18:20	389	53	0.138	0.125	17.8 (629)

^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 Trap was out of position during the beginning of this trial; therefore the results were considered invalid.

Table 3. Weekly summary of brood year 2009 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
12/13/09	0.046 ^d	327	7,187	1,128	5,584	9,367	5,377	9,679
12/20/09	0.091 ^a	911	10,011	1,112	8,340	11,897	8,090	12,257
12/27/09	0.091 ^a	86	945	102	796	1,123	771	1,175
01/03/10	0.091 ^a	1,014	11,143	1,239	9,380	13,439	8,915	14,069
01/10/10	0.093	3,222	34,704	4,972	27,763	42,712	26,867	45,021
01/17/10	0.091 ^a	1,459	16,033	1,667	13,638	19,053	13,220	19,932
01/24/10	0.095	269	2,836	410	2,269	3,582	2,195	3,781
01/31/10	0.040	260	6,399	1,006	5,045	8,198	4,770	8,745
02/07/10	0.091 ^a	57	626	70	522	744	506	767
02/14/10	0.099	37	375	37	320	446	307	463
02/21/10	0.125	11	88	6	78	99	77	101
02/28/10	0.091 ^a	3	33	3	28	39	27	41
03/07/10	0.091 ^a	15	165	17	139	196	136	202
03/14/10	0.091 ^a	18	198	21	168	239	161	246
03/21/10	0.091 ^a	11	121	12	102	144	100	148
03/28/10	0.091 ^a	19	209	20	176	248	172	260
04/04/10	0.091 ^a	54	593	66	494	716	480	738
04/11/10	0.091 ^a	37	407	45	339	483	329	498
04/18/10	0.091 ^a	121	1,330	143	1,119	1,580	1,085	1,653
04/25/10	0.091 ^a	87	956	101	805	1,120	780	1,153
05/02/10	0.091 ^a	81	890	98	749	1,074	727	1,107
05/09/10	0.091 ^a	35	385	43	324	457	317	478
05/16/10	0.091 ^a	16	176	20	146	212	142	219
05/23/10	0.091 ^a	19	209	22	176	252	170	260

Table 3. 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
05/30/10	0.091 ^a	33	363	39	302	431	293	444
06/06/10	0.091 ^a	14	154	16	130	180	127	188
06/13/10	0.091 ^a	2	22	2	19	26	18	27
Totals	---	8,218	96,555	5,939	87,762	106,735	86,392	110,047

^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.

^d The season average trap efficiency was converted to a half-cone efficiency for this week because the trap was operating with the half-cone modification.

Table 4. 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). 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
02/28/10	0.091 ^a	2	22	2	19	26	18	27
03/07/10	0.091 ^a	7	77	8	65	91	63	96
03/14/10	0.091 ^a	4	44	5	37	53	36	55
03/21/10	0.091 ^a	30	330	36	280	392	272	410
03/28/10	0.091 ^a	16	176	20	146	209	142	215
04/04/10	0.091 ^a	5	55	6	46	65	44	67
04/11/10	0.091 ^a	3	33	4	28	39	27	41
05/02/10	0.091 ^a	2	22	2	19	26	18	27
05/09/10	0.091 ^a	1	11	1	9	13	9	13
Totals	---	70	770	42	712	844	698	860

^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 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 2010 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		95% Confidence Interval ^c	
					Lower CI	Upper CI	Lower CI	Upper CI
Previous Brood Years (Age 1+)								
12/13/09	0.046 ^d	1	22	4	17	29	16	30
12/20/09	0.091 ^a	5	55	6	46	65	45	68
12/27/09	0.091 ^a	2	22	2	19	26	18	27
01/10/10	0.093	25	269	37	215	331	208	359
01/17/10	0.091 ^a	27	297	30	250	347	245	358
01/24/10	0.095	30	316	44	253	389	245	422
01/31/10	0.041	8	197	31	152	252	147	269
02/07/10	0.091 ^a	8	88	9	74	104	72	108
02/14/10	0.099	1	10	1	9	12	8	13
02/21/10	0.125	11	88	6	78	99	77	101
02/28/10	0.091 ^a	4	44	5	37	52	36	54
03/07/10	0.091 ^a	1	11	1	9	13	9	14
03/21/10	0.091 ^a	2	22	2	19	26	18	27
03/28/10	0.091 ^a	3	33	4	28	39	27	41
04/18/10	0.091 ^a	22	242	27	201	287	195	296
04/25/10	0.091 ^a	1	11	1	9	13	9	14
05/02/20	0.091 ^a	1	11	1	9	13	9	14
05/30/10	0.091 ^a	2	22	3	18	27	18	27
06/06/10	0.091 ^a	1	11	1	9	13	9	14
Totals	---	155	1,760	78	1,654	1,899	1,627	1,942

Table 5 Continued.

Brood Year 2009 (YOY)								
03/21/10	0.091 ^a	1	11	1	9	13	9	14
04/04/10	0.091 ^a	4	44	5	37	52	36	55
04/11/10	0.091 ^a	1	11	1	9	13	9	13
04/18/10	0.091 ^a	7	77	8	65	91	63	96
04/25/10	0.091 ^a	2	22	2	18	26	18	27
05/02/10	0.091 ^a	8	88	9	74	106	72	109
05/09/10	0.091 ^a	15	165	18	137	196	133	208
05/16/10	0.091 ^a	9	99	11	83	119	82	123
05/23/10	0.091 ^a	12	132	14	111	157	108	161
05/30/10	0.091 ^a	68	747	79	629	875	610	929
06/06/10	0.091 ^a	47	516	55	444	614	426	642
06/13/10	0.091 ^a	49	538	58	453	640	440	669
06/20/10	0.091 ^a	39	429	48	357	509	346	525
06/27/10	0.091 ^a	17	187	20	157	222	152	232
07/04/10	0.091 ^a	19	209	23	176	252	167	264
07/11/10	0.091 ^a	7	77	8	65	91	63	94
Totals	---	305	3,352	136	3,134	3,592	3,099	3,650

^a The season average trap efficiency (0.091) 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.

^d The season average trap efficiency was converted to a half-cone efficiency for this week because the trap was operating with the half-cone modification.

Table 6. Summary of spring and late-fall 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	Current Estimate	90% Confidence Interval		95% Confidence Interval	
			Lower CI	Upper CI	Lower CI	Upper CI
Spring	1998	1,199,077	809,007	1,814,925	758,222	2,060,077
	1999	245,388	179,535	345,756	168,932	373,311
	2000-partial ^a	48,553	N/A	N/A	N/A	N/A
	2001	21,786	14,205	32,474	13,479	37,183
	2002	18,941	13,901	25,604	13,344	27,552
	2003 ^c	152,657	115,865	202,950	110,663	218,387
	2004	30,090	19,970	45,938	18,948	52,651
	2005 ^d	N/A	N/A	N/A	N/A	N/A
	2006 ^e	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
	2009	96,555	87,762	106,735	86,392	110,047
Late-Fall	1999	212	177	261	170	273
	2000	50	36	70	35	78
	2001 ^a	N/A	N/A	N/A	N/A	N/A
	2002	7,628	5,950	9,969	5,753	10,604
	2003 ^c	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 ^d	N/A	N/A	N/A	N/A	N/A
	2007 ^e	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
	2010	770	712	844	698	860
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 ^a	N/A	N/A	N/A	N/A	N/A
2002 (1+)	1,348	1,201	1,607	1,170	1,666
2002 (YOY)	24,740	21,034	29,565	20,454	31,426
2003 (1+)	592	522	671	511	698
2003 (YOY)	7,087	6,441	7,769	6,349	7,978
2004 (1+)	826	753	903	741	917
2004 (YOY)	2,770	2,512	3,057	2,455	3,142
2005 (1+)	485	421	573	411	610
2005 (YOY)	5,490	4,355	7,074	4,231	7,431
2006 (1+) ^d	N/A	N/A	N/A	N/A	N/A
2006 (YOY) ^d	N/A	N/A	N/A	N/A	N/A
2007 (1+) ^e	N/A	N/A	N/A	N/A	N/A
2007(YOY) ^e	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
2010 (1+)	1,760	1,654	1,899	1,627	1,942
2010 (YOY)	3,352	3,134	3,592	3,099	3,650

^a Methods used to calculate the BY00 spring Chinook salmon passage estimate are describe in an internal memo as the trap was not fished past February 9, 2001. No late-fall Chinook salmon and rainbow trout/steelhead estimates were made as the trap did not fish during the primary migration period.

^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 This estimate likely includes fall Chinook salmon as several adult Fall Chinook salmon passed upstream of the barrier weir in late-August.

^d 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.

^e Methods used to calculate the BY06 spring Chinook salmon 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. No rainbow trout/steelhead passage estimates were made.

Figures

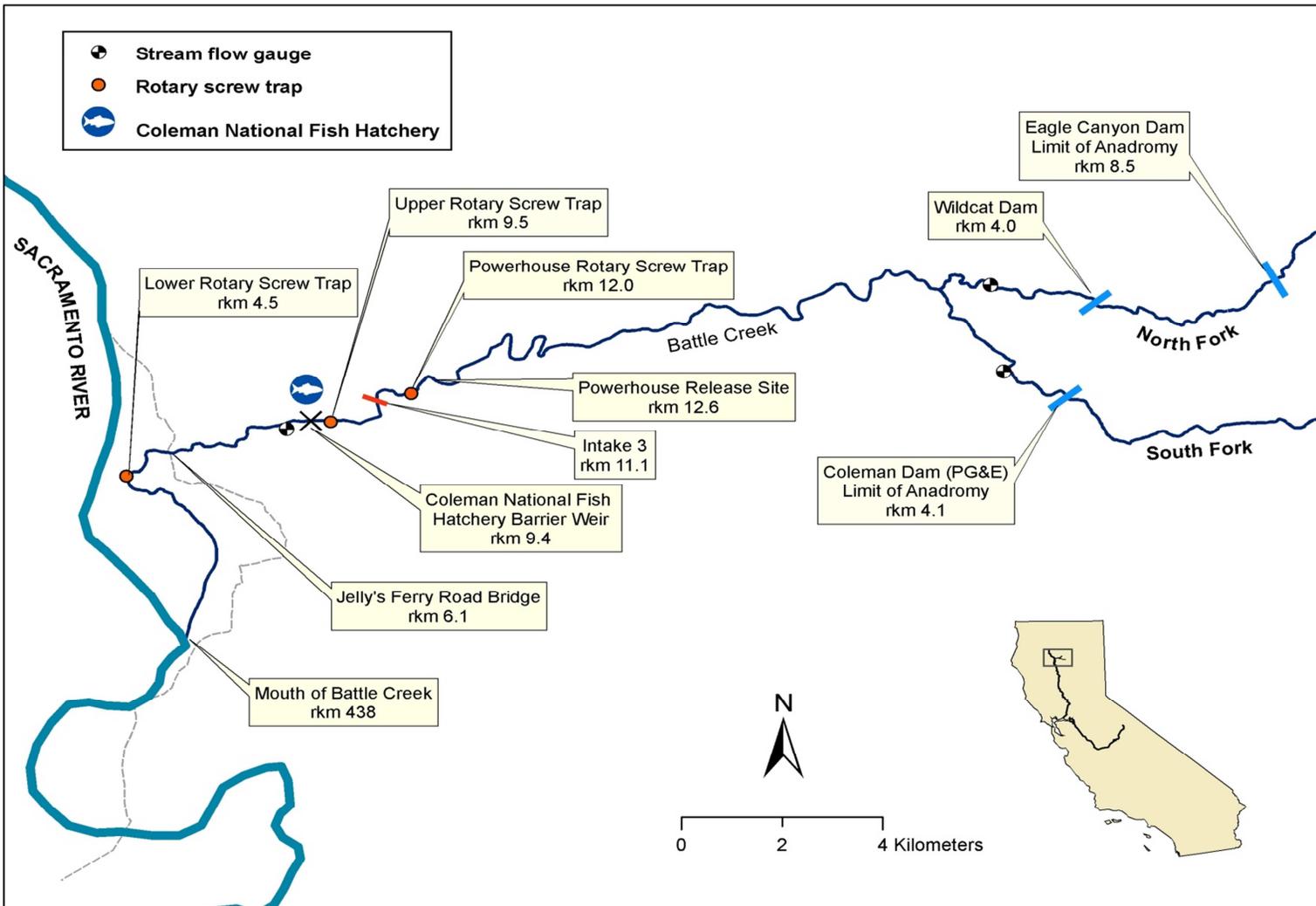


Figure 1. Map of Battle Creek depicting the location of USFWS' rotary screw traps and other important features.

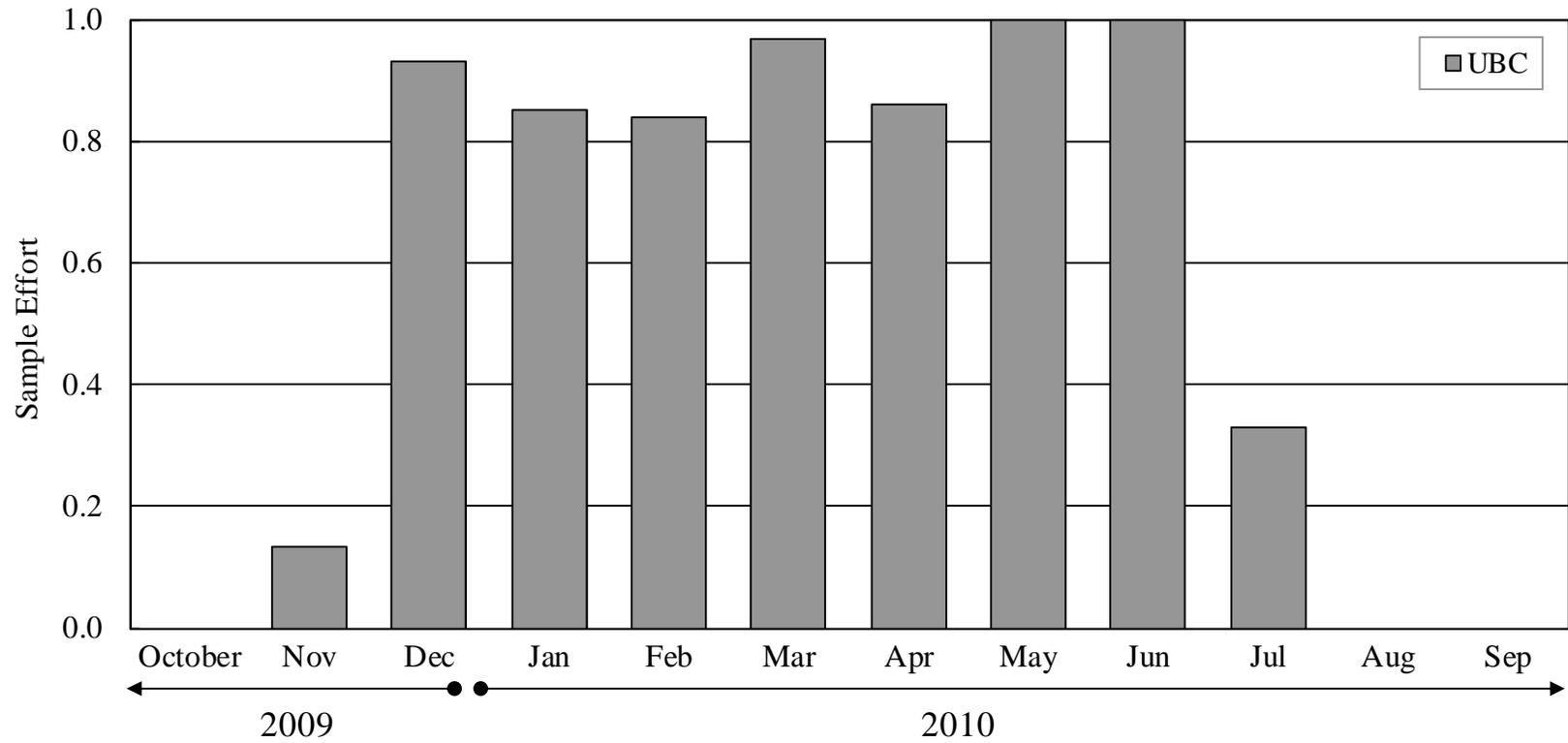


Figure 2. Sampling effort summarized as the proportion (range: 0 to 1) of days fished each month at the Upper Battle Creek rotary screw trap (UBC) from October 1, 2009 to September 30, 2010. Dates of trap operation were November 24, 2009 through July 16, 2010.

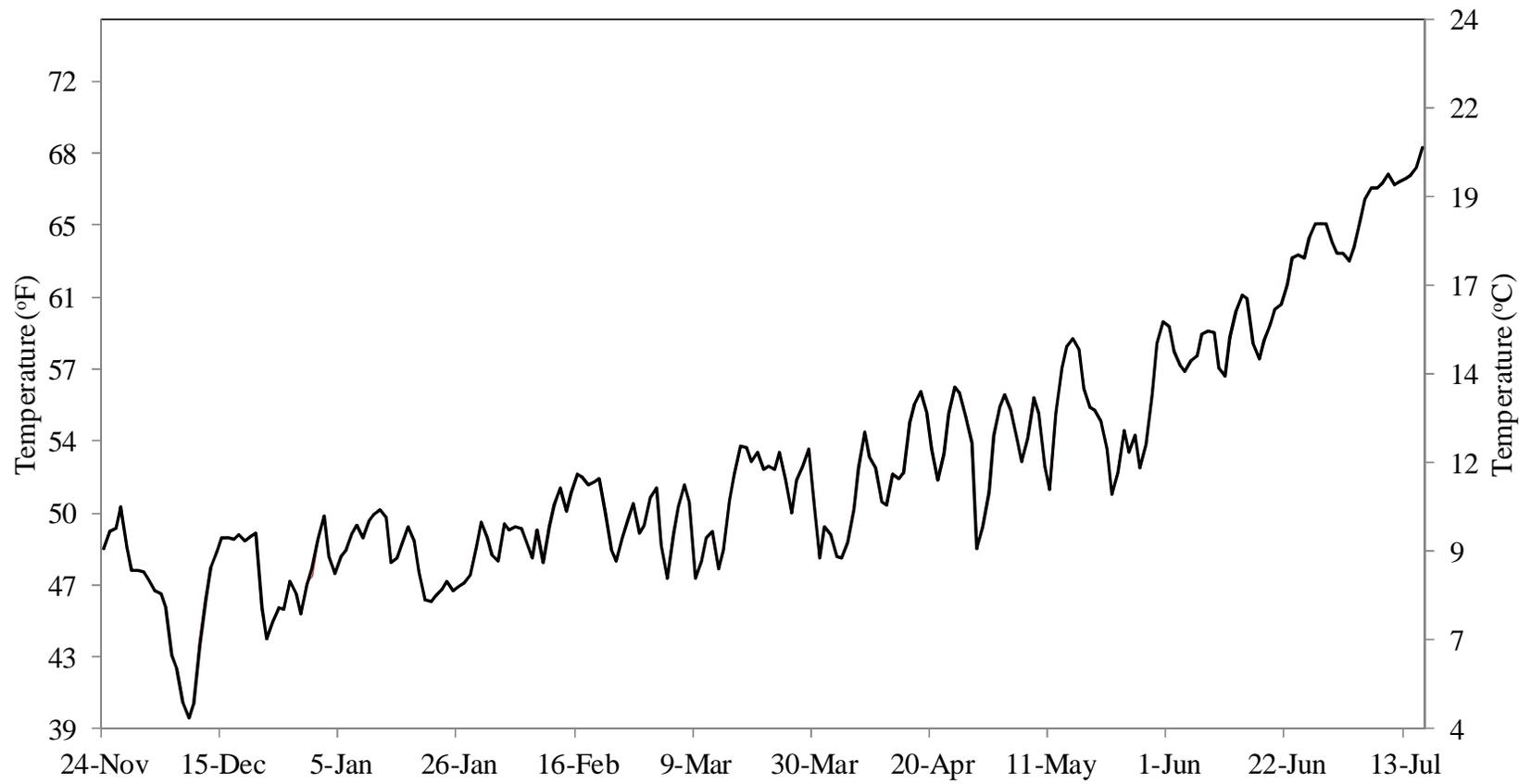


Figure 3. Mean daily water temperatures (°F and °C), at the Upper Battle Creek rotary screw trap from November 24, 2009 through July 16, 2010.

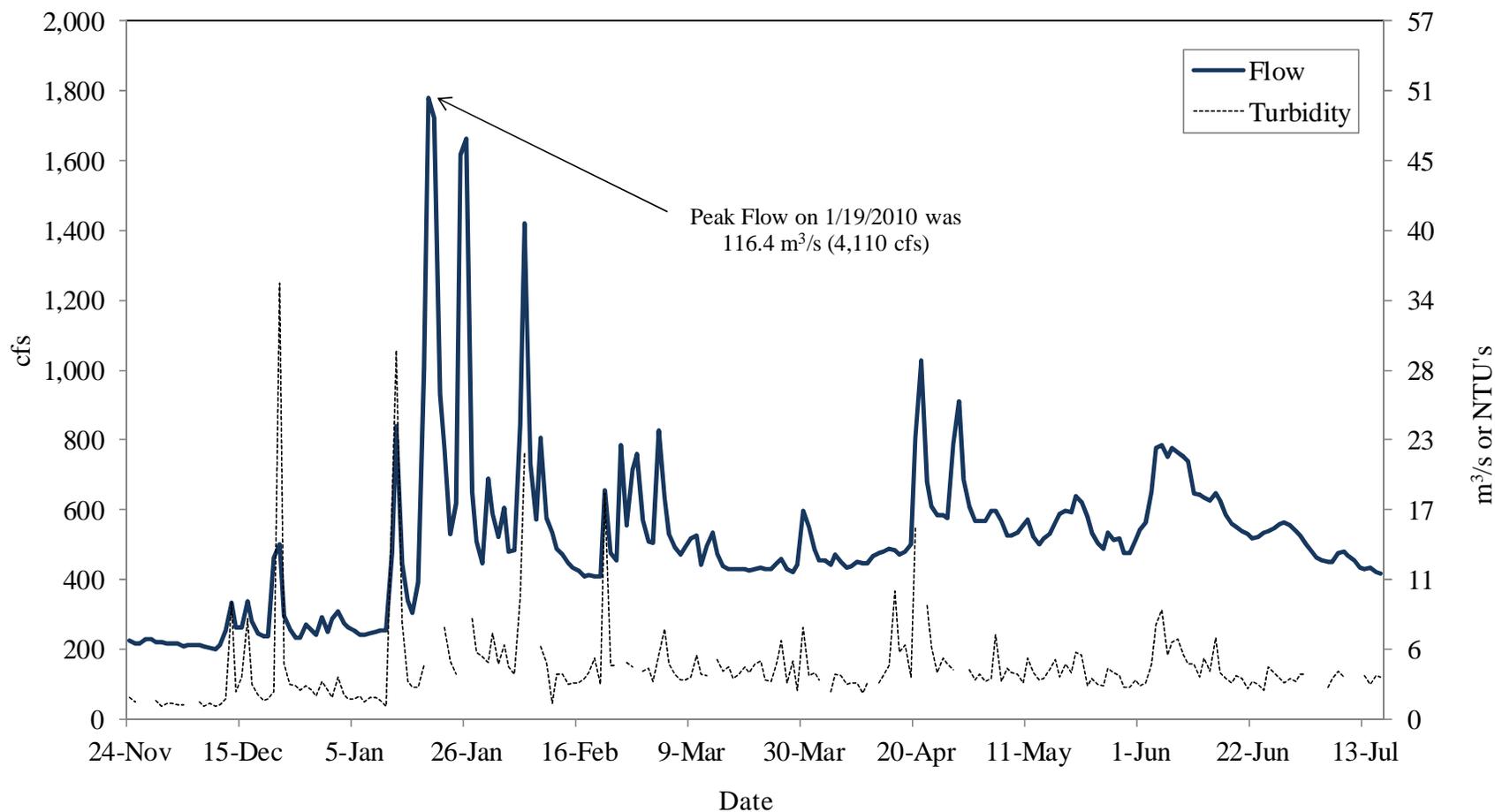


Figure 4. Mean daily flows (cfs and m^3/s) collected by the U.S. Geological Survey at the Coleman Hatchery gauging station (BAT #11376550) and turbidity measured at the UBC trap from November 24, 2009 through July 16, 2010. The gauge site is located below the Coleman National Fish Hatchery barrier weir and approximately 0.2 km downstream of the Upper Battle Creek rotary screw trap.

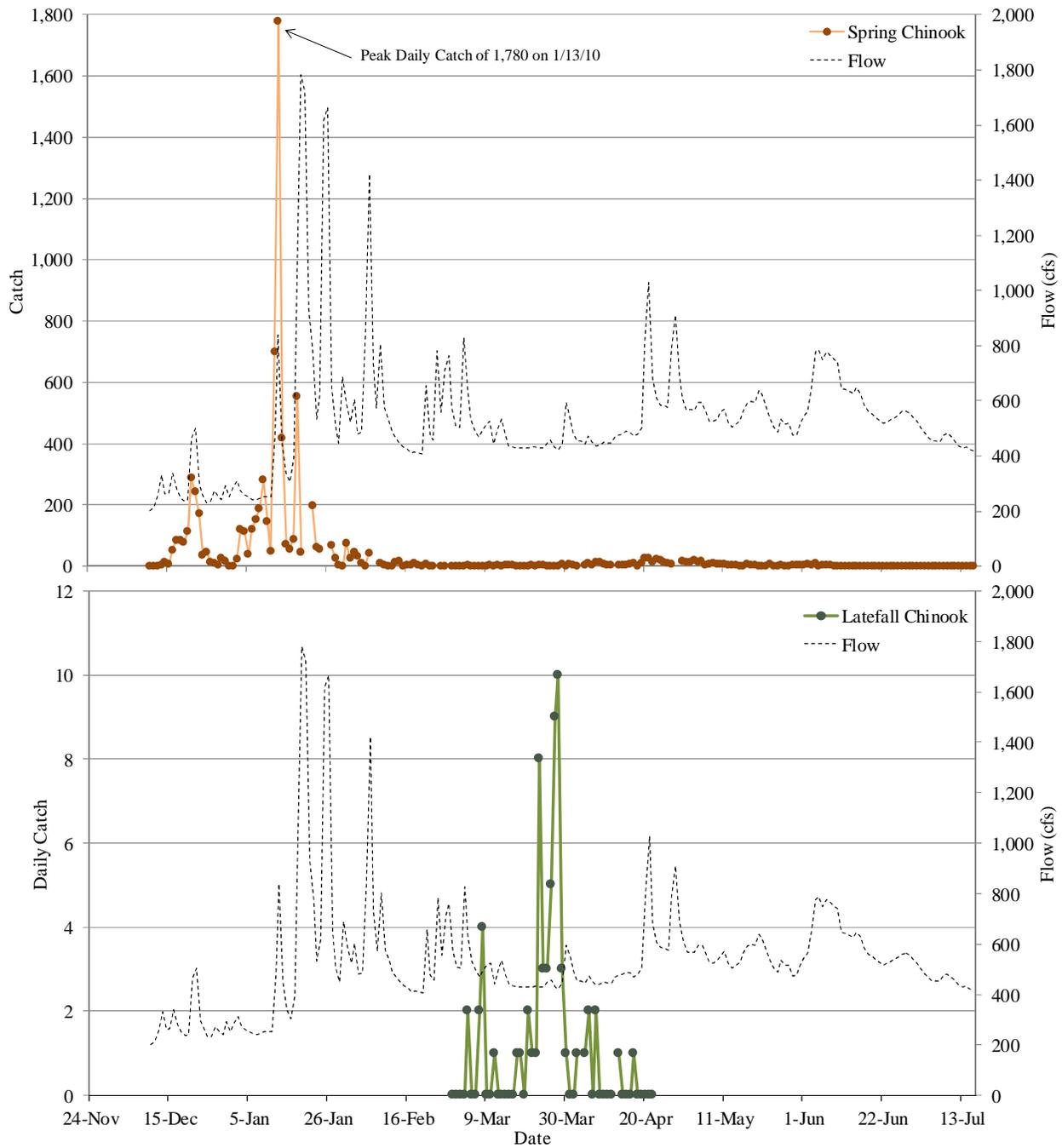


Figure 5. Mean daily flow and catch of spring and late-fall Chinook salmon captured at the Upper Battle Creek rotary screw trap from November 24, 2009 through July 16, 2010. Daily catch totals may be partial if the trap was not operated on all days of a week.

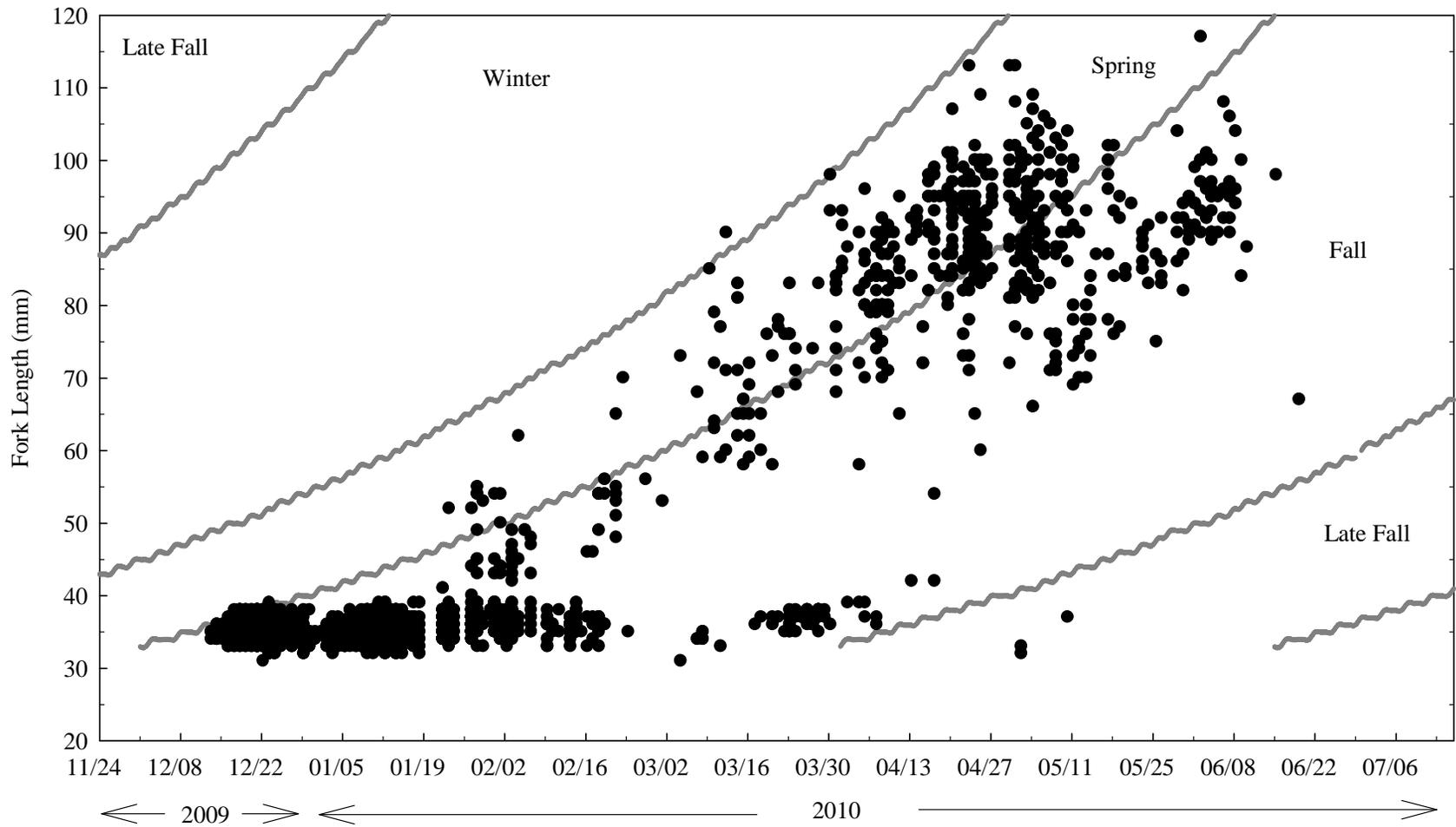


Figure 6. Fork length (mm) distribution by date and run for Chinook salmon captured at the Upper Battle Creek rotary screw trap from November 24, 2009 to July 16, 2010. Spline curves represent the maximum fork lengths expected for each run by date, based on criteria developed by the California Department of Water Resources (Greene 1992).

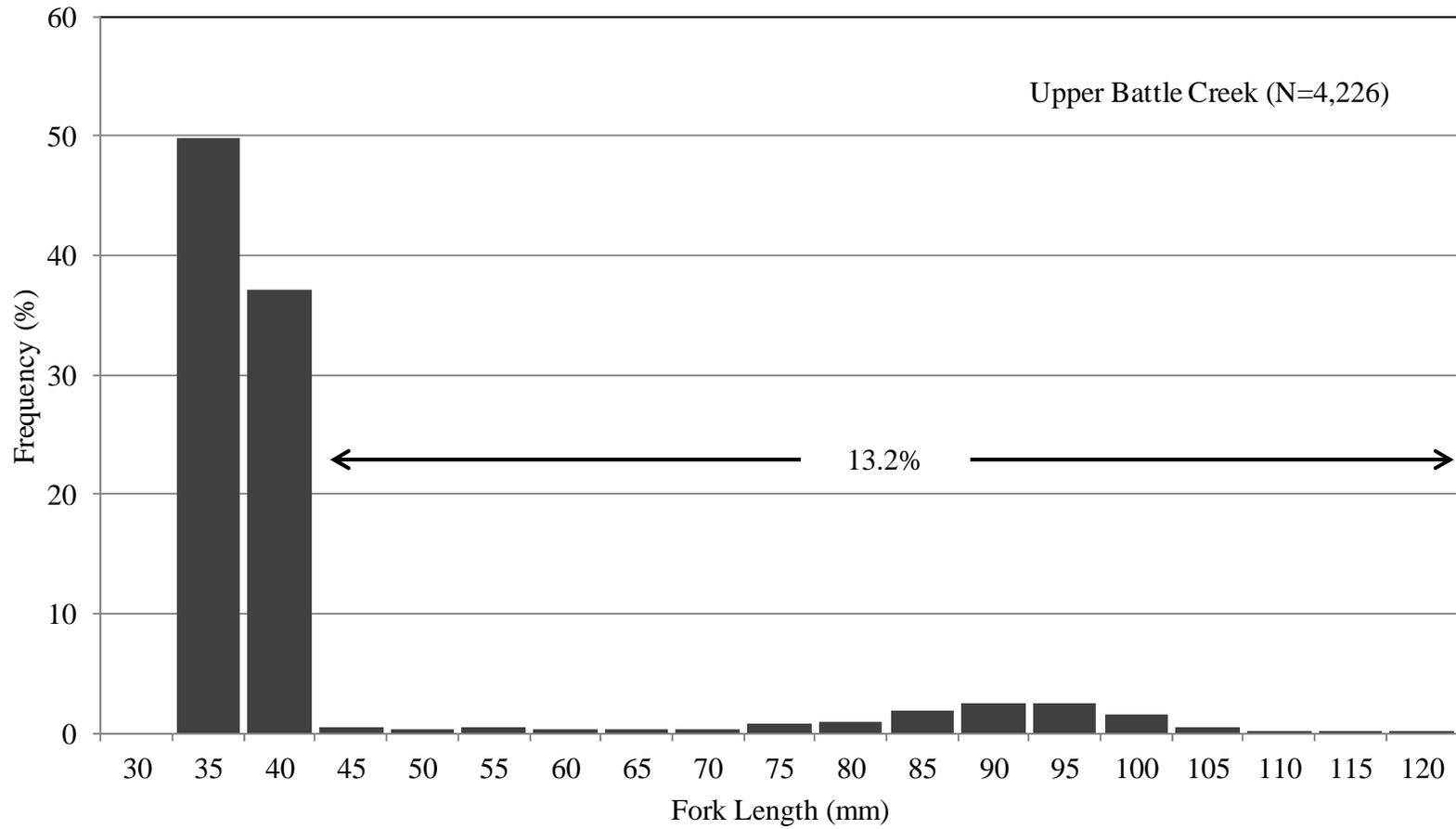


Figure 7. Length frequency (%) for all runs of Chinook salmon measured at the Upper Battle Creek rotary screw trap during November 24, 2009 through July 16, 2010. Fork length axis labels indicate the upper limit of a 5-mm length range.

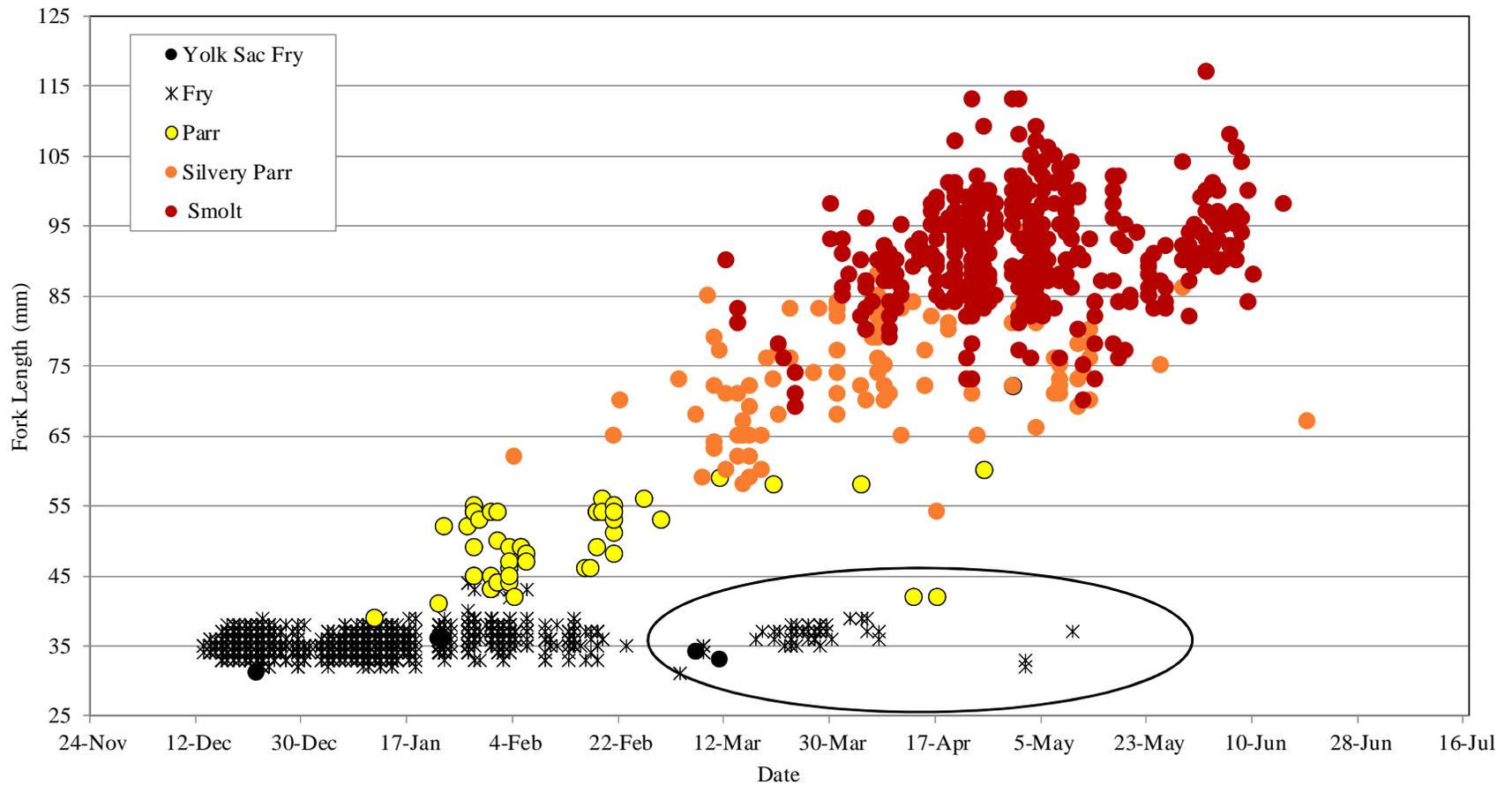


Figure 8. Life stage distribution for all runs of Chinook salmon measured at the Upper Battle Creek rotary screw trap during November 24, 2009 through July 16, 2010. Late-fall Chinook salmon captured in the trap are indicated by the oval.

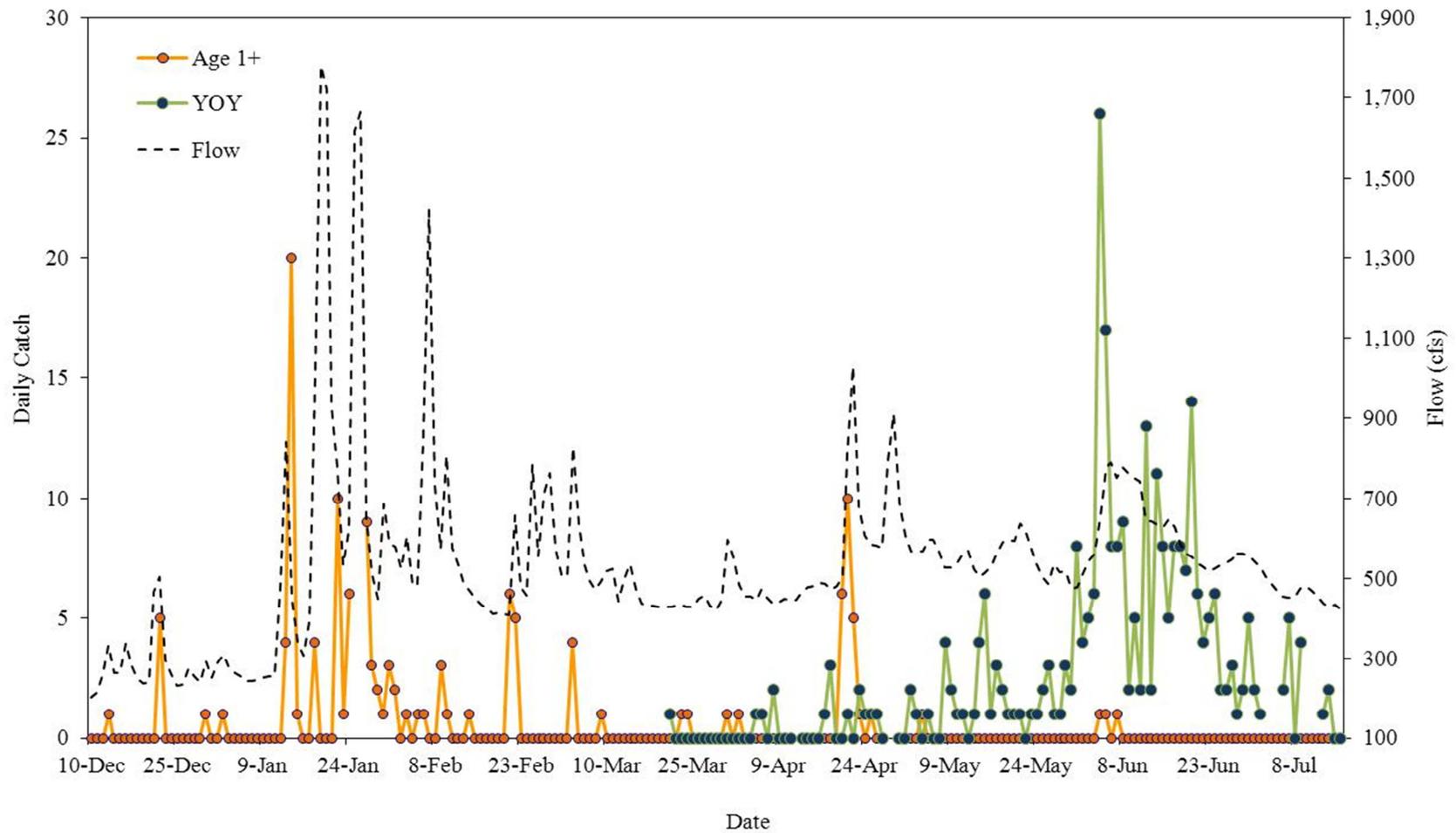


Figure 9. Mean daily flow and catch of age 1+ (Age 1+) and young-of-the-year (YOY) rainbow trout/steelhead captured at the Upper Battle Creek rotary screw trap from November 24, 2009 through July 16, 2010.

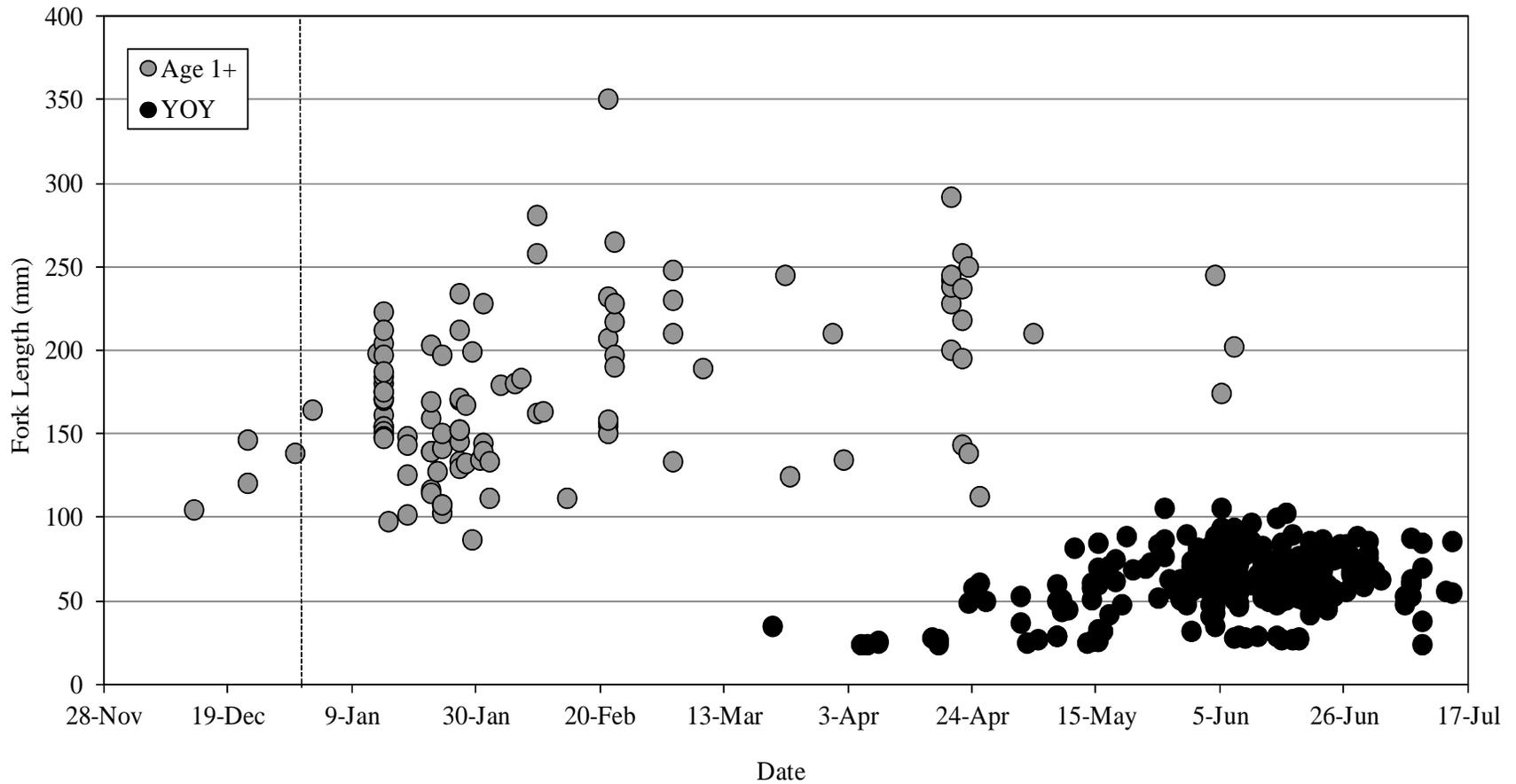


Figure 10. Fork length (mm) distribution by date for young-of-the-year (YOY) and age 1+ (Age1+) rainbow trout/steelhead measured at the Upper Battle Creek rotary screw trap during November 24, 2009 through July 16, 2010. Age 1+ fish may include individuals from multiple brood years.

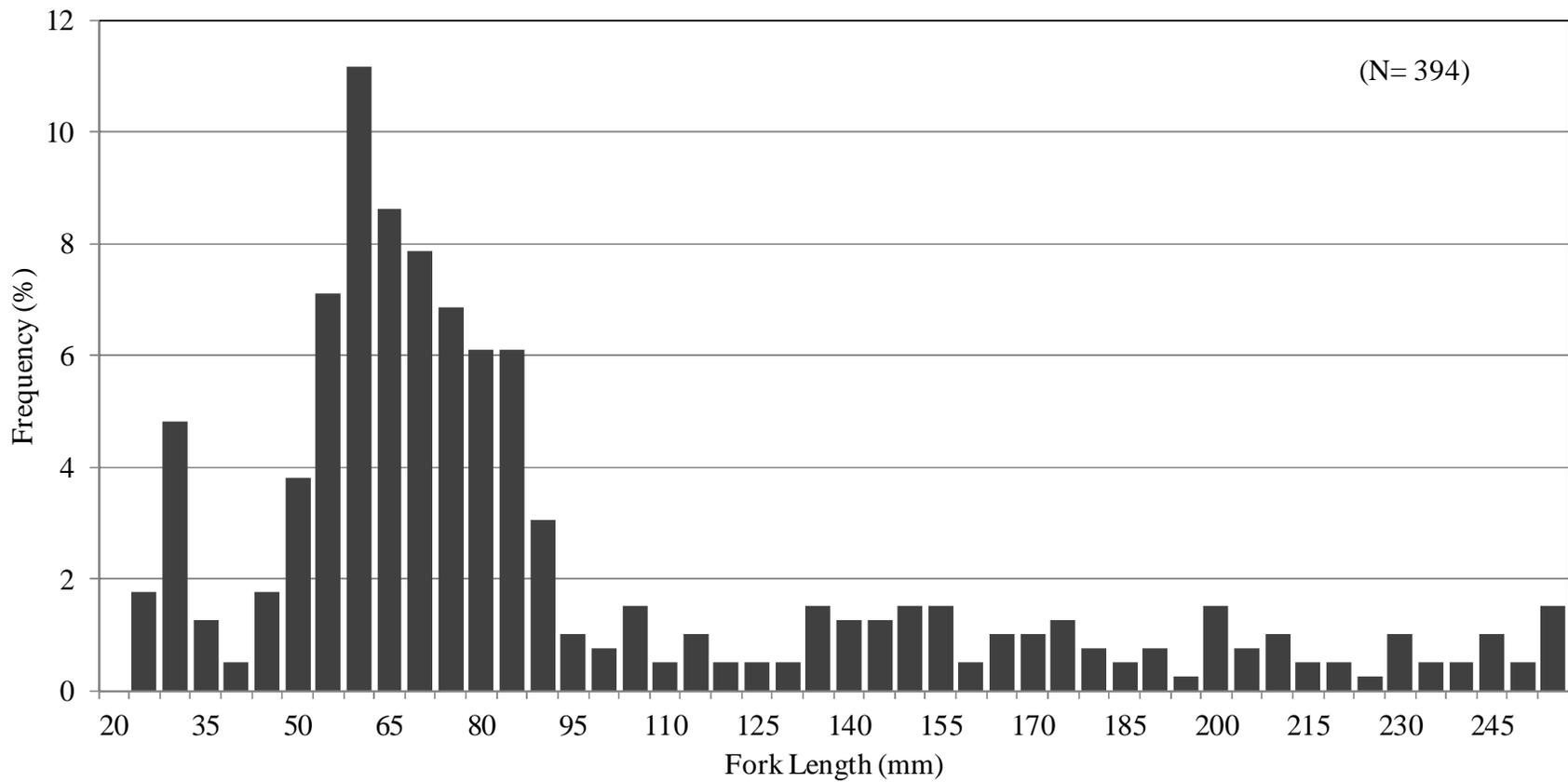


Figure 11. Fork length frequency (%) for rainbow trout/steelhead sampled at the Upper Battle Creek rotary screw trap during November 24, 2009 through July 16, 2010. Fork length axis labels indicate the upper limit of a 5-mm length range.

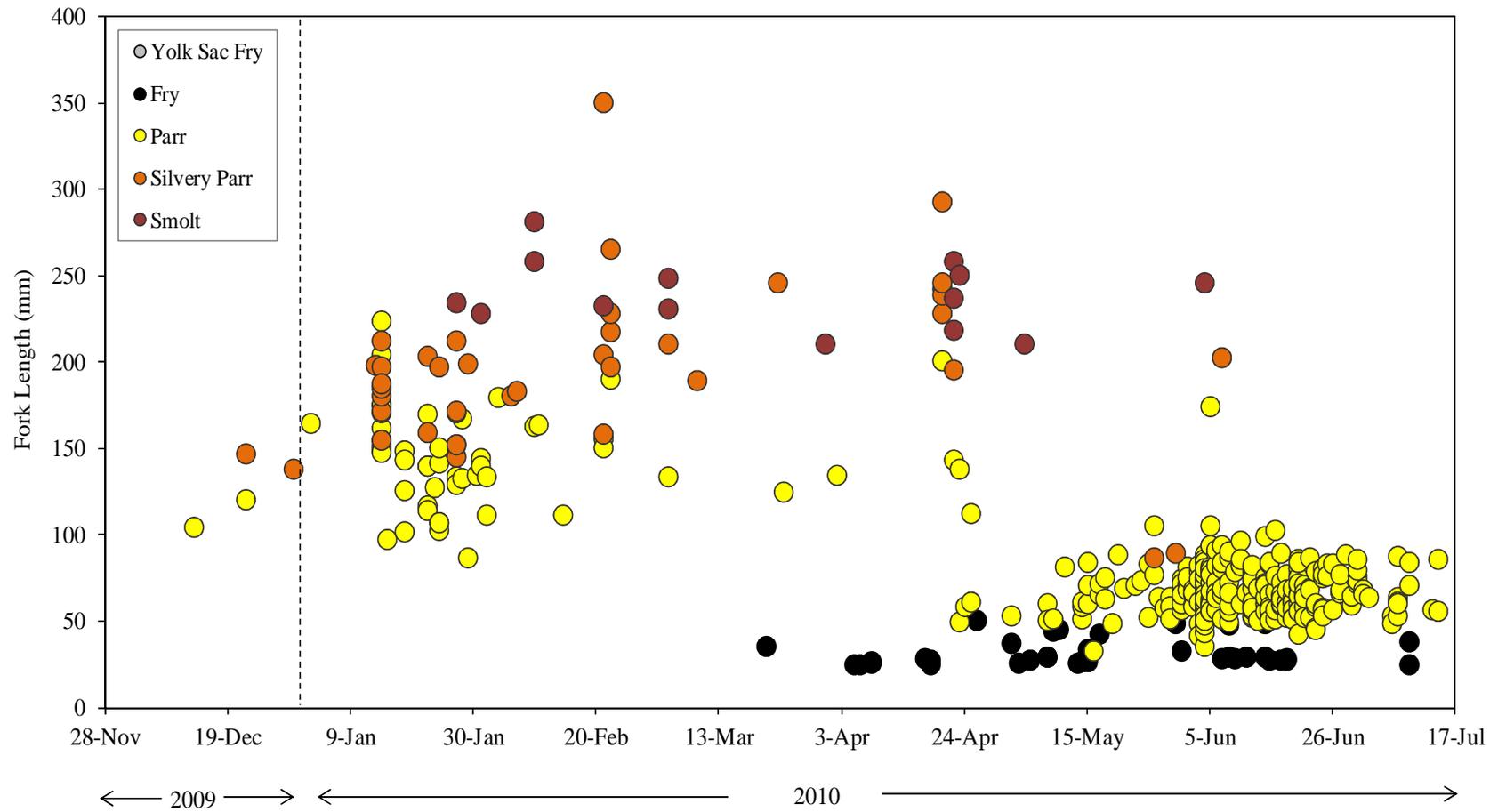


Figure 12. Rainbow trout/steelhead life-stage distribution at the Upper Battle Creek rotary screw trap during November 24, 2009 through July 16, 2010.

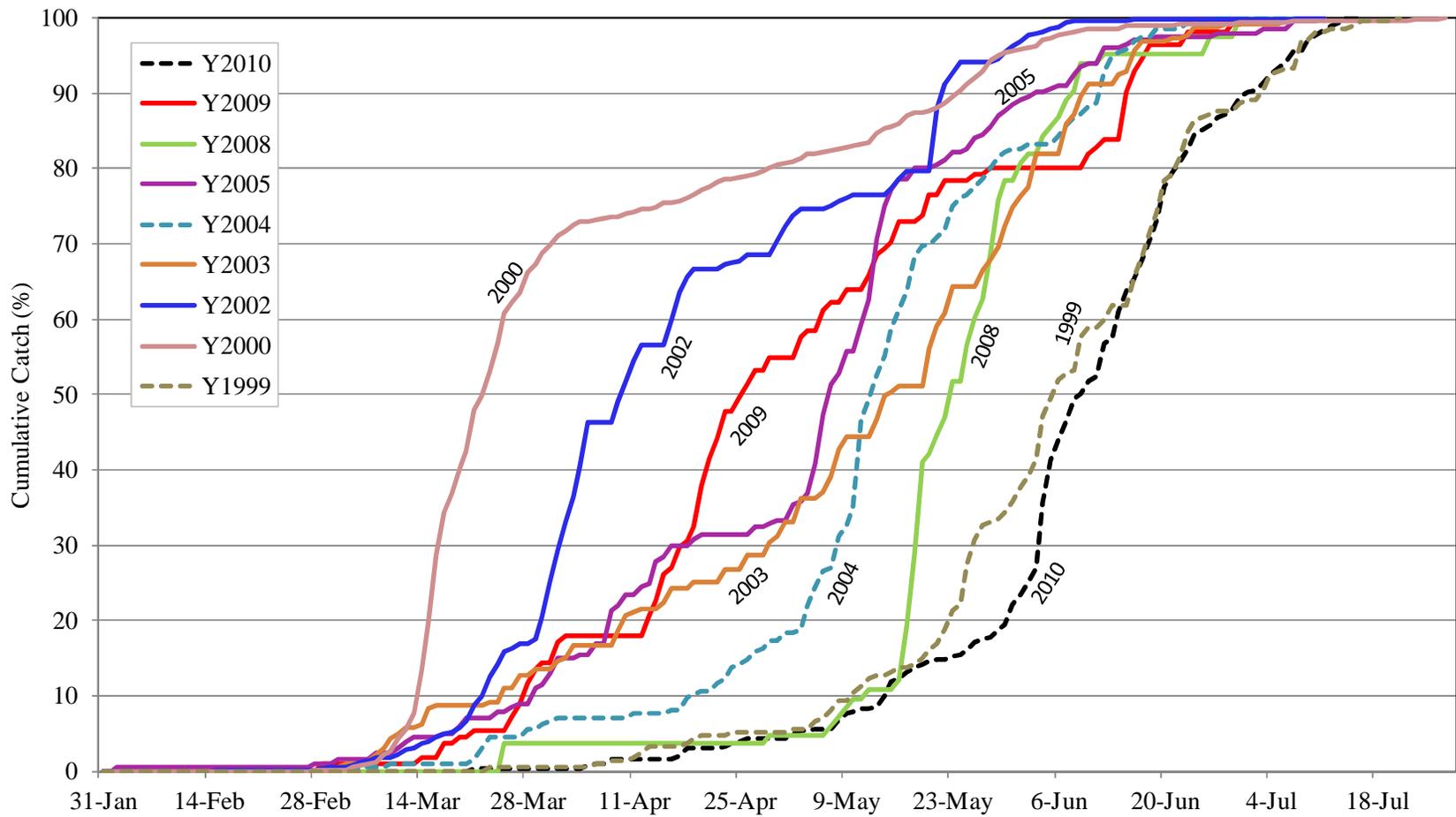


Figure 13. Cumulative rainbow trout/steelhead catch at the Upper Battle Creek rotary screw trap for the years 1999-2000, 2002-2005, and 2008-2010.

Appendix

Appendix 1. Summary of days the Upper Battle Creek rotary screw trap did not fish for approximately 24 hours during the report period (November 24, 2009 to July 16, 2010), including sample dates, hours fished, and reason for not fishing.

Sample Dates	Hours Fished (approx)	Reason
2009		
November 26-28	0.0	Holiday-No Fish
December 5-6	0.0	Reduced Schedule-No Fish
December 22	17.4	Trap Sunk (2 hr)/Pulled Over to Clear
2010		
January 19	9.75	High Flows
January 20-21	0.0	High Flows
January 22	21.0	High Flows
January 25	7.0	High Flows
January 26	0.0	High Flows
January 27	16.75	High Flows
February 5	12 .0	High Flows
February 7-8	0.0	High Flows/Trap Displaced
February 23	7.0	High Flows
February 27	0.0	High Flows
March 13	0.0	High Flows Predicted
April 3	7.0	High Flows Predicted
April 12	4.0	High Flows Predicted
April 21	5.3	High Flows
April 22	13 .0	High Flows
April 28	7.0	High Flows
April 29	7.8	High Flows
July 3-5	0	Reduced Sampling
July 10-12	0	Reduced Sampling

Appendix 2. Monthly catch of non-salmonid species in the Upper Battle Creek rotary screw trap from November 24, 2009 through July 16, 2010.

Species	Month									Total
	Nov ^a	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul ^a	
CAR	0	1	0	0	3	3	1	1	1	13
CENFRY	0	1	3	0	0	0	0	0	1	2
COTFRY	0	0	0	0	0	0	0	55	35	90
CYPRY	0	119	128	13	2	7	17	40	27	353
EAMMO	0	16	18	14	4	29	16	21	1	119
HH	0	70	148	51	10	45	94	315	27	760
LAMMO	0	3	6	1	2	0	0	2	2	16
PLT	0	504	512	0	0	5	0	1	0	1022
RFS	0	2	0	4	11	5	13	8	23	66
SASU	0	21	25	4	1	3	32	45	109	240
SPM	0	40	16	11	2	2	3	7	3	84
TP	0	1	2	0	0	0	1	1	6	11
TSS	0	7	0	2	0	0	1	1	1	12
UAMMO	0	1	0	1	0	0	0	0	0	2
WBL	0	0	0	0	0	1	1	3	0	5

^aTrap was not operated the entire month (dates of operation were November 24-30 and July 1-16, 2010).

Appendix 3. Species key for non-salmonid fish taxa captured at the Upper Battle Creek trap from November 24, 2009 through July 16, 2010.

Abbreviation	Common Name	Scientific Name
CAR	California roach	<i>Hesperoleucus symmetricus</i>
CENFRY	unknown centrarchidae	<i>Centrarchidae spp.</i>
COTFRY	cottus fry	<i>Cottus spp.</i>
CYPRY	unknown cyprinidae	<i>Cyprinidae spp.</i>
EAMMO	<i>Entosphenus</i> , lamprey fry	<i>Entosphenus spp.</i>
HH	hardhead	<i>Mylopharodon conocephalus</i>
LAMMO	<i>Lampetra</i> , lamprey fry	<i>Lampetra spp.</i>
PLT	Pacific lamprey, macrophthalmia	<i>Lampetra tridentata</i>
RFS	riffle sculpin	<i>Cottus gulosus</i>
SPM	Sacramento pikeminnow	<i>Ptychocheilus grandis</i>
SASU	Sacramento sucker	<i>Catostomus occidentalis</i>
TP	tule perch	<i>Hysterocarpus traski</i>
TSS	threespine stickleback	<i>Gasterosteus aculeatus</i>
UAMMO	unidentified lamprey fry	Unknown
WBL	western brook lamprey	<i>Lampetra richardsoni</i>