Juvenile Salmonid Monitoring in Battle Creek, California, October 2005 through September 2006

USFWS Report
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Juvenile Salmonid Monitoring in Battle Creek, California, October 2005 through September 2006

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Abstract- 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. In October 2005, the U.S. Fish and Wildlife Service continued an ongoing juvenile salmonid monitoring project on Battle Creek, California, using rotary screw traps. An additional rotary screw trap (Powerhouse Battle Creek) was installed upstream of the other two traps to determine the feasibility of operating the Upper Battle Creek trap in a new location. In December 2005, the Coleman Powerhouse went offline for an extended period of time, requiring Coleman National Fish Hatchery to use an unscreened intake to obtain water for hatchery operations; therefore a fyke net was installed in Coleman National Fish Hatchery's canal to estimate the proportion of juvenile passage being entrained to adjust our rotary screw trap passage estimates. From October 2005 through September 2006 four runs of Chinook salmon *Oncorhynchus tshawytscha*, rainbow trout/steelhead *Oncorhynchus mykiss*, and 13 species of non-salmonids were captured in either the rotary screw traps or the fyke net. To determine rotary screw trap and fyke net efficiency, we conducted one mark-recapture trial at the Lower Battle Creek trap, six at the Upper Battle Creek trap, six at the new Powerhouse Battle Creek trap, and four at the fyke net from January 30 to March 20, 2006. Rotary screw trap efficiencies based on valid trials ranged from 0.028 to 0.068, and fyke net efficiencies ranged from 0.54 to 0.951. During 2005 to 2006, we were unable to estimate juvenile passage at the rotary screw traps because high flows prevented us from operating the traps for long periods of time during the peak migration periods. Out of 8 years of sampling, this was the first year we were unable to estimate juvenile passage because of high flows. High flows and the Coleman Powerhouse outage also prevented us from completing our evaluation of the new trap location. We were able to successfully operate a fyke net in the canal, but our inability to develop rotary screw trap passage estimates and lack of funding prevented us from meeting our objective. However, we were able to document that entrainment of juvenile salmonids and other non-salmonid species was occurring through the unscreened intake.

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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). As a result of the declines, two populations of Chinook salmon (*Oncorhynchus tshawytscha*) and one population of steelhead (*O. mykiss*) in the Sacramento River watershed have been 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, which is currently owned by Pacific Gas and Electric Company (PG&E), has had severe impacts upon anadromous salmonids and their habitat (Ward and Kier 1999), including a reduction of instream flows, barriers to migration, loss of habitat, flow related temperature impacts, etc.

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

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

The U.S. Fish and Wildlife Services' Red Bluff Fish and Wildlife Office (RBFWO) began using rotary screw traps to monitor juvenile salmonids on Battle Creek, Shasta and Tehama Counties, California, in September 1998 (Whitton et al. 2006). However, during the current report period, the RBFWO installed and operated an additional rotary screw trap to test an alternative location to the current Upper Battle Creek trap location which is not ideal because of the stream channel geometry. Concurrent operation of both traps was necessary to preserve the utility of data collected in previous years by identifying factors that influence passage estimates at both locations. In addition, PG&E's Coleman Powerhouse was shutdown in December 2005 which required Coleman National Fish Hatchery (CNFH) to obtain most of its water from an alternative unscreened intake (Intake 2). Therefore, we operated a fyke net in the hatchery's canal to estimate the proportion of juvenile salmonid passage that was being entrained into the hatchery's canal, so that we could better compare current passage estimates with our previous annual estimates. The purpose of this report is to summarize rotary screw trap and fyke net data collected during the period October 1, 2005 through September 30, 2006. 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.

In 1998, the RBFWO installed and operated two rotary screw traps on Battle Creek, 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 current reporting 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 new site was designated Powerhouse Battle Creek (PHBC). In addition, the RBFWO operated a fyke net in the Coleman National Fish Hatchery's canal about 4.6 m (15 ft) downstream of the head of the canal (Figure 2). 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 and Fyke Net Operation

In October 2005, the Red Bluff Fish and Wildlife Office continued the operation of two rotary screw traps on Battle Creek. During the current reporting period (October 1, 2005 through September 30, 2006), the Lower Battle Creek trap (LBC) was operated from December 8, 2005 through April 23, 2006 and the Upper Battle Creek trap (UBC) was operated from October 10, 2005 through June 30, 2006. In December 2005, the RBFWO began operating an additional rotary screw trap 2.5 km (1.6 miles) upstream of the UBC trap. The Powerhouse Battle Creek trap (PHBC) was operated from December 1, 2005 through March 24, 2006. In addition, we operated a fyke net in Coleman National Fish Hatchery's canal from January 7 to March 3, 2006 to estimate the proportion of juvenile salmonid passage that was being entrained into the hatchery's canal, so that we could better compare current passage estimates with our previous annual estimates. Intake 2, an unscreened emergency-backup intake, became one of the hatchery's primary water sources when PG&E's Coleman Powerhouse went offline for an extended period of time.

Rotary screw traps.—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.

We attempted to operate the traps 24 h per day; 7 d each week, but at times high flows, trap repair, and other miscellaneous reasons limited our ability to operate the traps continuously (Appendices 1 and 2). In addition, when few or no salmonids were captured, we did not operate any of the traps or operated them on a reduced schedule. Traps were not operated when stream flows exceeded certain levels in order to prevent fish mortality, damage to equipment, and to ensure crew safety. The traps were 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. When flows allowed, the crews were able to access the traps by wading from the stream bank; however, during high flows access to the traps required that the crews use the cable and pulley system to pull the traps into shallow water. After or during sampling and maintenance, the traps were repositioned in the thalweg.

In October 2000 the LBC trap was modified by placing an aluminum plate over one of the two existing cone discharge ports and removing an exterior cone hatch cover (half-cone modification). As a result, half of the collected fish and debris were not discharged into the live box, but rather were discharged from the cone back into the creek. This effectively reduced our catch of both fish and debris by half, and also reduced crowding of fish in the live box by half. During the 2005 to 2006 reporting period, the LBC trap was operated with the half-cone modification on February 10, 2006, the UBC trap was operated with the half-cone modification from December 14, 2005 to June 30, 2006, and the PHBC trap was operated with the half-cone modification from December 7, 2005 to March 23, 2006. In previous years, additional modifications were made to the traps and daily operations to reduce the potential for 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.

Each time a trap was sampled, crews would sample fish present in the live box, remove debris from the cone and live box, collect environmental and trap data, and complete any necessary trap repairs. Data collected at each 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 continuously measured with an instream Onset Optic Stow Away® temperature data logger. Water velocity was measured as the average velocity from a grab-sample using an Oceanic® Model 2030 flowmeter (General Oceanics, Inc., Miami, Florida). The average velocity was measured for a minimum of 3 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 compare discharge and downstream migration patterns. The gauge site is located below the Coleman Fish Hatchery barrier weir and approximately 0.2 km downstream of the UBC trap (Figure 1).

Fyke net.—A fyke net constructed of 3 mm (1/8 in) mesh was attached to a 1.8 m (6 ft) square steel frame anchored into the center of the hatchery's canal with rope and t-fence posts. Initially wings of similar size mesh were attached to the frame and the adjacent banks at an angle which directed flow and debris to the opening of the fyke net. However, high flows and debris build-up eventually damaged the mesh wings; therefore, they were replaced with fixed aluminum frames covered with 3-mm diameter perforated stainless steel screen (Figure 2). The screens were anchored into the canal with t-fence posts. Sand bags were placed along the bottom of the fyke frame and wings to make the structure fish tight. A 1.2 m x 0.8 m x 0.8 trap box was attached to the downstream end (cod) of the fyke net and supported with flotation. Each time the fyke was sampled, crews would sample fish present in the trap box, remove debris from the trap box and fyke net, collect limited environmental and trap data, and complete any necessary repairs. Data collected at the fyke net included, dates and times of operation, fyke condition, type and amount of debris, and basic weather conditions. The amount of debris in the live box was volumetrically measured using a 44.0 liter (10-gallon) plastic tub. Water velocity was measured periodically with a Marsh-McBirney model 2000 flow meter at three locations (center of right and left wings and center of the fyke opening) immediately upstream of the fyke.

Biological Sampling

Juvenile sampling at the traps and fyke 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, a minimum number of each fish taxa captured were counted and then depending on the species, either fork length (FL) or total length (TL) was measured. 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. 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 traps or fyke all salmon were counted and measured for FL (to the nearest 1 mm). The measured juvenile salmon were also 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, late-fall, winter, or spring. Life-stage classification was based on morphological features and run designations were based on length-at-date criteria from Greene (1992). Length data for all Chinook salmon runs was combined for graphical purposes as the length-at date criteria developed for the mainstem Sacramento River may not be directly applicable to the tributary populations.

When more than approximately 250 juvenile salmon were captured, subsampling was conducted. All salmon in the subsample were identified, counted, and measured. These salmon were also assigned a life-stage classification and run designation, using the methods described above. All other salmon were counted and identified. A cylinder-shaped net with 3-mm mesh and a split-bottom construction was used for subsampling. The bottom of the subsampling net was constructed with a metal frame that created two equal halves. A closed mesh bag was sewed onto one half of the frame and an open mesh bag was sewed onto the other half of the frame. The subsampling net was placed in a 117-L (30-gallon) bucket that was partially filled with creek water. All captured juvenile salmon were poured into the bucket. Once the fish had distributed evenly throughout the bucket, the net was lifted and approximately half of the salmon were retained in the side of the net with the closed mesh bag, and approximately half of the salmon in the side with the open mesh bag were retained in the bucket. We continued to successively subsample (split) until approximately 150 to 250 individuals remained in a subsample. The number of successive splits that we used varied with the number of salmon collected. Subsampling was used to obtain a representative sample for measuring. To determine total catch, we counted all salmon in each split. All live fish captured in the traps were released downstream of the trap, and live fish captured in the fyke net were released downstream of the barrier weir. Chinook salmon biological data were summarized by brood year for each run designation.

Rainbow trout/steelhead.—Due to the smaller numbers encountered, all rainbow trout/steelhead captured in the traps were counted and FL measured to the nearest 1 mm. Life stages of juvenile trout were classified similarly as salmon, with the addition of a yolk-sac fry life stage, as requested by the Interagency Ecological Program (IEP) Steelhead Project Work Team. All live rainbow trout/steelhead > 50mm captured at both traps were weighed to the nearest 0.1 g for CDFG's Stream Evaluation Program.

Non-salmonid taxa.—All non-salmonid taxa that were captured were counted, but we only measured up to approximately 30 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 was collected.

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). However, during the current report period, we did not calculate weekly or annual JPI's because high flows limited our ability to operate traps for long periods of time during peak migration periods. In addition to high winter flows, the Coleman Powerhouse shutdown further limited our ability to operate the PHBC trap by increasing flows at this location by the amount of water which typically enters Battle Creek downstream of the PHBC trap when the powerhouse is operating.

During the current reporting period, late-fall Chinook salmon released by the Coleman National Fish Hatchery (CNFH) in December 2005 and January 2006 were all marked with an adipose clip; therefore, when they were captured in the LBC trap, they were subtracted from the daily catch. Fall Chinook salmon scheduled for release upstream of the LBC trap in April 2006 were not marked; therefore, we would not be able to subtract them from the daily catch; however, we did not operate the trap after April 2, 2006.

Mark-recapture trials.— Mark-recapture trials were conducted to estimate trap or fyke net 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, winter, and late-fall Chinook salmon were too low to conduct separate trials; therefore, trap efficiencies were estimated using primarily fall Chinook salmon fry. We attempted to use only naturally-produced (unmarked, unclipped, and untagged) juvenile salmon for the rotary screw trap mark-recapture trials. Hatchery produced fall Chinook salmon fry were used for the fyke net mark-recapture trials. Marked Chinook salmon that were recaptured in the traps were counted, measured, and subsequently released downstream of the trap to prevent them from being recaptured again.

During the 2005 to 2006 season, two marks were used during the one trial conducted at the LBC trap (Table 1). 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 injected pink Northwest Marine Technology ® Visible Implant Elastomer tags into the snout with a 29-gauge needle. After tagged 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). All salmon marked for the LBC trial were released at the Jelly's Ferry Bridge which is located approximately 1.3 km (0.8 mi) upstream of the trap (Figure 1). Six mark-recapture trials were conducted at the UBC trap (Table 1). Two marks were used for all trials, but during the February 10, 2006 trial, green elastomer tags were applied to Chinook salmon using methods described for the LBC trial. During all other trials, either an upper or lower-caudal fin-clip was applied using scissors to remove a small portion of the caudal fin. The second mark (Bismark Brown) was applied using methods described for LBC. 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 UBC trap (Figure 1). Six mark-recapture trials were conducted at the PHBC trap, and two marks were applied using methods described for the LBC and UBC trials (Table 1). White elastomer tags and Bismark brown were used for the February 10, 2006 trial, while upper or lower-caudal fin-clips and Bismark Brown were used for the other trials. The color of the elastomer tag or the location of the caudal fin-clip was selected to allow the crews to differentiate marked fish from the UBC and PHBC releases. Fish marked for the PHBC trials were released about 0.6 km (0.4 mi) upstream of the trap (Figure 1). Four mark-recapture trials were conducted at the fyke net to determine the capture efficiency of different parts of the gear rather than the efficiency of the hatchery's intake (Table 2). To determine potential sources of reduced capture efficiency in the fyke, marked fish were released in the trap box, in front of the fyke entrance, and at the head of the canal. Only a single mark was used during all trials which would allow us to distinguish fish released for the fyke net trials from fish released for the PHBC trials that were entrained into the canal through the unscreened intake. Either an upper or lower-caudal fin-clip was applied using methods similar to those used for rotary screw trap trials.

Prior to release, we measured the fork lengths of 30 to 50 salmon marked for rotary screw trap trials, and all salmon marked for fyke net trials (40 to 70). All recaptured salmon from screw trap and fyke net trials were also measured to allow for future comparisons. Salmon marked for screw trap and fyke net mark-recapture trials were generally held overnight and released the next day. Prior to release, mortalities and injured fish were removed and the remaining fish were counted and released. During most trials, marked fish were released after dark or at dusk 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).

Trap and fyke net efficiency.—Trap and fyke net efficiency were 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 and fyke efficiency were estimated by

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

where m_h is the number of marked fish released in week h and r_h is the number of marked fish recaptured in week h. Although trap and fyke net efficiency was calculated for all mark-recapture trials, only those trials with at least seven recaptures were used as suggested by Steinhorst et al. (2004). If two mark-recapture trials were conducted during the same week, the results were combined to calculate the average weekly trap efficiency.

Juvenile passage index(JPI).— Weekly JPI estimates for Chinook salmon and rainbow trout/steelhead were not calculated during the current report period because high flows and the Coleman Powerhouse shutdown prevented us from operating traps for extended periods of time during peak migration periods.

Results

Rotary Screw Trap and Fyke Net Operation

Lower Battle Creek (LBC).— During the current reporting period, the LBC trap was operated continuously from December 8, 2005 to April 23, 2006, except during high flows and for other miscellaneous reasons (Appendix 1). Of the 365 d available during the reporting period (October 1, 2005 through September 30, 2006), the trap was operated 53 d. No sampling due to few or no salmonids accounted for 160 d (51%; October 1 to December 7, 2005 and July 1 to September 30, 2006) of the missed sample days, high flows and subsequent trap repairs accounted for 82 d (26%), suspended sampling accounted for 68 d (22%; April 24 to June 30, 2006), and a trap switch accounted for 2 d (≈1%; Appendix 1). Monthly sampling effort from December 2005 through April 2006 varied from a low of 3% in April to a high of 79% in February (Figure 3). The trap was not operated from July 1 to September 30, 2006 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).

Mean daily water temperatures at the LBC trap varied from a low of 6.3ºC (43.2ºF) on December 5, 2005 to a high of 19.8ºC (67.6ºF) on June 27, 2006 (Figure 4). However, temperatures were not measured after June 30, 2006. Mean daily flow measured by the U.S. Geological Survey at the Coleman Hatchery gauging station (#11376550) varied from lows of 5.8 m^3/s (206 cfs) in early September 2005 to a peak mean daily flow of 148.0 m^3/s (5,228 cfs) on December 28, 2005 (Figure 5). Several large flow events >85 m^3/s (3,000 cfs) occurred during the reporting period with a peak flow of 255.1 m^3/s (9,010 cfs) occurring on December 28, 2005 (Figure 5). Turbidity at the LBC trap varied from a low of 1.2 NTU's on several days in December 2005 to a peak of 17.2 NTU's on December 18, 2005 (Figure 6). No observable trend associated with flow was apparent because turbidity was only measured when the trap was operational, and high flows prevented us from operating the LBC trap for long periods of time.

Upper Battle Creek (UBC).— During the current reporting period, the UBC trap was operated continuously from October 1, 2005 to June 30, 2006, except during high flows and periods of reduced sampling (Appendix 2). Of the 365 d available, the trap was operated approximately 170 d. Little or no salmonid catch accounted for 92 of the 195 missed sample days (47%), high flows accounted for 73 d (37%), and reduced sampling (e.g., sampling 4 or 5 d per week) accounted for the remaining 30 d (15%). The monthly sampling effort varied from a low of about 2% in April 2006 to a high of 97% in November 2005 (Figure 3, Appendix 2).

Mean daily water temperatures at the UBC trap varied from a low of 6.2ºC (43.2ºF) on December 5, 2005 to a high of 20.4ºC (68.8ºF) on July 24, 2006 (Figure 4). Mean daily flows for the UBC trap are the same as those reported for LBC as the same gauging station was used (Figure 5). Turbidity at the UBC trap varied from a low of 0.9 on October 18, 2005 to a high of 21.0 NTU's on February 27, 2006 (Figure 6). In general, turbidity increased with increasing flows, but increases in turbidity did not always appear to be related to similar increases in flow (Figure 4). However, turbidity was only measured when the trap was operating; therefore, it is likely that turbidity was higher during the high flow events.

Powerhouse Battle Creek (PHBC).—During the current reporting period, the PHBC trap was operated from December 1, 2005 to March 24, 2006 except during high flows (Appendix 3). Of the 365 d available, the trap was operated about 62 d. Little or no salmonid catch accounted for 92 of the missed sample days (30%), suspended sampling accounted for 88 d (29%), acquisition of the operating permit and trap preparation accounted for 61 d (20%), high flows accounted for 61 d (20%), and a trap switch accounted for the remaining 1 d (≈1%). The monthly sampling effort at the PHBC trap varied from a low of about 10% in March 2006 to a high of 79% in February 2006 (Figure 3, Appendix 3).

Mean daily water temperatures at the PHBC trap varied from a low of 5.7 ºC (42.3ºF) on March 3, 2006 to a high of 20.4ºC (68.6ºF) on July 24, 2006 (Figure 4). Mean daily flows for the PHBC trap were probably somewhat higher than those reported at the gauging station because water is diverted by the hatchery and other private landowners upstream of the gauge (Figure 5). Turbidity at the PHBC trap varied from a low of 1.0 NTU's on December 10, 2005 to a high of 20.4 NTU's on December 19, 2005 (Figure 6). However, turbidity was only measured when the trap was operating; therefore, it is likely that turbidity was higher during high flow events (Figure 6).

Fyke net.—The fyke net was operated from January 7 to March 3, 2006, but at times it was operated without being fish tight because high flows and debris build-up caused damage to the wings (Appendix 4).

Biological Sampling

Lower Battle Creek (LBC) salmonids.—Brood year 2005 (BY05) spring Chinook salmon were first captured at the LBC trap the week of December 5, 2005 with a peak weekly catch of 31 the week of February 13, 2006 (Figure 7 and Table 3). The last spring Chinook salmon was captured the week of March 27, 2006. The BY05 total spring Chinook salmon catch based on the length-at-date criteria was 41; however, the LBC trap was not operated for long periods of time during the peak migration period. Daily catch was not estimated for days the trap did not operate. Fork lengths of spring Chinook salmon sampled at the LBC trap varied from 27 to 83 mm with a mean fork length of 63 mm (N=19; Figure 8). Brood year 2005 fall Chinook salmon were the most abundant salmonid captured at the LBC trap, and were first captured at the trap

December 8, 2005, but the trap was not operating prior to December 8, 2005 (Figure 7 and Table 3). A peak weekly catch of 3,965 occurred the week of March 20, 2006 (Figure 7 and Table 3). The BY05 total fall Chinook salmon catch based on the length-at-date criteria was 18,904 but the trap did not operate from December 19, 2005 to January 27, 2006, which is the period of peak fry migration. Fall Chinook salmon fork lengths ranged from 27 to 72 mm with a mean fork length of 36 mm (N=8,646; Figure 8). According to the length-at-date criteria only one BY06 late-fall Chinook salmon was captured in the trap; therefore, no additional data will be provided (Figure 8 and Table 3). Winter Chinook salmon were first captured at the LBC trap on December 9, 2005, but the trap was not operated until December 8, 2005 (Figure 7 and Table 3). A peak weekly catch of eight occurred the week of December 12, 2005. The total catch for the sample period was 14, and the last day winter Chinook were captured at the trap was February 11, 2006 (Figure 7 and Table 3). Fork lengths of winter Chinook salmon sampled at the LBC trap varied from 63 to 105 mm with a mean fork length of 100 mm (N=10; Figure 8). Rainbow trout/steelhead were first captured at the LBC trap the week of February 6, 2006 with a peak weekly capture of two the week of February 13, 2006, and the total catch was five (Figure 7 and Table 3). Fork lengths for rainbow trout/steelhead ranged from 28 to 730 mm (N=5; Figure 9).

Lower Battle Creek (LBC) non salmonids.—From December 8, 2005 through April 1, 2006, eight native non-salmonid species were sampled at the LBC trap including, hardhead *Mylopharodon conocephalus* (N=35), Pacific lamprey *Lampetra tridentata* (N=2), prickly sculpin *Cottus asper* (N=2), riffle sculpin *Cottus gulosus* (N=13), Sacramento pikeminnow *Ptychocheilus grandis* (N=11), Sacramento sucker *Catostomus occidentalis* (N=14), tule perch *Hysterocarpus traski* (N=1), and threespine stickleback *Gasterosteus* aculeatus (N=5). In addition, western mosquitofish *Gambusia affinis* (N=2) was the only introduced non-salmonid captured at the LBC trap during the current report period. Next to Chinook salmon, hardheads were the most abundant species captured in the LBC trap. In addition, several unidentified cyprinid and lamprey fry were also captured in the trap.

Upper Battle Creek (UBC) salmonids.— Brood year 2005 spring Chinook salmon were first captured at the UBC trap the week of November 14, 2005 with a peak weekly catch of 19 the week of December 5, 2005 (Figure 10 and Table 4). The last BY05 spring Chinook salmon was captured May 12, 2006. The BY05 spring Chinook salmon total catch based on the length-at-date criteria was 50. The fork length of spring Chinook salmon sampled at the trap varied from 34 to 107 mm with a mean fork length of 50 mm (N=46; Figure 11). Brood year 2005 fall Chinook salmon were first captured in the trap the week of November 28, 2005 with the peak weekly catch of 97 occurring the week of January 30, 2006 (Figure 10 and Table 4). The last fall Chinook salmon captured at the UBC trap was June 16, 2006. The total number of BY05 fall Chinook salmon captured in the UBC trap on days that it was operated was 233. Fork lengths of fall Chinook salmon sampled at the UBC trap varied from 31 to 95 mm with a mean fork length of 38 mm (N=233; Figure 11). Brood year 2006 late-fall Chinook salmon were first captured at the trap the week of April 24, 2006, with the peak weekly capture of 24 occurring the same week (Figure 10 and Table 4). The last BY06 late-fall Chinook salmon was captured at the trap on May 19, 2006. The total catch of BY06 late-fall was 42. Fork lengths of late-fall Chinook salmon captured at the UBC trap varied from 34 to 37 mm with a mean fork length of 35 (N=42; Figure 11). According to the length-at-date criteria, no winter Chinook salmon were captured at the UBC trap. During the reporting period, 15 age 1+ and 4 young-of-the-year (yoy) rainbow trout/steelhead were captured at the UBC trap (Figure 10 and Table 4). They were first captured the week of November 7, 2005 with a peak weekly capture of four occurring the same week (Figure 10 and Table 4). Fork lengths of rainbow trout/steelhead ranged 23 to 230 mm (N=19; Figure 12).

Upper Battle Creek (UBC) non salmonids.— From October 3, 2005 through June 30, 2006, seven native non-salmonid species were captured in the UBC trap, including hardhead (N=334), Pacific lamprey (N=105), riffle sculpin (N=18), Sacramento pikeminnow (N=171), Sacramento sucker (N=336), tule perch (N=2), and threespine stickleback (N=5). In addition, green sunfish *Lepomis cyanellus* (N=1) was the only introduced non-salmonid species captured in the UBC trap. Cottid, cyprinid, and lamprey fry were also captured at the trap, but could not be identified to species. Besides Chinook salmon, Sacramento suckers and hardheads were the next most abundant species captured in the UBC trap.

Powerhouse Battle Creek (UBC) salmonids.— Brood year 2005 spring Chinook salmon were only captured at the PHBC trap the week of December 5, 2006 with a total catch of seven (Figure 13 and Table 5). The fork length of spring Chinook salmon sampled at the trap varied from 35 to 37 mm (Figure 14). Brood year 2005 fall Chinook salmon were first captured in the trap the week of December 5, 2005, but the trap was not operating until December 1 (Figure 13 and Table 5). A peak catch of 40 fall Chinook salmon occurred the week of December 12, 2005, and the last fall Chinook was captured January 31, 2006. The total fall Chinook salmon catch for the season was 76 (Table 5). Fork lengths of fall Chinook salmon sampled at the PHBC trap varied from 31 to 38 mm (Figure 14). No late-fall or winter Chinook salmon were captured at the PHBC trap. During the reporting period, 18 age 1+ and 0 young-of-the-year (yoy) rainbow trout/steelhead were captured at the PHBC trap. They were first captured the week of November 7, 2005 with a peak weekly capture of four occurring the same week (Figure 13 and Table 5). Fork lengths of rainbow trout/steelhead ranged from 154 to 305 mm (N=18; Figure 15).

Powerhouse Battle Creek (PHBC) non salmonids.— From December 1, 2005 through March 24, 2006, seven native non-salmonid species were captured in the PHBC trap, including, hardhead (N=157), Pacific lamprey (N=15), prickly sculpin (N=1), riffle sculpin (N=7), Sacramento pikeminnow (N=43), Sacramento sucker (N=64), and tule perch (N=6). Cottid, cyprinid, and lamprey fry were also captured at the trap, but could not be identified to species. Besides Chinook salmon, hardheads were the next most abundant species captured in the PHBC trap.

Fyke Net catch.— From January 7 to March 3, 2006, 14 Chinook salmon, 39 hardhead, 29 Sacramento suckers, 68 tule perch, 26 Sacramento pikeminnow, 111 lamprey fry, 38 cyprinid fry, 2 California roach *Hesperoleucus symmetricus*, 1 threespine sticklebacks, 2 green sunfish, 7 Pacific lamprey, 85 riffle sculpin, 1 speckled dace *Rhinicthys osculus*, 1 rainbow trout/steelhead, and 1 Pacific Brook Lamprey *Lampetra pacifica* were captured in the fyke net (Table 6).

Trap and Fyke Net Efficiency

Lower Battle Creek trap efficiency (LBC).—One mark-recapture trial was conducted at the LBC trap, and of the 295 marked Chinook salmon released, 19 were recaptured. The trap efficiency was estimated to be 0.068 during the week of February 10, 2006 (Table 1). The trial results were not used to estimate passage as the trap was not operated for extended periods of time during periods of peak migration.

*Upper Battle Creek trap efficiency (UBC).—S*ix mark-recapture trials were conducted at the UBC trap from January 31 to March 20, 2006 (Table 1). Five of the six trials had sufficient recaptures to estimate passage, but because the trap was not operated for extended periods of time, passage estimates were not made. The first trial conducted did not have sufficient recaptures because the trap was pulled the day after fish were released because of high flows. Trap efficiencies for the five valid trials ranged from 0.028 to 0.057. Two trials were conducted during the same week (February 6, 2006).

Powerhouse Battle Creek trap efficiency (PHBC).—Six mark-recapture trials were conducted at the PHBC trap from January 31 to March 20, 2006 (Table 1). Three of the six trials had sufficient recaptures to estimate passage, but because the high flows limited operation of the trap for extended periods of time during peak migration periods, passage estimates were not made. Trap efficiencies estimated for the three valid trials ranged from 0.038 to 0.051. Two trials were conducted during the same week (February 6, 2006), but one trial had no recaptures.

Fyke net trap efficiency.—Four mark-recapture trials were conducted at the fyke net, and all were considered valid as they all had more than seven recaptures. The fyke net efficiencies ranged from 0.543 to 0.951, but were not all equivalent as they were conducted to test separate portions of the fyke net setup (Table 2). The two trials that were used to test the trap box efficiency had the highest and lowest trap efficiencies (0.951 and 0.54); however, during the second trial the trap box was not fish tight where the fyke net attached to the box.

Discussion

Trap and Fyke Net Operation

Rotary screw traps.—High flows severely limited our ability to operate any of the rotary screw traps during peak migration periods in the current report period. Flows were the highest since we began operating the traps in September 1998, with eleven flow events over 56.6 m^3/s (2,000 cfs) mean daily occurring between early December and early May, and a peak flow of 255.1 m^3/s (9,010 cfs) occurring on December 28, 2005 (Figure 16). Most high flow events occurred during periods of peak migration for Chinook salmon and rainbow trout/steelhead, which prevented us from making useful or accurate estimates of juvenile passage. The LBC trap was not operated from December 19, 2005 to January 27, 2006 which is most of the migration period for fall and spring Chinook salmon fry. In addition, the trap could not be operated for half of March and most of April 2006 which is the peak migration period for late-fall Chinook salmon fry, rainbow trout/steelhead fry, and larger spring and fall Chinook salmon (parr and silvery parr). The PHBC trap was also not operated for a large portion of December and early January, and most of March. Consequently, because of our inability to make accurate or useful passage estimates, we stopped operating the LBC trap after April 23 and the PHBC trap after April 3, 2006. The UBC trap was operated until June 30, 2006, but as occurred with the LBC and PHBC traps, the trap could not be operated during high flow events that occurred during peak migration periods in December and April. In May and June we operated the UBC trap on a reduced schedule primarily because of staff and funding limitations, but our inability to make useful passage estimates because of high flows was also a consideration. None of the traps were operated from July 1 to September 30, 2006 because typically few or no salmonids are captured during this period and we did not a have a contract to operate the traps during this period.

During the current report period, the PHBC trap was installed and operated upstream of the UBC trap to determine whether the new site was a viable alternative to the UBC trap location. The current UBC trap location is not ideal because the channel geometry is similar to a wide uniform bath tub without a distinct thalweg. Consequently, velocities into the UBC trap are lower and the cone on the UBC trap often stops rotating during low flows reducing trap efficiency and possibly allowing captured fish to escape. In addition, when the cone hits the stream bottom during low flows it can damage the cone as well as collect sediment which ends up in the trap box. The accuracy of our annual passage estimates could increase if the PHBC trap efficiencies are higher than observed at the UBC trap. The location selected for the new PHBC trap, was the first site upstream of the UBC trap with suitable channel geometry.

Additional benefits of the new site were its close proximity to the current UBC site (1.6 miles), the average number of Chinook salmon redds observed between the two sites was <6%, and the new site was a better fit with the Restoration Project's footprint. In addition, there is potentially less water to sample at the new trap because water diverted into the Coleman Powerhouse returns to the creek downstream of the PHBC trap and upstream of the UBC trap. This means the PHBC trap would potentially collect less debris, it would be easier to maintain during elevated flows, and impacts to fish would be reduced.

To evaluate the usefulness of the new site, we had hoped to determine: (1) the operable range of flows, (2) whether the new site had a better channel configuration than the UBC trap location, (3) whether the trap had higher capture efficiencies, (4) whether there was a suitable mark-recapture release site, (5) whether there was less debris, and (5) whether the trap was easier to operate. Unfortunately the long-term shut down of PG&E's Coleman Powerhouse and unusually high flows during the current report period made it difficult to adequately evaluate the new trap location. We were only able to conclude the first of five evaluations of the PHBC trap. We had anticipated the PHBC trap would be operating in less water than the UBC trap because typically up to 9.6 m^3/s (340 cfs) are diverted into the Coleman Powerhouse, which are then returned to the creek downstream of the PHBC trap and upstream of the UBC trap. However, when the powerhouse went off line, base flows at the PHBC trap increased by the amount typically diverted; therefore, the PHBC trap was operated in more water than the UBC trap because CNFH typically diverts up to 3.5 m^3/s (122 cfs) upstream of the UBC trap. Much of this water is returned to the creek, but downstream of the UBC trap. We estimated the upper limit for the PHBC trap's operable range to be about 22.7 m^3/s (800 cfs). When flows were higher the trap would not remain in the thalweg but instead would pull towards the south bank (river left) of the creek. When the Coleman Power house is operating, the upper limit of operation would be approximately 32.3 m^3/s (1,140 cfs) as measured at the USGS gauge station. The flows measured at the USGS gauge station are up to 9.6 m^3/s (340 cfs) higher than the actual flows at the trap because of the water diverted by the Coleman Powerhouse. Since we do not measure flows at the trap site, the USGS stream gauge is used to manage trap operations. We concluded that under normal operating conditions the upper flow limit in which the PHBC and UBC traps would operate is roughly equivalent as measured at the USGS gauge station.

The lower range of operable flows was not determined during the report period; however, the trap was operated for a brief period in early October 2006 when mean daily flows at the USGS gauge ranged from 9.1 to 9.5 m^3/s (321 to 336 cfs). This suggests the trap was operating in about 2.1 m^3/s (75 cfs), which is the minimum instream flow under the Interim Flow Project. At these flows, we had difficulty operating the trap because too little water was flowing in the thalweg; therefore, to operate the trap we had to temporarily move some stream cobbles around to direct more of the flow towards the trap. This likely changed trap efficiency during a period when we are unable to conduct mark-recapture trials because of concerns for threatened and endangered species and the availability of sufficient numbers of juvenile Chinook salmon.

High flows during the current report period made it difficult to determine whether the channel configuration at the new site was an improvement over the UBC trap location. The PHBC and UBC traps appear to have similar upper flow limits at which they will operate. In other words, during a high flow event, operation of both traps would cease at a similar upper flow limit as measured at the USGS gauge station. However, the upper limit of the UBC trap occurs because it collects too much debris during high flows, which could potentially increase impacts to fish. In contrast, the inability of the PHBC trap to fish at high flows appears to be related to stream gradient or channel geometry because at high flows the trap pulls out of the thalweg towards the river left bank which likely reduces trap efficiency. One additional problem that occurs at the PHBC trap location during high flows is the creek spreads out into the floodplain which may also reduce trap efficiency. During low flows, the cone on both traps tends to stop rotating because water depth is limited.

We predicted trap efficiencies would be higher at the PHBC trap because we expected to operate in less water and sample a greater proportion of the channel cross-section. In fact, trap efficiencies for the three valid trials were higher than trap efficiencies conducted at the UBC trap during the same times (Table 1). However, three trials are not a sufficient sample size to draw any conclusions, and additional trials should be conducted. Our ability to conduct valid trials (i.e., greater than seven recaptures) may also be affected by particular flows. For instance, two mark-recapture trials were conducted the week of February 6, 2006 following a high flow event. For the first trial, marked fish were released on February 7, 2006 when the mean daily flow at the gauging station was 26.5 m^3/s (936 cfs), and there were no recaptures. However, during the second trial fish were released on February 10, 2006 when the mean daily flow was 21.2 m^3/s (749 cfs), and trap efficiency was 0.038 (10 recaptures). It appears that trap efficiency may decrease when the trap cannot be operated in the thalweg, but further evaluation should be done to verify this. In addition, the release location for this trap was not ideal as it required the crew to drive about 45 min to the release site. Other release locations were being considered, but some may not have been ideal because of their closer proximity to the trap. If the release location is too close to the trap, marked fish may not have time to disperse, which can influence trap efficiency. Paired trials to test release locations on each side of the creek were being planned, but high flow events prevented them from occurring.

We expected debris loads to be lower at the PHBC site, but that did not occur. On most days that both traps operated, debris loads were higher at the PHBC trap than the UBC trap. However, the PHBC trap was atypically operating in higher water levels than the UBC trap because the Coleman Powerhouse was offline; therefore, it is possible that debris loads would be lower when the powerhouse is operating and the PHBC trap is fishing less water than the UBC trap. This could be verified by operating the PHBC trap when the powerhouse in operating.

One additional question we wanted to answer, was whether the PHBC trap would be easier to operate than the UBC trap. We were able to access the trap site by vehicle, but it required more driving time than the UBC trap. Conducting mark-recapture trials was also more time-consuming because the release site was a 45-min drive from the office on a rough road rather than a 5-min drive to the UBC release site. Access onto the trap during normal flows did not appear to be any more difficult than the UBC trap. The crew could wade to the trap before the powerhouse went offline, but once base flows increased the trap had to be pulled to shore for access because of high water velocities. However at higher flows the trap could be fished near river right, whereas at low flows it had to be fished on river-left. The configuration of the cable system at the PHBC trap made it difficult to pull the trap out into the thalweg. Unfortunately, the configuration was limited by the location of available anchor trees. During high flow events, access to the trap from the vehicle was more difficult because as water levels rose the surrounding floodplain would begin to flood, reducing direct access.

Fyke net.—In addition to the new rotary screw trap, we installed and operated a fyke net in the CNFH canal after the Coleman Powerhouse went offline in December 2005. When the powerhouse was shut down, the hatchery's primary screened water source (Intake 1) was no longer available, requiring the use of an alternative unscreened intake (Intake 2) to obtain water (Figure 2). The hatchery's Intake 2 has a capacity of 1.4 m^3/s (50 cfs), which at times can be a significant portion of the Battle Creek base flows. The fyke net was operated in the CNFH canal to determine what proportion of passage above the UBC trap was being lost through the unscreened intake; otherwise, it may not have been possible to interpret differences in juvenile salmonid passage observed between years or between the UBC and PHBC traps. Unfortunately our inability to develop rotary screw trap passage estimates and lack of funding prevented us from meeting our objective, but we were able to document entrainment of Chinook salmon, rainbow trout/steelhead, and various non-salmonids.

We operated the fyke net successfully with some minor problems directly related to increased flows in Battle Creek that occurred during storm events. High flow events typically increased water turbulence at the head of the canal and increased debris loads in the fyke. During some high flow events, debris built up on the fyke net wings reducing water flow and causing the mesh wings to tear. When the mesh wings could no longer be repaired, they were replaced with wings made of angled aluminum frames covered with perforated stainless steel screen. The new screens proved to be very effective at funneling debris into the fyke; however during a very large storm event in late February (102.0 m^3/s {7,470cfs}) the fyke net and wings were damaged. At this time, operation of the fyke net was discontinued due to lack of funding. During low flows the time needed to operate the fyke was usually < 2 h/d, but during high flow events in Battle Creek, debris loads increased significantly, increasing the amount of time needed to clear the fyke of fish and debris (>3 h/d).

Biological Sampling

To effectively estimate passage and describe the biological characteristics of all runs of Chinook salmon on Battle Creek, the sampling methods used at the traps must be tested to ensure their applicability and accuracy. Currently, length-at-date criteria for determining run designation (Greene1992) are used on Battle Creek to differentiate runs of juvenile Chinook salmon captured in the traps. However, the criteria were developed for the mainstem Sacramento River, and are not accurate for tributary runs of Chinook salmon. There is significant size overlap between runs, particularly fall and spring Chinook salmon. This discrepancy is important when trying to accurately estimate the passage of threatened and endangered Chinook salmon. There is also overlap between fall and late-fall Chinook salmon fry in March through May. Considering the overlap between runs, genetic sampling is likely the most accurate method for assigning a run designation. However, it is expensive and will likely only be done on a portion of the total catch, which then requires the results to be extrapolated to the total catch. Also, current genetic techniques for run identification of Central Valley Chinook may need to be verified or refined for application specifically to Battle Creek populations.

Subsampling was used at the LBC trap to obtain a representative sample of Chinook salmon for measuring and estimating the length frequency distribution, but fish size or the abundance of uncommon runs may influence the accuracy of this method. Often only a few large Chinook salmon or those classified as spring and winter Chinook salmon were captured in the traps when fry or other runs were abundant. Run designation for Chinook salmon included in our subsample was assigned using the length-at-date criteria (Greene 1992). This information was then extrapolated to the unmeasured Chinook salmon to determine total daily catch for each run. This may have been problematic with larger fish or uncommon runs (spring and winter), because if no large fish were included in the subsample, then they were not represented in the final catch totals for that day. However, if they were included in the subsample and then extrapolated to the unmeasured catch, the catch of larger fish and uncommon runs may have been artificially inflated. This only occurred at the LBC trap because during the report period we did not subsample at the UBC and PHBC traps and the fyke net because total daily catch was always less than 250. In February 2006, spring Chinook numbers included in the LBC subsample were extrapolated to unmeasured catch, and numbers appeared to be significantly higher than seen on the days immediately preceding (Figure 7). Ideally some days they would be under represented, and other days over represented, but whether this occurs has not been determined and should be investigated.

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

Trap Efficiency and Juvenile Salmonid Passage

Trap efficiency.—During the current report period, we installed and operated an additional rotary screw trap which initially prevented us from conducting mark-recapture trials simultaneously at all three traps. In recent years, we have used a combination of Bismark brown and either an upper or lower-caudal fin-clip to mark the fish (Whitton et al. 2007b; Whitton et al. 2007c; Whitton et al. 2007d). However, with the addition of a third trap, we could not conduct three trials simultaneously without identifying a method to mark a third group of fish. Initially, we only conducted trials at the UBC and PHBC traps since the LBC trap would not be funded after the current report period, however, in February 2006, we tested a new method of marking fish which would allow us to mark several groups of fish. Northwest Marine Technology ® Visible Implant Elastomer tags allowed us to mark Chinook salmon with a variety of colors. Tags were injected into the snout with a 29-gauge needle, and once the fish had recovered, they were immersed in Bismark brown to apply the second mark. We concluded that elastomer tags had very high potential for marking multiple groups of fish because there are several colors available. The tags were highly visible even after fish were immersed in Bismark brown. The time necessary to tag about 1,200 fish was longer for the elastomer tagging than for fin-clipping, but the crew was inexperienced. We purchased a tagging kit with the intention of conducting additional trials at the traps and the fyke net, but unusually high flows prevented us from conducting additional trials.

In addition to limited tagging methods, high flow events during the current report period prevented us from conducting sufficient trials to estimate annual passage estimates. Only one trial was conducted at the LBC trap, while six were conducted at the UBC and PHBC traps. Trap efficiencies at the UBC trap were similar to previous years (Table 1; Whitton et al. 2007a and Whitton et al. 2007b). During high flows, the PHBC trap would not remain fishing in the thalweg, which appeared to affect the trap efficiency. For instance, two mark-recapture trials were conducted the week of February 6, 2006 following a high flow event. For the first trial, marked fish were released on February 7, 2006 when the mean daily flow at the gauging station was 26.5 m^3/s (936 cfs), and there were no recaptures (Table 1). However, during the second trial fish were released on February 10, 2006 when the mean daily flow was 21.2 m^3/s (749 cfs), and trap efficiency was 0.038 (10 recaptures). It appears that trap efficiency may decrease when the trap cannot be operated in the thalweg, but further evaluation should be done to verify this. In addition, the PHBC trap release location for mark-recapture trials was not ideal as it required the staff to drive 45 minutes with marked fish. We were planning to conduct multiple paired trials to evaluate additional sites, but were unable to implement our plans because of high flows.

After conducting mark-recapture trials for multiple years at the Battle Creek traps, we have determined that release groups should be large enough to ensure a minimum of seven recaptures and trials should be conducted during all weeks when sufficient numbers are available. This will reduce or eliminate the need to pool trials and reduce the number of weeks when a season average efficiency is used to estimate passage. The use of hatchery Chinook salmon and rainbow trout/steelhead is being explored for future mark-recapture trials. If hatchery Chinook salmon are available, paired trials with naturally produced Chinook salmon should be done to test whether behavioral differences exist at different sizes or life-stages. Roper and Scarnecchia (1996) found that trap efficiencies for hatchery and natural Chinook salmon were different because of differences in behavior, but they also determined that efficiencies for hatchery and natural Chinook salmon were similar for a trap operated in relatively high velocities. Differences in behavior may be small when hatchery fry are used as surrogates for naturally produced fry. The use of hatchery fry would allow us to conduct trials during the peak spring Chinook salmon outmigration when flows are more variable.

Ideally, daily mark-recapture trials provide the most accurate estimates of trap efficiency (Roper and Scarnecchia 1999), however, they are also time intensive (i.e., expensive). Conducting two trials per week allows us to account for some of the natural variability that occurs between trials. This method has been used by others such as Thedinga et al. (1994). One advantage of this method is that variations in flow which may affect trap efficiency during the week are accounted for with a weekly estimate. Pooling multiple trials conducted within the same week also ensures that sufficient recaptures occur to meet the minimum of seven as was recommended by Steinhorst et al. (2004). As we have determined from multiple years of trapping, mark-recapture release strategies can vary and the affects on the final estimates needs to be studied further to determine the most effective and efficient method for providing reasonable statistically-sound estimates of trap efficiency. Some studies have developed flow-trap efficiency models to allow the estimation of daily trap efficiencies (Martin et al. 2001). This method appears to be valid, but may not be applicable to all streams. The influence of several environmental variables (e.g., flow, turbidity, temperature) on trap efficiency should be studied during future trapping.

During the 2 months the fyke net was operated, we conducted four mark-recapture trials to test the efficiency of our gear, and the results suggested that with adequate equipment a fyke net can be operated in the canal at very high efficiency. If future operation is necessary, we recommend that mark-recapture trials be conducted to test all aspects of the fyke net including the trap box, opening of the fyke net, head of the canal, and the entrance to Intake 2. Conducting multiple trials allows identification of sources of reduced trap efficiency. We conducted trials in the first three locations, but were not able to conduct trials at the opening to Intake 2 due to lack of funding. Trap efficiency was generally very high except during the final trial, when we determined the trap box was not fish tight. This suggests that trials should be conducted periodically during fyke operation to test whether trap efficiency is consistent.

> ***Recommendation***: *Investigate methods for conducting mark-recapture trials that will improve the accuracy of trap efficiencies such as: (a) conducting robust day and nighttime trials and applying the results to day and nighttime catch, (b) increasing the size of release groups during periods when trap efficiencies are likely to be low (i.e., high flows), (c) marking Chinook salmon so that fish from a particular trial are distinguishable from other trials, and (d) testing the effect of trial frequency on weekly passage estimates.*

> ***Recommendation***: *Investigate the differences in capture efficiency of hatchery and naturally produced Chinook salmon at various life-stages. The ability to use hatchery fish at times when insufficient naturally produced fish are available would reduce the need to use the average season efficiency.*

Juvenile salmonid passage.—For the first time since we began using rotary screw traps to monitor juvenile salmonids on Battle Creek, unusually high flows prevented us from making useful or accurate estimates of juvenile passage (Figures 16 and 17). Of the seven years that juvenile fall Chinook salmon passage estimates were calculated, peak passage occurred in 1999, decreased for the next 3 years, and then increased in 2003 and 2004 (Figure 18). In four of the seven years, juvenile fall Chinook salmon passage was statistically similar varying from 4,040,686 to 5,451,599, but the 2000 passage estimate was a partial estimate as the trap was not operated after the fist week in February 2001. Adult escapement does not appear to be directly related to juvenile passage in all years. For example, in 2003 and 2004 adult escapement was significantly lower than the record escapement of 397,149 in 2002, but juvenile passage increased in those years. It appears that other factors (i.e., flows, temperature, etc.) also influence juvenile passage.

Spring Chinook salmon passage estimates at the UBC trap have been variable during the eight years we have operated the trap and appear be related to a combination of adult escapement and stream flows (Figure 19). The low spring Chinook Juvenile Passage Index (JPI) for BY01 and BY02 was likely a result of reduced flows and increased water temperatures (Whitton et al. 2007c). Interim flows (i.e., minimum instream flows) of at least 0.85 m^3/s (30 cfs) were provided in both the north and south forks of Battle Creek in 1998 through 2000 as well as 2003 and 2004. But, in 2001 and 2002, interim flows were greatly reduced in the South Fork Battle Creek (and therefore the mainstem also) for most or all of the holding and spawning period of spring Chinook salmon; down to about 0.14 m^3/s (5 cfs) in 2001 and 0.28 m^3/s (10 cfs) in 2002 (Whitton et al. 2007b). This led to high water temperatures and reduced habitat. In 2003 and 2004, the spring-run JPI's appear to reflect the relatively high adult escapement estimate in 2003 (N=221) and the lower escapement in 2004 (N=90). Our ability to estimate spring Chinook salmon passage at the UBC trap has been confounded by our inability to distinguish juvenile fall and spring Chinook salmon. Additional genetic sampling in the future may improve our ability to do this, as well as determine the amount of overlap between fall and late-fall Chinook salmon.

Late-fall Chinook salmon juvenile passage at the UBC trap (1) was low in 1999 and 2000, (2) decreased from 2002 through 2005, and (3) appeared related to adult late-fall Chinook escapement above the barrier weir (Figure 20). Prior to 2001, CNFH did not pass late-fall Chinook salmon upstream of the barrier weir; therefore, only those that were able to jump the weir during high flows or passed through the fish ladder at the end of the immigration period (after early March) escaped upstream of the UBC trap. This likely resulted in the low juvenile production estimates in 1999 and 2000. The CNFH began passing natural-origin (i.e., unclipped) adult late-fall Chinook salmon upstream of the barrier weir in 2001 but juvenile production estimates are not available for this brood year. In 2002, late-fall run juvenile production was the highest on record, corresponding to the highest escapement estimate during that period. Following 2002, both adult escapement and juvenile production have steadily declined. Reasons for this trend should be investigated.

Rainbow trout/steelhead juvenile passage was higher from 1999 to 2002 than 2003 to 2005, but during that time, CNFH was passing both unclipped and large numbers of clipped (hatchery) steelhead upstream of the barrier weir (Newton et al. 2007; Figure 21). In 2003, the number of clipped rainbow trout/steelhead passed by CNFH (N=769) was substantially lower than the number passed in 2001 and 2002 (N=1,352 and N=1,428, respectively). The number of clipped rainbow trout/steelhead passed in 2004 was further reduced to 314, and then starting in 2005 clipped rainbow trout/steelhead were no longer passed upstream. The steady decrease in adult steelhead/rainbow trout passage from 2002 to 2005 may explain a similar trend observed in juvenile passage. The one exception is that in 2005, adult escapement decreased, but in contrast juvenile passage increased. The reason for the higher juvenile passage in 2005 was not readily apparent but may have been the result of more favorable environmental conditions. Survival to emergence may also play an important role in both Chinook salmon and rainbow trout/steelhead juvenile passage, and should be investigated.

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References

Bailey, N. T. J. 1951. On estimating the size of mobile populations from capture-recapture data. Biometrika 38:293-306.

CDFG (California Department of Fish and Game). 2007. GrandTab (Updated: February 4, 2007). Native Anadromous Fish and Watershed Branch. Available: www.delta.dfg.ca.gov/AFRP/documents/GrandTab020407.xls. (June 2007).

CVPIA (Central Valley Project Improvement Act). 1997. CVPIA comprehensive assessment and monitoring program: standard protocol for rotary screw trapping. Central Valley Fish and Wildlife Restoration Program Office, Sacramento, CA.

Carlson, S. R., L. G. Coggins Jr., and C. O. Swanton. 1998. A simple stratified design for mark-recapture estimation of salmon smolt abundance. Alaska Fishery Research Bulletin 5(2):88-102.

Everest, F. H. and D. W. Chapman. 1972. Habitat selection and spatial interaction by juvenile chinook salmon and steelhead trout in two Idaho streams. Journal of the Fisheries Research Board of Canada 29:91-100.

Greene, S. 1992. Estimated winter-run Chinook salmon salvage at the state water project and Central Valley Project delta pumping facilities. Memorandum dated 8 May 1992, from Sheila Greene, State of California Department of Water Resources to Randall Brown, California Department of Water Resources. 3 pp., plus 15 pp. tables.

Healey, M. C. 1991. Life history of Chinook salmon. Pages 311 - 393 *in* C. Groot and L. Margolis, editors. Pacific salmon life histories. UBC Press, University of British Columbia, Vancouver, B.C, Canada.

Jones & Stokes. 2004. Battle Creek Salmon and Steelhead Restoration Project action specific implementation plan. Draft. April. (J&S 03-035.) Sacramento, CA.

Martin, C. D., P. D. Gaines and R. R. Johnson. 2001. Estimating the abundance of Sacramento River juvenile winter Chinook salmon with comparisons to adult escapement. Red Bluff Research Pumping Plant Report Series, Volume 5. U. S. Fish and Wildlife Service, Red Bluff, CA.

Newton, J. M., N. O. Alston, and M. R. Brown. 2007. Monitoring adult Chinook salmon, rainbow trout, and steelhead in Battle Creek, California, from March 2006 through November 2006. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Roper, B. and D. Scarnecchia. 1996. A comparison of trap efficiencies for wild and hatchery age-0 Chinook salmon. North American Journal of Fisheries Management 16:214-217.

Roper, B. and D. Scarnecchia. 1999. Emigration of age-0 Chinook salmon (Oncorhychus tshawytscha) smolts from the upper South Umpqua River basin, Oregon, USA. Canadian Journal of Fisheries and Aquatic Sciences 56: 939-946.

Steinhorst, K., Y. Wu, B. Dennis, and P. Kline. 2004. Confidence intervals for fish outmigration estimates using stratified trap efficiency methods. Journal of Agricultural, Biological, and Environmental Statistics 9: 284-299.

Thedinga, J. F., M. L. Murphy, S. W. Johnson, J. M. Lorenz, and K V. Koski. 1994. Determination of salmonid smolt yield with rotary-screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management 14:837-851.

USFWS (U.S. Fish and Wildlife Service). 1997. Revised Draft Restoration Plan for the Anadromous Fish and Restoration Program. A plan to increase natural production of anadromous fish in the Central Valley of California. Prepared for the U.S. Fish and Wildlife Service under the direction of the Anadromous Fish and Restoration Program Core Group. May 30, 1997.

USFWS (U.S. Fish and Wildlife Service). 2001. Biological assessment of artificial propagation at Coleman National Fish Hatchery and Livingston Stone National Fish Hatchery: program description and incidental take of Chinook salmon and steelhead trout. Red Bluff, CA.

USFWS (U.S. Fish and Wildlife Service) and USBR (U.S. Bureau of Reclamation). 2002. Comprehensive Assessment and Monitoring Program (CAMP) Annual Report 2000. Prepared by CH2M HILL, Sacramento, California.

Ward, M. B., and W. M. Kier. 1999. Battle Creek salmon and steelhead restoration plan. Report by Kier Associates to Battle Creek Working Group.

Whitton, K. S., J. M. Newton, D. J. Colby, and M. R. Brown. 2006. Juvenile salmonid monitoring in Battle Creek, California, from September 1998 to February 2001. USFWS

Data Summary Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, CA.

Whitton, K. S., J. M. Newton, and M. R. Brown. 2007a. Juvenile salmonid monitoring in Battle Creek, California, from July 2001 through September 2002. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, CA.

Whitton, K. S., J. M. Newton, and M. R. Brown. 2007b. Juvenile salmonid monitoring in Battle Creek, California, from October 2002 through September 2003. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, CA.

Whitton, K. S., J. M. Newton, and M. R. Brown. 2007c. Juvenile salmonid monitoring in Battle Creek, California, from October 2003 through September 2004. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, CA.

Whitton, K. S., J. M. Newton, and M. R. Brown. 2007d. Juvenile salmonid monitoring in Battle Creek, California, from October 2004 through September 2005. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, CA.

Tables

Table 1. Summary of the mark-recapture trials conducted at the Lower Battle Creek (LBC), the Upper Battle Creek (UBC), and the Powerhouse Battle Creek (PHBC) rotary screw traps from October 1, 2005 through September 30, 2006. Shaded rows indicate weeks where mark-recapture data were pooled to calculate the weekly trap efficiency. Trials highlighted with **bold text** were not used. All mark-recapture trials were conducted while the traps were operated with the half-cone modification.

Release Date	Time of Release	Number Released	Recaptures	Efficiency[a]	Pooled /Season Avg. Efficiency	Weekly Mean Flow, m^3/s (cfs)
			LBC Trap			
02/10/06	17:10	295	19	0.068	---	23.1 (817)
			UBC Trap			
01/31/06[b]	**16:00**	**197**	**3**	**---**	**---**	**39.9 (1,410)**
02/07/06	18:30	209	11	0.057	0.039	23.1 (817)
02/10/06	17:25	298	8	0.030	0.039	23.1 (817)
02/16/06	14:15	410	12	0.032	---	18.2 (644)
02/24/06	18:15	425	16	0.040	---	15.9 (562)
03/20/06	18:00	464	12	0.028	---	27.5 (972)
			PHBC Trap			
01/31/06[b]	**15:27**	**270**	**2**	**---**	**---**	**39.9 (1,410)**
02/07/06[c]	**18:00**	**207**	**0**	**---**	**---**	23.1 (817)
02/10/06[c]	16:05	288	10	0.038	---	18.2 (644)
02/17/06[c]	15:14	394	19	0.051	---	11.2 (394)
02/24/06[c]	17:16	448	19	0.040	---	15.9 (562)
03/21/06	**17:30**	**436**	**5**	**0.014**		27.5 (972)

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

[b] This trial was not used because the trap was pulled the day after marked fish were released.

[c] Some marked fish released during these trials were recaptured in the fyke net.

Table 2. Summary of the mark-recapture trials conducted at the fyke net located in Coleman National Fish Hatchery's canal.

Release Date	Release Time	Number Released	Recaptures	Efficiency[a]	Release Location
02/01/06	?	40	38	0.951	FykeTrap Box
02/10/06	15:03	40	35	0.879	Head of Canal
02/10/06	15:02	50	47	0.941	Fyke Entrance
02/24/06[b]	18:25	69	37	0.543	Fyke Trap Box

[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 box was not fish tight.

Table 3. Weekly summary of spring, fall, late-fall, and winter Chinook salmon and age1+ and yoy rainbow trout/steelhead (RBT) catch at the Lower Battle Creek (LBC) rotary screw trap.

	Days Trap	Catch					
Week	Operated	Spring	Fall	Late-Fall	Winter	RBT-Age 1+	RBT-YOY
12/05/05	5	2	23	0	1	0	0
12/12/05	7	0	81	0	8	0	0
01/23/06	2	0	596	0	0	0	0
01/30/06	3	0	1,132	0	0	0	0
02/06/06	6	0	2,875	0	5	1	0
02/13/06	7	31	3,277	0	0	1	1
02/20/06	7	0	3,965	0	0	1	0
02/27/06	1	0	1,267	0	0	0	0
03/06/06	3	2	664	0	0	0	0
03/13/06	7	2	2,529	0	0	0	1
03/20/06	3	0	2,051	0	0	0	0
03/27/06	3	4	444	1	0	0	0
Totals	***54***	***41***	***18,904***	***1***	***14***	***3***	***2***

Table 4. Weekly summary of spring, fall, late-fall, and winter Chinook salmon and age1+ and yoy rainbow trout/steelhead (RBT) catch at the Upper Battle Creek (UBC) rotary screw trap.

	Days Trap	Catch					
Week	Operated	Spring	Fall	Late-Fall	Winter	RBT-Age 1+	RBT-YOY
11/07/05	6	0	0	0	0	3	0
11/14/05	7	2	0	0	0	0	0
11/21/05	7	2	0	0	0	0	0
11/28/05	6	16	13	0	0	3	0
12/05/05	7	19	43	0	0	1	0
12/12/05	7	0	43	0	0	0	0
01/09/06	4	0	20	0	0	0	0
01/16/06	3	0	6	0	0	0	0
01/23/06	7	0	20	0	0	0	0
01/30/06	3	0	65	0	0	0	0
02/06/06	6	0	0	0	0	1	0
03/20/06	6	0	0	0	0	1	0
04/24/06	6	5	0	24	0	1	1
05/01/06	6	1	0	17	0	1	0
05/08/06	4	5	2	0	0	0	0
05/15/06	4	0	0	1	0	1	0
05/22/06	4	0	0	0	0	3	0
05/29/06	3	0	1	0	0	0	0
06/05/06	4	0	5	0	0	0	0
06/12/06	4	0	15	0	0	0	1
06/19/06	4	0	0	0	0	0	1
06/26/06	4	0	0	0	0	0	1
Totals	***54***	***50***	***233***	***42***	***0***	***15***	***4***

Table 5. Weekly summary of spring, fall, late-fall, and winter Chinook salmon and age1+ and yoy rainbow trout/steelhead (RBT) catch at the Powerhouse Battle Creek (PHBC) rotary screw trap.

	Days Trap	Catch					
Week	Operated	Spring	Fall	Late-Fall	Winter	RBT-Age 1+	RBT-YOY
12/05/05	7	7	17	0	0	7	0
12/12/05	7	0	40	0	0	4	0
01/02/06	4	0	2	0	0	0	0
01/09/06	5	0	2	0	0	0	0
01/16/06	3	0	1	0	0	0	0
01/23/06	7	0	4	0	0	1	0
01/30/06	4	0	11	0	0	1	0
02/13/06	7	0	0	0	0	1	0
02/20/06	7	0	0	0	0	2	0
03/20/06	3	0	0	0	0	2	0
Totals	***54***	***7***	***77***	***0***	***0***	***18***	***0***

Table 6. Weekly summary of fish species captured in the Coleman National Fish Hatchery canal fyke net, including Chinook salmon (CHN), rainbow trout (RBT), hardhead (HH), Sacramento sucker (SASU), tule perch (TP), Sacramento pikeminnow (SASQ), lamprey fry (LFRY), cyprinid fry (CYP FRY), California roach (CAR), threespine stickleback (TSS), green sunfish (GSF), Pacific lamprey (PL), riffle sculpin (RIF), speckled dace (DACE), and Pacific brook lamprey (PBL).

	Weekly Catch														
Week	CHN	RBT	HH	SASU	TP	SASQ	LFRY	CYP FRY	CAR	TSS	GSF	PL	RIF	DACE	PBL
01/02/06	0	0	3	0	0	0	4	0	0	0	0	0	0	0	0
01/09/06	2	0	11	2	14	1	7	3	0	0	0	0	0	0	0
01/16/06	0	0	10	8	1	0	5	2	1	1	1	0	0	0	0
01/23/06	10	0	1	1	1	1	8	12	0	0	0	2	2	0	0
01/30/06	11	0	4	14	36	8	59	5	0	0	1	0	17	1	0
02/06/06	6	1	2	3	13	5	11	3	0	0	0	0	23	0	0
02/13/06	5	0	1	1	2	7	7	6	1	0	0	5	18	0	1
02/20/06	0	0	6	0	0	4	6	4	0	0	0	0	28	0	0
02/27/06	0	0	1	0	1	0	4	3	0	0	0	0	1	0	0
Totals	***34***	***1***	***39***	***29***	***68***	***26***	***111***	***38***	***2***	***1***	***2***	***7***	***89***	***1***	***1***

Table 7. Summary of spring, fall, and late-fall Chinook salmon and rainbow trout/steelhead juvenile passage estimates at the Lower Battle Creek rotary screw trap including run designation, brood year, original CAMP estimate, current estimate (N), and the 90 and/or 95% confidence intervals for the current 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	---	---	---	---	---	---
	1999	---	---	---	---	---	---
	2000	---	---	---	---	---	---
	2001	---	8,978	8,113	10,002	8,003	10,160
	2002	---	2,315	2,078	2,628	2,037	2,713
	2003	---	14,809	13,139	16,632	12,809	16,922
	2004	---	7,983	6,434	10,015	6,256	10,884
	2005[e]	---	N/A	N/A	N/A	N/A	N/A
Fall	1998	4,909,700	4,897,569	---	---	4,238,511	5,732,692
	1999	16,697,610	18,708,768	---	---	14,103,348	26,372,818
	2000-partial[a]	---	5,451,599	---	---	4,270,908	7,182,598
	2001	---	4,040,686	3,721,942	4,413,372	3,676,854	4,522,353
	2002	---	581,677	542,513	625,834	537,926	636,193
	2003	---	3,143,957	2,863,640	3,492,043	2,821,952	3,598,515
	2004	---	4,349,127	3,822,231	4,993,838	3,724,470	5,174,112
	2005[e]	---	N/A	N/A	N/A	N/A	N/A
Late-Fall	1999	113,684	86,305	---	---	72,258	98,591
	2000	99,803	86,940	---	---	73,793	106,967
	2001	---	---	---	---	---	---
	2002	---	59,183	50,087	72,672	48,738	75,194
	2003	---	31,538	29,371	34,371	29,126	34,580
	2004	---	23,193	20,497	26,193	20,103	26,875
	2005	---	66,751	54,101	85,553	52,189	90,209
	2006[e]	---	N/A	N/A	N/A	N/A	N/A
RBT/Steelhead	1999[b]	---	7,057	---	---	6,196	8,368
	2000[b]	---	8,417	---	---	7,699	9,608
	2001	---	---	---	---	---	---
	2002 (1+)[d]	---	647	583	725	574	735

Table 7 (Cont.)

	2002 (YOY)	---	8,153	7,261	9,255	7,096	9,576
	2003 (1+)[d]	---	577	540	622	633	632
	2003 (YOY)	---	2,313	2,164	2,479	2,187	2,520
	2004 (1+)[d]	---	471	421	526	413	538
	2004 (YOY)	---	1,144	1,031	1,268	1,013	1,301
	2005 (1+)[d]		357	2,809	4,289	2,739	4,682
	2005 (YOY)		3,422	291	447	284	469
	2006 (1+)[e]		N/A	N/A	N/A	N/A	N/A
	2006 (YOY)[e]		N/A	N/A	N/A	N/A	N/A

[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] Passage estimates for age 1+ trout are not for the current brood year, but rather a mixture of previous year-classes captured during the reporting period.

[e] 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

Table 8. Summary of fall, late-fall, and spring Chinook salmon and rainbow trout/steelhead juvenile passage estimates at the Upper Battle Creek rotary screw traps including run designation, brood year, original CAMP estimate, current estimate (N), and the 90 and/or 95% confidence intervals for the current annual estimates. Shaded rows indicated estimates for the current reporting period.

				90% Confidence Interval		95% Confidence Interval	
Run	Brood Year	Original CAMP Estimate[c]	Current Estimate	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[e]	--	N/A	N/A	N/A	N/A	N/A
Fall	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[e]	--	N/A	N/A	N/A	N/A	N/A
Late-Fall	1999	---	212	177	261	170	273
	2000	---	50	36	70	35	78
	2001	---	N/A	N/A	N/A	N/A	N/A
	2002	---	7,628	5,950	9,969	5,753	10,604
	2003	---	6,673	5,835	7,409	5,679	7,631
	2004	---	1,145	809	1,732	768	1,968
	2005	---	147	112	198	109	213
	2006[e]	--	N/A	N/A	N/A	N/A	N/A
RBT/Steelhead	1999 (1+)[b]	---	1,011	832	1,272	813	1,333
	1999 (YOY)[b]		9,379	8,001	11,139	7,870	11,747
	2000 (1+)[b]	---	2,780	2,268	3,569	2,213	3,723
	2000 (YOY)[b]		23,019	19,513	27,001	18,957	28,343

Table 8 (Cont.)

	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

[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.

Figures

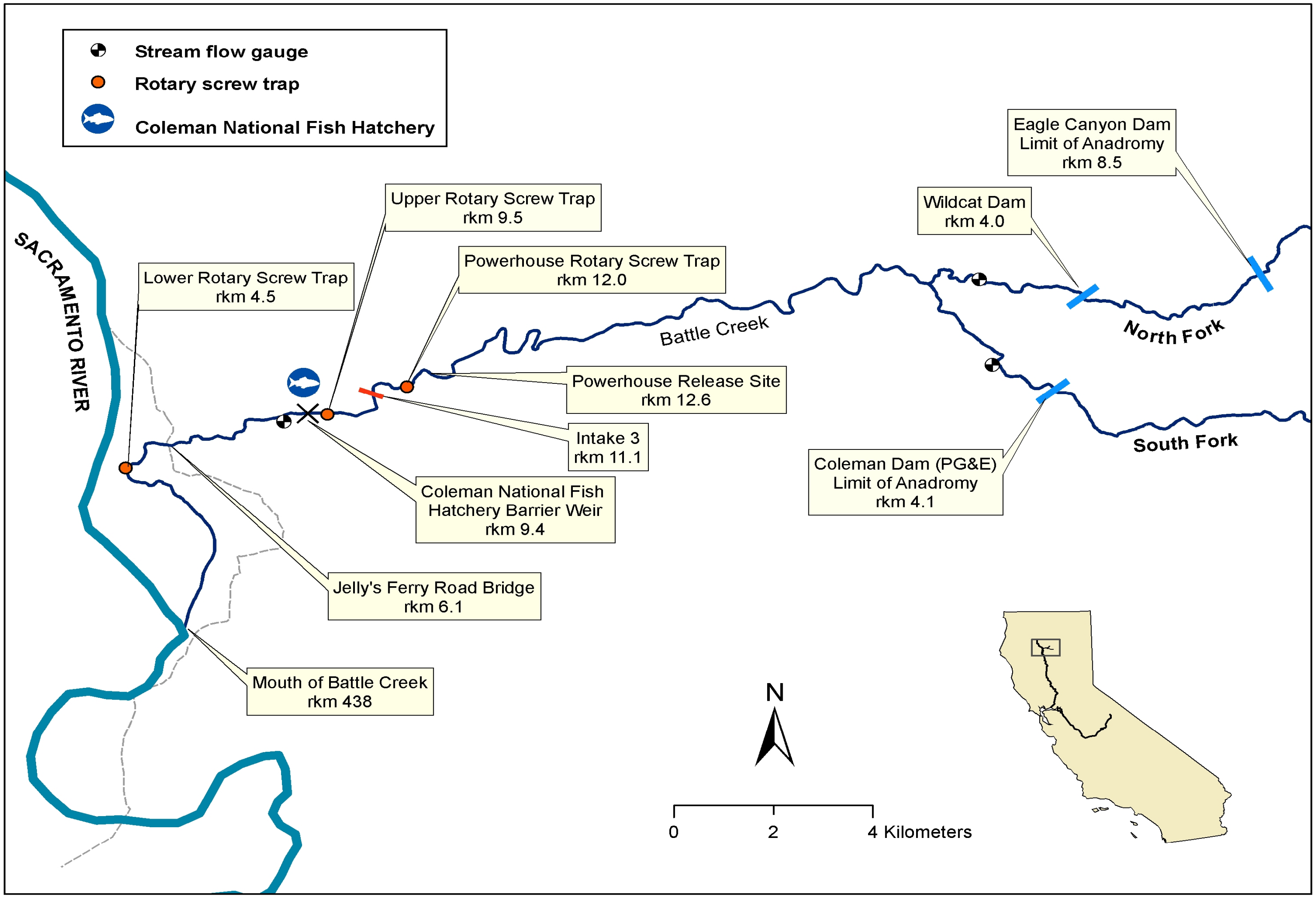

Figure 1. Map of Battle Creek depicting the location of USFWS' rotary screw traps and other important features.

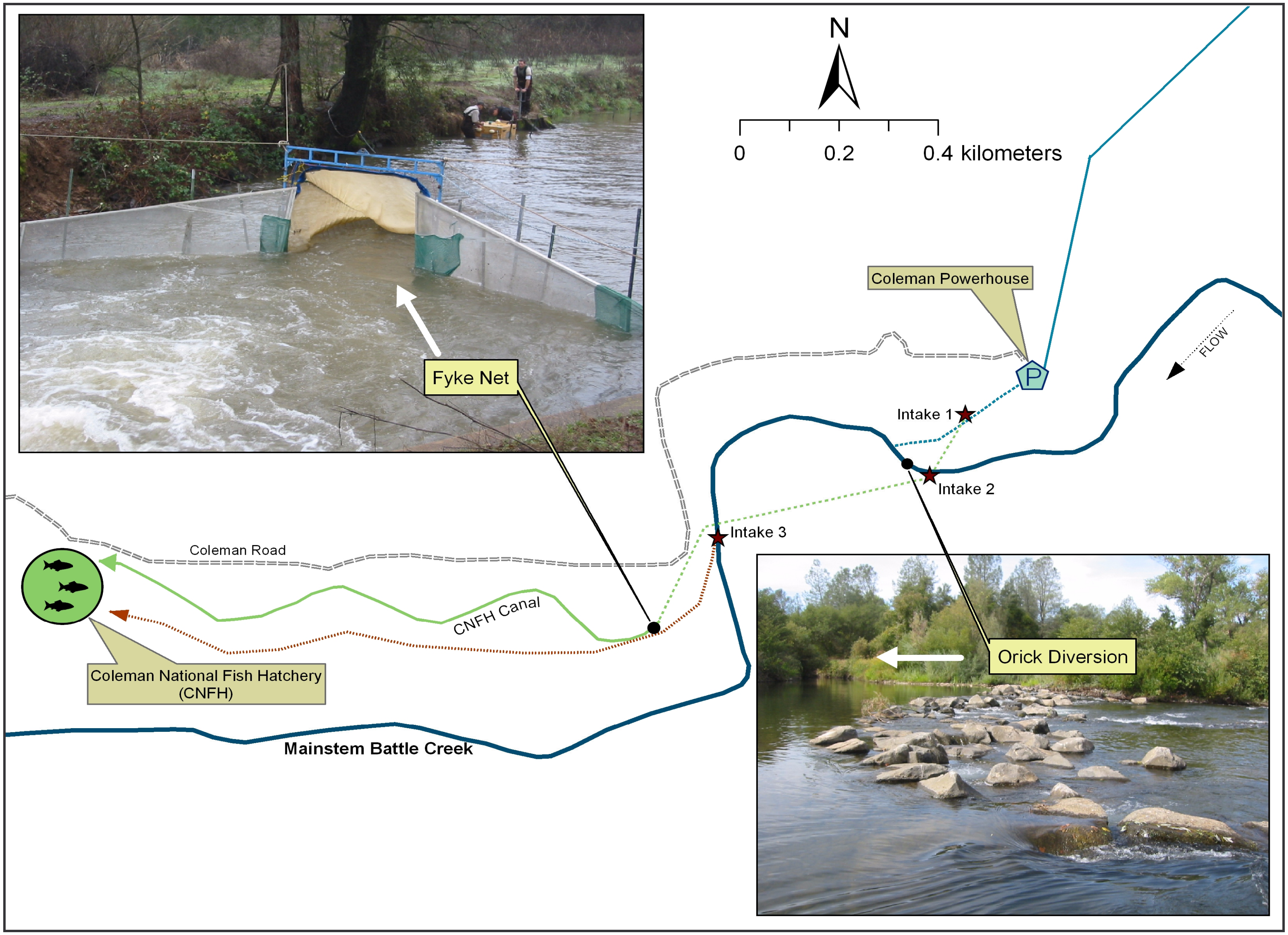

Figure 2. Map showing the fyke net location in the Coleman National Fish Hatchery's canal and its relationship to the water intakes, Coleman Powerhouse, and the Orwick Diversion.

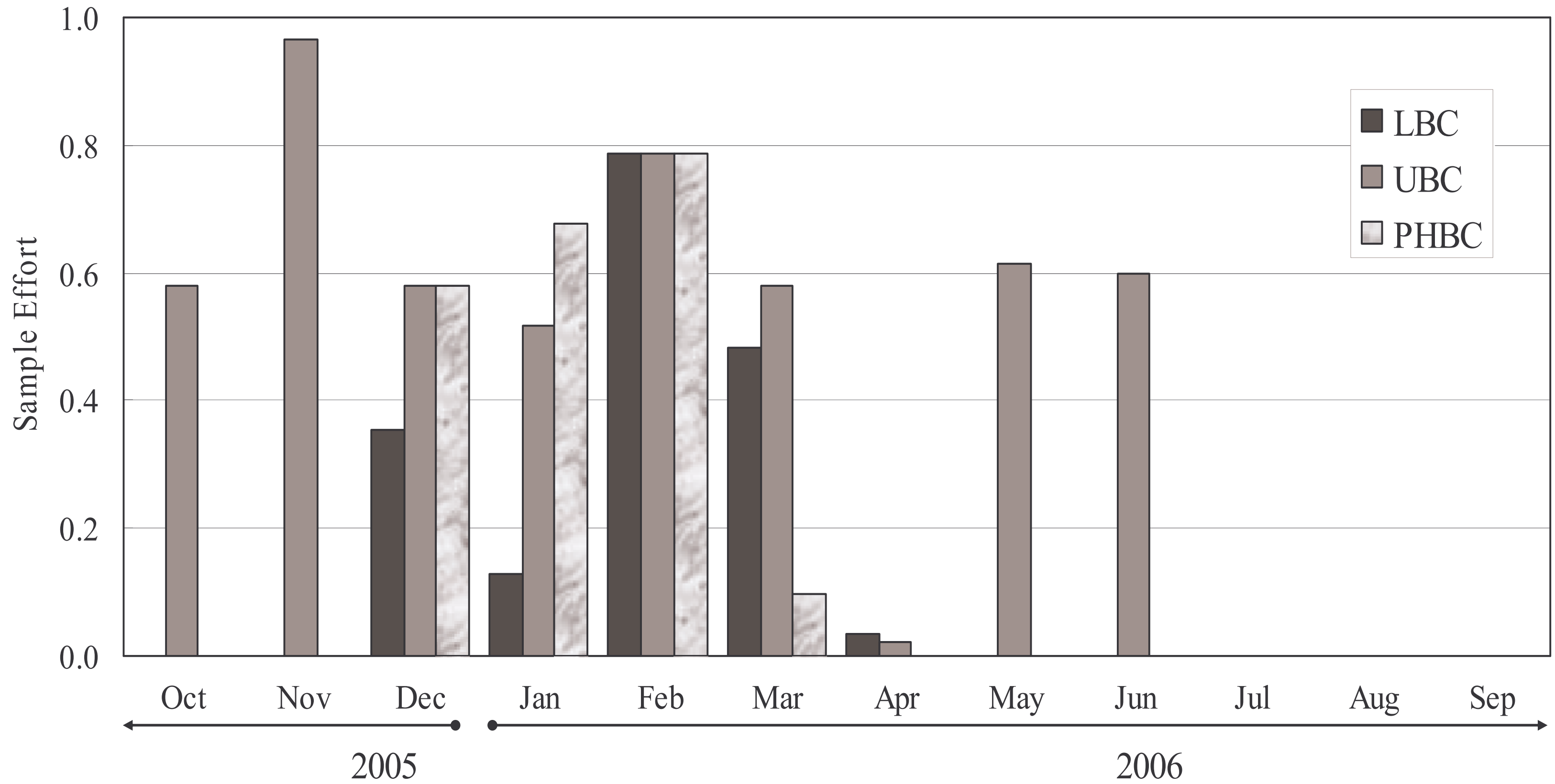

Figure 3. Sampling effort summarized as the proportion (range: 0 to 1) of days fished each month at the Lower, Upper, and Powerhouse Battle Creek rotary screw traps from October 1, 2005 to September 30, 2006. No traps were operated after June 30, 2006.

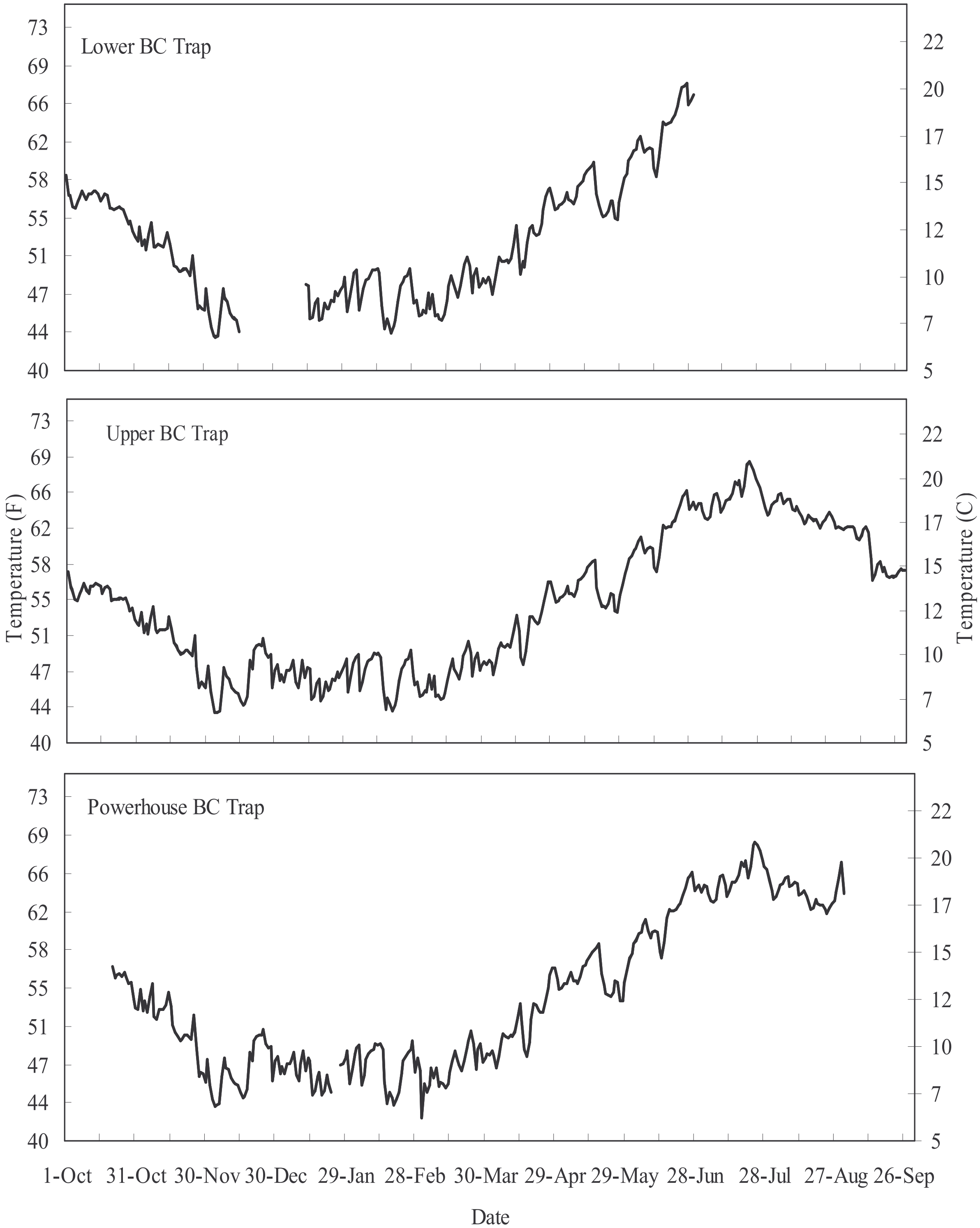

Figure 4. Mean daily water temperatures (ºC and ºF), at the Lower, Upper, and Powerhouse rotary screw traps from October 1, 2005 through September 30, 2006.

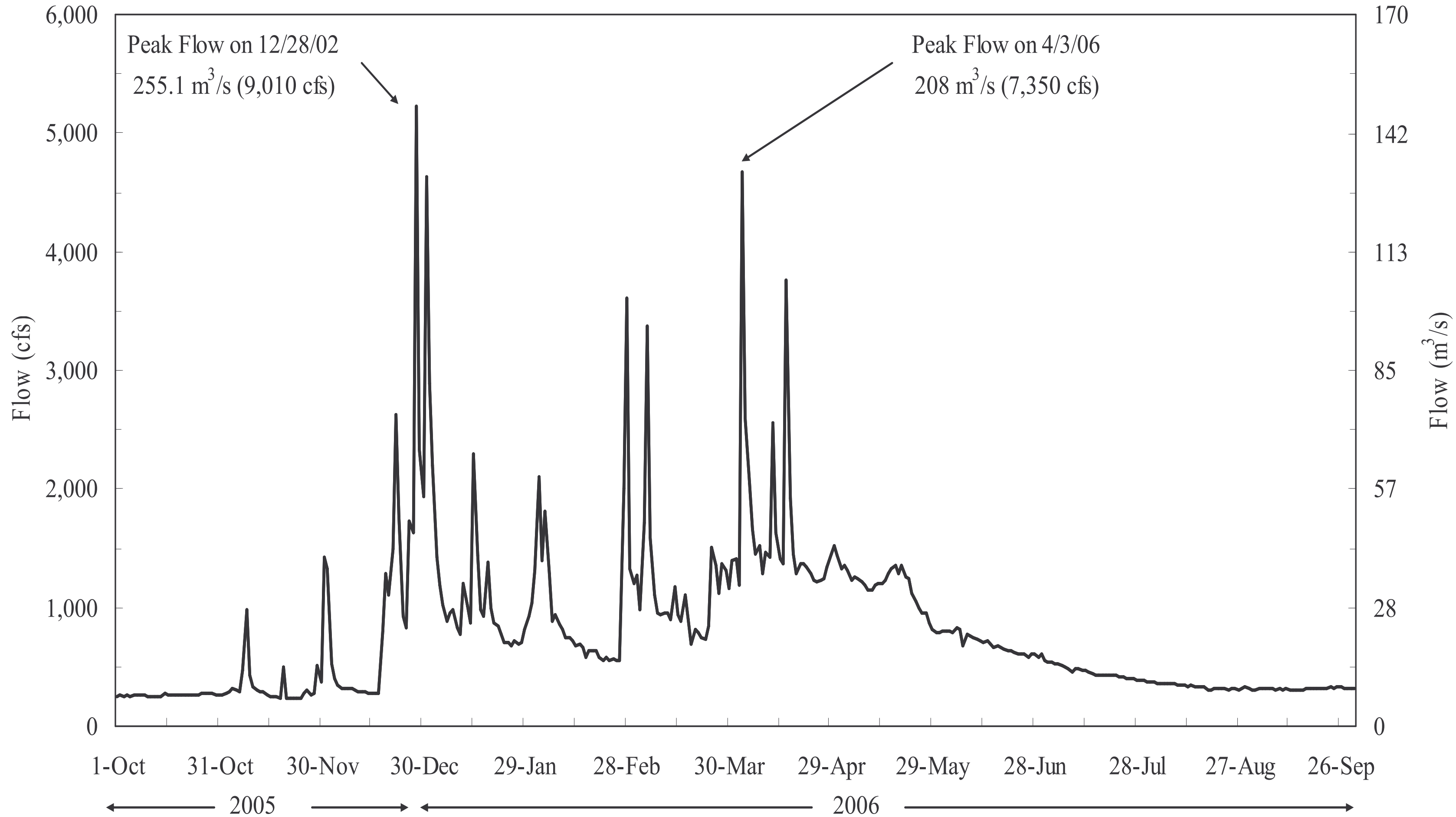

Figure 5. Mean daily flows (m^3/s and cfs) collected by the U.S. Geological Survey at the Coleman Hatchery gauging station (#11376550) from October 1, 2005 through September 30, 2006. The gauge site is located below the Coleman Fish Hatchery barrier weir and approximately 0.2 km downstream of the UBC trap.

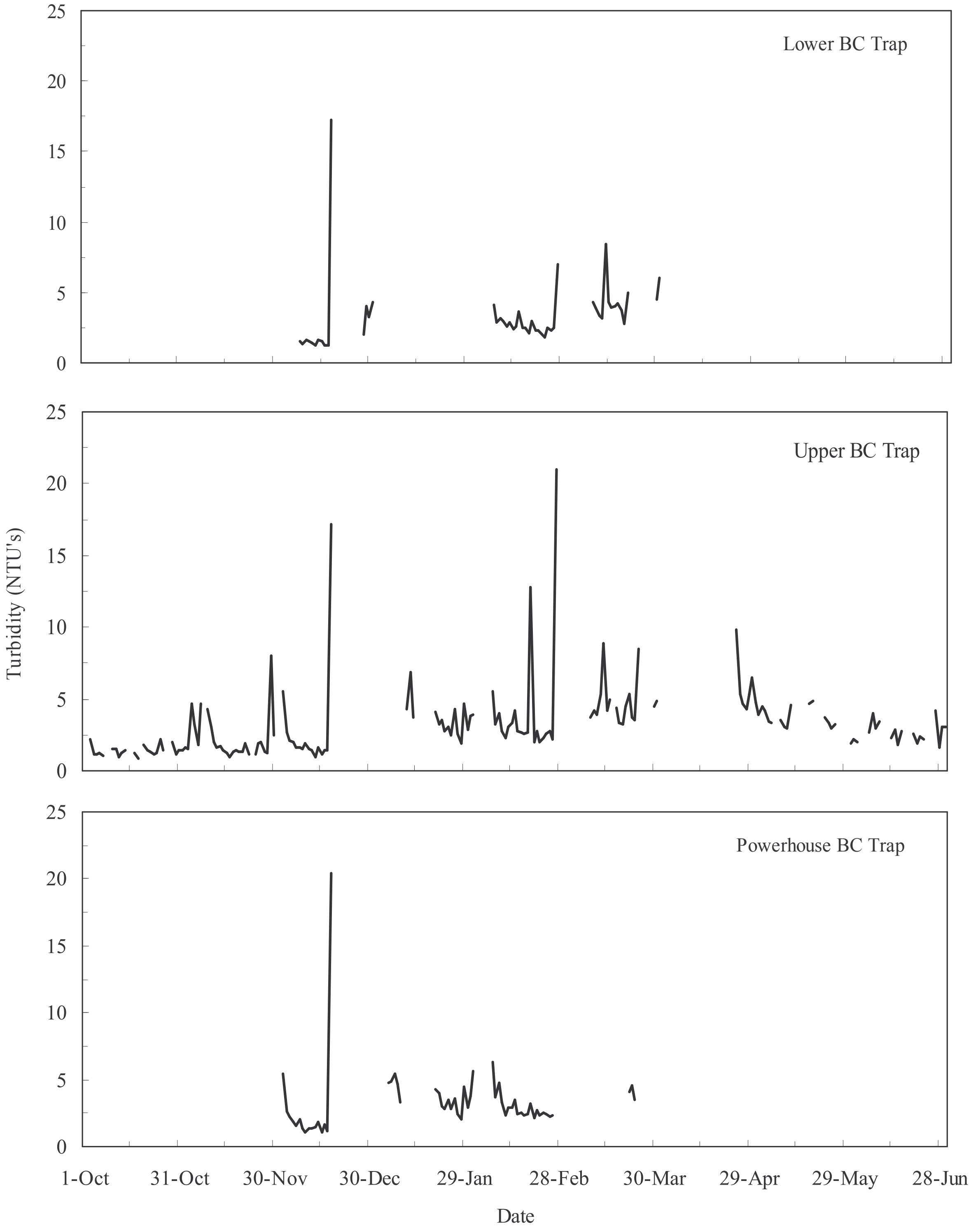

Figure 6. Daily turbidity (NTU's) measured at Lower, Upper, and Powerhouse Battle Creek rotary screw traps from October 1, 2005 through June 30, 2006. Turbidity was not measured at any trap after June 30, 2006.

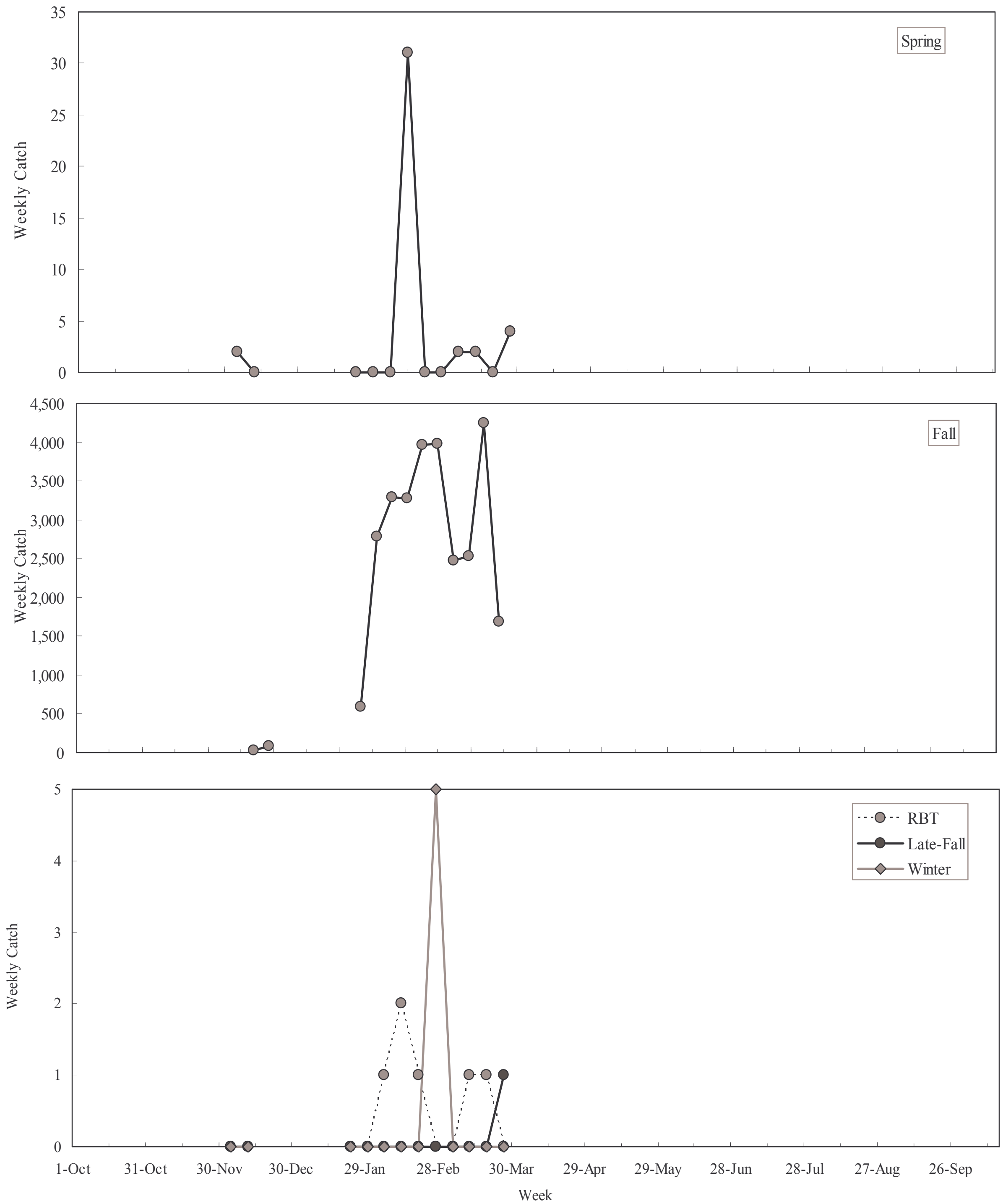

Figure 7. Weekly catch of spring, fall, late-fall, and winter Chinook salmon and rainbow trout/steelhead (RBT) captured at the Lower Battle Creek rotary screw trap from October 1, 2005 to September 30, 2006. Weekly catch totals may be partial if the traps were not operated on all days of a week.

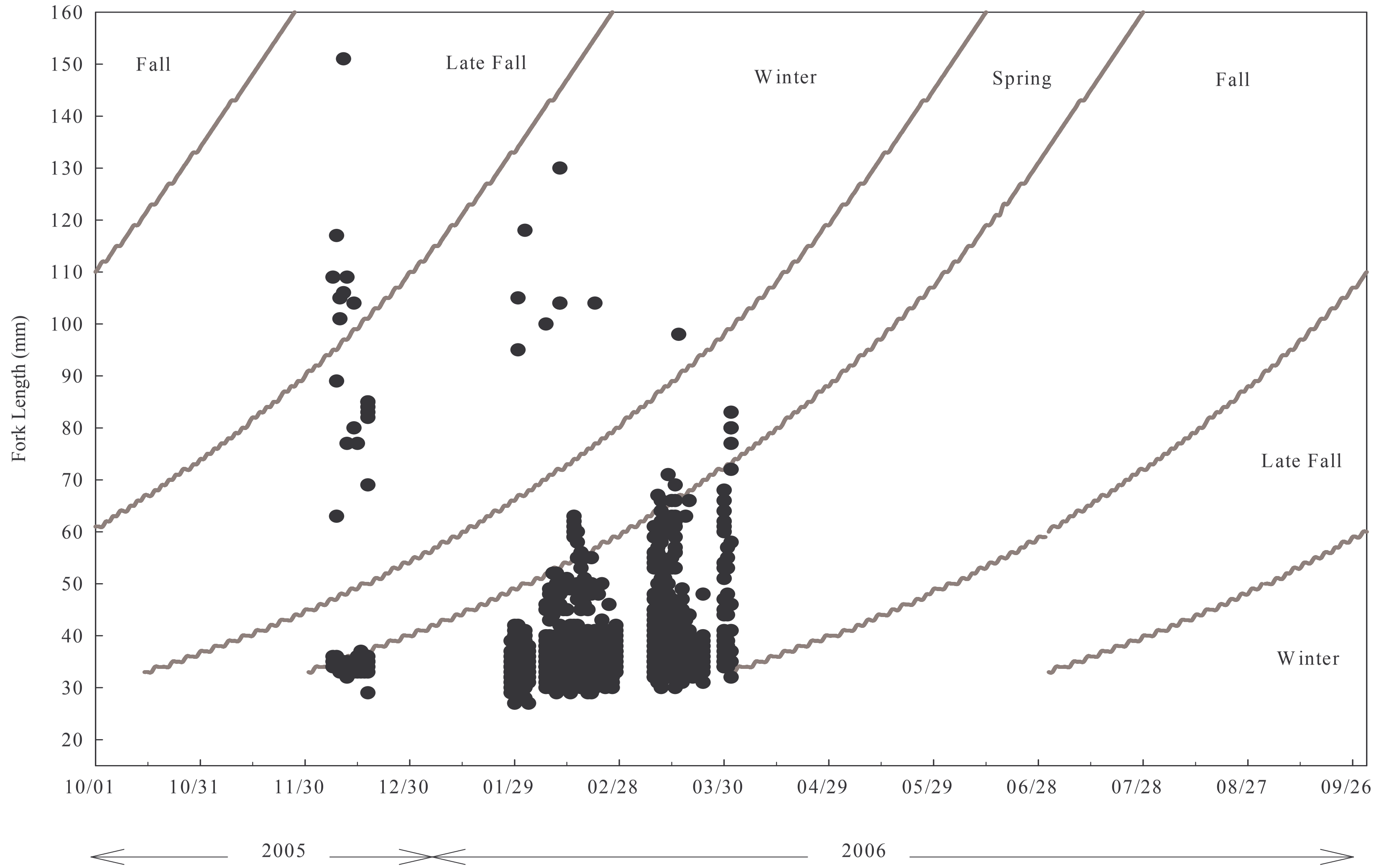

Figure 8. Fork length (mm) distribution by date and run for Chinook salmon captured at the Lower Battle Creek rotary screw trap from October 1, 2005 to September 30, 2006. Spline curves represent the maximum fork lengths expected for each run by date, based upon criteria developed by the California Department of Water Resources (Greene 1992). The trap was not operated until December 1, 2005 and after April 23, 2006.

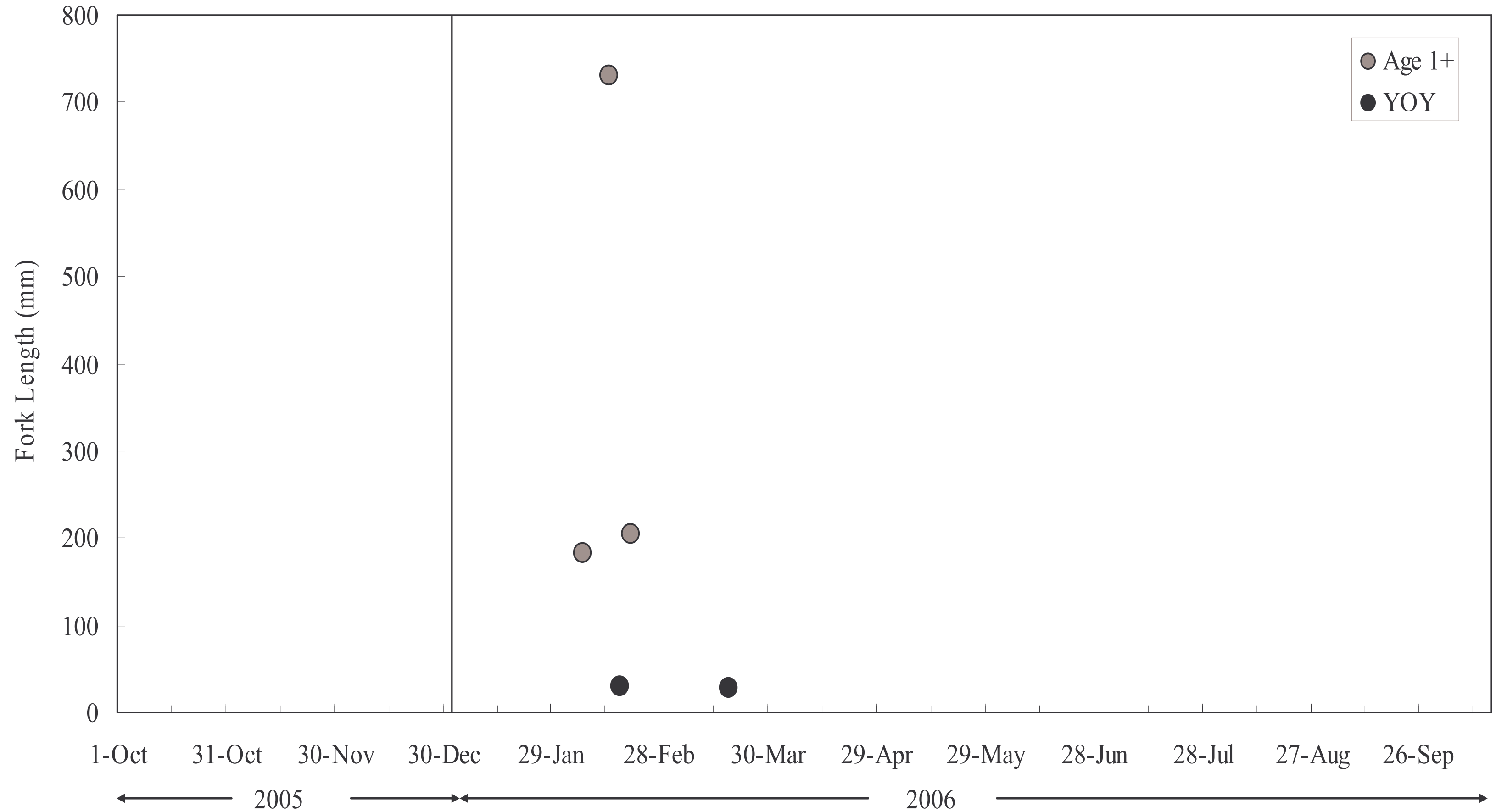

Figure 9. Fork length (mm) distribution for age 1+ and young-of-the-year (YOY) rainbow trout/steelhead sampled at the Lower Battle Creek rotary screw trap during October 1, 2005 through September 30, 2006. Age 1+ fish may include individuals from more than one year class. The trap was not operated before December 8, 2005 or after April 23, 2006.

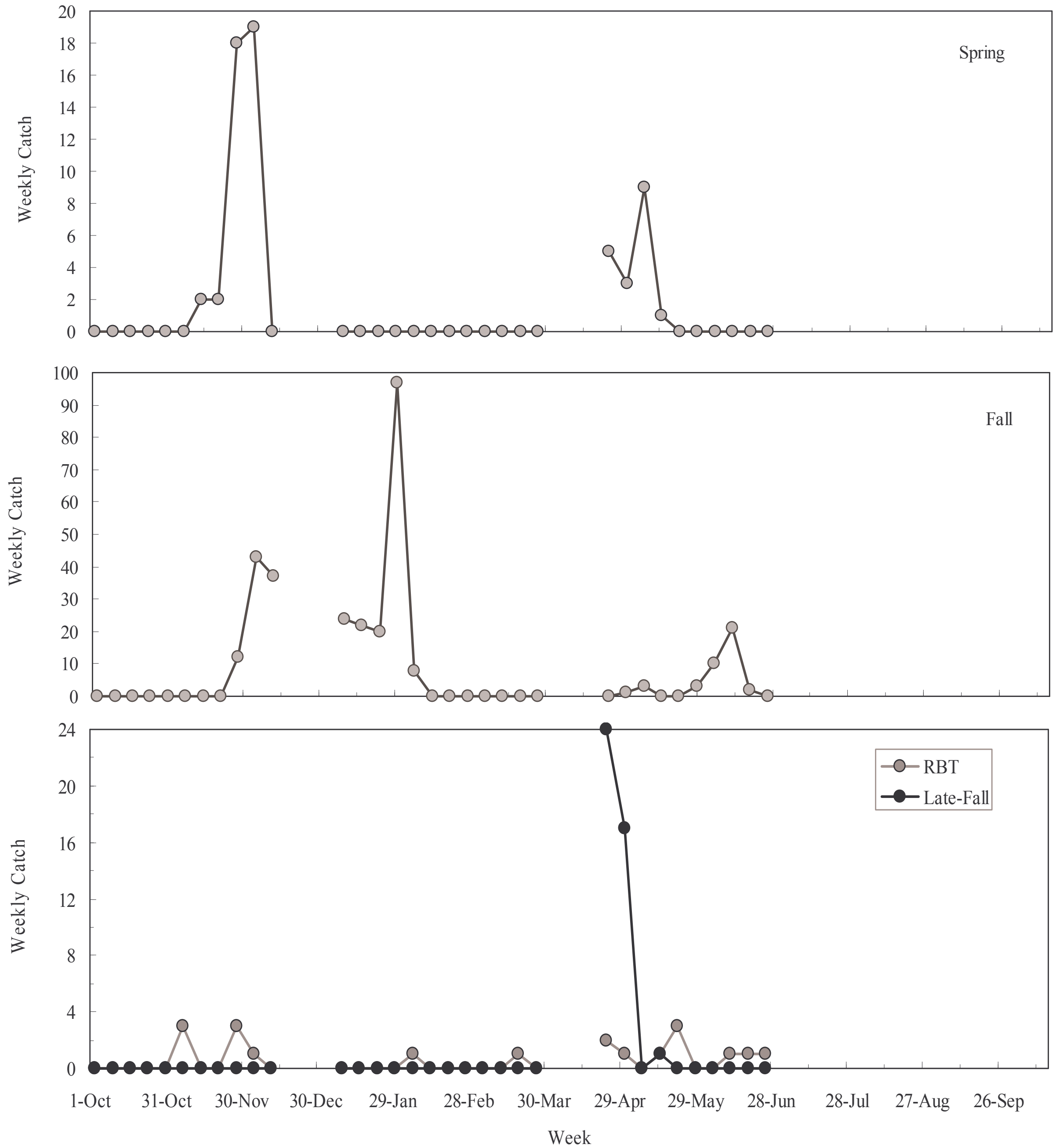

Figure 10. Weekly catch of spring, fall, late-fall, and winter Chinook salmon and rainbow trout/steelhead (RBT) captured at the Upper Battle Creek rotary screw trap from October 1, 2005 to September 30, 2006. Weekly catch totals may be partial if the traps were not operated on all days of a week.

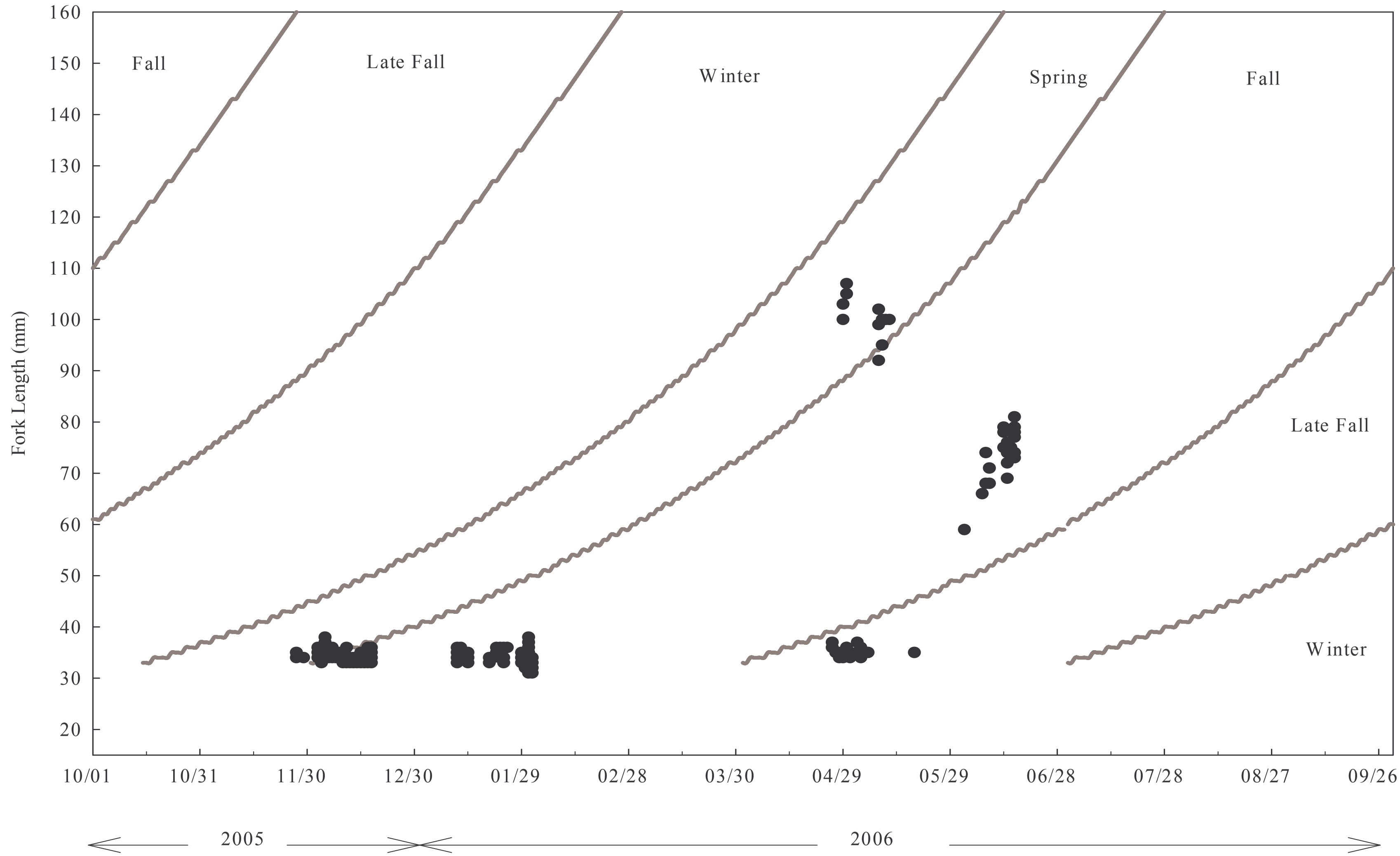

Figure 11. Fork length (mm) distribution by date and run for Chinook salmon captured at the Upper Battle Creek rotary screw trap from October 1, 2005 to September 30, 2006. Spline curves represent the maximum fork lengths expected for each run by date, based on criteria developed by the California Department of Water Resources (Greene 1992). Trap not operated after June 30, 2006.

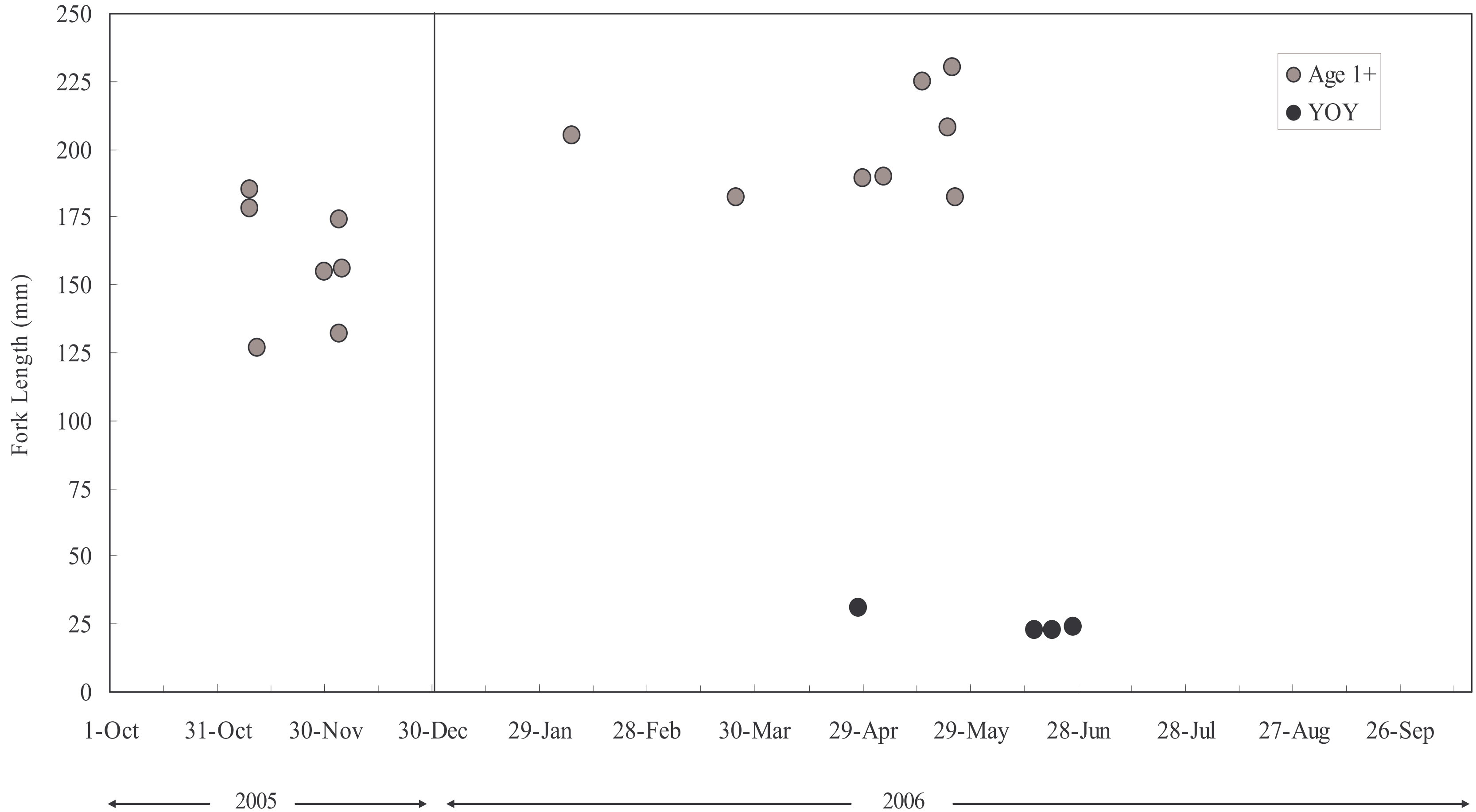

Figure 12. Fork length (mm) distribution by date for age 1+ and young-of-the-year rainbow trout/steelhead measured at the Upper Battle Creek rotary screw trap during October 1, 2005 through September 30, 2006. Age 1+ fish may include individuals from more than one year class.

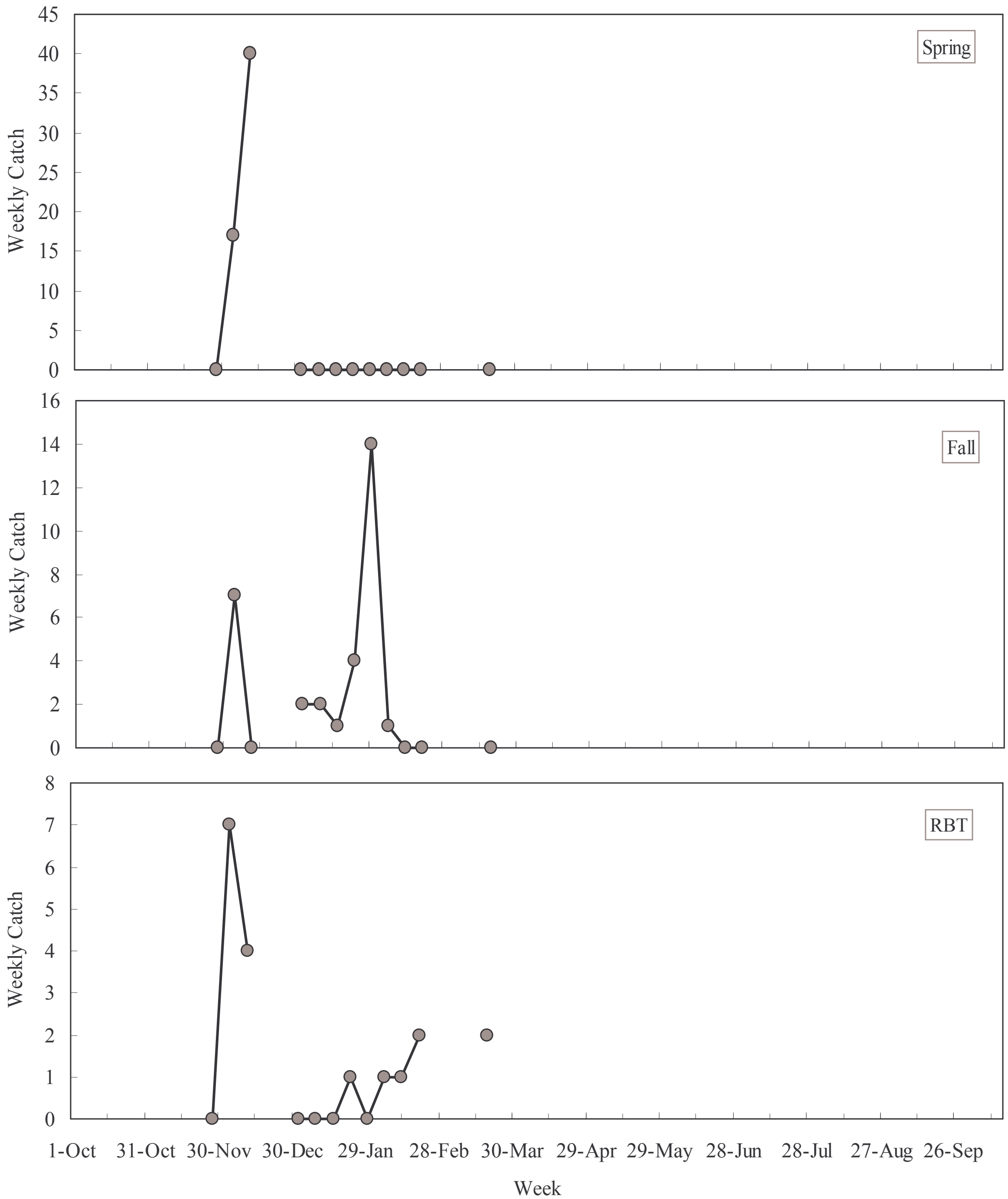

Figure 13. Weekly catch of spring and fall Chinook salmon and rainbow trout/steelhead (RBT) captured at the Powerhouse Battle Creek rotary screw trap (PHBC) from September 30, 2005 to September 30, 2006. Weekly catch totals may be partial if the traps were not operated on all days of a week. Trap operation began December 1, 2005.

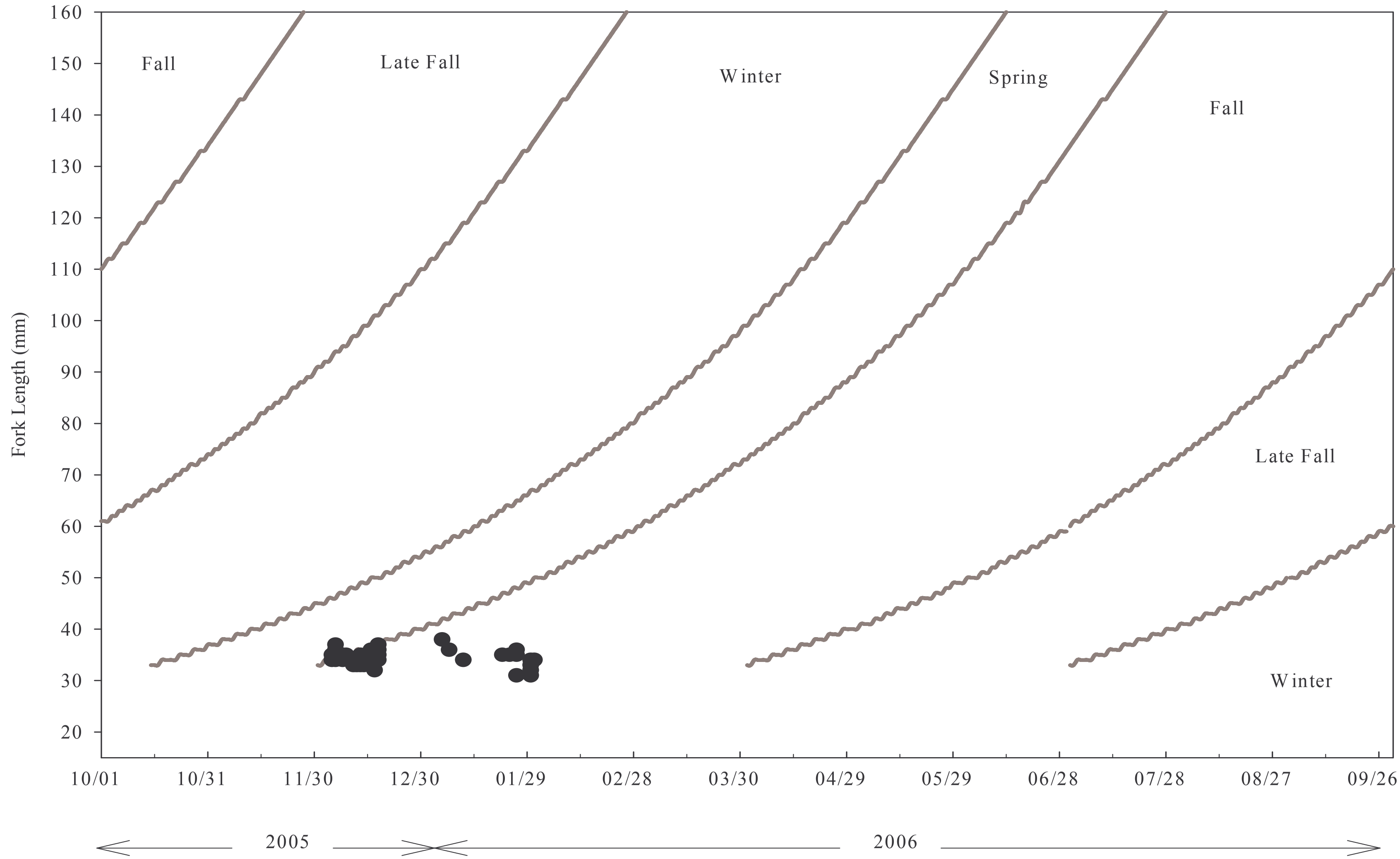

Figure 14. Fork length (mm) distribution by date and run for Chinook salmon captured at the Powerhouse Battle Creek rotary screw trap from October 1, 2005 to September 30, 2006. Spline curves represent the maximum fork lengths expected for each run by date, based on criteria developed by the California Department of Water Resources (Greene 1992). The trap was not operated before December 1, 2005 or after April 3, 2006.

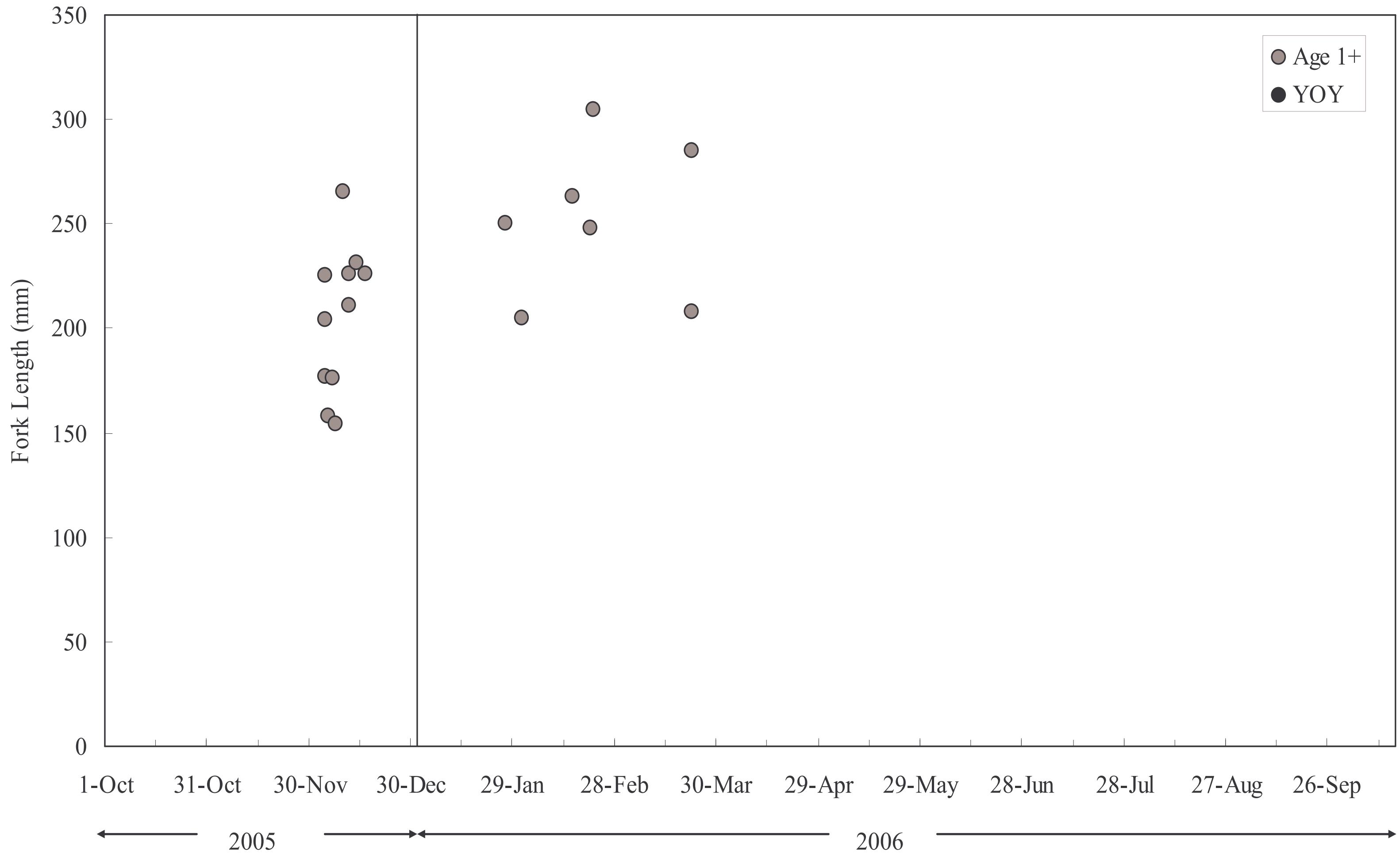

Figure 15. Fork length (mm) distribution by date for age 1+ and young-of-the-year (YOY) rainbow trout/steelhead measured at the Upper Battle Creek rotary screw trap during October 1, 2005 through September 30, 2006. Age 1+ fish may include individuals from more than one year class. The trap was not operated before December 1, 2005 or after April 3, 2006. No young-of-the-year were captured.

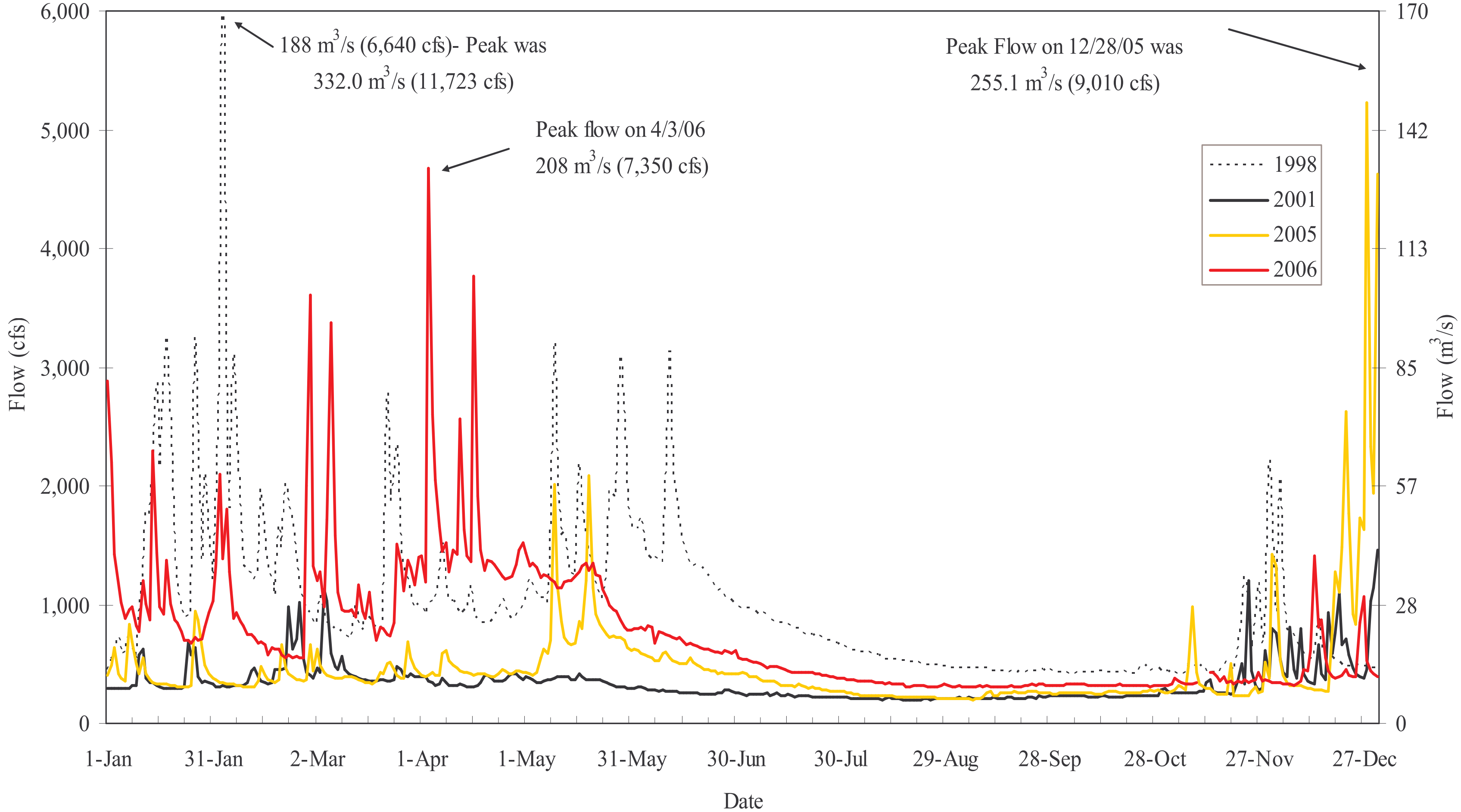

Figure 16. Mean daily flows (m^3/s) recorded at the U. S. Geological Survey gauging station (BAT-#11376550) located below the Coleman National Fish Hatchery barrier weir, January 1, 2004 to December 31, 2005. Flows for the wettest (1998) and driest (2001) years of sampling are included for comparison.

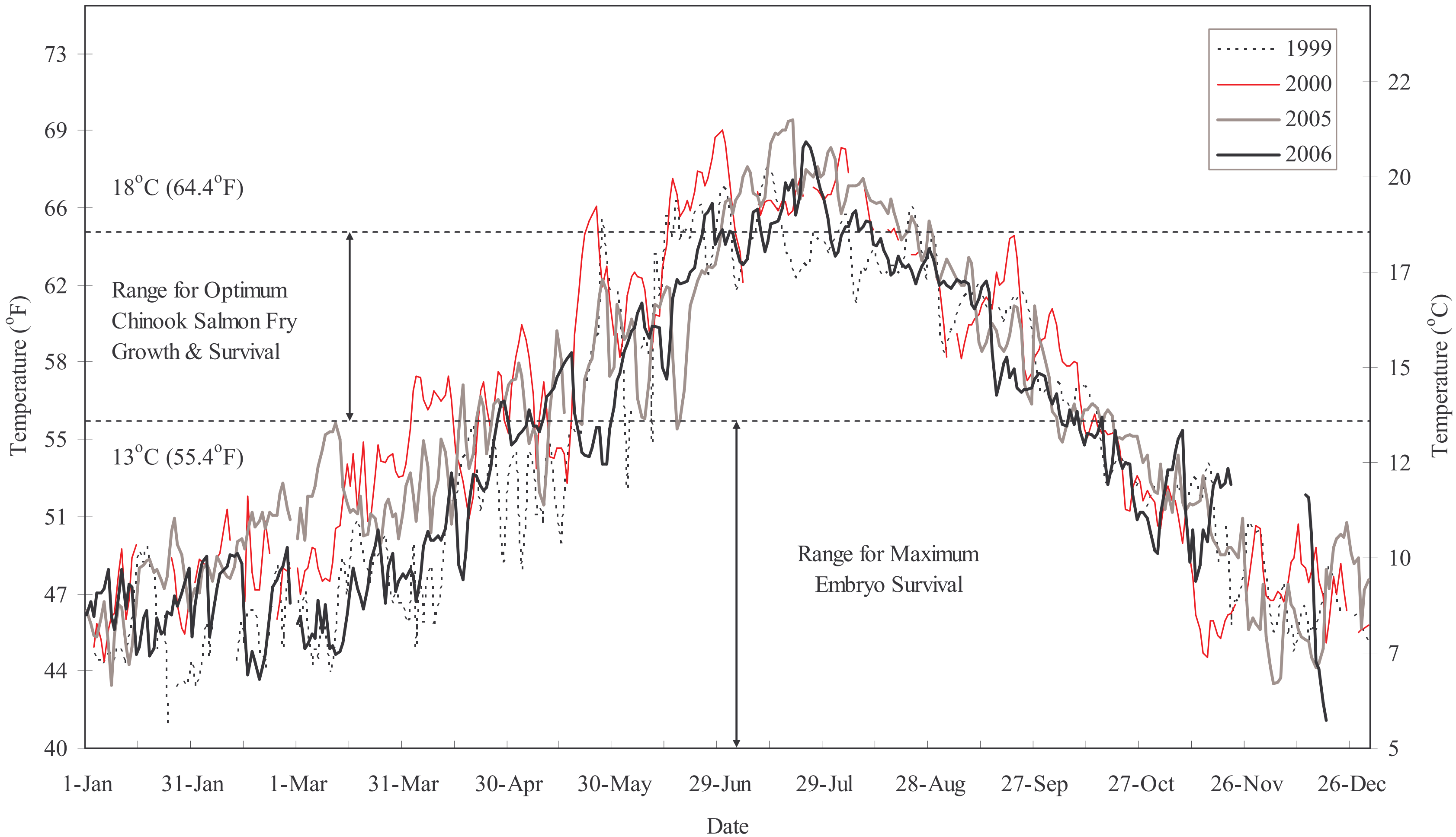

Figure 17. Mean daily water temperatures at the Upper Battle Creek rotary screw trap for 1999 through 2000 and 2005 through 2006. Temperatures for 1999 to 2000 were included to allow comparisons between the current sample period (October 1, 2005 to September 30, 2006) and years when temperatures in general were the coolest and warmest during monitoring. Temperature ranges for optimum Chinook salmon embryo survival and fry growth and survival are included.

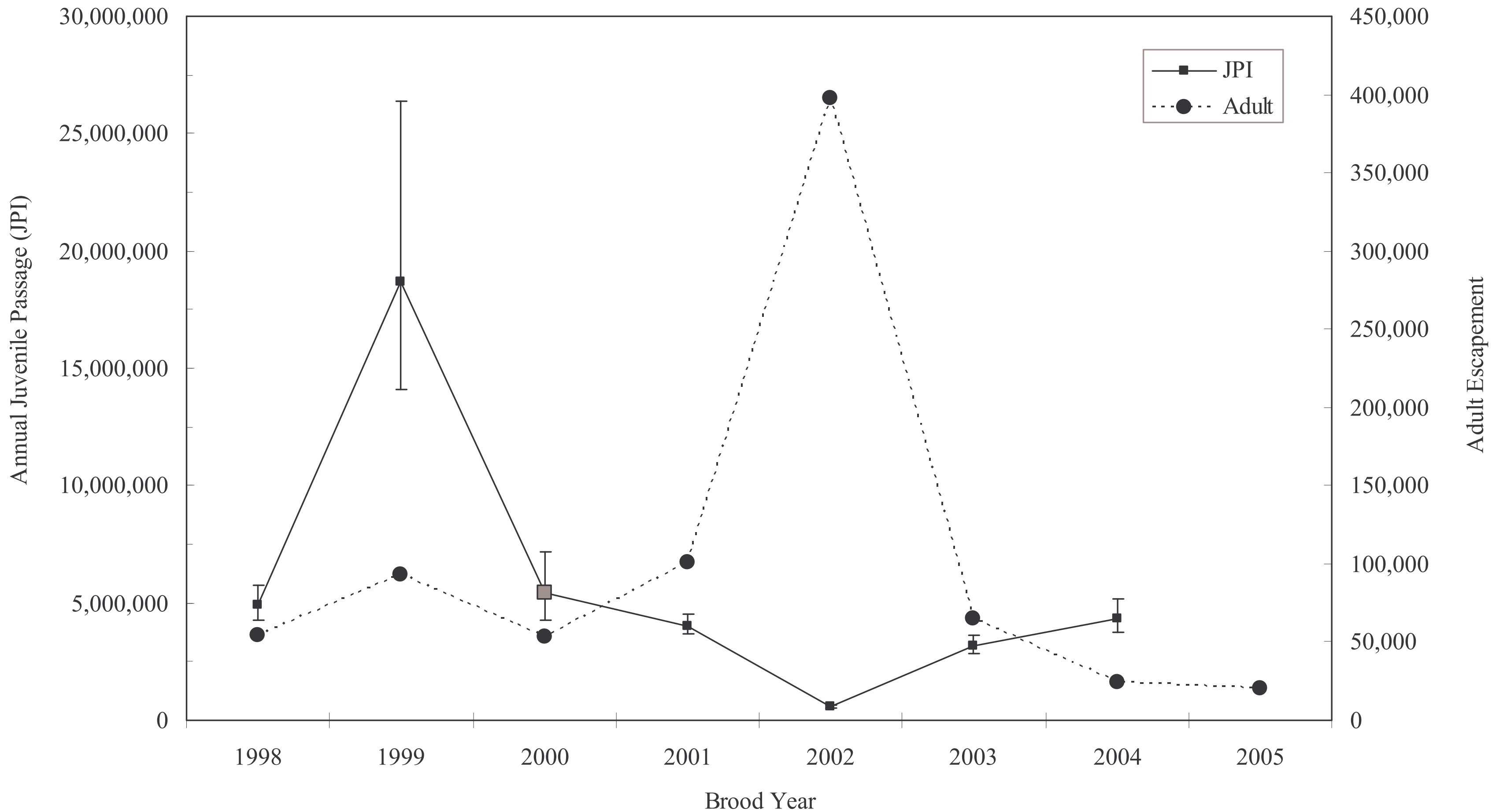

Figure 18. Fall Chinook salmon juvenile passage estimates and the 95% confidence intervals at the Lower Battle Creek trap (LBC) and estimated adult escapement below the barrier weir for brood years 1998-2004. The brood year 2000 juvenile passage estimate is a partial estimate as the trap was not operated after early February 2001.

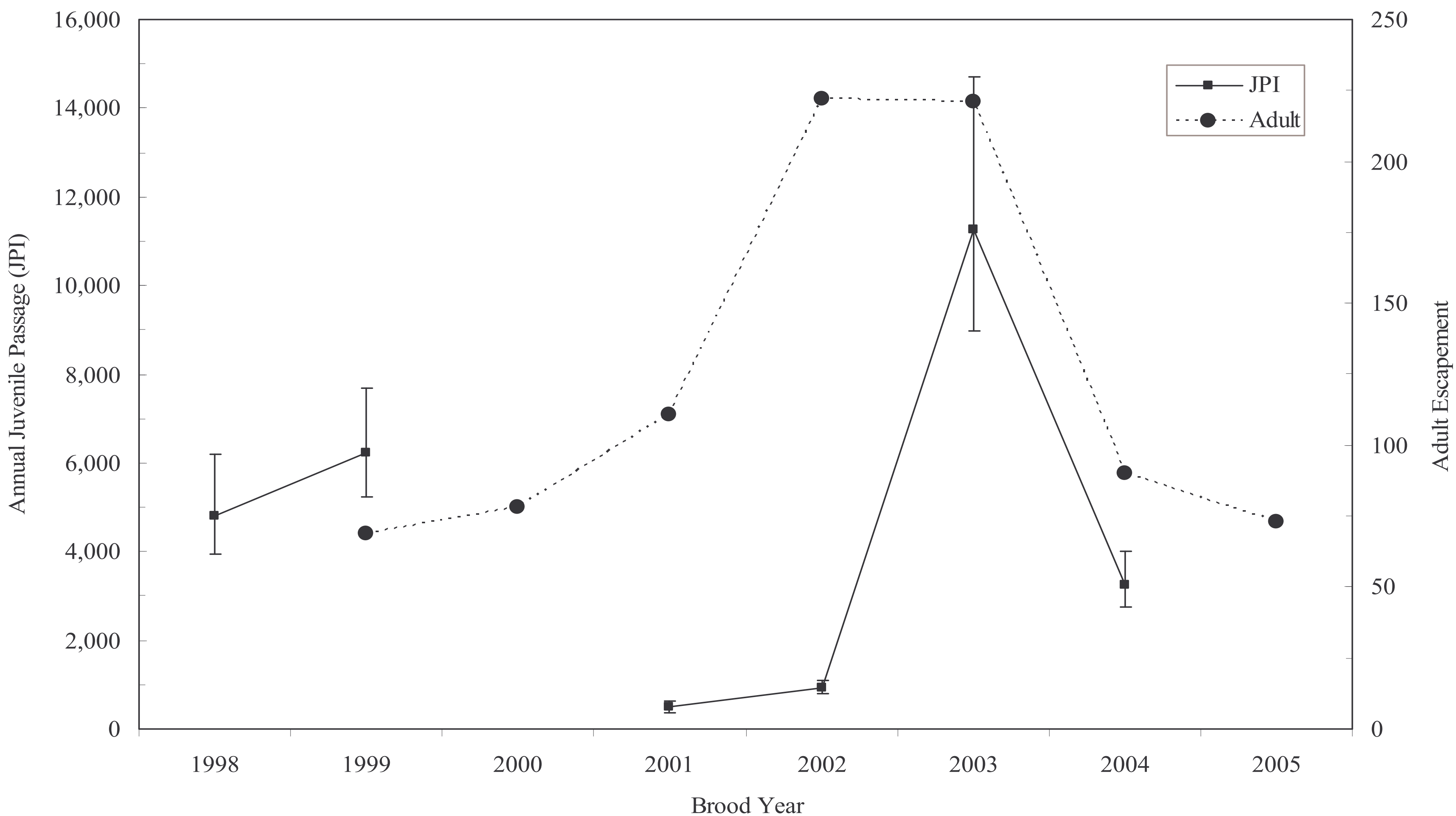

Figure 19. Spring Chinook salmon juvenile passage estimates and the 95% confidence intervals at the Upper Battle Creek trap (UBC) and adult escapement above the barrier weir for brood years 1998-1999 and 2001-2004. No estimate was made in 2000 as the trap was not operated after early February.

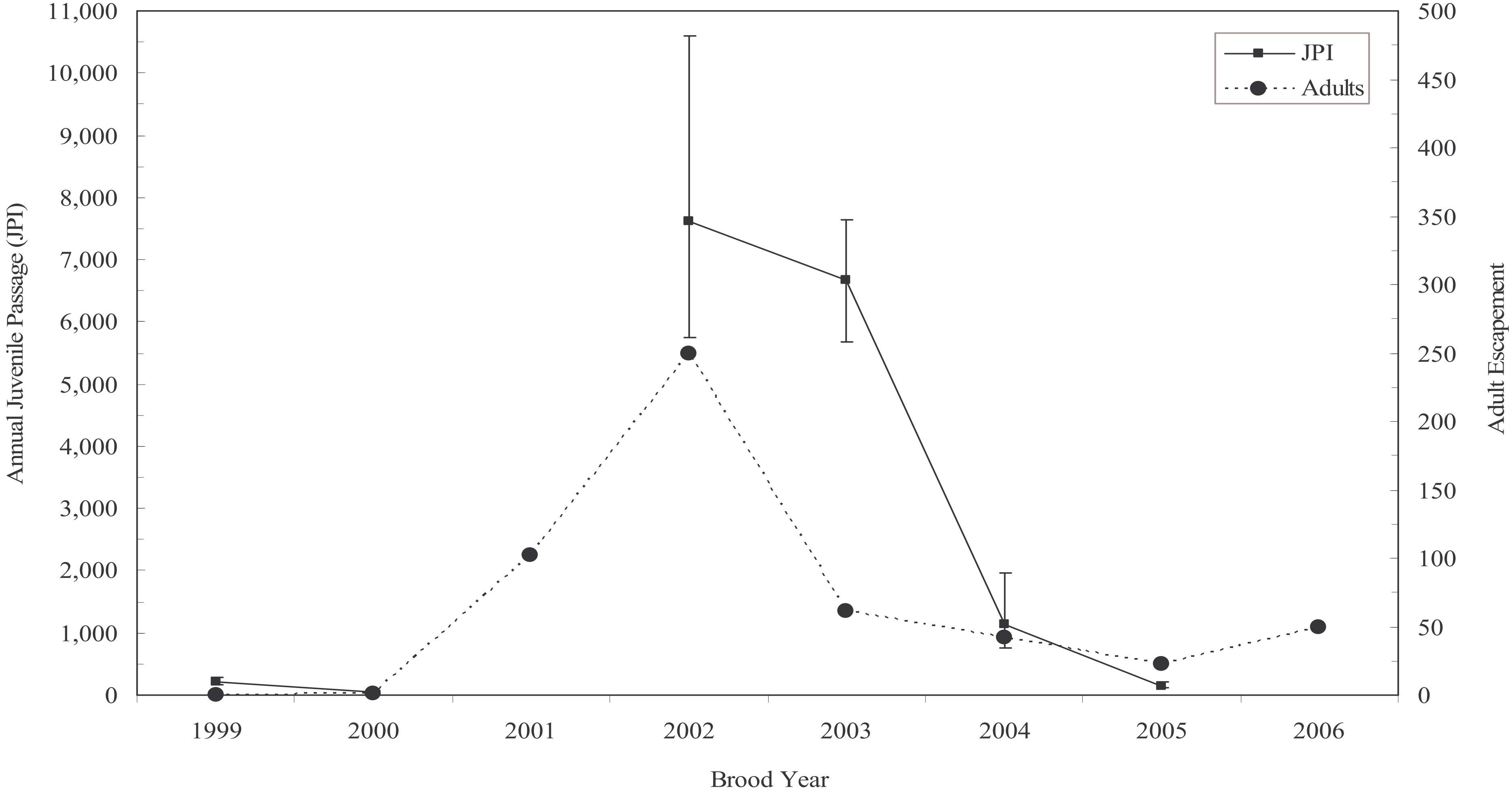

Figure 20. Late-fall Chinook salmon juvenile passage estimates and the 95% confidence intervals at the Upper Battle Creek rotary screw trap and adult escapement above the barrier weir for brood years 1999-2000 and 2002-2005. No juvenile passage estimate was possible for brood year 2001 because the trap was not operated after early February.

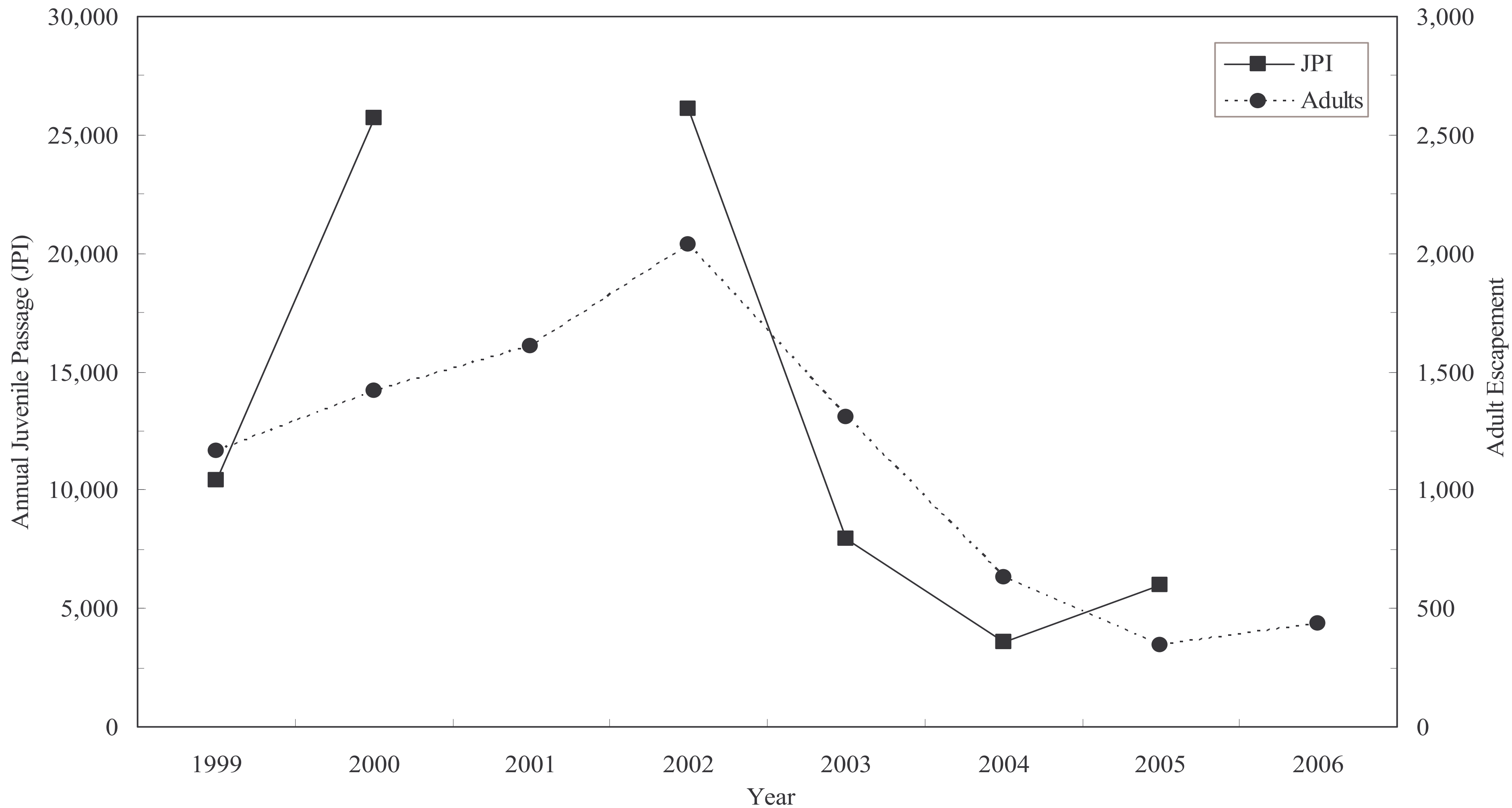

Figure 21. Rainbow trout/steelhead passage estimates at the Upper Battle Creek trap (UBC) and adult escapement above the barrier weir for brood years 1999-2000 and 2002-2005. No juvenile passage estimates were made in 2001 and 2006 because the trap was not operated after early February 2001 and unusually high flow, respectively. Adult passage estimates in 1999 and 2000 do not include trout passed at the barrier weir ladder after March 1.

Appendix

Appendix 1. Summary of days the Lower Battle Creek rotary screw trap did not fish during the report period (October 1, 2005 to September 30, 2006), including sample dates, hours fished, and reason for not fishing.

Sample Dates	Hours Fished (approx)	Reason
	2005	
October 1 to December 7	0	Little or No Salmonid Catch
December 19 – 31	6.5	High Flows & Tree Removal
	2006	
January 1 – 27	0	High Flows and Tree Removal
February 2 – 6	0	High Flows
February 28	0	High Flows
March 1 – 9	0	High Flows
March 22 – 23	0	Trap Switch with PHBC
March 25 – 29	0	High Flows
April 2 – 23	0	High Flows
April 24 to June 30	0	Further Sampling Not Warranted Due to Earlier High Flows
July 1 to September 30	0	Little or No Salmonid Catch

Appendix 2. Summary of days the Upper Battle Creek rotary screw trap did not fish during the report period (October 1, 2005 to September 30, 2006), including sample dates, hours fished, and reason for not fishing.

Sample Dates	Hours Fished (approx)	Reason
	2005	
October 1 – 9	0	Little or No Salmonid Catch
October 15 – 16 and 27 – 28	0	Reduced Sampling
November 8	0	High Flows
December 2	0	High Flows
December 20 – 31		High Flows
	2006	
January 1 – 10	0	High Flows
January 15 – 19	0	High Flows
February 2 – 6 and 28	0	High Flows
March 1 – 9	0	High Flows
March 17	0	High Flows
March 26 and 28 – 29	0	High Flows
April 2 – 24	0	High Flows
May 7 – 8	0	Reduced Sampling

Appendix 2 (Cont.)

May 13-15, 20-22, and 27-30	0	Reduced Sampling
June 3-5, 10-12, 17-19, and 24-26	0	Reduced Sampling
July 1 to September 30	0	Little or No Salmonid Catch

Appendix 3. Summary of days the Powerhouse Battle Creek rotary screw trap did not fish during the report period (October 1, 2003 to September 30, 2006), including sample dates, hours fished, and reason for not fishing.

Sample Dates	Hours Fished (approx)	Reason
	2005	
October 1 to November 30	0	Waiting for Operating Permit
December 2	0	High Flows
December 20-31	0	High Flows
	2006	
January 1 – 4, 12 and 15-19	0	High Flows
January 12	0	High Flows
February 3 – 6 and 27 – 28	0	High Flows
March 1 – 20	0	High Flows
March 21	0	Trap Switch with LBC
March 25 – 31	0	High Flows
April 1 – 3	0	High Flows
April 4 to June 30	0	Further Sampling Not Warranted Due to High Flows Earlier & Little or No Salmonid Catch
July 1 to September 30	0	Little or No Salmonid Catch

Appendix 4. Summary of days the fyke net was not fish tight or not operational during the period of operation (January 7 to March 3, 2006).

Date	Comments
January 13 – 15	Debris build-up caused the right wing to tear, fyke was not fish tight.
January 15	Right wing replaced with green wing, fyke not fish tight during switch.
January 22 – 24	Debris build-up caused one wing to tear, fyke was not fish tight.
January 25	Right wing was completely damaged because of debris build-up.
February 2	Installed perforated aluminum screen wings, not fish tight during switch.
February 6	Trap box lid not closing, fyke was not fish tight.
February 9	Trap box lid not closed all the way, fyke was not fish tight.
February 27-March 2	High Flow event and debris damaged wings, fyke not operating.