Monitoring Adult Chinook Salmon, Rainbow Trout, and Steelhead in Battle Creek, California, from March through October 2001

USFWS Report

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Abstract.—We estimate that 5 clipped and 111 unclipped Chinook (*Oncorhynchus tshawytscha*) passed through the Coleman National Fish Hatchery (CNFH) barrier weir fish ladder into upper Battle Creek between 3 March and 31 August 2001. It is difficult to precisely apportion these fish to individual runs of Chinook because of overlaps in migration timing between runs. However, based on a combination of information from migration timing, coded-wire tag recoveries, and genetic analyses, the following estimates were made; 0 to 4 were late-fall Chinook, 0 to few were winter Chinook, approximately 100 were spring Chinook, and 9 to 14 were fall Chinook. We believe relatively few fall Chinook were able to jump over the barrier weir and avoid detection at the fish ladder monitoring station, due to low flows in 2001. Low flows probably made jumping the weir more difficult and salmonids would have likely taken the easier route through the open fish ladder. These passage estimates were made while the fish ladder into Battle Creek was open which included almost the entire spring Chinook migration period, but did not include the entire migration period for winter, fall, and late-fall Chinook. When the fish ladder into Battle Creek was closed, an unknown number of salmonids may have jumped the barrier weir. Therefore estimates of winter, fall, and late-fall Chinook may be partial counts of salmon entering the watershed above the barrier weir. An additional 98 unclipped Chinook were passed above the barrier weir prior to 3 March by CNFH personnel during their late-fall Chinook propagation program. While these 98 Chinook could have been from any of the four runs of Chinook, they were most likely late-fall Chinook. Based on stream survey redd counts (32 total redds), we estimate a spawning population of 64 spring (and some fall) Chinook.

Overall, water temperatures in 2001 were adequate for spring Chinook to successfully produce juveniles but at a reduced number due to temperature-related spawner and egg mortality. During holding periods, all Chinook that we observed were subjected to water temperatures which could result in some mortality and reduced fertility. Some incubating Chinook eggs experienced high water temperatures in the South Fork, upper mainstem Battle Creek, and potentially in the North Fork. Spring Chinook appeared to delay spawning until temperatures were more suitable. Our temperature, redd distribution, and spawn timing data taken in combination suggest that most Chinook eggs were in good temperatures for the majority of their incubation period.

We estimate that 1,382 clipped and 225 unclipped rainbow trout (*Oncorhynchus mykiss*) passed above the CNFH barrier weir in 2001 for a total of 1,607 rainbow trout. Of these, we estimate that 1,386 were hatchery steelhead and 221 were natural-origin rainbow trout.

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Introduction

Battle Creek is important to the conservation and recovery of federally listed anadromous salmonids in the Central Valley of California. Restoration actions and projects planned or underway in Battle Creek focus on providing habitat for the endangered Sacramento River winter Chinook, (*Oncorhynchus tshawytscha*) the threatened Central Valley spring Chinook, and the threatened Central Valley steelhead (*Oncorhynchus mykiss*). The geographic range of the current winter Chinook Evolutionary Significant Unit is small and is limited to the mainstem of the Sacramento River between Keswick Dam and Red Bluff, 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 crucial to the recovery of spring Chinook and steelhead.

Since the early 1900's, a hydroelectric power generating system of dams, canals, and powerhouses, now owned by Pacific Gas and Electric Company (PG&E), has operated in the Battle Creek watershed in Shasta and Tehama Counties, California. The hydropower system has had severe impacts upon anadromous salmonids and their habitat (Ward and Kier, 1999). 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 including "to increase flows past PG&E's hydropower diversions in two phases to provide adequate holding, spawning, and rearing habitat for anadromous salmonids" (USFWS, 1997).

From 1995 until 2001, the CVPIA Water Acquisition Program contracted with PG&E to increase minimum stream flow in the lower reaches of the North Fork and South Fork of Battle Creek. This initial flow augmentation project was to provide flows between 25 and 35 cfs below Eagle Canyon Dam on the North Fork and below Coleman Diversion Dam on the South Fork.

The federal and State of California interagency program known as the CALFED Bay-Delta Program (CALFED) has funded, along with PG&E, the Battle Creek Salmon and Steelhead Restoration Project (Restoration Project). The Restoration Project may result in large increases in minimum instream flows in Battle Creek, removal of 5 dams, and construction of fish ladders and fish screens at 3 other dams.

Planning, designing, and permitting of the Restoration Project has taken longer than originally anticipated. Funds for increased minimum flows in Battle Creek from the CVPIA Water Acquisition Program ran out. Therefore, in 2001, CALFED funded the Battle Creek Interim Flow Project to obtain from PG&E flows of approximately 30 cfs in the North Fork downstream of Eagle Canyon Dam. These CALFED funded flows began in 2001 and will continue until the Restoration Project is under construction (currently scheduled for 2003). The intent of the Interim Flow Project 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.

PG&E currently has a requirement under its Federal Energy Regulatory Commission license to provide minimum instream flows of 3 cfs downstream of diversions on the North Fork and 5 cfs downstream of diversions on the South Fork. Under the Interim Flow Project, PG&E would increase instream flows up to 30 cfs through reductions in their hydropower diversions from May through October. The interim project was funded to provide 30 cfs in the North Fork, with no funds available for additional flows on the South Fork, however an agreement was reached which allows for changing flows on either of the forks based on environmental conditions. Relevant environmental conditions include water temperatures, numbers and locations of live Chinook and redds. In 2001, increased flows were provided only on the North Fork in part based on observations of higher Chinook spawning on the North Fork than on the South Fork. For instance, redd counts from 1995 to1998 indicated that 39% of spawning occurred in the North Fork versus 23% in the South Fork (RBFWO, unpublished data).

The goal of our monitoring project is to provide fisheries information for the adaptive management of anadromous salmonid restoration in Battle Creek including the Interim Flow Project. The following objectives were from the original proposal for the monitoring project with modifications shown in italics:

1) collect life history information on a potentially remnant population of spring Chinook;
2) assess the effectiveness of the winter Chinook propagation program; *This objective was subsequently restricted to verifying that hatchery-origin winter Chinook are no longer returning to Battle Creek.*
3) assess the feasibility of developing a winter Chinook population in Battle Creek; *We did not collect sufficient data to address this issue because contractual limitations and landowner access concerns delayed implementation of the stream surveys. Therefore, we did not perform stream surveys during the time when winter Chinook would be present in Battle Creek.*
4) evaluate the effectiveness of ongoing restoration actions. *We collected data useful in evaluating the flows obtained through the CVPIA Water Acquisition Program and the Interim Flow Project*.

Some objectives for the project were modified because of significant restoration progress that occurred between the time the monitoring project was proposed and the project was implemented. The proposal for the current investigations was developed in 1998 before the Restoration Project or the Interim Flow Projects were developed. Although the restoration actions to be monitored were not specified in the project proposal, when the Interim Flow Project was begun, the current project was ready to provide monitoring information that has proven useful for the adaptive management of Battle Creek flows. In addition, during the interim between the monitoring projects proposal and implementation, returns of hatchery-origin winter Chinook to Battle Creek ceased following transfer of the propagation program to Livingston Stone National Fish Hatchery. Therefore the effect of hatchery-origin winter Chinook returns was not assessed. Due to these modifications, our report focuses on objectives 1 and 4 especially as they relate to spring Chinook.

The current investigations were carried out in 2001 by the Red Bluff Fish and Wildlife Office (RBFWO) under a one year contract from the CALFED Bay Delta Program. Between 1995 and 2000, the RBFWO Hatchery Evaluation Program performed similar fisheries investigations related to the effects of the Fish and Wildlife Service winter Chinook propagation program that was formerly located at Coleman National Fish Hatchery (CNFH) on Battle Creek. The RBFWO intends on reporting not only the results of adult salmonid monitoring efforts from 1995 to the present, but also the results of juvenile salmonid monitoring efforts from 1998 to the present. The interpretation of the accumulated adult and juvenile monitoring data is beyond the scope of this one year report. A second CALFED grant has been secured by the RBFWO to fund adult salmonid monitoring in Battle Creek beginning in 2002. This second grant was designed to support most of the monitoring needs of the Restoration Project Adaptive Management Plan.

Study Area

Battle Creek is located in northern Tehama and southern Shasta counties, California, and is fed by the volcanic slopes of Lassen Peak in the southern Cascade Range and numerous springs (Figure 1). Battle Creek eventually enters the Sacramento River (river mile (rm) 272) east of the town of Cottonwood, California. Battle Creek is comprised of the North Fork Battle Creek (approx. 29.5 miles in length from head waters to confluence), the South Fork Battle Creek (approx. 28 miles in length from headwaters to confluence), the mainstem Battle Creek (16.6 miles from the confluence of the north and south forks to the Sacramento River), and many tributaries. Battle Creek has been identified as having high potential for fisheries restoration because of its relatively high and consistent flow of cold water. It has the highest base flow (dry-season flow) of any tributary to the Sacramento River between the Feather River and Keswick Dam (Ward and Kier, 1999). Our specific areas of study (Figure 1) were at the Coleman National Fish Hatchery (CNFH) barrier weir on the mainstem Battle Creek (rm 5.8) and on the North Fork below Eagle Canyon Dam (5.3 miles in length), the South Fork below Coleman Diversion Dam (2.5 miles in length), and the mainstem Battle Creek above rm 2.8 (13.8 miles in length). Eagle Canyon Dam and Coleman Diversion Dam were considered the upstream limits of salmonid distribution during the study because fish ladders on the dams were closed.

Methods

We used CNFH barrier weir fish trapping and video counting along with stream surveys to monitor adult salmonids in Battle Creek between 3 March and 31 October 2001. Chinook salmon and steelhead returning to Battle Creek were identified as either having an adipose fin (unclipped) or not having an adipose fin (clipped). We considered all clipped fish to be hatchery-origin and unclipped fish to be either natural-origin or hatchery-origin (not all hatchery fish are clipped). Unclipped Chinook returning to Battle Creek during our monitoring period could be mostly spring Chinook. However, it is also possible that some unclipped Chinook could be late-fall, winter, or fall run due to overlapping periods of migration. Therefore, we chose not to explicitly classify all unclipped Chinook as spring run. We use the term rainbow trout to refer to all *Oncorhynchus mykiss*, including anadromous steelhead, because of the difficulties in differentiating the anadromous and non-anadromous forms.

Coleman National Fish Hatchery Barrier Weir

Operation of the CNFH barrier weir (the barrier weir) blocked upstream passage of fish through the fish ladder (rm 5.8) from 1 September 2000 through 3 March 2001. During this period, fish were periodically directed into holding ponds at CNFH where fall and late-fall Chinook and steelhead were used in propagation programs. Passage of fishes upstream of the barrier weir in Battle Creek was afforded from 3 March through 31 August 2001 by opening the fish ladder. Fish passage was monitored during this time period using live trapping until 8 May followed by underwater videography until 31 August.

Trapping.—A false bottom fish trap was used to capture Chinook, rainbow trout, and other non-targeted species as they passed through the fish ladder at the barrier weir. The trap was placed in the upstream end of the vertical slot fish ladder. Personnel from the Red Bluff Fish and Wildlife Office (RBFWO) and CNFH operated the trap approximately 8 hours a day (07:30 - 15:15), 7 days a week from 3 March through 8 May 2001. During hours when the trap was not operated (15:15 - 07:30), fish were allowed to enter the trap, but the exit was closed blocking fish passage. Prior to operation each morning, the trap was cleaned, weather conditions were noted, and water temperature was documented. Water temperature was recorded hourly by an Onset Stowaway probe located at the bottom of the trap. When water temperature exceeded 60°F, trapping for that day was terminated to minimize the effects of handling. Trapping was terminated for the season and videography began when water temperatures exceeded 60°F for a majority of the trap operation period.

The trap was checked at least every 30 minutes. However, it was serviced more often if fish were observed. Captured non-target fish were usually identified to species, counted, and released upstream. Captured salmonids were netted from the trap and immediately transferred to a 250 to 400 gallon fish distribution tank. Water temperature in the fish distribution tank was maintained to within 5.4°F of Battle Creek water temperature. Sodium chloride (1.0%) and Poly Aqua™ (artificial slime; 1.0%) were added to the tank to reduce fish stress and preserve their slime coat. While in the fish tank, Chinook and rainbow trout were anesthetized with CO_2.

Anesthetized salmonids were measured (fork length) to the to the nearest millimeter, examined for scars and tissue damage, observed for the presence or absence of a mark (an adipose-fin clip or floy tag), and gender identified when possible. Clipped Chinook were sacrificed and coded-wire tags were recovered and decoded to determine run designation, hatchery of origin, and age. We did not sacrifice clipped rainbow trout. Unclipped Chinook (after genetic sampling) and rainbow trout (clipped and unclipped) were placed in an 96 x 25 cm aluminum tube for recovery from anesthetization prior to being volitionally released upstream of the barrier weir.

Video counts.—An underwater video camera (Fish Eye Pro) was used to record Chinook, rainbow trout, and other non-target species as they passed through the fish ladder at the barrier weir. The camera was placed in a modified weir at the upstream end of the fish ladder. Video monitoring of fish passage was conducted from 8 May through 31 August. A lighting system allowed for 24 hour monitoring. A time-lapse video recorder was used to reduce maintenance and viewing time. The time mode on the video cassette recorder was set to 24 hours and 120 minute-8 mm tapes were used. A time-date stamp was recorded. Tapes were viewed until a fish was observed, then reviewed at slow playback speed or "freeze frame" mode to assist in identification and mark detection. The certainty of the observation was rated as good, fair, or poor. A good rating signified complete confidence in determining species and presence or absence of an adipose fin; fair suggested confidence in determining species and presence or absence of an adipose fin but additional review was needed to classify the fish; and poor suggested uncertainty in determining species and presence or absence of an adipose fin.

The quality of the picture was also rated as good, fair, or poor. Good signified a clear picture throughout the day; fair suggested objects were discernable throughout the day but extra review was needed; and poor suggested that objects were indistinguishable most of the day.

All Chinook and rainbow trout passing the barrier weir were recorded onto a file tape and the tape was reviewed by more experienced personnel to confirm species identification and presence or absence of an adipose fin. The total number of clipped and unclipped Chinook and rainbow trout observed was recorded. If the adipose fin was unidentifiable, then Chinook and rainbow trout were classified as unknown clip status. Additionally, the hours of fish passage and the hours of video recorded fish passage were logged.

Passage estimation.—We estimated the number of clipped and unclipped Chinook and rainbow trout passing through the barrier weir fish ladder in 2001. For each week of trapping, total passage of clipped and unclipped salmonids was estimated by apportioning unknown clip status Chinook or rainbow trout counts (e.g. fish that accidently escaped the trap prior to being examined for an adipose fin) according to the proportion of clipped and unclipped fish captured during the same week. For each week of video monitoring, total passage was estimated by apportioning any unknown clip status fish and then expanding observed counts according to the amount of time passage was allowed but not recorded due to poor video quality or equipment malfunction. Total passage for 2001 was calculated by summing weekly passage estimates at the barrier weir as well as the number of clipped and unclipped Chinook and rainbow trout released into upper Battle Creek by CNFH prior to 3 March. The equations used for estimating passage during barrier weir trapping were:

$$\mathrm{P}_{\mathrm{tu}} = \sum_{i=1}^{10} \left(\left[\left(\frac{u_i}{(c_i + u_i)} \right) * unk_i \right] + u_i \right)$$

$$\mathrm{P}_{\mathrm{tc}} = \sum_{i=1}^{10} \left(\left[\left(\frac{c_i}{(c_i + u_i)} \right) * unk_i \right] + c_i \right)$$

where:

P_{tu} = passage estimate for unclipped Chinook or rainbow trout during barrier weir fish trap operation;

P_{tc} = passage estimate for clipped Chinook or rainbow trout during barrier weir fish trap operation;

c = actual number of clipped Chinook or rainbow trout observed passing the barrier weir during the week;

u = actual number of unclipped Chinook or rainbow trout observed passing the barrier weir during the week;

unk = actual number of unknown clip status Chinook or rainbow trout observed passing the barrier weir during the week;

The equations used for estimating passage during barrier weir video counting were:

$$P_{vu} = \sum_{i=1}^{17} \left(\left[\left(\frac{u_i}{(c_i + u_i)} \right) * unk_i \right] + u_i \right) * \left(\frac{T_i}{V_i} \right)$$

$$P_{vc} = \sum_{i=1}^{17} \left(\left[\left(\frac{c_i}{(c_i + u_i)} \right) * unk_i \right] + c_i \right) * \left(\frac{T_i}{V_i} \right)$$

where:

P_{vu} = passage estimate for unclipped Chinook or rainbow trout during barrier weir video monitoring;

P_{vc} = passage estimate for clipped Chinook or rainbow trout during barrier weir video monitoring;

c = actual number of clipped Chinook or rainbow trout observed passing the barrier weir during the week;

u = actual number of unclipped Chinook or rainbow trout observed passing the barrier weir during the week;

unk = actual number of unknown clip status Chinook or rainbow trout observed passing the barrier weir during the week;

T = number of hours of unrestricted fish passage at the barrier weir during the week; and,

V = number of hours of actual good and fair video recorded fish passage at the barrier weir during the week.

Estimates of the total number of clipped and unclipped rainbow trout returning to Battle Creek in 2001 are not equivalent to estimates of hatchery and natural-origin rainbow trout because CNFH has not always clipped 100% of their steelhead production. We estimate that 99.74% of hatchery-origin steelhead returning to Battle Creek in 2001 were clipped based on the age distribution of hatchery steelhead returning to CNFH (Table 1; K. Niemela, U.S. Fish and Wildlife Service, personal communication) and yearly mark rates for steelhead from CNFH (Table 1; R. Rickert, U.S. Fish and Wildlife Service, personal communication). The total number of hatchery fish passed above the barrier weir was calculated by dividing the total number of clipped fish by 0.9974. The total number of natural-origin rainbow trout was calculated by subtracting the number of hatchery steelhead from the total of all rainbow trout passing above the barrier weir in 2001. The estimated mark rate of steelhead returning in 2001 was calculated using the following standard formula for weighted means (Porkess, 1991):

$$MR_{2001} = \frac{w_{'97}x_{'97} + w_{'98}x_{'98} + w_{'99}x_{'99}}{w_{'97} + w_{'98} + w_{'99}}$$

where:

MR_{2001} = mark rate (percentage clipped) for all hatchery steelhead returning in 2001;

w = weighting factor (percentage returning in 2001 from a given brood year);

x = mark rate (percentage clipped) for a given brood year;

such that:

$$MR_{2001} = \frac{(1\% \bullet 74\%) + (27\% \bullet 100\%) + (72\% \bullet 100\%)}{(1\% + 27\% + 72\%)} = 99.74\%$$

Migration timing.—Migration timing past the barrier weir was determined using fish trap and video counting data. The number of clipped and unclipped Chinook and rainbow trout passing the barrier weir was summed weekly and plotted. Peak as well as onset and termination of migration was noted.

Size, sex, and age composition.—We recorded fork length and sex of Chinook and rainbow trout captured in the barrier weir fish trap and from Chinook carcasses retrieved during stream surveys. Length frequency distributions were developed and male to female sex ratios were calculated. The age of returning Chinook was determined for coded-wire tagged fish. Age vs. length plots were developed for tagged Chinook.

Stream Surveys

We conducted stream surveys of Battle Creek once a month from July through October 2001. The 21.6 mile survey was divided into 7 reaches (Table 2; Figure 1) and required 6 to 7 days to complete, depending on personnel availability. Monthly surveys were scheduled on consecutive week days beginning at the uppermost reaches and working downstream. Reach 7, located below the barrier weir, was not surveyed in September or October due to the abundance of non-target fall Chinook.

Snorkel type surveys were used on all reaches, except for Reach 3. Moving downstream with the current, two or three snorkelers counted Chinook and rainbow trout, carcasses, and redds. Rainbow trout were divided into three size categories; small, medium, and large (we did not count young-of-the-year). We categorized rainbow trout with parr marks as small, rainbow trout with no parr marks but less than 22 inches long as medium, and rainbow trout greater than 22 inches as large. Generally, snorkelers were adjacent to each other in a line perpendicular to the flow. When entering large plunge pools where Chinook could be concealed below bubble curtains, one snorkeler would portage around and enter at the pool tail to count Chinook while the other two snorkelers would enter at the head of the pool through the bubble curtain. When groups of Chinook were encountered, snorkelers would confer with each other to make sure salmon were not missed or double counted.

Reach 3, our only survey reach in the South Fork, was surveyed by two personnel walking upstream along the stream banks. Snorkel surveys were not possible due to the extremely shallow water in the South Fork during the summer of 2001 (stream flows were approx. 7 cfs). On Reach 3, survey personnel counted Chinook, carcasses, and redds but did not count rainbow trout.

When survey personnel encountered carcasses, they would collect genetic tissue samples and scale samples, and record biological information such as fork length, sex, retention of eggs, presence or absence of a tag, and presence or absence of an adipose fin. Heads were collected from all adipose-fin clipped carcasses and from carcasses where the presence of a fin clip could not be determined due too decomposition. Coded-wire tags were later extracted from heads in the laboratory.

Stream flow, water turbidity, and water temperature can all influence the effectiveness of snorkel surveys (Thurow, 1994). We collected data on these three parameters for each snorkel survey. Stream flow was measured at three California Department of Water Resources (DWR) gaging stations. The gaging stations on the North Fork, South Fork, and mainstem Battle Creek were at Wildcat Road Bridge (rm 0.9), Manton Road Bridge (rm 1.7), and CNFH (rm 5.8) respectively. Stream flows are presented as mean daily flow in cubic feet per second (cfs). Turbidity samples were taken at the beginning and end of each reach and analyzed the same day using a Model 2100 Hach Turbidimeter. An average turbidity value was then assigned to each survey day. (In the cases where only one sample was taken, we used that value.) Water temperatures were measured at the beginning and end of each reach using a hand held submersible thermometer.

Holding location.—We located holding areas of Chinook through stream surveys. The date and number of Chinook observed per reach were recorded and exact coordinates of holding locations were documented using a hand held Global Positioning System (GPS) receiver. We used thermal criteria presented by Ward and Kier (1999) to evaluate the suitability of water temperatures in Battle Creek for spring Chinook holding (Table 3). We labeled Ward and Kier's four categories as good, fair, poor, and very poor. We evaluated water temperature data, collected by DWR (S. McReynolds, Department of Water Resources, personal communication), at an upstream site and a downstream site on the South Fork (Reach 3), North Fork (Reach 1-2), and mainstem Battle Creek (Reach 4-6) from 1 June through 30 September. Evaluating temperatures at these sites provide a range of conditions Chinook may have been exposed to when holding in each of these three creek segments.

Spawning location and timing.—We located Chinook spawning areas and estimated time of spawning. The date of first observance and number of redds per reach were recorded and exact coordinates of redds were documented using a GPS receiver. All redds were marked in the field with flagging in order to differentiate between old and new redds. An attempt was made to determine the beginning, peak, and end of Chinook spawning.

We used thermal criteria presented by Ward and Kier (1999) to evaluate the suitability of water temperatures in Battle Creek for spring Chinook egg incubation to the eyed-egg stage (Table 3). Development to the eyed-egg stage would take approximately 17 days at 58˚F (Piper et al. 1982). We labeled Kier's four categories as good, fair, poor, and very poor. Using these criteria we evaluated water temperature data at an upstream site and a downstream site on the South Fork (Reach 3), North Fork Reach (Reaches 1-2), and mainstem Battle Creek (Reach 4-6) from 15 September through 31 October. Evaluating temperatures at these sites provide a range of conditions Chinook eggs may have been exposed to in each of these three creek segments.

Tissue collection for genetic analyses

Tissue samples were collected from unclipped Chinook captured at the fish trap and from carcasses collected during stream surveys. Scissors were used to obtain three small pieces of fin tissue. Two pieces were stored in small vials containing T.E.N. buffer (Tris, EDTA, and NaCl) and one was dried and stored in a scale envelope. One vial sample was sent to Bodega Marine Laboratory (BML) for genetic analyses and the other two samples were archived at the RBFWO. At BML, DNA was extracted using the Puregene method and individuals were genotyped at 7 loci (Hedgecock et al. 2001). Two separate methods were then used to analyze the genetic information; mixed stock analysis (MSA) and individual assignment (WHICHRUN). MSA does not assign a run to individual fish but assigns proportions of a mixed stock to specific runs. MSA has a minimum sample size requirement of approximately 100. WHICHRUN is used to determine if an individual fish is a winter Chinook or non-winter Chinook.

Results

Coleman National Fish Hatchery Barrier Weir

Trapping.—A total of 45 Chinook were captured in the barrier weir trap between 3 March and 8 May 2001. Of these, 14 were clipped, 30 were unclipped, and 1 escaped (unknown clip status) which was designated as unclipped (Table 4).

We retrieved coded-wire tags from the 14 clipped Chinook captured in the trap. Tag codes revealed all 14 to be late-fall Chinook from CNFH (Appendix A). All tagged CNFH Chinook were from hatchery releases where 100% of the fish received a tag and an adipose-fin clip. We did not recover any coded-wire tagged winter Chinook.

A total of 86 rainbow trout were captured in the barrier weir trap. Of these, 25 were clipped, 57 were unclipped, and 4 escaped prior to being examined for an adipose fin (Table 5). We designated the 4 unknown clip status rainbow trout as unclipped based on the proportion of clipped and unclipped observed for that particular week (or surrounding weeks). We released all rainbow trout upstream of the weir and therefore did not recover coded-wire tags.

Video counts.—A total of 74 Chinook were observed passing through the barrier weir fish ladder between 8 May and 31 August 2001. Of these, 4 were clipped, 68 were unclipped, and 2 were of unknown clip status. We designated the 2 unknown clip status Chinook as unclipped based on the proportion of clipped and unclipped observed for that particular week (Table 6). During the video monitoring period, 81% (2254.7 hours) of the afforded passage was video recorded with a good or fair picture quality (Table 6). Video equipment malfunctioned and no recordings were made from 10 July through 24 July. However, for this period we have other data that suggested that no Chinook were passing; 1) a VAKI Riverwatcher electronic fish counting system (installed at the video monitoring station) did not detect any Chinook; 2) no Chinook were observed passing 10 days prior to and 20 days following the unrecorded period; and 3) water temperatures during this period at the mouth of Battle Creek averaged 70°F. High water temperatures may have discouraged Chinook from entering Battle Creek. Therefore, using the combination of monitoring methods including video and the VAKI system, we monitored 95% of afforded Chinook passage past the barrier weir during this period.

A total of 35 rainbow trout were observed on video tape passing through the barrier weir fish ladder. Of these, 4 were clipped, 30 were unclipped, and 1 was of unknown clip status (Table 7). We designated the unidentified rainbow trout as unclipped based on the proportion of clipped and unclipped observed for that particular week. The VAKI system was not used to count rainbow trout. Therefore, using video alone, we monitored 81% of afforded rainbow trout passage by the barrier weir during this period. No passage estimate was made for the period when video equipment malfunctioned (10 July through 24 July) since rainbow trout were not observed passing the barrier weir 6 days prior to and 20 days following the unrecorded period.

Passage estimation.—Passage estimates for clipped and unclipped salmonids are higher than actual numbers observed due to our accounting for unknown clip status fish and our estimates made during periods of poor video quality. We estimate 5 clipped and 111 unclipped Chinook passed through the barrier weir fish ladder into upper Battle Creek between 3 March and 31 August 2001. An additional 98 unclipped Chinook were released above the barrier weir by CNFH personnel prior to opening the barrier weir fish ladder on 3 March (Table 8). These 98 Chinook were diverted from lower Battle Creek into the hatchery as part of the late-fall Chinook propagation program. Because CNFH personnel mark 100% of their late-fall production with an adipose-fin clip and coded-wire tag, these 98 Chinook were considered natural-origin and were released into Battle Creek to spawn naturally.

We estimate 30 clipped and 94 unclipped rainbow trout passed through the barrier weir fish ladder between 3 March and 31 August 2001. An additional 1,352 clipped and 131 unclipped rainbow trout were released above the barrier weir by CNFH prior to 3 March (Table 8). The rainbow trout released above the barrier weir prior to 3 March were taken into the hatchery as part of the steelhead propagation program but were not used as brood stock. Based on a total passage estimate of 1,382 clipped steelhead and a mark rate of 99.74%, we estimate a total hatchery-origin contribution of 1,386 (clipped and unclipped) and a total natural-origin contribution of 221.

Migration timing.—The migration of unclipped Chinook past the barrier weir began the week of 3-10 March (the first week the fish ladder was open) and peaked the week of 13-19 May. The middle 50% of the run (Interquartile Range) passed between 28 April and 7 June (Figure 2). There was a continuous 44 day period (30 June through 13 August) in which Chinook did not appear to migrate above the weir. Following this period, migration of unclipped Chinook was observed during the final 3 weeks of barrier weir fish ladder operation.

The temporal distribution of clipped Chinook observed at the barrier weir appears to be different from that of unclipped Chinook (Figure 2). The migration of clipped Chinook also began the week of 3-10 March but peaked the second week of trap operation and declined steadily through May. One additional clipped Chinook was observed on 26 August. Coded-wire tags revealed that at least the first 14 observed (out of 18 total) were late-fall Chinook from CNFH.

Rainbow trout migrating past the barrier weir showed primary and secondary peaks in passage numbers (Figure 3). Passage of rainbow trout was greatest during the initial week of trap operation (3-10 March), after which weekly counts of rainbow trout gradually declined until 12 May when counts began rising again. A smaller secondary peak of rainbow trout passage occurred the week of 18-26 May. Following the secondary peak, weekly counts of rainbow trout again declined, eventually reaching zero for a period of 41 days (4 July - 13 August). Unlike Chinook, the temporal distributions of clipped and unclipped rainbow trout do not appear to be different.

Size, sex, and age composition.—Chinook captured in the barrier weir trap had a mean fork length of 70 cm and ranged in length from 43 cm to 91 cm (n=41). The length-frequency distribution was approximately normal with a mode of 71-75 cm (Figure 4). The distribution was nearly continuous with gaps at 46-50 cm and 56-60 cm.

Rainbow trout captured in the barrier weir trap had a mean fork length of 45 cm and ranged from 6 to 72 cm (n=81). The length-frequency distribution for rainbow trout was approximately normal with a mode of 46-50 cm (Figure 5). The distribution of rainbow trout lengths was continuous after excluding data from two juveniles (6-15 cm) captured in the trap.

The ratio of male to female Chinook captured in the barrier weir trap was very different for clipped and unclipped fish. The sex ratio for clipped Chinook (which were all late-fall run) was 1:1.8 (n=14). The sex ratio for unclipped Chinook was 1:28.0 (n=29). For rainbow trout, the ratio of male to female was 1:1.9.

Age was determined from tagging records for all coded-wire tagged Chinook captured in the barrier weir trap. The ages of tagged Chinook included 3-year-olds (n=7), 4-year-olds (n=5), and 5-year-olds (n=2). There was overlap in fork length between Chinook of different ages (Figure 6). Age was not determined for unclipped Chinook. Also, age was not determined for rainbow trout, as all coded-wire tagged rainbow trout were released above the barrier weir.

Stream Surveys

During regularly scheduled monthly stream surveys, we observed 22 adult Chinook in July, 27 in August, 25 in September, and 16 in October (Table 9). During regular monthly surveys and supplemental surveys, we observed a total of 32 redds above the barrier weir: 1 in September and 31 in October. We recovered a total of 8 carcasses: 3 in July and 5 in October. One carcass, recovered on 19 October, was an adipose-fin clipped (coded-wire tagged) 3-year-old spring Chinook from Feather River Hatchery (Figure 6; Appendix A). Genetic analysis of the other 7 carcasses is reported in the section *Tissue collection for genetic analyses*.

Total rainbow trout observed by month show that the highest number of trout was 3,300 in August followed by 2,829 in July, 2,698 in September, and 2,515 in October (Table 11). Rainbow trout were counted and categorized as small, medium, and large in all reaches except Reach 3 (Table 10). Small rainbow trout were the dominant size group in the North Fork (reaches 1 and 2) while medium rainbow trout were the dominant size category in mainstem reaches 4 and 5. Mainstem reaches 6 and 7 had near equal numbers of smalls and mediums. Large rainbow trout were most common in the lowest reach (Reach 7). Mean rainbow trout numbers by reach (Table 11) show that Reach 4 had the greatest abundance (896) followed by Reach 1 (698). The fewest rainbow trout were observed in Reach 6 (192). Reach 7 was excluded from the means because it was only surveyed 2 of the 4 months.

Conditions for snorkel type surveys (all reaches except Reach 3) were good to excellent: stream flows were stable (Figure 7), temperatures ranged from 54˚ to 74˚F, and average daily turbidity was low (0.6 to 1.8 NTU). Conditions for walking and helicopter surveys of Reach 3 were excellent as creek flows were low (approx. 7 cfs) and average daily turbidity was very low (0.5 to 0.8 NTU). The presence or absence of an adipose fin usually could not be determined for Chinook seen during our surveys.

Holding location.—Monitoring results indicate Chinook held in Battle Creek for about 4 months (from early June through early October) prior to spawning. Barrier weir monitoring showed that 75% of unclipped Chinook migrating into Battle Creek had passed the weir by 7 June. Stream surveys indicated that most Chinook did not spawn until early October (see below). Therefore, we considered survey observations made during July, August, and September to be during the holding period for spring Chinook in 2001.

From July through September, 68% of Chinook held in the South Fork (Reach 3) and 32 % in the mainstem (reaches 4-7). We did not observe Chinook holding in the North Fork during these three months (Table 9).

Counts of Chinook in the South Fork (Reach 3) were very consistent throughout the summer; either 16 or 17 fish. The majority of these Chinook presumably moved into the South Fork under extremely low-flow conditions (approx. 7 cfs) sometime between 31 May and 19 July. On 31 May during a preliminary helicopter survey, we observed zero Chinook but, by the time regular surveys began on 19 July, we counted 17 Chinook. Throughout the survey period, we repeatedly observed Chinook holding in a few pools, primarily between rm 1.7 and 2.5. Coleman Diversion Dam (rm 2.5) was the upper limit to fish migration on the South Fork due to the impassable fish ladder.

Counts of Chinook in the mainstem were 5 in July, 10 in August, 9 in September, and 7 in October (Table 9). We observed the majority of the Chinook repeatedly in a large deep pool in Reach 4. We observed the other Chinook in changing locations throughout the summer.

Using the Ward and Kier (1999) thermal criteria, we evaluated South Fork water temperatures at Coleman Diversion Dam (rm 2.5) and Manton Road Bridge (rm 1.7; Figure 8). Chinook holding in the South Fork were located between these two sites with the exception of 3 Chinook holding at rm 0.6. At the upstream site, mean daily temperatures were classified as good 73 days (60%) and fair 49 days (40%) between 1 June and 30 September. At the downstream site, temperatures were good 12 days (10%), fair 46 days (38%), and poor 58 days (48%) during the same period with no data available for 6 of the days. Mean daily water temperatures at Manton Road Bridge were on average 5.4˚F higher (SD 1.4) and up to 7.3˚F higher than at Coleman Diversion Dam .

We evaluated North Fork holding temperatures at Eagle Canyon Dam (rm 5.2) and the Coleman Canal crossing (rm 0.1; Figure 9). Fish were not able to pass above Eagle Canyon Dam. At the upstream site, mean daily temperatures were classified as good 122 days (100%) between 1 June and 30 September. At the downstream site, temperatures were good 23 days (19%), fair 97 days (79%), and poor 2 days (2%) during the same period. Average flow in the North Fork was 41 cfs (SD 3.8) during this time period.

We evaluated mainstem Battle Creek holding temperatures near the confluence of the two forks (rm 16.0) and above the Coleman Powerhouse tailrace (rm 7.6; Figure 10). At the upstream site, mean daily temperatures were classified as good 14 days (11%), fair 64 days (52%), and poor 9 days (6%) between 1 June and 30 September with no data available for 35 of the days. At the downstream site, temperatures were good 3 days (2%), fair 36 days (30%), and poor 83 days (68%) during the same period.

Spawning location and timing.—We observed 12 redds in the South Fork, 11 in the North Fork, and 9 in the mainstem (Table 9). In the South Fork, Chinook began spawning by 18 September (1 redd), constructed the majority of their redds in the first two weeks of October, and finished spawning by 16 October (Table 9). Our last survey on the South Fork was a supplemental survey on 31 October. In the North Fork, Chinook began spawning between our surveys on 17 September and 16 October. Our last survey on the North Fork was 16 October. In the mainstem, Chinook began spawning between our surveys on 19 September and 19 October. Our last survey on the mainstem was 19 October. Redds on the South Fork remained clearly visible during subsequent surveys for up to 6 weeks. All other redds were observed during the final survey of the season.

Seventy-two percent of Chinook redds were located in the North Fork and South Fork of Battle Creek. Most of the redds in the South Fork were close to the Coleman Diversion Dam where the fish ladder was impassable. On the North Fork, an open fish ladder allowed Chinook to pass above Wildcat Dam (rm 2.50) and potentially continue up as far as Eagle Canyon Dam (rm 5.25) where the fish ladder was closed. We observed redds above Wildcat Dam, but only as far up as rm 3, which is downstream of a narrow high-velocity cascading waterfall. Downstream of the waterfall, we observed a series of four redds, located within 0.15 miles of each other, on the first four available spawning riffles. One live Chinook was observed in the pool below the waterfall. The waterfall was roughly 4 feet high and 4 feet long.

Using the Ward and Kier (1999) thermal criteria, we evaluated South Fork water temperatures at Coleman Diversion Dam (rm 2.5) and Manton Road Bridge (rm 1.7; Figure 8). Chinook redds in the South Fork were located between these two sites with the exception of 1 redd downstream at rm 1.1. At the upstream site, mean daily temperatures were classified as good 41 days (87%) and fair 6 days (13%) between 15 September and 31 October. At the downstream site, temperatures were good 27 days (57%), fair 7 days (15%), poor 7 days (15%), and very poor 6 days (13%). Average flow in the South Fork was 8 cfs (SD 2.0) during this period.

We evaluated North Fork incubation temperatures at Eagle Canyon Dam (rm 5.2) and Coleman Canal crossing (rm 0.1; Figure 9). Fish were not able to pass above Eagle Canyon Dam. At the upstream site, mean daily temperatures were classified as good 47 days (100%) between 15 September and 31 October. At the downstream site, temperatures were good 28 days (59%), fair 13 days (28%), and poor 6 days (13%). Average flow in the North Fork was 43 cfs (SD 1.8) during this time period.

We evaluated mainstem Battle Creek incubation temperatures near the confluence of the two forks (rm 16.0) and above the Coleman Powerhouse tailrace (rm 7.6; Figure 10). At the upstream site, mean daily temperatures were classified as good 27 days (57%), fair 10 days (21%), poor 8 days (17%), and very poor 2 days (4%) between 15 September and 31 October. At the downstream site, temperatures were good 14 days (30%), fair 8 days (17%), poor 4 days (8%), and very poor 21 days (45%). Average flow for this creek segment was not determined as there is no gaging station above the Coleman Powerhouse tailrace.

Tissue collection for genetic analyses

Samples from 35 Chinook (27 from barrier weir trapping and 8 from carcasses collected after July 18) were analyzed by BML (Hedgecock et al. 2002). Using the WHICHRUN individual run assignment methodology, 33 of the sampled fish were determined to be non-winter Chinook and 2 could not be analyzed due to the poor quality of the tissue samples (Appendix B). Although mixed stock analysis (MSA) is not recommended for sample sizes below 100, the MSA results suggested the sample contained no winter Chinook, and assigned 92% of the sample as spring Chinook and 8% as fall Chinook.

Discussion

We estimate 5 clipped and 111 unclipped Chinook passed through the Coleman National Fish Hatchery (CNFH) barrier weir fish ladder into upper Battle Creek between 3 March and 31 August 2001. It is difficult to precisely apportion these fish to individual runs of Chinook because of overlaps in migration timing between runs. However, based on a combination of information from migration timing, coded-wire tag recoveries, and genetic analyses, the following estimates were made: 0 to 4 were late-fall Chinook, 0 to few were winter Chinook, approximately 100 were spring Chinook, and 9 to 14 were fall Chinook. We believe relatively few fall Chinook were able to jump over the barrier weir and avoid detection at the fish ladder monitoring station, due to low flows in 2001. These passage estimates were made while the fish ladder into Battle Creek was open which included almost the entire spring Chinook migration period, but did not include the entire migration period for winter, fall, and late-fall Chinook. When the fish ladder into Battle Creek was closed, an unknown number of salmonids may have jumped the barrier weir. Therefore estimates of winter, fall, and late-fall Chinook may be partial counts of salmon entering the watershed above the barrier weir. Our use of “few”, “about”, “approximately”, and numerical ranges are deliberate to describe the degree of certainty and variability of our estimates.

An additional 94 unclipped Chinook were passed above the barrier weir prior to 3 March by CNFH personnel during their late-fall Chinook propagation program. Late-fall Chinook broodstock are collected at CNFH from mid-December through February. Since 1992, CNFH has adipose-fin clipped and coded-wire tagged 100% of their late-fall production. Therefore, unclipped Chinook taken into the hatchery during this period are considered to be natural-origin late-fall and are released above the barrier weir. Of the released fish, some could have been late-arriving fall Chinook (hatchery or natural-origin), natural-origin winter Chinook, or natural-origin spring Chinook. Based on run timing and the absence of winter Chinook passing the barrier weir during the period of trap operation, we suggest that most of the 94 unclipped fish released prior to 3 March were late-fall Chinook and perhaps a few were early returning spring Chinook. Genetic samples were not collected from the released fish.

Run identification of Chinook is difficult for the period of trap operation at the barrier weir (3 March to 8 May) because this period coincides with the end of the upper Sacramento River late-fall run migration, the middle and end of the winter run migration, and the beginning of the spring run migration (Vogel and Marine, 1991). We believe that nearly all unclipped Chinook (n=29) released above the barrier weir during trap operation were spring Chinook for the following reasons: 1) our estimate of unclipped late-fall Chinook was 0 or 1; 2) no winter Chinook were genetically identified; 3) the temporal distribution coincides with other nearby spring Chinook populations; and 4) MSA genetic analysis suggests that most were spring Chinook. We recovered coded-wire tags from all clipped fish captured in the trap (n=14), all of which were identified as late-fall Chinook. It may be that 1 unclipped Chinook released above the barrier weir during this same period may have been a late-fall run considering that a 1:11 ratio of unclipped to clipped late-fall Chinook entered CNFH in 2001. Tissue samples from 27 of the unclipped Chinook captured in the trap were submitted for genetic analyses. The WHICHRUN genetic method determined all to be non-winter Chinook. The MSA genetic method (which included 8 additional samples collected later during the stream survey period), although not recommended for sample sizes less than 100, suggested that none were winter Chinook and apportioned 92% as spring Chinook, 8 % as fall Chinook, 0% as late-fall Chinook.

The first half of the video monitoring period (8 May through 1 July) coincides with the very end of late-fall Chinook migration, the end of winter Chinook migration, the middle and end of spring Chinook migration, and possibly the very beginning of fall Chinook migration. We estimate 4 clipped Chinook passed the barrier weir during this period and they appear to represent the tail end of the hatchery late-fall migration (Figure 2). (One clipped and coded-wire tagged spring Chinook from Feather River Hatchery was recovered during a stream survey and may have passed during this period.) The 1:11 ratio of unclipped to clipped late-fall Chinook entering CNFH in 2001, and the 4 clipped fish video observations suggest that it is unlikely that any unclipped late-fall passed the weir during this period.

After video monitoring was initiated, the migration of unclipped Chinook continued to increase, peaked the week of 13-19 May, and then gradually declined to zero by 30 June (Figure 2). This temporal distribution resembles the migration timing of spring Chinook in upper Sacramento River tributaries such as Mill and Deer creeks which typically begins in March, peaks during May, and ends in early July (C. Harvey Arrison, California Department of Fish and Game, personal communication). Unclipped Chinook also could have been winter run but we believe few to none were because winter run were not detected during the period of trap operation. We also believe it is unlikely that unclipped fall Chinook passed the barrier weir prior to 1 July as less than 5% of the run are reported to pass Red Bluff Diversion Dam (located on the Sacramento River 29 miles downstream of Battle Creek) by 15 July (Vogel and Marine, 1991).

The second half of the video monitoring period (1 July through 31 August) began with 45 consecutive days during which Chinook did not pass above the barrier weir and ended with a final pulse of an estimated 14 Chinook (1 clipped) passing the barrier weir from 14-31 August. The 1 clipped Chinook was most likely either a CNFH fall run (CNFH marked 8% of their fall run production in 1998) or the Feather River Hatchery spring run recovered during a stream survey. Unclipped Chinook passing the weir in August may have been either spring or fall Chinook. The distinct and prolonged temporal separation between the primary and secondary (August) migration periods of unclipped Chinook suggests that these fish were from two separate populations with the August fish representing the beginning of the fall Chinook migration. MSA genetic test results indicate that 8% of the genetic samples were fall Chinook. Applying the 8% fall Chinook of the genetic samples to the 111 unclipped Chinook passing the barrier weir suggests that 9 of the unclipped Chinook were fall run. Application of MSA population percentages should be viewed with caution due to our small sample size and because genetic sampling was not evenly distributed throughout the entire monitoring period. Based on the temporal distribution of genetic sampling, fall Chinook would have been underrepresented; 27 of the samples were collected during barrier weir trapping, prior to fall Chinook migration, and only 8 samples were collected during the stream survey period from either spring or fall Chinook. High water temperatures at the mouth of Battle Creek during July and early August may have created a thermal barrier, discouraging Chinook from entering Battle Creek and delaying the migration of some spring run. Therefore, some of the 14 Chinook passing the weir in August could have been spring Chinook.

Chinook have been observed jumping over the CNFH barrier. It may be that at flows less than 350 cfs, the water flowing over the apron of the barrier weir is too shallow for most salmonids to gain enough speed to jump the height of the weir (USFWS, 2001). During the 2001 monitoring period, mean daily flows were below 350 cfs for 116 days (64% of the monitoring period). Low flows probably made jumping the weir more difficult and salmonids would have likely taken the easier route through the open fish ladder and our monitoring station.

After the fish ladder was closed on 31 August, flows remained below 350 cfs until 20 November effectively blocking the passage of fall Chinook above the barrier weir and reducing the potential for fall Chinook to interbreed with spring Chinook. Stream survey counts of live Chinook can be an indicator of fall Chinook jumping the barrier weir in October when large numbers of fall Chinook are in Battle Creek below the barrier weir. For example, 1998 was a high flow year and average monthly stream survey counts of adult Chinook in July, August, September, and October were 7, 26, 65, and 253 (the barrier weir was closed on 1 July in 1998). In contrast, 2001 was a low flow year and stream survey counts for the same months were 22, 27, 25, and 16. These results suggest that relatively few fall Chinook jumped the weir in 2001.

No winter Chinook were captured during trapping based on coded-wire tag data and genetic analyses. Zero to few were estimated to have passed during video monitoring based on migration timing and the absence of winter Chinook during trapping. Winter Chinook may have jumped the barrier weir or may have been a portion of the 94 Chinook passed upstream of CNFH during late-fall Chinook propagation.

Sex ratio was determined for clipped and unclipped Chinook captured in the barrier weir trap. The male to female sex ratio was 1 to 1.8 (n=14) for clipped Chinook and 1 to 28.0 (n=29) for unclipped Chinook. The sex ratio for clipped (late-fall) Chinook is within the normal range of values reported from other Central Valley Chinook investigations (Snider et al.1998; Snider et al. 1999), but the sex ratio for unclipped Chinook is well outside the normal range. One explanation for the extreme difference in sex ratios is that male late-fall Chinook (clipped) captured in the trap are almost ready to spawn, express sex products when gently squeezed, display fully developed secondary sex characteristics such as a hooked jaw and large teeth, and were accurately and easily classified as males. In contrast, unclipped male Chinook captured in the trap may likely be spring Chinook entering Battle Creek several months prior to spawning. Spring Chinook entering the trap would not be ripe (sex products could not be extruded by gently squeezing the belly), would not display well developed secondary sex characteristics, and may have been misidentified as females. The unlikely sex ratio for unclipped Chinook captured in the trap may support the hypothesis that the majority of these fish were spring Chinook.

We estimate 1,382 clipped and 225 unclipped rainbow trout were released above the CNFH barrier weir in 2001 for a total of 1,607 rainbow trout. Of these, we estimate that 1,386 were hatchery steelhead and 221 were natural-origin rainbow trout. Because CNFH has marked 100% of their steelhead production since 1998 and CNFH steelhead return as either 2, 3, or 4 year-old fish (Table 1), this is the last year that we would expect to find unclipped hatchery steelhead in Battle Creek.

The video recorded portion of barrier weir monitoring began 8 May and continued through 31 August. During this period, we were able to monitor 95% of Chinook passage (81% using video footage and 14% using the VAKI electronic fish counter when video equipment malfunctioned) and 81% of rainbow trout passage. We installed the VAKI system in 2001 on a trial basis to test its usefulness as a backup system to video taping. The VAKI system counted adult Chinook passage but its infrared imaging system could not reliably detect the presence or absence of an adipose fin or differentiate between species of smaller size.

We monitored the movement and spawning of adult Chinook observed migrating into upper Battle Creek by conducting stream surveys. Surveys began in late July and ended in late October. In past years, surveys typically began in early June but were postponed in 2001 due to delays in acquiring written permission from landowners to access private lands. Survey dates allowed for effective monitoring of spring Chinook but were too late in the year to effectively monitor the movement and spawning of late-fall or winter Chinook. We recommend beginning future surveys in early May to be able to detect possible winter Chinook spawning.

Stream survey results indicate many Chinook held in Battle Creek for about 4 months prior to spawning; from early June through early October. Chinook held mainly in the South Fork Battle Creek and, to a lesser degree, in the mainstem Battle Creek. Chinook were not observed in the North Fork until after spawning began in October suggesting either that we missed fish in the North Fork due to flow and complex geomorphology or that Chinook holding in the mainstem moved up into the North Fork to spawn. Actual Chinook numbers in the North Fork may have been higher than we counted. Stream survey counts are not population estimates but indexes of abundance.

Stream surveys in the two forks may have observed very different proportions of Chinook, because lower flow in the South Fork made observation easier and geomorphology in the North Fork made observation more difficult. The North Fork stream channel contains complex rock and stream channel formations including clusters of large boulders, narrower canyon walls which cast shadows, a steeper gradient resulting in more bubble curtains and more turbulence, and more safety distractions for snorkelers, all of which can reduce the likelihood of seeing Chinook.

We were nonetheless surprised to observe up to 17 Chinook holding in the South Fork and none holding in the North Fork since conditions were often poor in the South Fork and much better in the North Fork. In the North Fork, the Interim Flow Project provided base flows of approximately 30 cfs resulting in suitable water temperatures for spring Chinook holding. In contrast, South Fork flows downstream of Coleman Diversion Dam were reduced for the season to 5 cfs on 31 May, causing water temperatures to rise quickly.

During May, PG&E stopped diverting water from the South Fork at Coleman Diversion Dam during maintenance of the Coleman Powerhouse. The planned powerhouse outage resulted in increased flows in the South Fork for a few weeks before flows decreased to 5 cfs for the remainder of the dry season. The increased flows may have attracted Chinook into the South Fork where they would have been negatively impacted by high water temperatures and lack of habitat when flows decreased following the outage. Flows at Manton Road Bridge were as high as 132 cfs for several weeks. Flows were ramped down to 58 cfs on 21 May, and to 25 cfs on 22 May. On 23 May we surveyed the South Fork by helicoptor and on the ground and saw 2 Chinook the same day that PG&E personnel reported seeing 4 Chinook just downstream of Coleman Diversion Dam. Flows were ramped down to 15 cfs later that day and then maintained for a week to allow Chinook to back out of the South Fork. On 31 May we surveyed by helicopter and on the ground and saw no Chinook on the South Fork. Flows were ramped to 5 cfs later that day. On 19 July our stream survey counted 17 Chinook and 3 carcasses on the South Fork. On 30 July our stream survey counted 16 Chinook and our helicopter survey saw 14 Chinook in the South Fork suggesting that our helicopter surveys successfully detected Chinook. Subsequent stream surveys saw similar numbers of Chinook suggesting that they stayed put under adverse temperature conditions and that they did not back down. Decreased flows and resulting high water temperatures in the South Fork apparently did not prevent Chinook from moving in as the majority entered the South Fork following the 31 May flow reduction (0 Chinook were observed before and a maximum of 17 Chinook were observed after the flow reduction).

Observations on the South Fork suggest four possibilities: 1) that few Chinook were attracted into the South Fork during the outage; 2) that many Chinook were attracted into the South Fork during the outage but that they moved back out as flows were ramped down. We have no evidence for this and we suggest that if so, they must have backed down before our helicopter surveys; 3) that Chinook were attracted into the South Fork later during low flows because they were returning to their natal stream. Chinook returning to the South Fork may have originated from that creek and chose to return to their natal stream in spite of unfavorable conditions. Assuming most spring Chinook return as 3-year-old fish, adults returning in 2001 would have been spawned in 1998. In 1998 conditions in the South Fork were favorable for Chinook production as stream flows were approximately 34 cfs in August and September and 85 redds were observed in the South Fork; and 4) that Chinook were falsely attracted into the South Fork later during low flows due to extensive mixing of North Fork water into the South Fork by the PG&E hydropower system (Ward and Kier, 1999). We have no means to distinguish this possibility from number 3.

During the holding period, all Chinook that we observed were subjected to “fair” water temperatures which could result in some mortality and reduced fertility. At Manton Road Bridge (South Fork rm 1.7) water temperatures were “poor” for 58 days (48%) between 1 June and 30 September. Spring Chinook holding in poor conditions do not spawn successfully. Most Chinook holding in the South Fork were distributed upstream of the bridge in cooler water but three Chinook were repeatedly observed downstream of the bridge.

Chinook spawned in all six survey reaches above the barrier weir. The greatest density of redds occurred in the South Fork (Reach 3) followed by the lower North Fork (Reach 2). For Reach 3, twice-a-month surveys indicate that spawning began in mid-September, peaked in early October, and ended by mid-October. In all reaches other than Reach 3, spawning was only documented on the final monthly survey of the year (15-19 October) at which time live Chinook were also observed and may have spawned at a later date.

We did not survey often enough to establish specific spawning dates for determining the complete temperature regime that incubating Chinook eggs experienced. We were able to determine that Chinook eggs incubating in the South Fork and upper mainstem Battle Creek (reaches 4 and 5) experienced water temperatures at least as bad as “fair” which possibly caused some egg mortality. In addition, it is possible that incubating Chinook eggs experienced water temperatures as bad as “fair” in the North Fork and “poor” in mainstem Reach 5 and in the South Fork. Redds in Reach 6 were constructed below the Coleman Powerhouse tailrace which introduces relatively cold water, suitable for egg incubation, back into Battle Creek.

Spawning of potential spring Chinook may have been delayed as 95% of upper Sacramento River spring run are reported to spawn by mid-September (Vogel and Marine, 1991). On Mill Creek, the peak of spawning activity for spring Chinook was estimated to be the last week of September and the first week of October (Harvey Arrison, 2001). In Battle Creek, in previous years with better water temperatures, spring Chinook began spawning by mid-September (RBFWO, unpublished data). In 2001, Chinook holding in the South Fork may have delayed spawning because of unsuitably high water temperatures and low flows. We observed redds in the South Fork being built progressively farther downstream as the spawning season progressed. We observed the first redd in the coolest water immediately below Coleman Diversion Dam (rm 2.5) on 18 September. At this time water temperatures for egg incubation were rated as fair at the dam but very poor (lethal) downstream at Manton Road Bridge (rm 1.7). By the following survey on 3 October, water temperature ratings had upgraded to good at the dam and poor at the bridge and we observed new redds midway between the dam and the bridge. On 16 October, our next survey, water temperatures at the bridge were rated as good for egg incubation and we observed a new redd just downstream of the bridge. Because spawning of potential spring Chinook holding in the South Fork was delayed, their progeny would likely be mis-classified as fall Chinook juveniles according to length criteria commonly used for upper Sacramento River juvenile Chinook.

Overall, water temperatures in 2001 were adequate for spring Chinook to successfully produce juveniles but at a reduced number due to temperature-dependant spawner and egg mortality. During holding periods, all Chinook that we observed were subjected to "fair" temperatures which could result in some mortality and reduced fertility. Some incubating Chinook eggs experienced high water temperatures in the South Fork, upper mainstem Battle Creek, and potentially in the North Fork. Chinook appeared to delay spawning until temperatures were more suitable. Our temperature, redd distribution, and spawn timing data taken in combination suggest that most Chinook eggs were in "good" temperatures for the majority of their incubation period.

Based on redd counts (32 total redds), we estimate a spawning population of 64 Chinook. This estimate assumes a 1:1 sex ratio, each female constructed one redd, all redds were observed, and that no redds were constructed following the conclusion of the stream survey. A 1:1 sex ratio has been used to estimate spring Chinook spawning populations based on redd counts on Mill Creek (Harvey Arrison, 2001). Redds on the South Fork remained clearly visible during subsequent surveys for up to 6 weeks suggesting that we would have had a high likelihood of seeing redds during our surveys that occurred every 4 weeks. Nine Chinook were seen during the final stream survey of each reach, and some of these fish may have spawned subsequent to the survey.

The difference between the spawning estimate of 64 Chinook and the barrier weir count of 116 suggests that not all of the fish that entered the watershed spawned and that there may have been significant pre-spawning mortality. Possible causes of mortality include animal predation, poaching by fishermen, and high water temperatures. One case of poaching was communicated to us by a game warden and the local landowner. We found remains of three other pre-spawning mortalities for a total of 4. In the past few years, biologists have recovered only low numbers of carcasses during stream surveys and we likely missed many pre-spawning carcasses during our surveys as well. Therefore, pre-spawning mortality may be significant during the summer holding period.

This year's estimate of 64 spawning adult Chinook indicates a cohort replacement rate of 0.13 from the 1998 redd-based spawning population estimate of 494 (247 total redds). The low replacement rate could in part be due to a large number of CNFH fall Chinook spawning above the barrier weir in 1998. Relatively high flows at the barrier weir in 1998 probably allowed fall Chinook to jump over the weir and spawn in the upper reaches of Battle Creek. In 2001, low flows over the weir made it nearly impassable for fall Chinook following the closure of the fish ladder on 31 August. There are likely additional unknown causes for the low replacement rate as 67% of 1998 redds were constructed during the spring Chinook spawning period (i.e. prior to 1 October) suggesting that most redds were not from fall Chinook.

Our detection rate of live adult Chinook by stream surveys may have been higher on the South Fork than on other reaches. Based on redd observations, we estimate a total spawning population of 64 and our highest count of live Chinook during monthly stream surveys was 27. Yet, when considering the South Fork only (Reach 3), redd-based estimates and survey counts are much closer; 24 and 17, respectively. As noted previously, differences in flow and geomorphology between reaches may be responsible for differences in detection rate.

Observations of live Chinook and redds on the North Fork indicate that a narrow high-velocity waterfall located at rm 3.05 (Reach 1) may have been a barrier to Chinook migration. One Chinook was seen in the pool below the waterfall and four redds were located on the first four available spawning riffles downstream of the waterfall. No Chinook or redds were seen upstream suggesting that Chinook may not have been able to pass this waterfall at the 30 cfs released below Eagle Canyon Dam during the summer of 2001. Future monitoring is needed to determine if Interim Flow Project (e.g. 25 cfs in 2002) or Restoration Project (35 cfs; NMFS et al. 1999) flows are sufficient for passage at this temporary barrier. The barrier was not identified in a survey of fish passage barriers conducted in 1988, 1989, and 1990 (TRPA, 1998). Increasing stream flow above 30 cfs, at least periodically, would likely allow Chinook to pass this potential barrier.

During stream surveys, we observed the highest number of rainbow trout in the upper mainstem Battle Creek (Reach 4). Possibly a combination of increased habitat due to the higher stream flows of the mainstem and cooler water temperatures in the upstream portion of the mainstem made conditions most favorable in Reach 4. We did not observe any rainbow trout redds as our survey period was well outside their spawning season.

Monthly stream surveys provided important information on the life history of Chinook and rainbow trout populations in Battle Creek and possible effects of the Interim Flow Project on these populations. Additional surveys (e.g. twice-a-month) of all reaches from May through November would provide improved: 1) carcass recovery for genetic analyses and coded-wire tag recovery; 2) run determination; 3) redd based spawner population estimates; 4) evaluation of the effects of water temperature and water flow on spawning location, spawning timing, and egg survival; 5) monitoring of the spatial and temporal separation of threatened spring Chinook and fall Chinook; 6) assessment of the effectiveness of the barrier weir at blocking fish passage; 7) detection of hydropower system induced flow fluctuations which could attract salmonids and potentially induce spawning in unsuitable locations; and 8) response time for adaptive management of flows.

Recommendations

Based on our findings, we make the following recommendations to enhance conditions in Battle Creek for the conservation and restoration of Chinook and steelhead and to improve the effectiveness of our future monitoring efforts. The Fish and Wildlife Service is already implementing 13 of the 16 recommendations.

1. Consider closing the CNFH barrier weir fish ladder earlier in August to inhibit the passage of fall Chinook above the weir and the possibility of fall Chinook interbreeding with spring Chinook.

2. Consider reinstalling the trap in August to collect genetic data to determine run and assess the genetic risks of passing Chinook during August. If genetic techniques capable of quickly determining if an individual Chinook is a spring run become available, selectively passing only spring Chinook could also be considered.

3. Collect tissue samples from unclipped Chinook released above the barrier weir during the CNFH late-fall spawning season for genetic analyses to determine run.

4. Analyze tissue samples from unclipped Chinook collected in 2001 and previous years using newly developing genetic techniques capable of determining if individual fish are spring Chinook or non-spring Chinook.

5. Study the effectiveness of the CNFH barrier weir in blocking Chinook passage while the fish ladder is closed. Relate the number of Chinook jumping over the weir to flow.

6. Study the impact of barrier weir trap operation on the passage of salmonids through the fish ladder.

7. Evaluate the rate of salmonid recapture in the barrier weir trap using the fin clipped during genetic tissue sampling as the identifying mark.

8. When feasible, increase summer flows in the South Fork Battle Creek below Coleman Diversion Dam to provide more suitable water temperatures for Chinook holding.

9. If increased flows cannot be provided throughout the summer in the South Fork, do not attract Chinook into the creek in May during annual maintenance on Coleman Powerhouse. This can be achieved by requesting PG&E to re-schedule the annual maintenance or by physically blocking fish passage using a weir.

10. Begin stream surveys in early May to detect possible winter Chinook spawning and recover carcasses for genetic analysis.

11. Continue stream surveys through November to more accurately determine the beginning, peak, and end of spring and fall Chinook spawning.

12. Increase frequency of stream surveys from May through November to twice a month to provide improved: 1) carcass recovery for genetic analysis and coded-wire tag recovery; 2) run determination; 3) redd based spawner population estimates; 4) evaluation of the effects of water temperature and water flow on spawning location, spawning timing, and egg survival; 5) monitoring of the spatial and temporal separation of threatened spring Chinook and fall Chinook; 6) assessment of the fish-tightness of the barrier weir; 7) detection of hydropower system induced flow fluctuations which could attract salmonids and potentially induce spawning in inappropriate locations; and 8) response time for adaptive management of flows.

13. Investigate the feasibility of monitoring steelhead spawning populations in Battle Creek by conducting stream surveys from December through April.

14. Investigate the feasibility of performing replicate stream surveys to develop confidence intervals for counts of live chinook, carcasses, and redds.

15. Continue to monitor potential fish barriers on the North Fork Battle Creek and consider releasing short term pulse flows below Eagle Canyon Dam to provide improved passage routes for Chinook and steelhead.

16. Install water temperature recording devices at the downstream boundary of stream survey reaches 4 and 5 to better evaluate temperature effects on Chinook adults and egg survival.

Acknowledgments

This monitoring project was funded by the CALFED Ecosystem Restoration Program. We would like to thank the Red Bluff Fish and Wildlife Office staff who worked on this project: Todd Allison, Monty Currier, Melissa Dragan, Chris Eggleston, Shea Gaither, Sarah Giovannetti, Tom Kisanuki, Bill McKinney, Lia McLaughlin, Miguel Morena, Kevin Niemela, Bob Null, Keith Paul, Bill Poytress, Randy Rickert, and Jim Smith. We thank the Coleman National Fish Hatchery staff, especially Scott Hamelberg, Mike Keeler, Fred Peery, John Scott, and Jeff Lauarie for assisting with barrier weir activities, accommodating our project at the hatchery, and the loan of the VAKI fish counting device. We thank the Pacific Gas and Electric staff, especially Jean Oscamou, Chip Stalica, and Dan Kogut, for their cooperation and knowledge which they so freely shared. We are grateful to the landowners of Battle Creek that provided us access and information critical to this project. We thank Sharon Paquin-Gilmore of the Battle Creek Watershed Conservancy and Peggy McNutt of The Nature Conservancy for helping us develop relationships with landowners in the watershed. We thank professor Charles Nelson and Brian Lasagna from California State University, Chico for providing superb maps of the Battle Creek watershed. We thank all the reviewers who provided helpful comments on drafts of this report.

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Tables

TABLE 1.—Mark rates and age distribution of CNFH steelhead returning to Battle Creek in 2001.

Brood year	Percent clipped	Age (in 2001)	Age distribution (for 2001)[a]
1996	0%	5	0%
1997	74%	4	1%
1998	100%	3	27%
1999	100%	2	72%

[a] Based on a 4 year study (1991-1994) of the age distribution of coded-wire tagged steelhead (n=1427) returning to CNFH (K. Niemela, U.S. Fish and Wildlife Service, personal communication).

TABLE 2.—Reach numbers and locations with associated river miles (rm) for Battle Creek stream surveys in 2001.

	Upstream		Downstream	
Reach	Location	rm	Location	rm
1 (North Fork)	Eagle Canyon Dam	5.25	Wildcat Dam	2.50
2 (North Fork)	Wildcat Dam	2.50	Confluence of forks	*0.00*
3 (South Fork)	Coleman Diversion Dam	2.54	Confluence of forks	*0.00*
4 (mainstem)	Confluence of forks	*16.61*	Mt. Valley Ranch	12.79
5 (mainstem)	Mt. Valley Ranch	12.79	Ranch Road	9.32
6 (mainstem)	Ranch Road	9.32	Barrier weir	5.83
7 (mainstem)	Barrier weir	5.83	Lower rotary screw trap	2.84

TABLE 3.—Temperature criteria used to evaluate the suitability of Battle Creek water temperatures for spring Chinook. Criteria are taken from Ward and Kier (1999).

Life stage	Mean daily water temperature (˚F)	Response	Suitability category
Adult holding	≤60.8	Optimum	Good
	>60.8 to ≤66.2	Some mortality and infertility	Fair
	>66.2	No successful spawning	Poor
	≥80	Lethal	Very Poor
Egg incubation to the eyed-egg stage	≤58	<8% mortality	Good
	>58 to ≤60	15 to 25% mortality	Fair
	>60 to ≤62	50 to 80% mortality	Poor
	>62	100% mortality	Very Poor

TABLE 4.—Chinook captured at CNFH barrier weir trap and associated passage estimates[a] for 2001.

Dates	Actual number clipped	Actual number unclipped	Actual number unknown	Passage estimate: clipped[b]	Passage estimate: unclipped
3-10 March	3	3	0	0	3
11-17 March	4	0	0	0	0
18-24 March	3	1	0	0	1
25-31 March	1	2	0	0	2
1-7 April	0	1	0	0	1
8-14 April	1	2	0	0	2
15-21 April	0	1	0	0	1
22-28 April	2	13	0	0	11[c]
29 April-5 May	0	4	1	0	5
6-8 May	0	3	0	0	3
Totals	14	30	1	0	29

[a] Passage estimates include unknown clip status Chinook apportioned relative to the proportion of clipped and unclipped observed for that particular week.
[b] All clipped fish captured in the trap were sacrificed for coded-wire tag recoveries.
[c] Two unclipped Chinook not released upstream.

TABLE 5.—Rainbow trout captured at CNFH barrier weir trap and associated passage estimates [a] for 2001.

Dates	Actual number clipped	Actual number unclipped	Actual number unknown	Passage estimate: clipped	Passage estimate: unclipped
3-10 March	16	22	0	same as actual number clipped	22
11-17 March	6	7	0		7
18-24 March	1	13	0		13
25-31 March	0	5	0		5
1-7 April	0	0	0		0
8-14 April	0	1	1		2
15-21 April	0	4	0		4
22-28 April	1	3	1		4
29 April-5 May	1	2	0		2
6-8 May	0	0	2		2
Totals	25	57	4	25	61

[a] Passage estimates include unknown clip status rainbow trout apportioned relative to the proportion of clipped and unclipped observed for that particular week (or surrounding weeks).

TABLE 6.—Chinook video recorded passing the CNFH barrier weir fish ladder and associated passage estimates[a] for 2001.

Dates	Hours of passage	Hours of taped passage	Actual number clipped	Actual number unclipped	Actual number unknown	Passage estimate: clipped	Passage estimate: unclipped
8-12 May	120	70.2	1	6	0	2	10
13-19 May	168	121.4	1	16	1	1	23
20-26 May	168	168	0	12	0	0	12
27 May-2 June	168	168	1	6	0	1	6
3-9 June	168	168	0	8	0	0	8
10-16 June	168	168	0	8	0	0	8
17-23 June	168	168	0	0	0	0	0
24-30 June	168	168	0	1	1	0	2
1-7 July	168	168	0	0	0	0	0
8-14 July	168	41.3	0	0	0	0	0
15-21 July	168	0	0	0	0	0	0
22-28 July	168	83.7	0	0	0	0	0
29 July-4 Aug	168	168	0	0	0	0	0
5-11 August	168	168	0	0	0	0	0
12-18 August	168	168	0	1	0	0	1
19-25 August	168	168	0	6	0	0	6
26-31 August	133	90.1	1	4	0	1	6
Totals	2773	2254.7	4	68	2	5	82

[a] Passage estimate calculations include unknown clip status Chinook apportioned to clipped or unclipped status as well as estimated passage during hours not taped.

TABLE 7.—Rainbow trout video recorded passing the CNFH barrier weir fish ladder and associated passage estimates [a] for 2001.

Dates	Hours of passage	Hours of taped passage	Actual number clipped	Actual number unclipped	Actual number unknown	Passage estimate: clipped	Passage estimate: unclipped
8-12 May	120	70.2	1	1	0	2	2
13-19 May	168	121.4	0	2	0	0	3
20-26 May	168	168	1	10	1	1	11
27 May-2 June	168	168	2	7	0	2	7
3-9 June	168	168	0	2	0	0	2
10-16 June	168	168	0	1	0	0	1
17-23 June	168	168	0	1	0	0	1
24-30 June	168	168	0	1	0	0	1
1-7 July	168	168	0	1	0	0	1
8-14 July	168	41.3	0	0	0	0	0
15-21 July	168	0	0	0	0	0	0
22-28 July	168	83.7	0	0	0	0	0
29 July-4 Aug	168	168	0	0	0	0	0
5-11 August	168	168	0	0	0	0	0
12-18 August	168	168	0	2	0	0	2
19-25 August	168	168	0	2	0	0	2
26-31 August	133	90.1	0	0	0	0	0
Totals	2773	2254.7	4	30	1	5	33

[a] Passage estimate calculations include unknown clip status rainbow trout apportioned to clipped or unclipped status as well as estimated passage during hours not taped.

TABLE 8.—Total passage estimates for Chinook and rainbow trout above CNFH barrier weir in 2001.

Passage route	Chinook passage: clipped	Chinook passage: unclipped	Rainbow trout passage: clipped	Rainbow trout passage: unclipped
CNFH	0	98	1352	131
Barrier weir: trap	0	29	25	61
Barrier weir: video	5	82	5	33
Total passage	5	209	1382	225

TABLE 9.—Chinook adults, carcasses, and redds observed during the 2001 Battle Creek stream survey.

Reach	Date	Chinook[a]	Carcasses	Redds
1	07/23/2001	0	0	0
1	08/20/2001	0	0	0
1	09/17/2001	0	0	0
1	10/15/2001	1	0	4
2	07/24/2001	0	0	0
2	08/22/2001	0	0	0
2	09/18/2001	0	0	0
2	10/16/2001	1	0	7
3	05/23/2001[b,c]	2	0	0
3	05/31/2001[b,c]	0	0	0
3	07/19/2001	17	3	0
3	07/30/2001[b,c]	14	0	0
3	07/30/2001[c]	16	0	0
3	08/21/2001	17	0	0
3	09/18/2001	16	0	1
3	10/03/2001[c]	13	0	3
3	10/16/2001	7	0	8
3	10/31/2001[c]	0	3	0
4	07/25/2001	3	0	0
4	08/23/2001	10	0	0
4	09/19/2001	6	0	0
4	10/17/2001	0	1	3
5	07/27/2001	1	0	0
5	08/27/2001	0	0	0
5	09/20/2001	0	0	0
5	10/18/2001	4	0	3
6	07/31/2001	1	0	0
6	08/28/2001	0	0	0
6	09/21/2001	3	0	0
6	10/19/2001	3	1	3
7	08/01/2001	0	0	0
7	08/29/2001	0	0	0

[a] Monthly counts may have included multiple observations of the same Chinook.
[b] Helicopter survey.
[c] Supplemental surveys added to the normal monthly survey schedule.

TABLE 10.—Rainbow trout numbers observed during the 2001 Battle Creek stream survey.

Reach	Date	Small[a]	Medium[a]	Large[a]	Total
1	07/23/2001	619	52	0	671
1	08/20/2001	566	46	0	612
1	09/17/2001	740	43	0	783
1	10/15/2001	671	56	0	727
2	07/24/2001	658	49	2	709
2	08/22/2001	529	78	0	607
2	09/18/2001	360	13	0	373
2	10/16/2001	253	21	0	274
3	no rainbow trout data collected during walking surveys				
4	07/25/2001	283	368	6	657
4	08/23/2001	543	838	0	1381
4	09/19/2001	321	369	0	690
4	10/17/2001	414	441	0	855
5	07/27/2001	183	368	3	554
5	08/27/2001	188	366	0	554
5	09/20/2001	238	405	0	643
5	10/18/2001	173	312	0	485
6	07/31/2001	162	74	2	238
6	08/28/2001	71	75	0	146
6	09/21/2001	110	98	1	209
6	10/19/2001	88	84	2	174
7	08/01/2001	16	24	17	57
7	08/29/2001	18	19	7	44

[a] Small fish bear parr marks and are older than young-of-the-year. Medium fish lack parr marks and are less than 22 inches in length. Large fish are greater than 22 inches.

TABLE 11.—Rainbow trout totals by month and mean count by reach (all sizes) observed during the 2001 Battle Creek stream survey. [a]

Reach	July	August	September	October	Mean
1	671	612	783	727	698
2	709	607	373	274	491
4	657	1381	690	855	896
5	554	554	643	485	559
6	238	146	209	174	192
Total	2829	3300	2698	2515	

[a] No rainbow trout data collected during walking surveys of Reach 3. Reach 7 is not included because it was only surveyed in July and August.

Figures

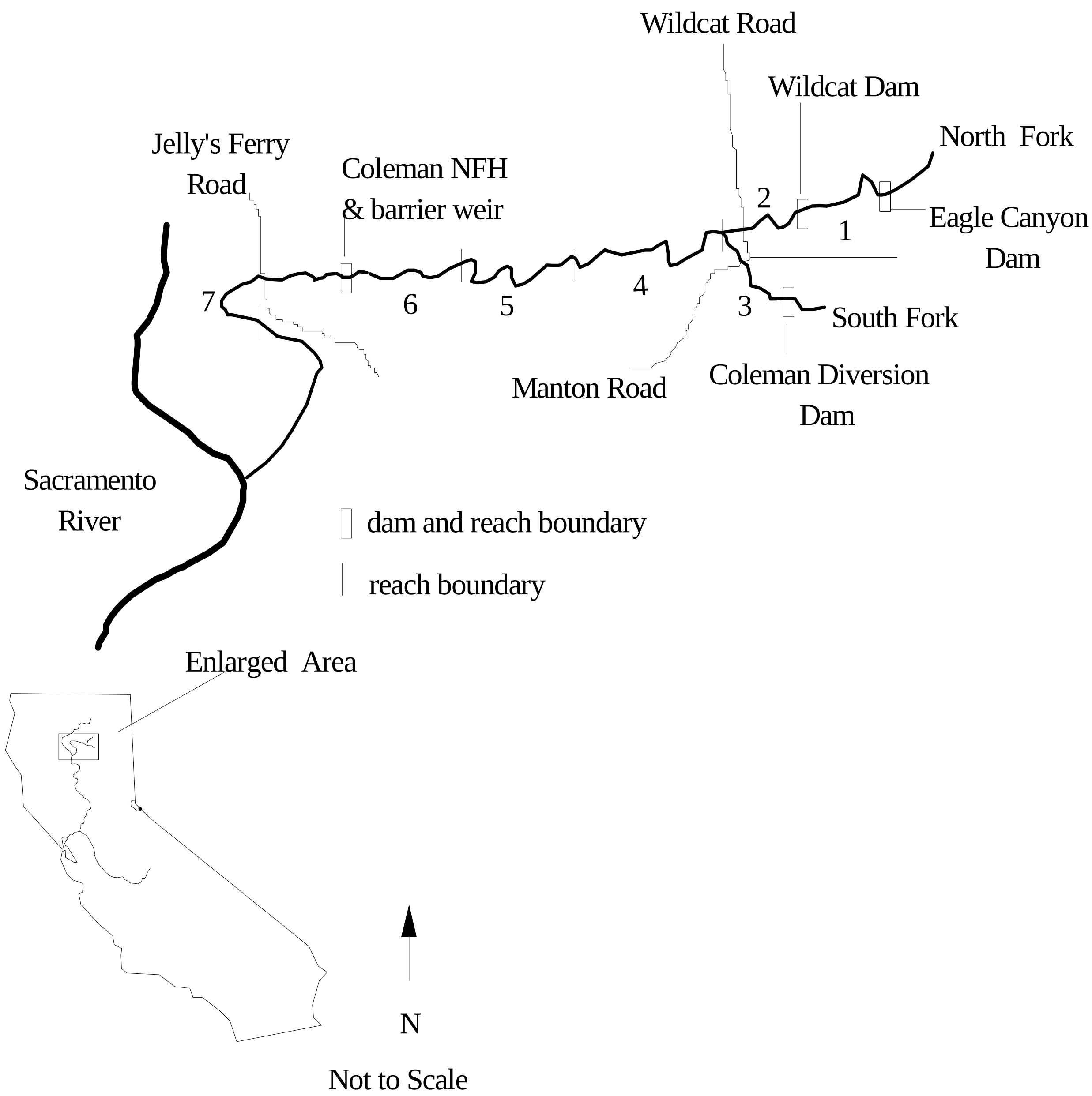

FIGURE 1.—Map of Battle Creek depicting location of the Coleman National Fish Hatchery barrier weir and stream survey reaches for 2001.

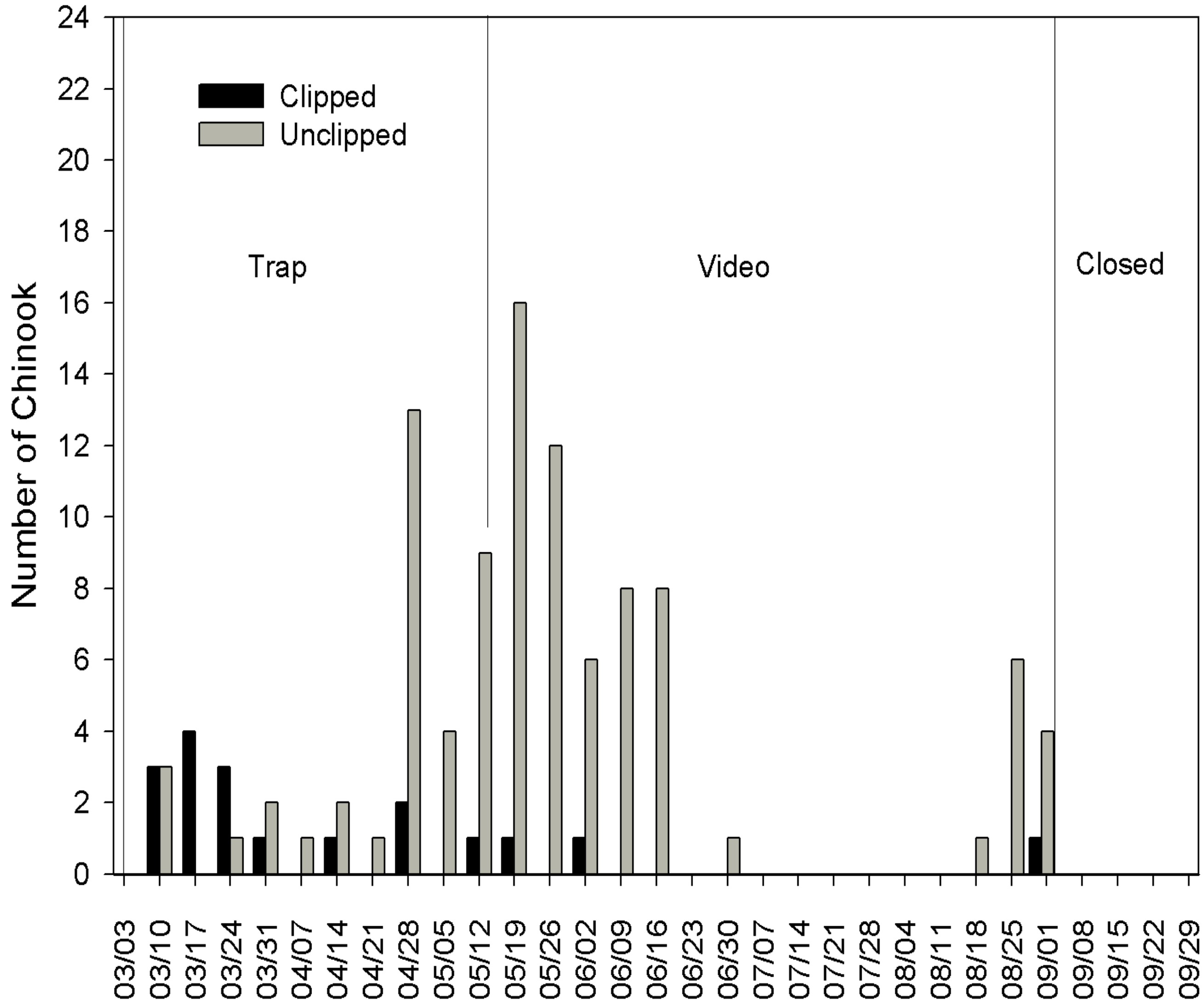

FIGURE 2.—Clipped and unclipped Chinook observed passing through the Battle Creek barrier weir fish ladder in 2001.

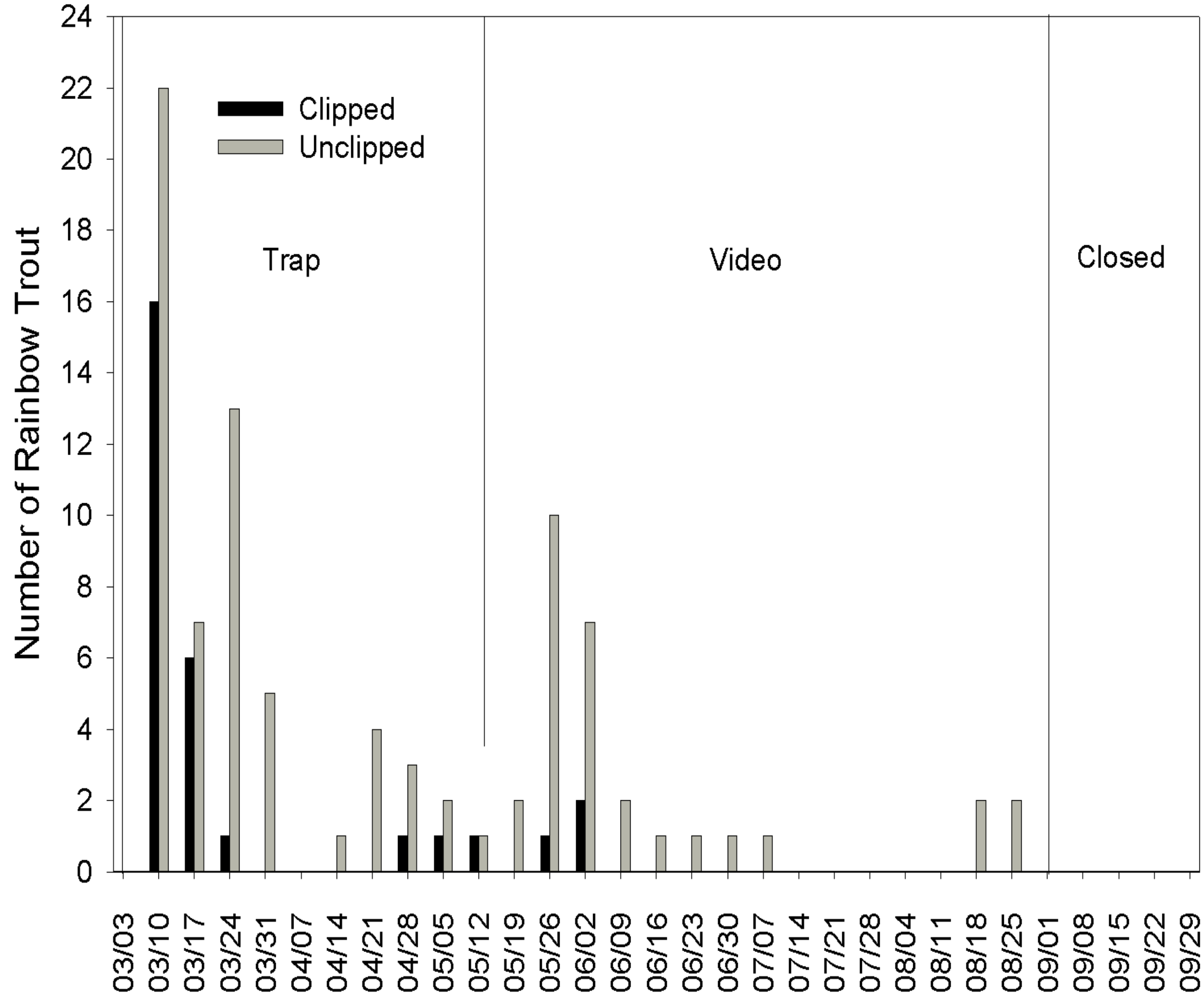

FIGURE 3.—Clipped and unclipped rainbow trout observed passing through the Battle Creek barrier weir fish ladder in 2001.

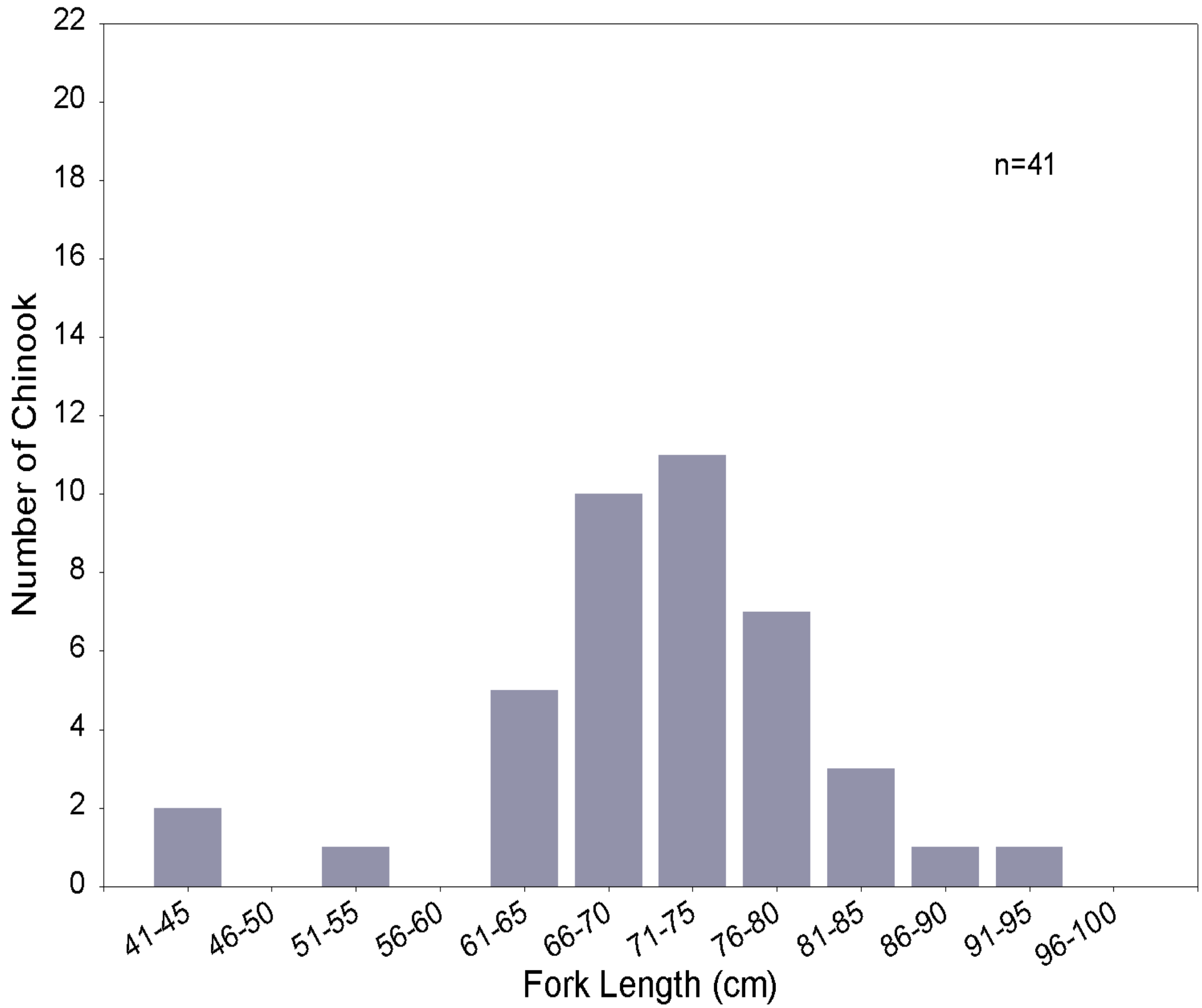

FIGURE 4.—Length frequency distribution of Chinook captured in the Battle Creek barrier weir fish trap in 2001.

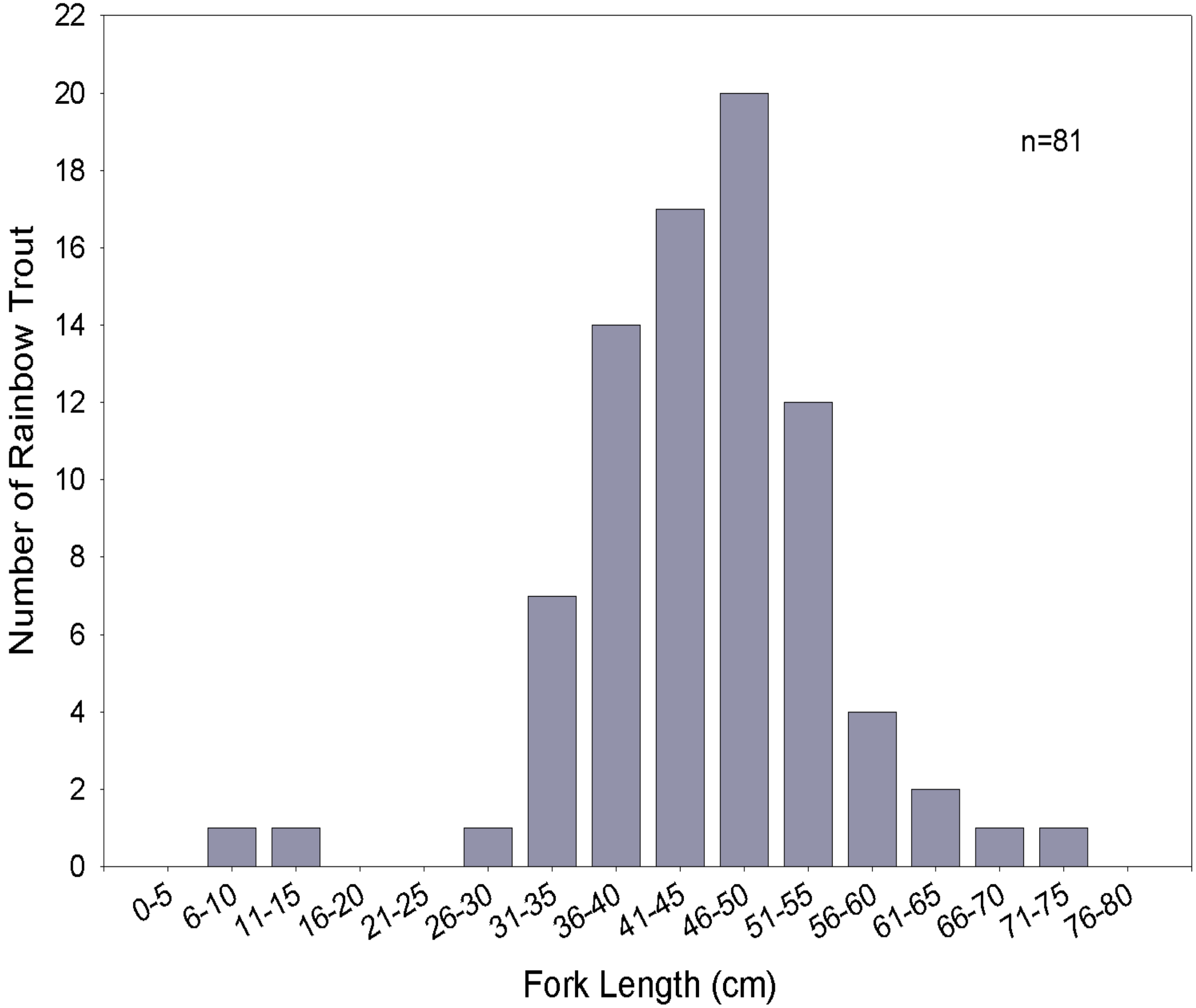

FIGURE 5.—Length frequency distribution of rainbow trout captured in the Battle Creek barrier weir fish trap in 2001.

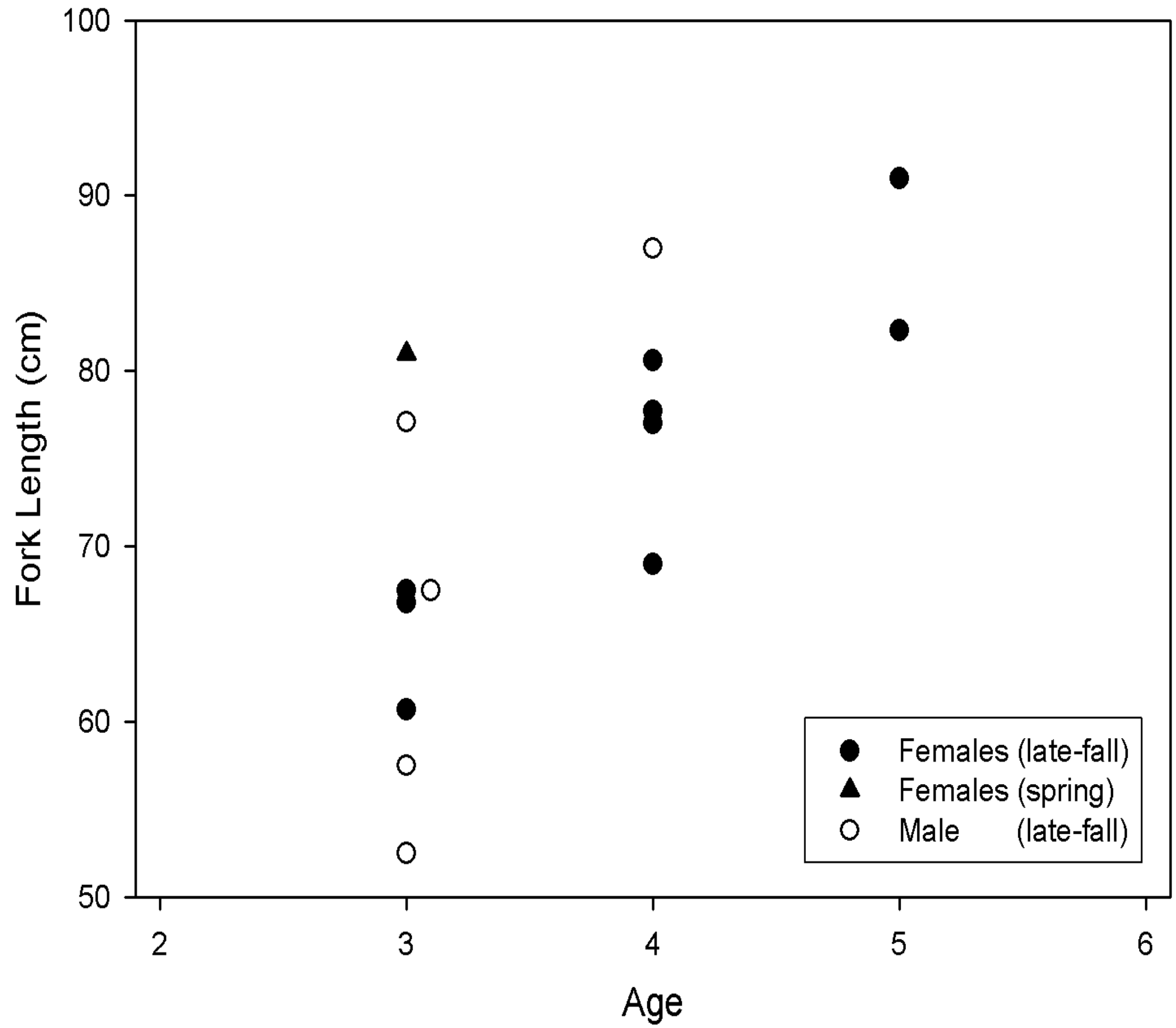

FIGURE 6.—Relationship between fork length and age for coded-wire tagged Chinook captured in the Battle Creek barrier weir fish trap and recovered as carcasses during stream surveys in 2001.

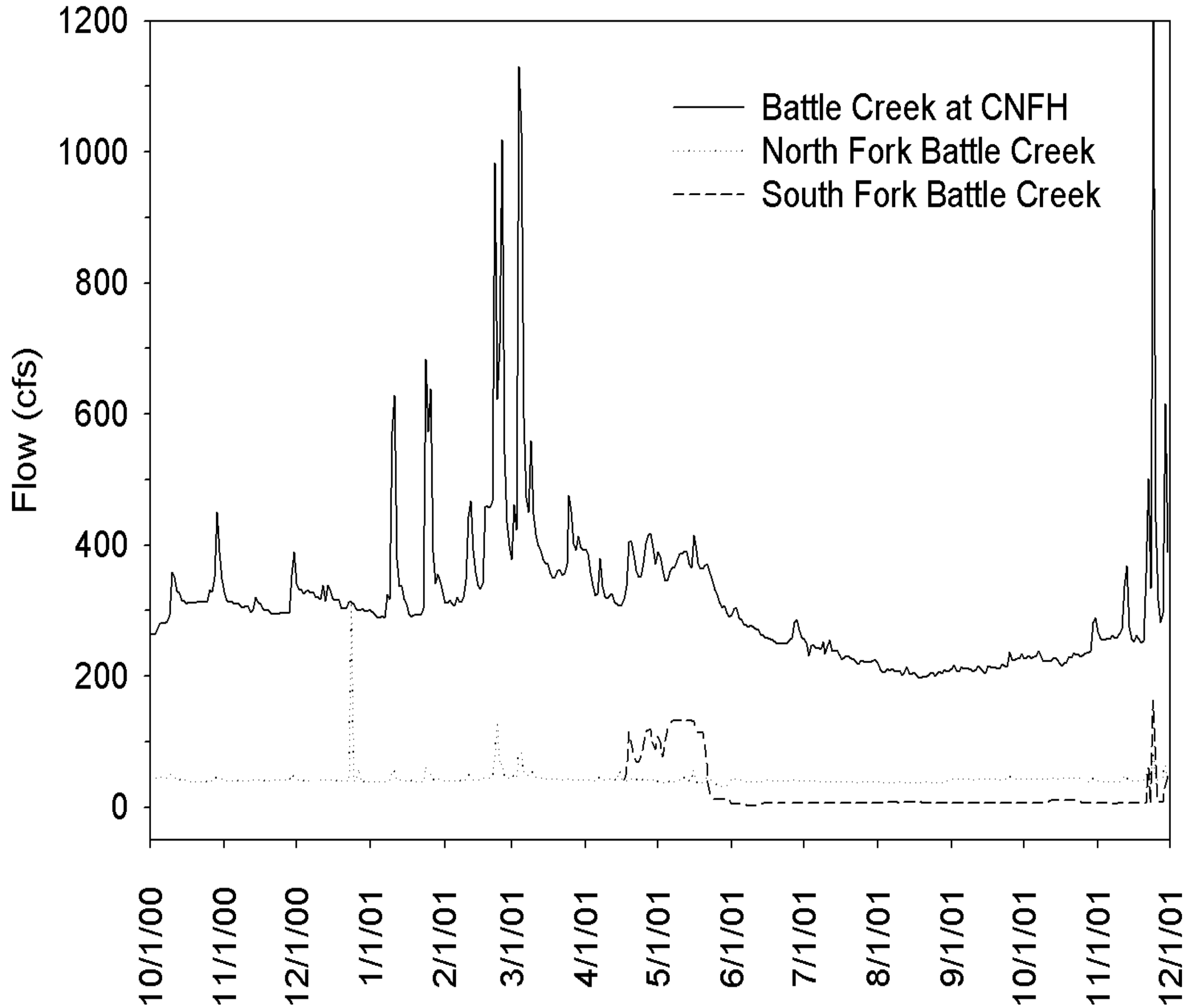

FIGURE 7.—Mean daily flows at the Battle Creek barrier weir (mainstem rm 5.8), Wildcat Road Bridge (North Fork rm 0.9), and Manton Road Bridge (South Fork rm 1.7) for water year 2001. No data available for the South Fork prior to 17 April 2001.

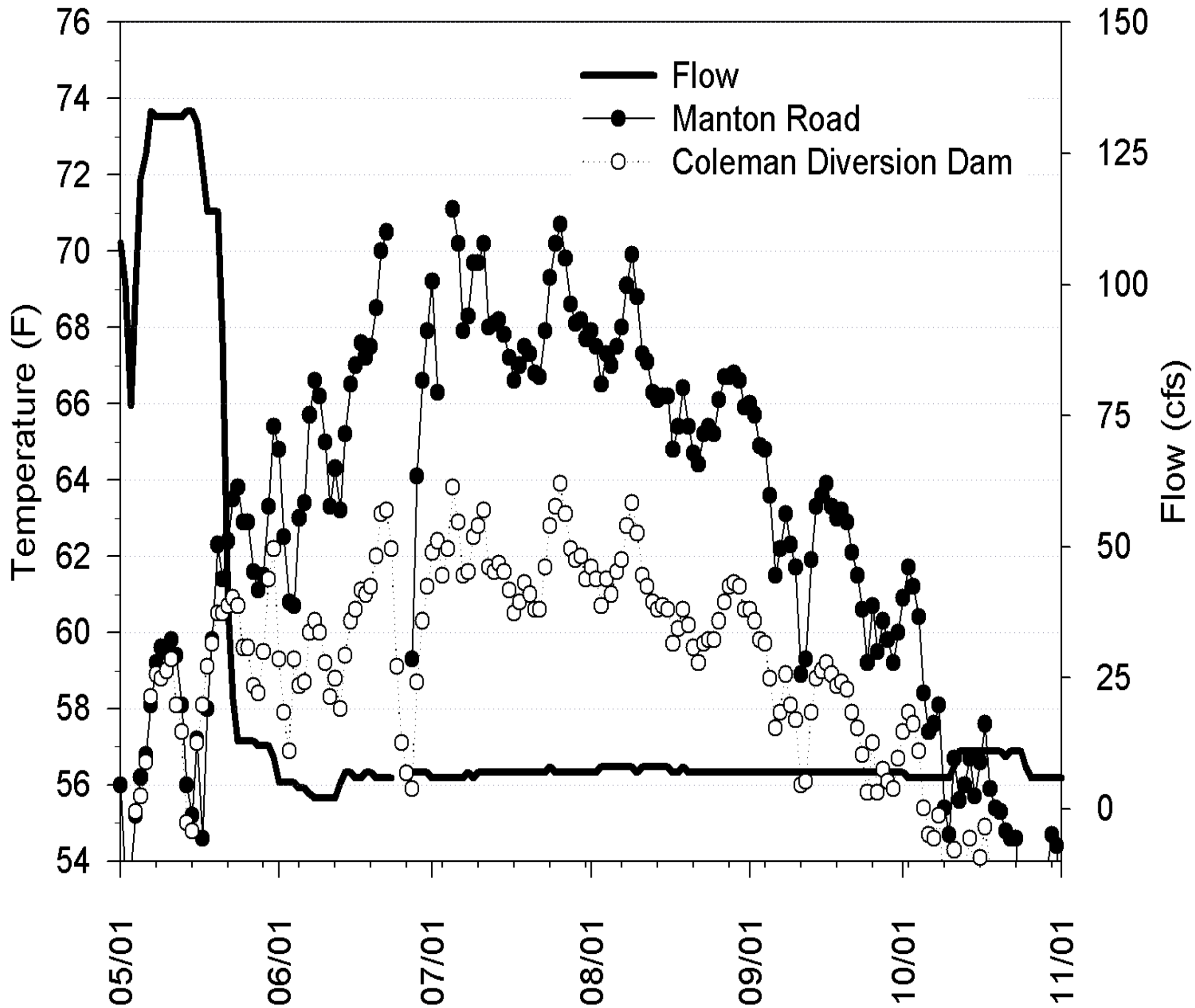

FIGURE 8.—South Fork Battle Creek mean daily flows at Manton Road Bridge (rm 1.7) and mean daily water temperatures at Manton Road Bridge and Coleman Diversion Dam (rm 2.5) during 2001. No data available for the South Fork prior to 17 April 2001.

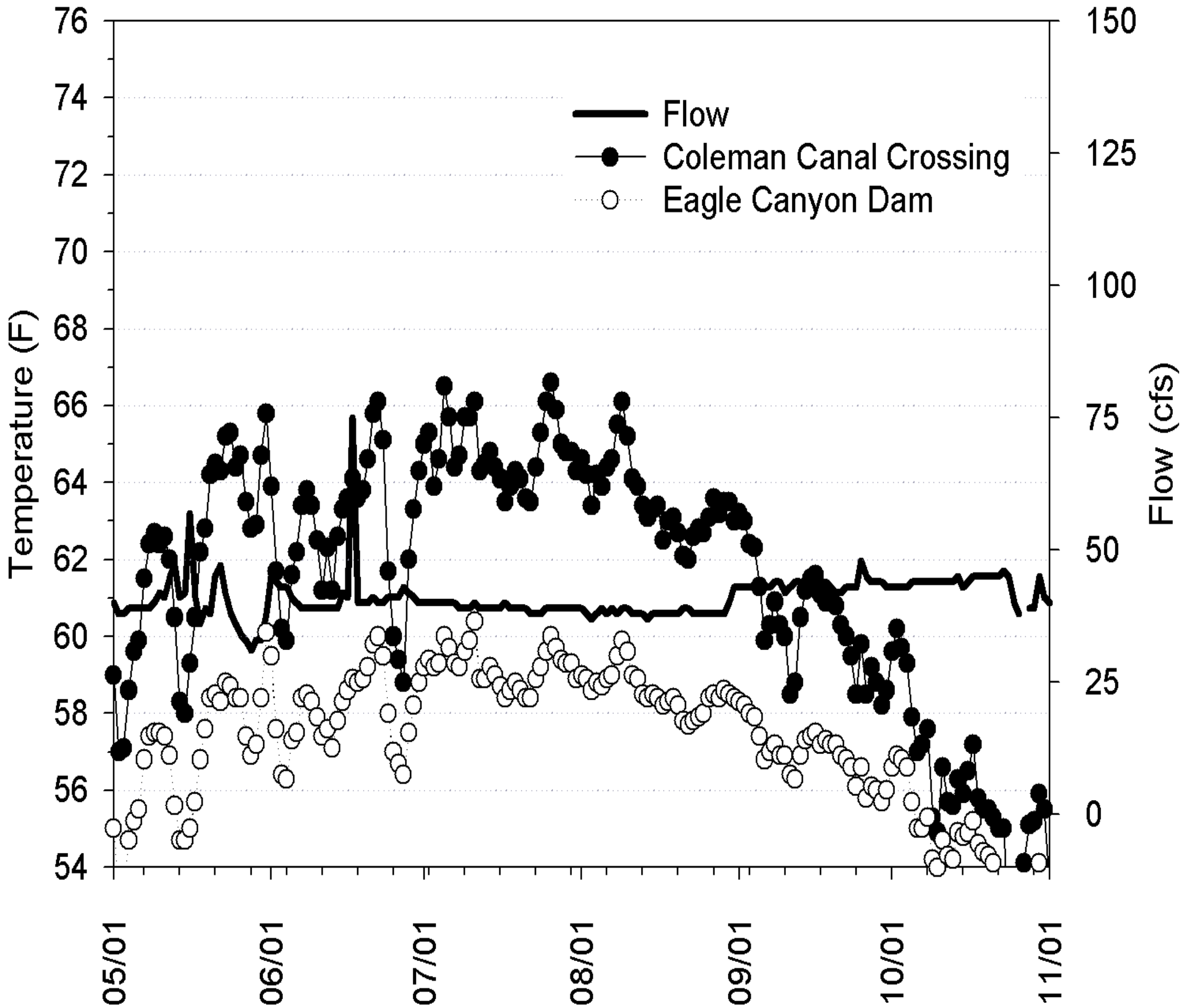

FIGURE 9.—North Fork Battle Creek mean daily flows at Wildcat Road Bridge (rm 0.9) and mean daily water temperatures at Coleman Canal crossing (rm 0.1) and Eagle Canyon Dam (rm 5.3) during 2001.

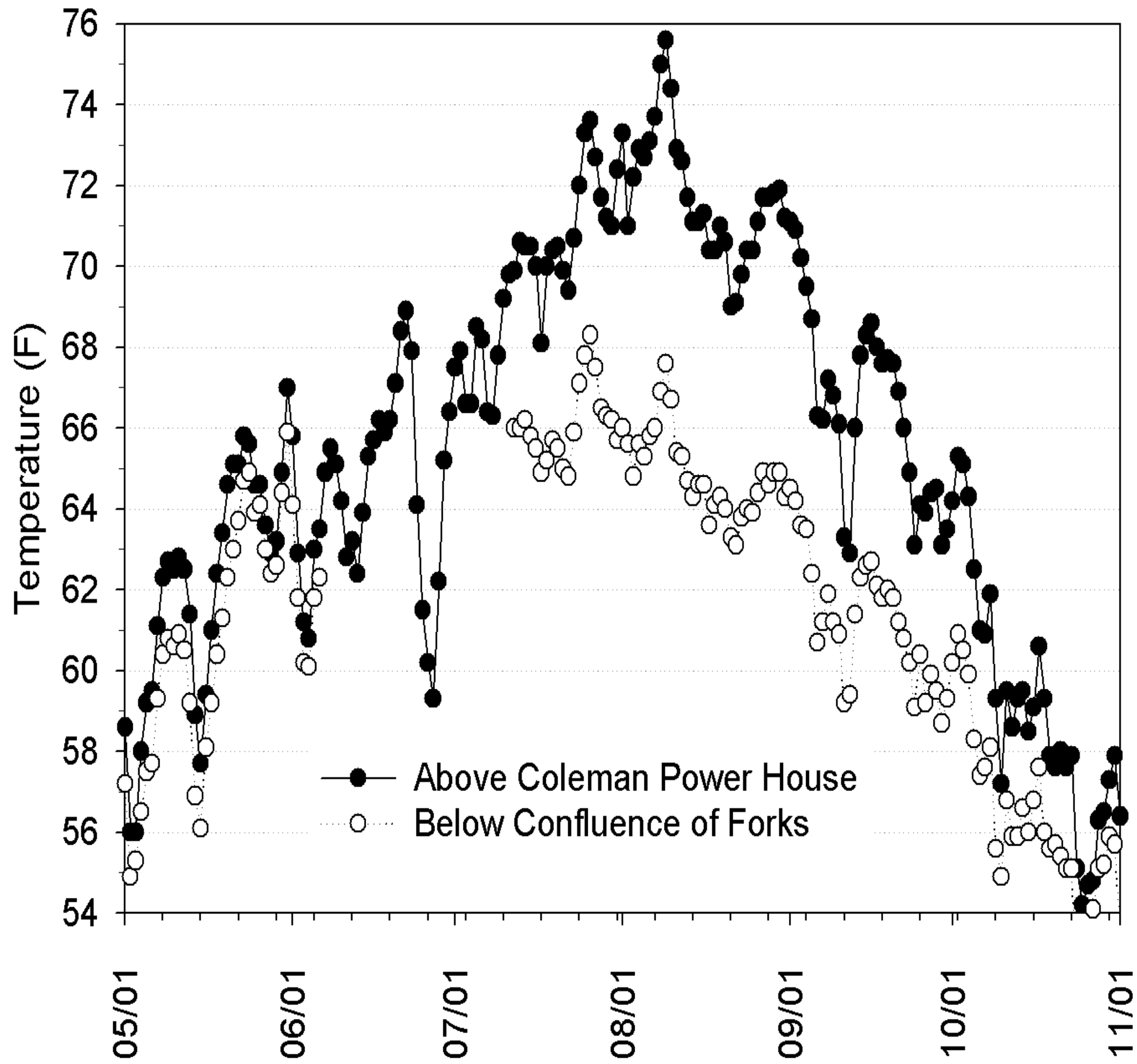

FIGURE 10.—Mainstem Battle Creek mean daily water temperatures above Coleman Powerhouse Tailrace (rm 7.6) and below the confluence of the north and south forks (rm 16.0) during 2001.

Appendices

Appendix A.—Coded-wire tags recovered during Battle Creek adult Chinook monitoring activities in 2001.

Collection date	Collection location	Species	Sex	Fork length (cm)	Tag code	Hatchery of origin	Run	Brood year
03/05/2001	Barrier weir	Chinook	Female	80.6	55048	CNFH[a]	Late-fall	1997
03/05/2001	Barrier weir	Chinook	Female	91.0	54237	CNFH	Late-fall	1996
03/11/2001	Barrier weir	Chinook	Male	52.5	52319	CNFH	Late-fall	1998
03/11/2001	Barrier weir	Chinook	Female	66.8	52313	CNFH	Late-fall	1998
03/11/2001	Barrier weir	Chinook	Male	77.1	52317	CNFH	Late-fall	1998
03/15/2001	Barrier weir	Chinook	Male	87.0	55058	CNFH	Late-fall	1997
03/20/2001	Barrier weir	Chinook	Female	77.0	55054	CNFH	Late-fall	1997
03/20/2001	Barrier weir	Chinook	Female	60.7	54128	CNFH	Late-fall	1998
03/21/2001	Barrier weir	Chinook	Female	67.5	54129	CNFH	Late-fall	1998
03/22/2001	Barrier weir	Chinook	Male	57.5	54129	CNFH	Late-fall	1998
03/28/2001	Barrier weir	Chinook	Male	67.5	54128	CNFH	Late-fall	1998
04/11/2001	Barrier weir	Chinook	Female	82.3	54231	CNFH	Late-fall	1996
04/22/2001	Barrier weir	Chinook	Female	69.0	55057	CNFH	Late-fall	1997
04/28/2001	Barrier weir	Chinook	Female	77.7	55058	CNFH	Late-fall	1997
10/19/2001	Reach 6	Chinook	Female	81.5	601060903	FRH[b]	Spring	1998

[a] Coleman National Fish Hatchery.
[b] Feather River Hatchery.

Appendix B.—Genetic samples taken during Battle Creek adult Chinook monitoring activities in 2001.

Collection date	Collection location	Species	Sex[a]	Fork length (cm)	Sample ID	Run
03/05/2001	Barrier weir	Chinook	Female	72.5	01-2301	Non-winter
03/08/2001	Barrier weir	Chinook	Female	75.5	01-2302	Non-winter
03/09/2001	Barrier weir	Chinook	Female	81.0	01-2303	Non-winter
03/20/2001	Barrier weir	Chinook	Female	67.6	01-2304	Non-winter
03/25/2001	Barrier weir	Chinook	Female	74.9	01-2305	Non-winter
03/25/2001	Barrier weir	Chinook	Female	70.5	01-2306	Non-winter
04/11/2001	Barrier weir	Chinook	Female	72.1	01-2307	Non-winter
04/12/2001	Barrier weir	Chinook	Female	71.3	01-2308	Non-winter
04/19/2001	Barrier weir	Chinook	Female	77.0	01-2309	Non-winter
04/24/2001	Barrier weir	Chinook	Female	70.5	01-2310	Non-winter
04/24/2001	Barrier weir	Chinook	Female	66.7	01-2311	Non-winter
04/24/2001	Barrier weir	Chinook	Female	65.2	01-2312	Non-winter
04/26/2001	Barrier weir	Chinook	Female	73.8	01-2313	Non-winter
04/26/2001	Barrier weir	Chinook	Female	63.9	01-2314	Non-winter
04/26/2001	Barrier weir	Chinook	Female	68.4	01-2315	Non-winter
04/27/2001	Barrier weir	Chinook	Female	73.4	01-2316	Non-winter
04/27/2001	Barrier weir	Chinook	Female	71.0	01-2317	Non-winter
04/27/2001	Barrier weir	Chinook	Female	78.3	01-2318	Non-winter
04/28/2001	Barrier weir	Chinook	Female	70.5	01-2319	Non-winter
04/28/2001	Barrier weir	Chinook	Female	67.8	01-2320	Non-winter
04/28/2001	Barrier weir	Chinook	Male	43.3	01-2321	Non-winter
04/28/2001	Barrier weir	Chinook	Female	75.5	01-2322	Non-winter
05/01/2001	Barrier weir	Chinook	Female	68.0	01-2323	Non-winter
05/02/2001	Barrier weir	Chinook	Female	67.0	01-2324	Non-winter
05/03/2001	Barrier weir	Chinook	Female	75.0	01-2325	Non-winter
05/04/2001	Barrier weir	Chinook	Female	61.5	01-2326	Non-winter
05/07/2001	Barrier weir	Chinook	Female	43.6	01-2327	Non-winter
07/19/2001	Reach 3	Chinook	Female		01-1721	Non-winter
07/19/2001	Reach 3	Chinook	Unknown		01-1710	Non-winter
07/19/2001	Reach 3	Chinook	Unknown		01-1703	No data
07/21/2001	Reach 4[b]	Chinook	Unknown	68.6	01-1800	Non-winter
10/17/2001	Reach 4	Chinook	Female		01-1707	Non-winter
10/31/2001	Reach 3	Chinook	Female	66.0	01-1719	Non-winter
10/31/2001	Reach 3	Chinook	Female	71.0	01-1722	Non-winter
10/31/2001	Reach 3	Chinook	Female	67.0	01-1728	No data

[a] Some males were likely misidentified as females.

[b] Collected by California Department of Fish and Game.