Monitoring Adult Chinook Salmon, Rainbow Trout, and Steelhead in Battle Creek, California, from November 2004 through November 2005

USFWS Report

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June 2007

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The suggested citation for this report is:

Newton, J. M., N. O. Alston, and M. R. Brown. 2007. Monitoring adult Chinook salmon, rainbow trout, and steelhead in Battle Creek, California, from November 2004 through November 2005. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Monitoring Adult Chinook Salmon, Rainbow Trout, and Steelhead in Battle Creek, California, from November 2004 through November 2005

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Abstract.—We estimated that zero clipped and 73 unclipped Chinook salmon *Oncorhynchus tshawytscha* passed through the Coleman National Fish Hatchery (CNFH) barrier weir fish ladder into upper Battle Creek between March 1 and August 1, 2005. It is difficult to precisely apportion these fish to individual runs of Chinook because of the overlap in migration timing between runs. However, based on a combination of information from migration timing, coded-wire tag recoveries, and genetic analyses, we estimated there were 0 winter Chinook, 67 spring Chinook, 6 fall Chinook, and zero late-fall Chinook. These passage estimates were made while the fish ladder was open, which encompassed nearly the entire spring Chinook migration period but only part of the migration period for winter, fall, and late-fall Chinook. Some salmonids are able to jump the weir and circumvent the fish ladder, especially at high flows. While the fish ladder was open, flows exceeded 2,000 cfs on three days in mid-May possibly allowing some Chinook and steelhead to pass upstream undetected. After the ladder was closed on August 1, flows remained low through November 6 suggesting that few CNFH fall Chinook jumped the barrier weir in 2005. An additional 23 unclipped Chinook were passed above the barrier weir prior to March 1 by CNFH during their late-fall Chinook propagation program. While these 23 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 (47 total redds), we estimate a spawning population of 94 spring Chinook.

Overall, water temperatures in 2005 were adequate for spring Chinook to successfully produce juveniles but possibly at a reduced number due to high temperatures during the spring Chinook holding period. We documented unsuitably high water temperatures in the most utilized holding pool which likely led to some reduced fertility or adult mortality. Mean daily water temperatures at redds were categorized as excellent for 98.9% of the days during egg incubation, suggesting there was little or no temperature-related egg mortality.

We estimate that zero clipped and 344 unclipped rainbow trout *Oncorhynchus mykiss* passed above the CNFH barrier weir in 2005. Of these, 270 unclipped rainbow trout were passed by the hatchery prior to March 1 during their steelhead propagation program.

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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 three federally listed species in the Central Valley Evolutionary Significant Unit (ESU); the endangered winter Chinook salmon *Oncorhynchus tshawytscha*, threatened spring Chinook salmon (Chinook), and threatened steelhead *Oncorhynchus mykiss*. Currently, the geographic range of the winter Chinook ESU is limited to a small area in the mainstem of the Sacramento River between Keswick Dam and Red Bluff, California, where it may be susceptible to catastrophic loss. Establishing a second population in Battle Creek could reduce the possibility of extinction. Battle Creek also has the potential to support significant, self-sustaining populations of spring Chinook and steelhead, which is crucial to their recovery.

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 several actions necessary to restore Battle Creek, including the following: "to increase flows past PG&E's hydropower diversions in two phases, to provide adequate holding, spawning, and rearing habitat for anadromous salmonids (USFWS 2001a)."

The Ecological Restoration Program (ERP) of the federal and State of California interagency program known as CALFED, along with PG&E, is planning to fund the Battle Creek Salmon and Steelhead Restoration Project (Restoration Project). The Restoration Project will provide large increases in minimum instream flows in Battle Creek, remove five dams, and construct fish ladders and fish screens at three other dams. Planning, designing, and permitting of the Restoration Project have taken longer than originally anticipated.

PG&E is required under its current Federal Energy Regulatory Commission (FERC) license to provide minimum instream flows of 3 cubic feet per second (cfs) downstream of diversions on the North Fork Battle Creek (North Fork) and 5 cfs downstream of diversions on the South Fork Battle Creek (South Fork). Beginning in 1995, the CVPIA Water Acquisition Program (1995 to 2000) and ERP (2001 to present) contracted with PG&E to increase minimum instream flows in the lower reaches of the North Fork and South Fork. In general, flows were increased to 30 cfs plus or minus 5 cfs below Eagle Canyon Dam on the North Fork and below Coleman Diversion Dam on the South Fork. Increased flows were not provided on the South Fork in 2001 and most of 2002, due in part to lack of funds. Based on an agreement in 2003, flows can be redistributed between the forks to improve overall conditions for salmonids, based on water temperatures and the distribution of live Chinook and redds.

The ERP funded Interim Flow Project will continue until the Restoration Project construction begins (currently scheduled for winter 2007-08). The intent of the Interim Flow Project is to provide immediate habitat improvement in the lower reaches of Battle Creek to sustain current natural salmonid populations while implementation of the more comprehensive Restoration Project moves forward.

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 and the Restoration Project when it comes online. The current investigations were carried out in 2005 by the Red Bluff Fish and Wildlife Office (RBFWO) under a 5-year grant from ERP. This grant was designed to support most of the monitoring needs of the Restoration Project's Adaptive Management Plan (Terraqua Inc. 2004). Our monitoring investigations included (1) salmonid escapement estimates at the Coleman National Fish Hatchery (CNFH) barrier weir fish ladder, (2) stream surveys documenting salmonid spawning distributions upstream of the barrier weir, and (3) juvenile salmonid production estimates (not included in this report). Tables summarizing data from previous years are included in this report (Tables 1-6).

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 (approx. 29.5 miles in length from head waters to confluence), the South Fork (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 study areas were at the CNFH barrier weir on the mainstem Battle Creek (rm 5.8), 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)(Figure 1). Eagle Canyon Dam and Coleman Diversion Dam were considered the upstream limits of anadromous salmonid distribution during the study because fish ladders on the dams were closed.

Methods

We used the CNFH barrier weir fish trap and video counts along with stream surveys to monitor adult salmonids in Battle Creek between December 15, 2004 and November 15, 2005. Chinook salmon and steelhead returning to Battle Creek were classified as either unclipped (having an adipose fin) or clipped (not having an adipose fin). We considered all clipped Chinook and rainbow trout to be hatchery-origin and unclipped Chinook to be either natural-origin or hatchery-origin (not all hatchery Chinook are clipped). We considered all unclipped rainbow trout to be natural-origin as CNFH has clipped 100% of their steelhead production since 1998. It is likely that unclipped Chinook returning to Battle Creek during our monitoring period are mostly spring Chinook. However, it is possible that some unclipped Chinook are late-fall, winter, or fall run due to overlapping periods of migration. Therefore, we chose not to 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 resident forms in the field.

Coleman National Fish Hatchery Barrier Weir

Operation of the CNFH barrier weir (the barrier weir) blocked upstream passage of fish through the fish ladder from August 1, 2004 to March 1, 2005. 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. Fish passage upstream of the barrier weir in Battle Creek was afforded from March 1 through August 1, 2005 by opening the fish ladder. Passage was monitored until May 26 using a live trap, followed by underwater videography until August 1. The fish ladder was closed on August 1, 2005.

Trapping.—A false bottom fish trap, located at the upstream end of the fish ladder, was used to capture Chinook, rainbow trout, and other non-target species as they migrated upstream. The trap was operated approximately 10 h a day, 7 d a week from March 1 through May 26, 2005. To decrease potential passage delays for Chinook, the hours of trap operation were progressively shifted earlier over the trapping season. We implemented three time shifts based on diel movement patterns observed in previous years: 0900-1900 from March 1-April 16, 0530-1530 from April 17-May 14, and 0430-1430 from May 14-May 26. During hours when the trap was not operated, fish were allowed to enter the trap, but the exit was closed blocking upstream passage. Prior to operation each morning, the trap was cleaned, weather conditions were noted, and water temperature and stream stage elevation were documented. Every 2 h, temperature and stage gauge levels were recorded. When water temperature exceeded 60°F, trapping was terminated for that day to minimize the handling effects. Trapping was terminated for the season and videography began when water temperatures exceeded 60°F for a majority of the daily trap operation period.

During operation, the trap was checked every 30 min. Non-target fish were identified to species, counted, and released upstream. 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 within 2°F of Battle Creek water temperatures. Sodium chloride (1.0%) and Poly Aqua™ (artificial slime coat; 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 if needed.

Salmonids were measured (fork length) to the nearest 0.5 cm, examined for scars and tissue damage, examined for the presence or absence of a mark (an adipose-fin clip or floy tag), and identified to gender when possible. A tissue sample was taken from unclipped Chinook for genetic analysis. All clipped Chinook were sacrificed and coded-wire tags (CWTs) extracted and decoded to determine run designation, hatchery of origin, and age. Since only a fraction of clipped rainbow trout are tagged with a CWT, they were first scanned using a “V” detector (Northwest Marine Technology, Field Sampling Detector FSD-I). Clipped trout with CWTs were sacrificed for tag recovery and all others were released upstream of the barrier weir. Anesthetized Chinook and rainbow trout were placed in a recovery tank then release upstream or placed in the creek in a 38 x 10 in aluminum tube until they could swim out on their own.

For each time shift, we evaluated the diel timing of Chinook and rainbow trout/steelhead entering the barrier weir trap by calculating the adjusted total catch (ATC) for each time slot (e.g., 0900, 0930, 1000, etc.). Calculating an adjusted total was necessary to standardize for times when the trap was temporarily closed due to high water temperatures. The equation used to calculate the adjusted total catch was

$$ATC_{ia} = \frac{TC_{ia}}{I_{ia}} \cdot TPI_a$$

where $ATC_{i\,a}$ = adjusted total catch at time *i* (e.g., at 1030) during time shift *a*, $TC_{i\,a}$ = total catch at time *i* during time shift *a*, $I_{i\,a}$ =number of trap inspections at time *i* during time shift *a*, and TPI_a = number of total possible trap inspections at each half hour interval during time shift *a*. Data were summarized on an hourly basis by summing adjacent pairs of $ATC_{i\,a}$ (e.g., $ATC_{0900\,a}$ + ATC_{0930a}).

Video counts.—An underwater video camera (Lorex CVC-6991) was used to record Chinook, rainbow trout, and other non-target species as they passed through the fish ladder. The camera was placed in the modified fish trap at the upstream end of the fish ladder. Video monitoring of fish passage was conducted from May 26 through August 1. A lighting system allowed for 24-h 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 h, and 160-min VHS tapes were used. A time-date stamp was recorded on the video.

In conjunction with video equipment, we installed a VAKI infrared fish counter as a backup system and to test its effectiveness for monitoring fish passage in our situation, especially during periods of high turbidity. The VAKI was used to investigate the accuracy of our video counts.

Video tapes were later viewed until a fish was observed, then reviewed at slow playback speed or "freeze frame" mode to assist in species 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 the presence or absence of an adipose fin; fair suggested confidence in determining species and the presence or absence of an adipose fin but additional review was needed; and poor suggested uncertainty in determining species and the presence or absence of an adipose fin.

Picture quality was also rated as good, fair, or poor. Good signified a clear picture; fair indicated that objects were discernable but extra review was needed; and poor indicated that some objects were indistinguishable. Passage was estimated for periods of poor picture quality based on passage rates during adjacent periods of good and fair picture quality.

All Chinook and rainbow trout passing the barrier weir were recorded onto a file tape which was reviewed by more experienced personnel to confirm species identification and the 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 possible 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. 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 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 March 1. The equations used for estimating passage during barrier weir trapping were

$$P_{tu} = \sum_{i=1}^{13} \left(\left[\frac{u_i}{c_i + u_i} \cdot unk_i \right] + u_i \right)$$

and

$$P_{tc} = \sum_{i=1}^{13} \left(\frac{c_i}{c_i + u_i} \cdot unk_i \right)$$

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_i = actual number of clipped Chinook or rainbow trout observed passing the barrier weir during week *i*; u_i = actual number of unclipped Chinook or rainbow trout observed passing the barrier weir during week *i*; and unk_i = actual number of unknown clip status Chinook or rainbow trout observed passing the barrier weir during week *i*. The equations used for estimating passage during barrier weir video counting were

$$P_{vu} = \sum_{i=1}^{10} \left(\left[\frac{u_i}{c_i + u_i} \cdot unk_i \right] + u_i \right) \cdot \left(\frac{T_i}{V_i} \right)$$

and

$$P_{vc} = \sum_{i=1}^{10} \left(\left[\frac{c_i}{c_i + u_i} \cdot unk_i \right] + c_i \right) \cdot \left(\frac{T_i}{V_i} \right)$$

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_i = actual number of clipped Chinook or rainbow trout observed passing the barrier weir during week *i*; u_i = actual number of unclipped Chinook or rainbow trout observed passing the barrier weir during week *i*; unk_i = actual number of unknown clip status Chinook or rainbow trout observed passing the barrier weir during week *i*; T_i = number of hours of unrestricted fish passage at the barrier weir during week *i*; and V_i = number of hours of actual good and fair video recorded fish passage at the barrier weir during week *i*.

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 and length-at-age plots were developed.

Jumpers. —In 2005, we conducted the second year of a monitoring study evaluating the number of fall Chinook circumventing the weir (i.e., jumping over) after the fish ladder was closed on August 1. This study helped determine the potential for hybridization and redd superimposition between fall and spring Chinook as well as helped interpret juvenile production estimates from an associated USFWS study. We installed three video surveillance cameras which provided a complete and clear view of the entire width of the barrier weir. All three video images were displayed simultaneously onto one monitor and recorded with a time-lapse video recorder. VHS tapes were later reviewed to count salmonids successfully jumping or swimming over the weir. We monitored the barrier weir during daylight hours from August through November. Instantaneous flow was recorded at the time of each successful jump. Tape viewers rated days as good, fair, or poor viewing quality. Poor was used for any period that viewing was not possible due to lighting, camera obstruction, or other factors. Fair was used for any partial viewing difficulty, but still with moderate certainty of viewing accuracy. Good was used for good viewing conditions.

Stream Surveys

We conducted snorkel surveys on Battle Creek between May 16 and November 15, 2005. Surveys occurred once-a-month for the period May-August and twice-a-month for the period September-November. The primary purpose of these surveys was to collect data on the spatial and temporal distribution of spring Chinook and, to a lesser degree, rainbow trout. The 21.6 mile survey was divided into seven reaches (Table 7; Figure 1) and usually required 4 d to complete, depending on personnel availability and flow conditions. Surveys were scheduled on consecutive weekdays beginning at the uppermost reaches and working downstream. Reach 7, located below the barrier weir, was not surveyed in October or November due to the abundance of non-target fall Chinook.

While 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. The small size range was “larger than young-of-the-year” to 16 in. The medium size range was 16-22 in. And the large size range was >22 in. 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 and rainbow trout, 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.

When survey personnel encountered carcasses, they would collect tissue for genetic analyses, scales for age determination, and record biological information such as fork length, sex, egg retention, and presence or absence of a tag and 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 to decomposition or lack of a complete carcass. 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 therefore collected data on these three parameters for each snorkel survey. Stream flow was measured at three gauging stations operated by California Department of Water Resources (DWR) or the US Geological Survey. The gauging 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. 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 calculated for each survey day. For surveys when only one turbidity 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 snorkel 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 adult spring Chinook holding from June 1 through September 30. We labeled Ward and Kier's four categories as good, fair, poor, and very poor. Continuous water temperature data was collected at three locations on the South Fork (reach 3), four locations on the North Fork (reaches 1 and 2), and five locations on the mainstem (reaches 4-6). Temperature data was obtained from Onset Stowaway™ temperature loggers installed and maintained by the RBFWO and from two DWR gauging stations located at the Manton Road Bridge on the South Fork and the Wildcat Road Bridge on the North Fork. Evaluating temperatures at these sites provided a range of conditions Chinook may have been exposed to when holding in Battle Creek.

Spawning location and timing.—We located Chinook spawning areas and estimated time of spawning. The number of redds per reach and the date each redd was first observed were recorded. Coordinates of redds were documented using a GPS receiver. All redds were marked in the field with flagging and given a unique identification number 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 modified from Ward and Kier (1999) to evaluate the suitability of water temperatures in Battle Creek for spring Chinook egg incubation. We added an additional category of ≤56˚F to Ward and Keir's four category system for water temperatures (Table 8). This additional category was added because other Central Valley streams have ≤56˚F as a temperature target for Chinook egg incubation (NMFS 2002, USFWS 2001a). We labeled the five categories as excellent, good, fair, poor, and very poor.

Using these thermal criteria, we evaluated the potential effect of water temperature on egg survival at each individual Chinook redd. Mean daily temperatures (MDTs) at redd locations were estimated by plotting daily temperature monitoring data (X-axis = river mile, Y-axis = MDT) and using the equation of a straight line connecting two adjacent monitoring sites to interpolate MDT for a redd at a given river mile. Estimated days of exposure to each temperature category was based on the criteria that (1) 1,850 Daily Temperature Units (DTU = $MDT_{°F}$ - $32_{°F}$) were required for egg incubation to time of emergence and (2) the redds were constructed the day preceding the survey when they were first observed. This redd construction (fertilization) date results in a "best-case-scenario" because choosing an earlier date would result in more exposure to higher temperatures in late summer. The 1,850 DTU requirement is within the reported range for juvenile Chinook (Heming 1982, Murray and McPhail 1988) and was estimated specifically for Battle Creek based on rotary screw trap catch data and stream survey data (Earley and Brown 2004).

We measured spring Chinook redd dimensions, depths, water velocities and dominant substrate size. Redd dimensions included maximum length and maximum width. Redd area was calculated using the formula for an ellipse (area = $\pi \bullet \frac{1}{2}$ width$\bullet \frac{1}{2}$ length). Depth measurements were maximum depth (redd pit), minimum depth (redd tailspill), and pre-redd depth (measured immediately upstream of the redd). Mean column velocity was measured at the same location as the pre-redd depth. Velocity measurements were taken with a General Oceanics model 2030 mechanical flow meter. Dominant substrate size was classified using methods described by USFWS (2005).

Winter steelhead redd surveys.—We conducted winter steelhead redd surveys on Battle Creek twice-a-month between December 15, 2004 and April 12, 2005. Steelhead in the upper Sacramento Valley typically spawn from early winter through early spring. Inflatable kayaks (Hyside®) were used to conduct surveys on the mainstem. Kayak surveys were preferred over snorkel surveys in the winter because of high stream flows, elevated turbidities (2-5 NTU), and low water temperatures (44-52˚F). For optimal viewing conditions, observers wore polarized sunglasses and kneeled on pontoons or stood up in the kayak. Moving downstream with the current, three kayakers, spanning the width of the creek, documented the location and number of redds. We conducted snorkel surveys on the North and South Forks because flows were generally too low to operate kayaks. A GPS reading was taken at each redd and redds were flagged and labeled with a unique number.

Tissue Collection for Genetic Analyses

Tissue samples were collected from unclipped Chinook captured at the fish trap and from carcasses collected during stream surveys. We used either scissors or a hole punch to obtain four small pieces of fin tissue. Three 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 (not collected from weir trap samples). One vial sample was sent to Hatfield Marine Science Center, Oregon State University, for genetic analyses by Dr. Michael Banks. The other samples were archived at the RBFWO. A new method of genetic analysis was used beginning in 2004 which was not used in previous years. The new method classifies individual fish as either spring, winter, fall, or late-fall Chinook. Each run assignment had an associated confidence probability. The individual run assessment technique was developed based on Central Valley Chinook.

In previous years, genetic analyses were preformed using two other techniques; “WHICHRUN” which identified individual salmon as either winter Chinook or non-winter Chinook and “Mixed Stock Analysis” which estimates the proportion of spring, winter, fall, and late-fall Chinook in a group but did not classify individual fish.

Age Structure

Age determination of returning spring Chinook was done by reading scales collected from carcasses recovered upstream of the CNFH barrier weir. Scales were removed from the left side of the fish and from the second or third row above the lateral line in the region bisected by a line drawn between the back of the dorsal fin and the front of the anal fin. Scales were dried for about 24 h and stored in scale envelopes. Scales were prepared for reading by rehydrating and cleaning them in soapy water. Scales were mounted sculptured side up between two glass microscope slides held together with tape. A microfiche reader was used to count the number of annuli. The age was determined to be the number of annuli plus one (Borgerson 1998). Each scale was independently aged by two readers. If results were different, the scale was read a third time cooperatively by the same two readers. If an agreement was not reached, that scale was not included in our data set. Scale readers were trained using fall and late-fall Chinook of known age from CNFH.

Results

Coleman National Fish Hatchery Barrier Weir

Trapping.—A total of 95 Chinook were captured in the barrier weir trap between March 1 and May 26, 2005. Of these, 69 were clipped and 26 were unclipped (Table 9). We retrieved coded-wire tags (CWT) from 66 clipped Chinook captured in the trap. Tag codes revealed that all were CNFH late-fall Chinook (Table A.1). We did not recover any coded-wire tagged winter Chinook.

A total of 49 rainbow trout were captured in the barrier weir trap and 44 were released upstream (escapement). Of the 49 that were captured, 5 were clipped, 43 were unclipped, and 1 was unknown (Table 10). No clipped rainbow trout had a CWT.

The hours of trap operation were progressively shifted earlier over the trapping season. Three time shifts were implemented which began at 0900, 0530, and 0430. Within these three time shifts, diel timing of Chinook entering the barrier weir trap showed some variation throughout the trapping season (Figure 2). Clipped Chinook were captured most frequently during the first trap check of the day (fish were allowed to enter and hold in the trap throughout the night) with a second peak in ATC occurring in the afternoon from 1500 to 1700 hours (Figure 3). Ninety-six percent of all clipped Chinook were trapped in the first time shift (March 1- April 16). Unclipped Chinook were trapped more in the morning hours with the highest ATCs generally occurring during the first few hours of trap operation in all three time shifts (Figure 3).

Diel timing of rainbow trout entering the barrier weir trap also showed some variation throughout the trapping season (Figure 4). During the first time shift, rainbow trout were trapped throughout the hours of trap operation with a slight peak of ATC occurring at from 1500 to 1700 hours (Figure 5). Very few rainbow trout passed during the second time shift. During third time shift, all rainbow trout were trapped after 0900 and the majority were trapped after 1130. Sixty-nine percent of rainbow trout passed during the first time shift.

Video counts.—A total of 43 Chinook were observed passing through the barrier weir fish ladder between May 26 and August 1, 2005. Of these, all were unclipped (Table 11). Extrapolation for poor picture quality or video equipment malfunction resulted in a passage estimate of 47 unclipped Chinook. From July 19 through August 1, no Chinook were observed passing (Figure 6). Similar periods of no fish passage from mid-July through early-August occurred in 2000-2004 (Brown and Newton 2002; Brown et al. 2005; Brown and Alston 2007; Alston et al. 2007). During the video monitoring period, 88% of the allowed passage was video recorded with a good or fair picture quality.

A total of 28 rainbow trout were observed on video tape passing through the barrier weir fish ladder. Of these, all were unclipped (Table 12). Extrapolation for poor viewing quality or equipment malfunction resulted in a passage estimate of 30 rainbow trout.

Diel timing of passage during video monitoring indicated that Chinook passed the barrier weir throughout the entire day until about June 20. Following June 20, Chinook primarily passed in the early morning between 0000 and 1100 hours (Figure 6). Over the entire video monitoring period, peak passage occurred between 0600 and 0800 hours (Figure 7). Diel timing of rainbow trout passage indicated that passage occurred exclusively during daylight hours (Figure 8). Rainbow trout passage peaked between 1700 and 1800 hours (Figure 9).

Passage estimation.—Passage estimates for unclipped salmonids are higher than actual numbers observed due to estimates made for periods of poor video quality. We estimated that zero clipped and 73 unclipped Chinook passed through the barrier weir fish ladder into upper Battle Creek between March 1 and August 1, 2005 (Tables 9, 11, and 13). An additional 23 unclipped Chinook were released above the barrier weir by CNFH personnel prior to opening the barrier weir fish ladder on March 1 (Tables 1, 2, and 13). These 23 Chinook were diverted from lower Battle Creek into the hatchery as part of the late-fall Chinook propagation program. Because CNFH personnel attempt to mark 100% of their late-fall production with an adipose-fin clip and CWT, these 23 Chinook were considered natural-origin and were released into Battle Creek upstream of the barrier weir to spawn naturally.

We estimated that zero clipped and 74 unclipped rainbow trout passed upstream of the barrier weir fish ladder between March 1 and August 1, 2005 (Tables 10, 12, and 13). An additional 270 unclipped rainbow trout were released above the barrier weir by CNFH prior to March 1 (Tables 1, 2, and 13). These rainbow trout were taken into the hatchery as part of the steelhead propagation program, but were not used as brood stock.

Migration timing.—The migration of unclipped Chinook past the barrier weir began March 13 and peaked the week of June 12-18 (Figure 10). The middle 50% of the run passed between May 4 and June 23. Chinook did not appear to migrate above the weir during the 2 weeks preceding the ladder closure on August 1.

The temporal distribution of clipped Chinook observed at the barrier weir is different from that of unclipped Chinook. Observations of clipped Chinook began March 1, peaked during the first 2 weeks of trap operation and declined steadily until May (Figure 10).

Rainbow trout migrating past the barrier weir exhibited a bimodal migration pattern. The two periods of peak passage were March 1-12, when trap operation began, and May 22-June 4 (Figure 11).

Size, sex, and age composition.— Chinook captured in the barrier weir trap had a mean fork length of 76.5 cm and ranged in length from 51.5 to 101.5 cm (n = 94). The length-frequency distribution was continuous and was approximately normal with a mode at about 71-75 cm (Figure 12). Rainbow trout captured in the barrier weir trap had a mean fork length of 40.1 cm and ranged from 21.5 to 53.5 cm (n = 48)(Figure 13).

The ratio of male to female clipped Chinook captured in the barrier weir was 1:2.6 (n=68). The sex ratio for unclipped Chinook was not determined due to the difficulty in determining the sex of spring Chinook before the appearance of secondary sex characteristics. For the majority of rainbow trout, the sex was undetermined.

Tagging records were used to determine the age of most coded-wire tagged Chinook captured in the barrier weir trap. The ages of tagged Chinook included 2-year-olds (n=3), 3-year-olds (n = 28), 4-year-olds (n = 28), and 5-year-olds (n = 2). There was overlap in fork length between Chinook of ages three through five (Figure 14, Table A.1). Age was not determined for unclipped Chinook.

Jumpers.— We selected a subsample of 33 days of video monitoring data to review for salmonids jumping the barrier weir. Jumper video tapes were recorded from August 1 to November 30, 2005. During the selected 33 days, we observed 7 Chinook jumping or swimming over the weir during daylight hours. All but one jump occurred in the afternoon between about 1515 and 1830 hours (Table 14). The average instantaneous flow during successful jumps was 324 cfs with the lowest flow being 225 cfs and the highest being 394 cfs.

Stream Surveys

During snorkel surveys conducted from June through November in reaches 1-6, observations of live adult Chinook peaked at 23 in October (Tables 15 and 16). Also, we observed a total of 47 redds above the barrier weir, of which 13 were observed in September, 33 were in October, and 1 was in November. We recovered a total of six adult Chinook carcasses above the barrier weir in October and one juvenile carcass in September (156 mm fork length).

Small rainbow trout were the dominant size group in all the reaches. Medium rainbow trout were most abundant in Reach 4. Large rainbow trout counts were ≤5 on all surveys of reaches 1-6 (Table 17). Reach 2 had the highest monthly mean rainbow trout counts, followed by Reach 1 (Table 18). The lowest monthly mean counts were observed in reaches 6 and 7.

Conditions for snorkel surveys were good to excellent. Stream flows were stable and were always <113 cfs on reaches 1-6a (Figures 15-18). Temperatures ranged from 50˚ to 74˚F. Average turbidity was 1.5 NTU with a range of 0.7 to 3.8 NTU. The presence or absence of an adipose fin usually could not be determined for Chinook seen during our surveys.

Holding location.—Barrier weir counts and snorkel survey observations of live Chinook and redds indicated that most spring Chinook held in Battle Creek for 3 to 5 months (between early May and late September) prior to spawning (Figure 10, Table 15). Surveys indicated that most Chinook spawned from the mid-September through mid-October (Table 15). We considered survey observations made from June through early September to be during the primary holding period for spring Chinook in 2005.

Using the Ward and Kier (1999) thermal criteria for holding (Table 8), we evaluated MDTs for the holding period at three locations on the South Fork, four locations on the North Fork and five locations on the mainstem (Table 19). On the South Fork, the percentage of MDTs categorized as good ranged from 56% at the upstream most site to 47% at the downstream most site. On the North Fork, the percentage of MDTs categorized as good ranged from 92% at the upstream most site to 32% at the downstream most site. On the mainstem, the percentage of MDTs categorized as good ranged from 41% at the upstream most site to 31% at the downstream most site.

We identified two primary holding pools where Chinook tended to congregate during the summer. These pools were informally named C.D.D. Pool and B. Pool. Estimated MDTs at C.D.D. Pool (Reach 3) were categorized as follows; 56% good, 44% fair, and 0% poor and very poor. Estimated MDTs at B. Pool (Reach 4) were categorized as follows; 43% good, 53% fair, 4% poor, and 0 % very poor.

The upstream most observation of a live Chinook on the North Fork occurred on August 8 at rm 5.0, downstream of a natural barrier (rm 5.06) identified as "nearly impassable by all fish at all flows (TRPA 1998, barrier NF5.14)." The upstream most observation of a live

Chinook on the South Fork was immediately below Coleman Diversion Dam which blocks fish passage.

Spawning location and timing.—We observed 24 redds in the North Fork, 6 in the South Fork, and 17 in the mainstem (Table 15). In the North Fork, South Fork, and mainstem Battle Creek, Chinook began spawning between September 14 and 28, with the exception of one redd created prior to September 14. Chinook finished spawning by October 26, with the exception of 1 redd created after this date (Table 15). 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). Similar to 2004, in 2005 there were no redds observed above Wildcat Dam (Reach 1) even though at least three live Chinook were observed in this reach earlier in the season. The upstream most redd on the North Fork was located at rm 1.7, well downstream of Wildcat Dam. The upstream most redd on the South Fork was located at rm 2.2, downstream of Coleman Diversion Dam which blocks fish passage.

We estimated MDT at each Chinook redd during the egg incubation period. On average, the incubation period lasted 111 days, based on an 1,850 DTU requirement. During the incubation period, the average percentage of days that redds were exposed to each temperature category were 98.9% excellent, 1.0% good, 0.1% fair, and 0% poor and very poor (Table 20, Table A.2). Temperature exposures were similar between survey reaches with a minimum of 93.1% of days classified as excellent for redds in Reach 6 (mainstem).

In addition to estimating water temperatures at each redd, we also evaluated spawning temperatures at our fixed sites. We used spawning criteria modified from Ward and Kier (1999) for the dates of September 15 through October 31, 2005. On the North Fork, the percentage of MDTs categorized as good or excellent ranged from 100% at the upstream most site to 74% at the downstream most site. On the South Fork, the percentage categorized as good or excellent ranged from 100% at the upstream most site to 96% at the downstream most site (Table 21). On the mainstem, the percentage categorized as good or excellent ranged from 94% at the upstream most site to 73% at the downstream most site (rm 9.3).

Measurements were taken on 47 spring Chinook redds (Table A.3). Redd area ranged from 14 to 282 square feet (ft^2) with an average of 106 ft^2. Redd depths (pre-construction) ranged from 0.7 to 3.8 ft with an average of 1.5 ft. Water velocities ranged from 0.3 to 4.9 ft/s with an average of 1.8 ft/s. All measurements of redd area, depth, and water velocity were within the ranges reported for stream type (spring run) Chinook (Healey 1991). Redd substrate particles had a median size range of 1-3 in, a minimum of 1 in, and a maximum range of 3-4 in.

Spawning status was determined for 2 of the 6 Chinook carcasses recovered during stream surveys. Of the two carcasses, both were spawned. Spawning status frequently could not be determined due an advanced state of decay, carcasses being partially eaten by scavengers, or apparent skinning and fileting by poachers.

Winter steelhead redd surveys.—The number of steelhead redd surveys completed per reach ranged from six to seven (Table 22). Surveys generally occurred as scheduled due to relatively few storm events during the 2004-2005 winter. We observed a total of 166 rainbow trout/steelhead redds upstream of the CNFH barrier weir. Of the 166 redds, 71.1% were in the North Fork, 12.6% were in the South Fork, and 16.3% were in the mainstem. The highest number of rainbow trout/steelhead redds were observed in early February. Redds were observed as early as December 17, our first survey, and as late as April 12, our last survey. Nine fall or late-fall Chinook redds were also observed during the winter steelhead redds survey (Table 22).

Measurements were taken on 15 rainbow trout/steelhead redds (Table A.4). Redd area ranged from 3 to 107 ft^2 with an average of 20 ft^2. Redd depths (pre-construction) ranged from 0.4 to 3.0 ft with an average of 1.2 ft. Water velocity ranged from 0.4 to 3.3 ft/s with an average of 1.6 ft/s. Redd substrate particles had a median size range of 1-2 in, with a minimum of 1 in and a maximum range of 2-4 in.

Tissue Collection for Genetic Analyses

Genetic analysis was completed on tissue samples from 25 of the 26 unclipped Chinook captured in the barrier weir trap (March 1 - May 26). The quality of one sample was too poor to analyze. Results indicated that 76% were spring run, 24% were fall run, 0% were late-fall run, and 0% were winter run (M. A. Banks, Oregon State University, personal communication). The average confidence probabilities were equal for spring-run and fall-run at 0.93. Individuals identified as fall run were captured throughout the entire trapping period although the reported migration period for fall Chinook does not begin until sometime between mid-June and mid-July (Vogel and Marine 1991), which is after the period when we collected the tissue samples.

In some cases, individuals had a secondary run call. For example, the primary run call might be fall run with an 0.80 confidence probability and the secondary call might be spring run with a 0.20 confidence probability. Of the six samples from the barrier weir trap which were classified as fall run, three had a secondary run call of spring run and zero had a secondary run call of late-fall. Of the 19 samples classified as spring run, five had a secondary run call of fall run and zero had a secondary run call of late-fall.

We collected seven samples from Chinook carcasses encountered during the winter steelhead redd survey (January 5 - February 10, 2005). Of these, one was genetically classified as a late-fall run and the quality of the remaining six samples was too poor to analyze.

We collected seven samples from Chinook carcasses encountered during snorkel surveys (September 28 - October 26, 2005). Of these, one juvenile Chinook recovered on September 28 was genetically classified as a fall run (0.59 confidence probability) with a secondary call of spring run (0.41 confidence probability). The quality of the remaining six samples from adult carcasses was too poor to analyze.

Age Structure

Age was estimated from scale samples collected from carcasses sampled during snorkel surveys. In 2005, five readable scale samples were collected from Chinook during the spring run immigration and spawning period. Although five samples are likely too few to be representative of the entire population, one was a 2-year-old, three were 3-year-olds, and one was a 4-year-old.

Discussion

Chinook Salmon Population and Passage Estimates

We estimated that zero clipped and 73 unclipped Chinook passed the CNFH barrier weir between March 1 and August 1, 2005. We generally use the unclipped passage total (73 in 2005) to estimate the “maximum potential spring Chinook” escapement. It is likely that a proportion of this maximum estimate were actually winter, fall, and late-fall Chinook due to overlap in migration periods. Run-specific Chinook salmon population estimates presented in previous annual reports were based, in part, on the Mixed Stock Analysis genetic methods which classifies proportions of a sample group as winter, spring, fall, or late-fall run (Brown and Newton 2002, Brown et al. 2005, Brown and Alston 2007). Recently, improved genetic analysis techniques became available which were capable of assigning individuals to a particular run. Based on this new technique, we estimated approximately zero winter run, 67 spring run, 6 fall run, and zero late-fall run passed through the CNFH barrier weir ladder in 2005.

The 26 Chinook passing the weir during the trapping period (March 1-May 26) were assigned to a particular run according to genetic analysis results: 20 spring run and 6 fall run. This being said, we recognize that fall run may actually be mis-classified spring or late-fall run. Vogel and Marine (1991) report that fall Chinook do not begin migrating past Red Bluff Diversion Dam on the Sacramento River until sometime between mid-June and mid-July which is after the trapping period. The Red Bluff Diversion Dam is 29 miles downstream from the mouth of Battle Creek. This suggests that they are not fall run. Analysis of genetic data and run timing from 1996 to 2005 suggests that the potentially mis-classified Chinook are more likely spring run than late-fall run. Chinook classified as fall run were evenly distributed throughout the trapping period and not just in the early trapping period when late-fall Chinook are much more numerous. In 2005, three of the fall run had a secondary run assignment of spring run and five of the spring run had a secondary assignment of fall run, but none were secondarily classified as late-fall run. Because of the temporal and spatial overlap in spawn timing between fall and spring Chinook in Battle Creek, some hybridization may have occurred, making it difficult to genetically differentiate these two runs. Furthermore, the genetic analysis did not include any Battle Creek spring Chinook as a baseline for comparison. It is possible that some of the “fall” run Chinook fish may be remnant Battle Creek spring Chinook (M. A. Banks, Oregon State University, personal communication).

Recommendation: We recommend further population genetic analyses with existing data or incorporation of phenotypic Battle Creek spring Chinook into the genetic baseline to help determine if genetically classified fall Chinook are mis-classified spring Chinook, spring-fall hybrids, or late-fall Chinook.

We assumed that all 47 unclipped Chinook passing during the video monitoring period were spring Chinook. This assumption was made because the large majority of Chinook reported to migrate during this period (May 26-August 1) are spring run (Vogel and Marine 1991). This assumption is consistent with run estimation methods used in previous annual reports.

The total escapement estimate for rainbow trout was much lower in 2005 than escapement estimates from 2001 through 2004 (Table 1). This decrease was largely due to a decision by the USFWS and CNFH to discontinue passing clipped CNFH steelhead upstream of the barrier weir. In recent years, CNFH has passed some clipped steelhead upstream to aid in the timely recovery of steelhead in upper Battle Creek. The decision to no longer pass clipped steelhead was made based on concerns of the CALFED Technical Review Panel and the Battle Creek Watershed Conservancy concerning possible negative impacts of hatchery fish on naturally-spawning populations with respect to fitness and productivity (Busack et al. 2004).

During the trapping period, peak flows exceeded 2,000 cfs on three days in mid-May: 3,640 cfs on May 9, 3,560 cfs on May 18, and 2,970 cfs on May 19. At flows greater than 2,000 cfs, the trap cannot be operated and salmonids can pass over the weir with relative ease. Primarily unclipped Chinook and unclipped rainbow trout were passing during this period and some likely passed above the weir without being counted at our monitoring station.

During the video monitoring period, a total of seven Chinook and 17 rainbow trout were detected passing upsteam of the barrier weir by the VAKI infrared fish counter which were missed by video viewers. This indicates that there is some error and a negative bias in passage estimates based on video monitoring methods alone. We did not include these numbers in the escapement estimates because the VAKI was not used prior to 2004 and passage estimates would not be comparable if these fish were included.

Recommendation: We recommend using a secondary fish counting device such as a VAKI to improve the accuracy of video counts and to count fish during periods of high turbidity when video observations are not possible.

Following the 2003 sampling season, we recommended that the upstream fish ladder of the CNFH barrier weir be closed August 1 instead of August 31 in order to inhibit the passage of fall Chinook above the weir. Fall Chinook could potentially superimpose redds on spring Chinook redds or interbreed with spring Chinook. In most years that barrier weir passage has been monitored by underwater video, we have observed a decrease in passage followed by a gap of zero passage during July. In 2000 through 2003 video monitoring continued through August, and during these years we observed passage continuing in August after the gap in July. It is likely that these fish returning in August are fall Chinook returning to CNFH. California Department of Fish and Game (CDFG) and National Marine Fisheries Service (NMFS) agreed with the recommendation and the fish ladder was closed August 1 in 2004 and 2005. Similar to previous years, we observed a 13-day gap in passage in late July, 2005.

In 2005 we continued investigating diel passage timing of salmonids through the barrier weir fish ladder. Similar to previous years, we observed clipped Chinook passing early in the season in the afternoon, with the exception of high numbers being caught in the first trap check of the day. The high numbers captured in the first trap check may have resulted from fish being allowed to congregate in the trap throughout the night. Unclipped fish primarily passed a few hours after sunrise later in the season. Operating the trap at progressively earlier times of day from March through May resulted in lower water temperatures during trapping, potentially less stress on trapped fish, and a longer trapping season.

There are some uncertainties in accurately determining Chinook population estimates because the CNFH barrier weir is not fish tight. During August through March when the ladder to upstream Battle Creek is closed to passage, there is the potential for salmonids to escape upstream by jumping or swimming over the barrier weir. The ability of salmonids to successfully jump or swim over the weir may be affected by flow, concentration of salmonids below the weir, or other factors (USFWS 2001b). In the fall of 2005, our video monitoring of “jumpers” confirmed that some fall Chinook jumped over the weir at flows as low as 225 cfs. More study is needed to accurately relate the number of Chinook jumping the weir to flow.

Evaluation and Adaptive Management of Battle Creek Stream Flow

Increase North Fork flows to test barrier hypothesis.—A potential low-flow barrier at rm 3.04 on the North Fork (Reach 1) was identified in 2001 and 2002 as potentially impassible to Chinook at 30 cfs (current interim flow level). This raised concern as to whether it would be impassable at the future Restoration Project flow level of 35 cfs during this time of the year (NMFS et al. 1999). In 2005, summer MDFs decreased to summer base flow levels by July 12. One to three live Chinook were observed upstream of rm 3.04 on five separate surveys between June 20 and September 27 (Table 16). It is possible that these Chinook passed above rm 3.04 during higher flows in May and early June. No redds or carcasses were observed in Reach 1. Although we cannot determine the total number of Chinook and the exact flows at which they passed above the potential low-flow barrier, the possibility remains that this site is impassible to Chinook at current interim flow levels.

In a survey of fish barriers in Battle Creek, Thomas R. Payne and Associates (TRPA) identified a nearly impassable barrier on the North Fork at rm 5.06. TRPA (1998) suggested this barrier may be passable to steelhead and spring Chinook in good condition at flows >88 cfs. In 2005, we observed one Chinook as far up as rm 5.0 but nothing above this barrier. North Fork flows were >88 cfs until June 12. From 2001 through 2004, we did not observe Chinook above this barrier.

The effect of Interim Flows on South Fork Battle Creek.—In 2001 and most of 2002, interim flows of 30 cfs were not provided in the South Fork which resulted in higher water temperatures during the spring Chinook holding and early spawning periods. Coincidentally, in 2001 and 2002, an above average proportion of Chinook held and spawned in the South Fork (Tables 4 and 5). Since most spring Chinook return as 3-year-olds and some as 4-year-olds (Fisher 1994), most of the progeny from these two year classes would be expected to return in 2004 and 2005. Our 2001 and 2002 estimates for unclipped Chinook were 98 and 180 respectively, excluding passage in August (August passage was not allowed in 2004 and 2005). In comparison, our 2004 and 2005 estimates were 90 and 73, respectively. This decrease in escapement may have been caused, in part, by low flows in the South Fork in 2001 and 2002.

We also estimated the number of juveniles produced per unclipped female Chinook to explore differences in environmental condition between years with and without interim flows in the South Fork. Annual juvenile production estimates upstream of the CNFH barrier weir were made by an associated RBFWO monitoring project using rotary screw traps (K. S. Whitton, USFWS, unpublished data). We estimated the annual number of adult female Chinook by dividing the unclipped escapement estimate by two. For adults spawning in 2001 and 2002, juvenile production per unclipped female Chinook was 387 and 171, respectively. In comparison, juvenile production per female in 2003 and 2004 was 1,283 and 626, respectively. Data are not available for 2005. The lower juvenile production rates from adults returning in 2001 and 2002 may have been the result of poor holding and spawning conditions caused by the lack of interim flows in the South Fork in those years. Alternatively, inter-annual variation in juveniles per female may have been the result of (1) inaccuracies in estimates of adult females or juvenile production or (2) conditions during the winter and spring high flow period such as redd scour and variable entrainment rates at unscreened diversions.

Holding and spawning water temperatures.—The largest and most utilized holding pool for spring Chinook is in the upper mainstem Battle Creek (Reach 4). Classification of mean daily water temperatures in this pool from June 1 to September 30 included: 43% good, 53% fair, and 4% poor. Fair water temperatures can lead to some mortality and infertility and poor temperatures can result in unsuccessful spawning. Although we could not quantify exposure time for individual Chinook, it is likely that water temperatures at this location had negative impacts on holding adults prior to their spawning.

Our temperature analysis of each individual redd indicated that Chinook egg incubation temperatures were excellent on the large majority of days. We feel that incubating eggs did not experience any adverse effects from water temperatures. This may be a combination of interim flows providing cooler water temperatures, spawners waiting until water temperatures were suitable for spawning, and spawners selecting upstream locations with cooler water temperatures.

In the past five years of stream surveys, Chinook redd density (redds/mile) was highest in Reach 2 (lower North Fork) with the exception of 2001 (Table 6). Conversely, spawning density in Reach 1, located upstream of Reach 2, has been relatively low or nonexistent although it has the most suitable water temperatures for holding and spawning. Possible explanations as to why Chinook appear to prefer Reach 2 over Reach 1 include (1) proximity to large holding pools, (2) differences in the quantity and quality of spawning gravel, and (3) potential passage problems at Wildcat Dam fish ladder or natural barriers.

Winter steelhead redd surveys.—Pilot steelhead redd surveys were initiated in 2002 to explore the feasibility of using a combination of kayak and snorkel methods to determine the number and distribution of redds. In 2005, we were able to complete regularly scheduled surveys with the greatest frequency since surveys began in 2002. Throughout the winter, flows and turbidity was relatively low and viewing conditions were good. Winter steelhead redd surveys in 2005 were adequate to produce a relative population abundance index (i.e., number of redds), produce a spawning frequency index (e.g., number of redds per steelhead passing above the barrier weir), and document the spatial and temporal spawning distribution of steelhead. In previous years, weather, high flows, and high turbidity made it difficult to complete surveys and data were only useful to document some spawning locations. Also, unpredictable weather conditions made it difficult to schedule surveys in coordination with other monitoring work on Clear Creek and Battle Creek.

> **Recommendation**: We recommend discontinuing our winter steelhead redd survey used for obtaining redd counts and the spatial and temporal distribution of steelhead spawning. In most years, winter flow conditions in Battle Creek only allow for infrequent surveys leading to inaccurate and incomplete data. Steelhead passage estimates from CNFH spawning operations and barrier weir fish ladder counts can be used to track population trends.

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: Felipe Carrillo, Joe Chigbrow, David Colby, Michael Cotter, Jim Earley, Jimmy Faukner, Robert Feamster, Jessica Fischer, Shea Gaither, Sarah Giovannetti, Andy Hill, Ethan Jankowski, Tim Loux, Matt McCormick, Ed Martin, Phil Moeller, Laurie Stafford, Jonathan Sutliff, Brandon Thompson, Jonathan Thompson, Paul Walfoort, Angela Webb, David White, Lael Will, and Kara Yetishefsky. We thank the Coleman National Fish Hatchery staff, especially Scott Hamelberg, Mike Keeler, and Kurt Brown for assisting with barrier weir activities, and accommodating our project at the hatchery. We thank the Pacific Gas and Electric staff, especially Chip Stalica, for their cooperation and knowledge which they freely shared. We are grateful to the landowners of Battle Creek that provided us access and information critical to this project.

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Tables

TABLE 1.—Multi-year summary of the number of adult late-fall Chinook and steelhead trout passed upstream of Coleman National Fish Hatchery (CNFH) barrier weir during the CNFH broodstock collection and spawning program. Late-fall Chinook are generally passed from late December through February and steelhead from October through February. (R. Null, US Fish and Wildlife Service, unpublished data)

Year	Late-fall Chinook		Steelhead	
	Clipped	Unclipped	Clipped	Unclipped
2000-**2001**	0	98	1352	131
2001-**2002**	0	216	1428	410
2002-**2003**	0	57	769	416
2003-**2004**	0	40	314	179
2004-**2005**	0	23	0	270

TABLE 2.—Multi-year summary of estimated escapement in Battle Creek of clipped and unclipped Chinook salmon and rainbow trout/steelhead passing upstream through the Coleman National Fish Hatchery (CNFH) barrier weir fish ladder from March through August (Brown and Newton 2002, Brown et al. 2005, Brown and Alston 2007, Alston et al. 2007).

Year	Ladder Open (m/dd)	Chinook		Rainbow trout / steelhead	
		Clipped	Unclipped	Clipped	Unclipped
2001	3/03-8/31	5	111	30	94
2002	3/01-8/30	0	222	14	183
2003	3/03-8/29	13	221	3	118
2004	3/02-8/01	2	90	15	125
2005	3/01-8/01	0	73	0	74

TABLE 3.—Multi-year summary of total estimated escapement in Battle Creek of winter, spring, fall, and late-fall Chinook salmon and rainbow trout/steelhead passing upstream of the Coleman National Fish Hatchery (CNFH) barrier weir. Total estimated escapement includes Chinook salmon and steelhead passed during the CNFH broodstock collection and spawning program (prior to March) and Chinook and rainbow trout/steelhead passed through the barrier weir fish ladder (March-August). Maximum potential spring Chinook includes all unclipped salmon passed from March through August. Estimated spring Chinook escapement is a reduced estimate based on apportioning some Chinook to the winter, fall, or late-fall runs. Estimated late-fall Chinook escapement is all Chinook (unclipped) passed by CNFH plus a portion of Chinook passed through the fish ladder.

Year	Winter Chinook	Spring Chinook		Fall Chinook	Late-fall Chinook	Rainbow trout / steelhead	
		Maximum	Estimate			Clipped	Unclipped
2001	0+	111	100	9 to 14	98 to 102	1382	225
2002	3	222	144	42	249	1442	593
2003	0	221	100	130	61	772	534
2004	0	90	70	20	42	329	304
2005	0	73	67	6	23	0	344

TABLE 4.—Multi-year summary of total live Chinook (n) observed in August and their distribution among the North Fork, South Fork, and mainstem Battle Creek. Observations were made during August snorkel surveys.

Year	n =	North Fork	South Fork	Mainstem
2001	27	0 %	63 %	37 %
2002	88	0 %	58 %	42 %
2003	94	7 %	33 %	60 %
2004	26	0 %	8 %	92 %
2005	6	33%	33%	33%
Average	48	8%	39%	53%

TABLE 5.—Multi-year summary of total Chinook redds (n) observed between August and November and their distribution among the North Fork, South Fork, and mainstem Battle Creek. Observations were made during spring Chinook snorkel surveys.

Year	n =	North Fork	South Fork	Mainstem
2001	32	34 %	38 %	28 %
2002	78	35 %	21 %	45 %
2003	176	45 %	15 %	40 %
2004	34	73 %	9 %	18 %
2005	47	51%	13%	36%
Average	73	48%	19%	33%

TABLE 6.—Multi-year summary of Chinook redd density (redds / mile) in Battle Creek snorkel survey reaches.

Year	North Fork (Reaches 1-2)	South Fork (Reach 3)	Mainstem (Reaches 4-6)	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
2001	2	5	1	1	3	5	1	1	1
2002	5	6	3	3	8	6	4	4	2
2003	15	10	7	5	26	10	12	3	5
2004	5	1	1	0	10	1	2	0	0
2005	5	2	2	0	10	2	3	2	<1

TABLE 7.—Reach numbers and locations with associated river miles (rm) for Battle Creek stream surveys.

Reach	Reach length (miles)	Upstream		Downstream	
		Location	rm	Location	rm
1 (North Fork)	2.75	Eagle Canyon Dam	5.25	Wildcat Dam	2.50
2 (North Fork)	2.50	Wildcat Dam	2.50	Confluence of forks	0.00
3 (South Fork)	2.54	Coleman Diversion Dam	2.54	Confluence of forks	0.00
4	3.82	Confluence of forks	16.61	Mt. Valley Ranch	12.79
5	3.47	Mt. Valley Ranch	12.79	Ranch road	9.32
6	3.49	Ranch road	9.32	Barrier weir	5.83
7	2.99	Barrier weir	5.83	Lower Rotary Screw Trap	2.84

TABLE 8.—Temperature criteria used to evaluate the suitability of Battle Creek water temperatures for Spring Chinook. Criteria are modified 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	≤56	Optimum	Excellent
	>56 to ≤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 9.—Chinook captured at Coleman National Fish Hatchery barrier weir trap and associated passage estimates for 2005.

Dates	Actual number clipped	Actual number unclipped	Actual number unknown	Passage estimate: clipped	Passage estimate: unclipped
1-5 March	24	0	0	0	0
6-12 March	21	0	0	0	0
13-19 March	7	2	0	0	2
20-26 March	6	1	0	0	1
27 March-2 April	6	2	0	0	2
3-9 April	2	1	0	0	1
10-16 April	0	3	0	0	3
17-23 April	0	4	0	0	4
24-30 April	1	4	0	0	4
1-7 May	0	2	0	0	2
8-14 May	2	2	0	0	2
15-21 May	0	0	0	0	0
22-26 May	0	5	0	0	5
Total	69	26	0	0	26

TABLE 10.—Rainbow trout/steelhead captured at Coleman National Fish Hatchery barrier weir trap and associated passage estimates for 2005.

Dates	Actual number clipped	Actual number unclipped	Actual number unknown	Passage estimate: clipped	Passage estimate: unclipped
1-5 March	4	9	0	0	9
6-12 March	0	9	1	0	10
13-19 March	0	1	0	0	1
20-26 March	0	1	0	0	1
27 March-2 April	0	3	0	0	3
3-9 April	0	4	0	0	4
10-16 April	0	2	0	0	2
17-23 April	0	0	0	0	0
24-30 April	0	1	0	0	1
1-7 May	0	1	0	0	1
8-14 May	0	3	0	0	3
15-21 May	0	6	0	0	6
22-26 May	1	3	0	0	3
Total	5	43	1	0	44

TABLE 11.—Chinook salmon video recorded passing the Coleman National Fish Hatchery barrier weir fish ladder and associated passage estimates for 2005. Passage estimates include estimated passage during hours not video recorded.

Dates	Hours of passage	Hours of taped passage	Actual number clipped	Actual number unclipped	Actual number unknown	Passage estimate: clipped	Passage estimate: unclipped
26-28 May	58.5	58.5	0	2	0	0	2
29 May-4 June	168	148.1	0	5	0	0	5.7
5-11 June	168	162.6	0	5	0	0	5.2
12-18 June	168	142.5	0	10	0	0	11.8
19-25 June	168	167.8	0	6	0	0	6.0
26 June-2 July	168	167.8	0	5	0	0	5.0
3-9 July	168	157.4	0	6	0	0	6.4
10-16 July	168	134.5	0	3	0	0	3.7
17-23 July	168	142.8	0	1	0	0	1.2
24 July-1 August	200.5	125.9	0	0	0	0	0
Total	1603	1407.9	0	43	0	0	47

TABLE 12.—Rainbow trout/steelhead video recorded passing the Coleman National Fish Hatchery barrier weir fish ladder and associated passage estimates for 2005. Passage estimates include estimated passage during hours not video recorded.

Dates	Hours of passage	Hours of taped passage	Actual number clipped	Actual number unclipped	Actual number unknown	Passage estimate: clipped	Passage estimate: unclipped
26-28 May	58.5	58.5	0	7	0	0	7
29 May-4 June	168	148.1	0	10	0	0	11.3
5-11 June	168	162.6	0	4	0	0	4.1
12-18 June	168	142.5	0	1	0	0	1.2
19-25 June	168	167.8	0	0	0	0	0
26 June-2 July	168	167.8	0	2	0	0	2.0
3-9 July	168	157.4	0	2	0	0	2.1
10-16 July	168	134.5	0	2	0	0	2.5
17-23 July	168	142.8	0	0	0	0	0
24 July-1 August	200.5	125.9	0	0	0	0	0
Total	1603	1407.9	0	28	0	0	30

TABLE 13.—Total passage estimates for Chinook and rainbow trout/steelhead above the Coleman National Fish Hatchery (CNFH) barrier weir in 2005.

Passage Route	Chinook Passage: Clipped	Chinook Passage: Unclipped	Steelhead Passage: Clipped	Steelhead Passage: Unclipped
CNFH	0	23	0	270
Barrier Weir: Trap	0	26	0	44
Barrier Weir: Video	0	47	0	30
Total	0	96	0	344

TABLE 14.—Date, time, and stream flow for adult Chinook observed jumping over the Coleman National Fish Hatchery barrier weir (n=7). Video monitoring was conducted during daylight hours from August 1 to November 30, 2005 and a subsample of 33 days were reviewed to detect jumpers.

	Jump #1		Jump #2	
Date of Successful Jumps	Flow (cfs)	Time	Flow (cfs)	Time
8/17/05	225	0730		
9/9/05	394	1829	394	1832
9/12/05	336	1515	336	1520
10/19/05	268	1616		
11/25/05	318	1628		

TABLE 15.—Chinook salmon live adults, carcasses, and redds observed during the 2005 Battle Creek snorkel surveys.

Reach	Date	Chinook	Carcasses	Redds
1	6/20/05	2	0	0
1	7/12/05	3	0	0
1	8/8/05	2	0	0
1	9/12/05	1	0	0
1	9/27/05	2	0	0
1	10/11/05	0	0	0
1	10/25/05	0	0	0
1	11/7/05	0	0	0
2	6/15/05	1	0	0
2	7/13/05	1	0	0
2	8/9/05	0	0	0
2	9/14/05	2	0	1
2	9/28/05	4	1	5
2	10/12/05	10	1	17
2	10/25/05	3	0	1
2	11/10/05	0	0	0
3	6/15/05	0	0	0
3	7/13/05	4	0	0
3	8/9/05	2	0	0
3	9/14/05	1	0	0
3	9/28/05	4	0	2
3	10/12/05	4	0	3
3	10/26/05	1	3	1
3	11/10/05	0	0	0
4	6/16/05	2	0	0

TABLE 15.—Continued

Reach	Date	Chinook	Carcasses	Redds
4	7/14/05	6	0	0
4	8/10/05	2	0	0
4	9/15/05	9	0	0
4	9/29/05	8	0	3
4	10/13/05	5	1	5
4	10/26/05	0	1	1
4	11/14//05	3	0	1
5	6/16/05	0	0	0
5	7/14/05	0	0	0
5	8/10/05	0	0	0
5	9/15/05	0	0	0
5	9/29/05	0	0	1
5	10/13/05	3	0	5
5	10/28/05	0	0	0
5	11/14/05	0	0	0
6	6/17/05	0	0	0
6	7/15/05	0	0	0
6	8/11/05	0	0	0
6	9/16/05	0	0	0
6	9/30/05	0	0	1
6	10/13/05	1	0	0
6	10/28/05	0	0	0
6	11/15/05	0	0	0
7	6/17/05	0	0	0
7	7/15/05	0	0	0
7	8/11/05	0	0	0

TABLE 15.—Continued

Reach	Date	Chinook	Carcasses	Redds
7	9/16/05	114	0	0
7	9/30/05	2928	0	0
Total (Reaches 1-6)			7	47

TABLE 16.—Counts of live Chinook observed on Battle Creek snorkel surveys in 2005. Totals only include reaches above the Colman National Fish Hatchery barrier weir (reaches 1-6).

Reach	**June** 14-17	**July** 11-15	**August** 8-12	**September** 12-16	**September** 26-30	**October** 11-14	**October** 24-28	**November** 7-10
1	2	3	2	1	2	0	0	0
2	1	1	0	2	4	10	3	0
3	0	4	2	1	4	4	1	0
4	2	6	2	9	8	5	0	3
5	0	0	0	0	0	3	0	0
6	0	0	0	0	0	1	0	0
7	0	0	0	114	2928			
Total (Reaches 1-6)	5	14	6	13	18	23	4	3

TABLE 17.—Rainbow trout/steelhead observed during the 2005 Battle Creek snorkel survey. Small fish are larger than young-of-the-year up to 16 inches. Medium fish are from 16 to 22 inches. Large fish are greater than 22 inches.

Reach	Date	Small	Medium	Large	Total
1	6/14/05	586	2	0	588
1	7/12/05	489	0	0	489
1	8/8/05	458	1	0	459
1	9/12/05	377	0	0	377
1	9/27/05	460	0	0	460
1	10/11/05	636	1	0	637
1	10/25/05	515	1	0	516
1	11/7/05	276	0	0	276
2	6/15/05	393	9	1	403
2	7/13/05	587	1	0	588
2	8/9/05	820	4	0	824
2	9/14/05	718	3	0	721
2	9/28/05	568	3	0	571
2	10/12/05	356	1	0	357
2	10/25/05	356	5	0	341
2	11/10/05	244	1	0	245
3	6/15/05	197	7	0	204
3	7/13/05	325	20	0	345
3	8/9/05	147	0	0	147
3	9/14/05	376	5	0	381
3	9/28/05	572	10	0	582
3	10/12/05	217	12	1	230
3	10/26/05	184	0	0	184
3	11/10/05	86	15	2	103
4	6/16/05	264	22	0	286

TABLE 17.—Continued

Reach	Date	Small	Medium	Large	Total
4	7/14/05	527	20	1	548
4	8/10/05	109	8	0	117
4	9/15/05	572	6	2	580
4	9/29/05	543	22	0	565
4	10/13/05	363	29	1	393
4	10/26/05	349	13	0	362
4	11/14/05	351	19	3	373
5	6/16/05	95	3	0	98
5	7/14/05	158	19	0	177
5	8/10/05	58	3	0	61
5	9/15/05	317	15	0	332
5	9/29/05	273	13	0	286
5	10/13/05	242	20	0	262
5	10/28/05	231	18	1	250
5	11/14/05	295	1	0	296
6	6/17/05	76	1	0	77
6	7/15/05	57	4	0	61
6	8/11/05	26	1	0	27
6	9/16/05	68	3	0	71
6	9/30/05	79	10	5	94
6	10/13/05	83	3	1	87
6	10/28/05	140	4	1	145
6	11/15/05	33	2	1	36
7	6/17/05	17	0	0	17
7	7/15/05	89	30	5	124
7	8/11/05	51	15	2	68

TABLE 17.—Continued

Reach	Date	Small	Medium	Large	Total
7	9/16/05	93	55	11	159
7	9/30/05	94	33	7	134

TABLE 18.—Counts of rainbow trout/steelhead observed on Battle Creek snorkel surveys in 2005. Totals only include reaches above the Colman National Fish Hatchery barrier weir (reaches 1-6).

Reach	June 14-17	July 11-15	August 8-12	September 12-16	September 26-30	October 11-14	October 24-28	November 7-10	Reach Average
1	588	489	459	377	460	637	516	276	475
2	403	588	824	721	571	357	361	245	509
3	204	345	147	381	582	230	184	103	272
4	286	548	117	580	565	393	362	373	403
5	98	177	61	332	286	262	250	296	220
6	77	61	27	71	94	87	145	36	74.8
7	17	124	68	159	134				100
Total (Reaches 1-6)	1656	2208	1635	2462	2558	1966	1818	1329	

TABLE 19.—Number of days mean daily temperatures met Ward and Keir's (1999) suitability categories for spring Chinook holding from June 1 through September 30, 2005 at select monitoring sites in Battle Creek.

Site Name	Location	River Mile	No Data	Very Poor	Poor	Fair	Good
Eagle Canyon Dam	North Fork	5.3[a]	22	0	0	8	92
Wildcat Dam	North Fork	2.5[a]	0	0	0	41	81
Wildcat Road Bridge	North Fork	0.9[a]	0	0	8	61	53
Above confluence of forks	North Fork	0.05[a]	17	0	10	61	34
Coleman Diversion Dam	South Fork	2.5[a]	0	0	0	54	68
Manton Road Bridge	South Fork	1.7[a]	0	0	0	53	69
Above confluence of forks	South Fork	0.1[a]	0	0	9	56	57
Below confluence of forks	Mainstem	16.0[b]	0	0	12	60	50
Reach 4 Upper	Mainstem	15.9[b]	9	0	5	60	48
Reach 4 Lower	Mainstem	12.9[b]	0	0	28	51	43
Reach 5 Upper	Mainstem	12.2[b]	11	0	28	39	44
Reach 5 Lower	Mainstem	9.3[b]	37	0	39	20	26
Total			96	0	139	564	665

[a] From confluence of the North Fork and South Fork Battle Creek
[b] From confluence with the Sacramento River

TABLE 20.—Estimated percent of days that spring Chinook egg incubation fell within water temperature suitability categories in Battle Creek in 2005. Parentheses include the mean number of days redds were exposed to each category.

Reach	Location	n = (Redds)	Very Poor	Poor	Fair	Good	Excellent
1	North Fork	0					
2	North Fork	23	0%	0%	0.04% (<1)	0.9% (1)	99.1% (104)
3	South Fork	6	0%	0%	0%	0%	100% (125)
4	Mainstem	10	0%	0%	0%	0%	100% (122)
5	Mainstem	6	0%	0%	0.4% (<1)	3.8% (4)	95.8% (102)
6	Mainstem	1	0%	0%	0%	6.9% (7)	93.1% (95)
7	Mainstem	0					
Total		46	0%	0%	0.1% (<1)	1.0% (1)	98.9% (110)

TABLE 21.—Number of days mean daily temperatures met Ward and Keir's (1999) suitability categories for spring Chinook egg incubation from September 15 through October 31, 2005 at select monitoring sites in Battle Creek.

Site Name	Location	River Mile	No Data	Very Poor	Poor	Fair	Good	Excell-ent
Eagle Canyon Dam	North Fork	5.3[a]	0	0	0	0	5	42
Wildcat Dam	North Fork	2.5[a]	0	0	0	0	7	40
Wildcat Road Bridge	North Fork	0.9[a]	0	0	0	2	13	32
Above confluence of forks	North Fork	0.05[a]	0	0	0	12	5	30
Coleman Diversion Dam	South Fork	2.5[a]	0	0	0	0	2	45
Manton Road Bridge	South Fork	1.7[a]	0	0	0	0	8	39
Above confluence of forks	South Fork	0.1[a]	0	0	0	2	11	34
Below confluence of forks	Mainstem	16.0[b]	0	0	0	3	11	33
Reach 4 Upper	Mainstem	15.9[b]	19[c]	0	0	7	8	32[c]
Reach 4 Lower	Mainstem	12.9[b]	0	0	2	10	5	30
Reach 5 Upper	Mainstem	12.2[b]	19[c]	0	0	10	6	31[c]
Reach 5 Lower	Mainstem	9.3[b]	2	2	6	4	15	18
Total			2	2	8	50	96	406

[a] From confluence of the North Fork and South Fork Battle Creek
[b] From confluence with the Sacramento River
[c] Temperatures were estimated for 19 days (October 13-31) based on correlation with the nearest site.

TABLE 22.—Number of rainbow trout/steelhead redds observed upstream of Coleman National Fish Hatchery barrier weir during winter steelhead redd surveys on Battle Creek from December 15, 2004 through April 12, 2005. Numbers in parentheses are the number of Chinook redds observed during the winter steelhead redd surveys.

Date	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Week Total
12/15/04-12/17/04	0	0	0	2	2	0 (1)	4
1/5/05-1/13/05	10		6 (1)	0	1 (1)	0	17
1/18/05-1/25/05	3 (1)	12 (2)	5				20
2/7/05-2/10/05	16	26 (1)	7	9	3	0	61
2/22/05-2/25/05	8	10	2	4 (1)	0	0	24
3/7/05-3/11/05	8	19	1 (1)	4	0	0	32
4/5/05-4/12/05	6	0	0	1	1	0	8
Total	51	67	21	20	7	0	166 (9)

Figures

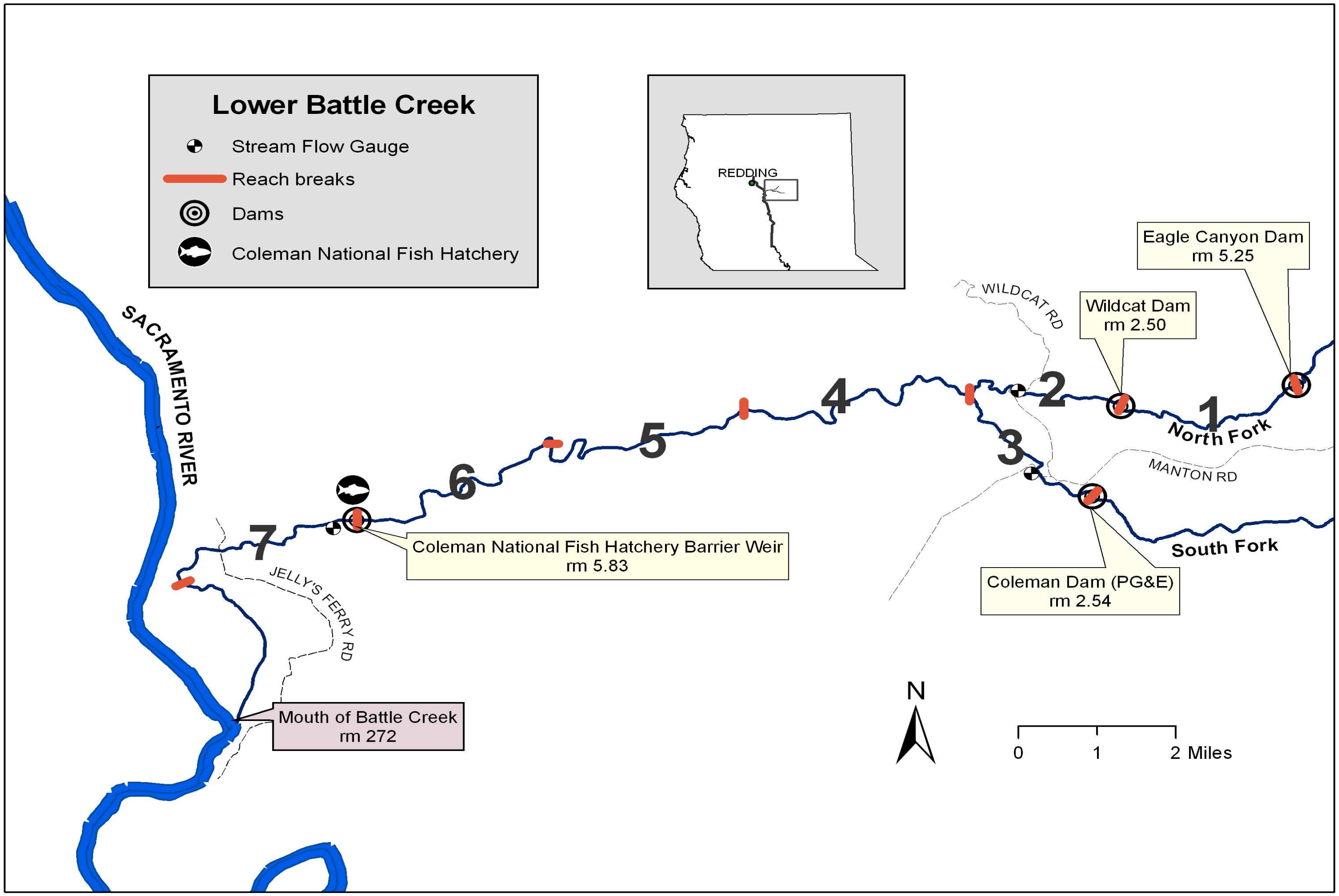

FIGURE 1.—Map of Battle Creek depicting the location of the Coleman National Fish Hatchery barrier weir and stream survey reaches.

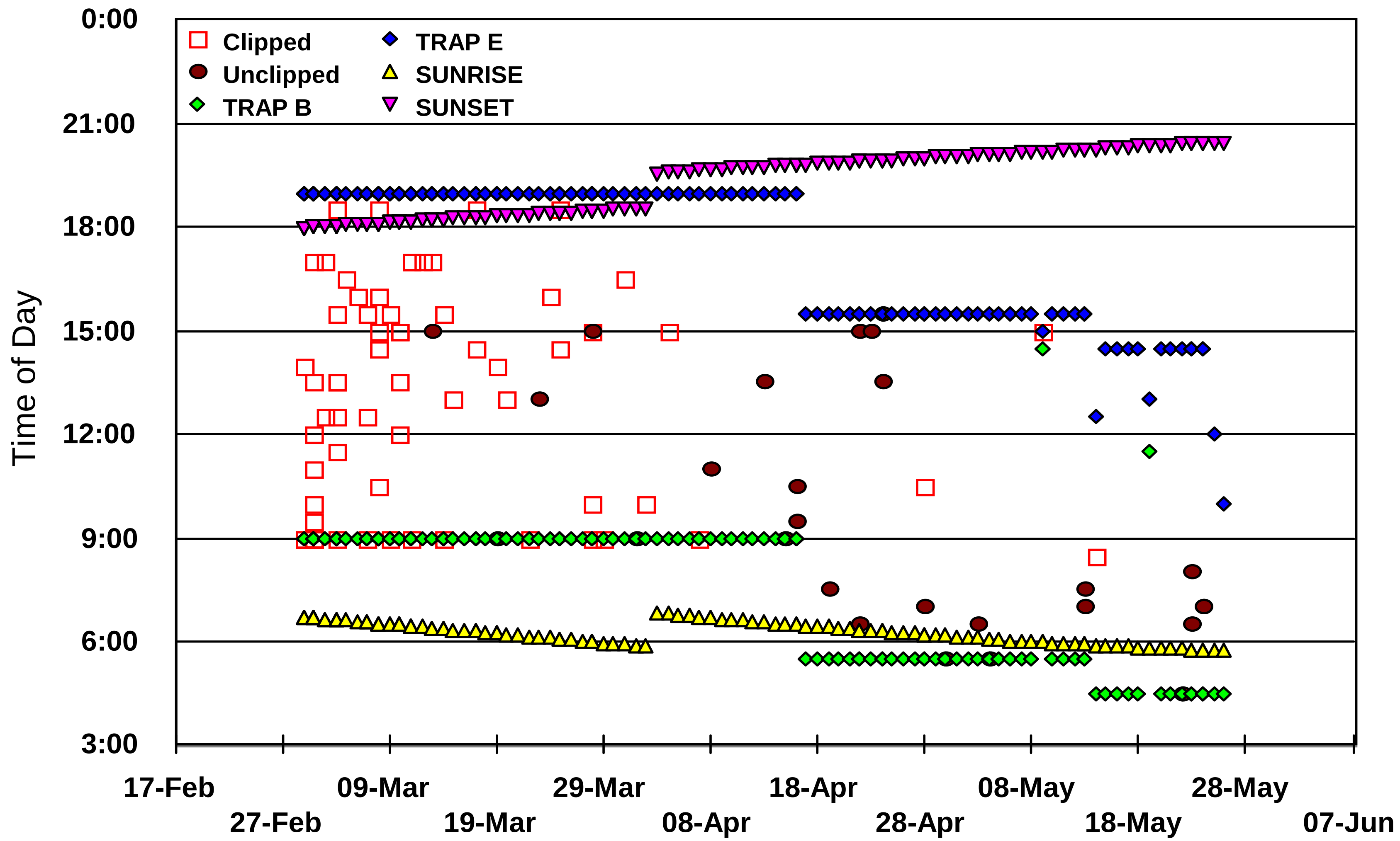

FIGURE 2.—Diel migration timing of Chinook (clipped and unclipped) caught in the Coleman National Fish Hatchery barrier weir trap in 2005. Also included are times of sunrise, sunset, beginning of trap operation (Trap B), and end of trap operation (Trap E).

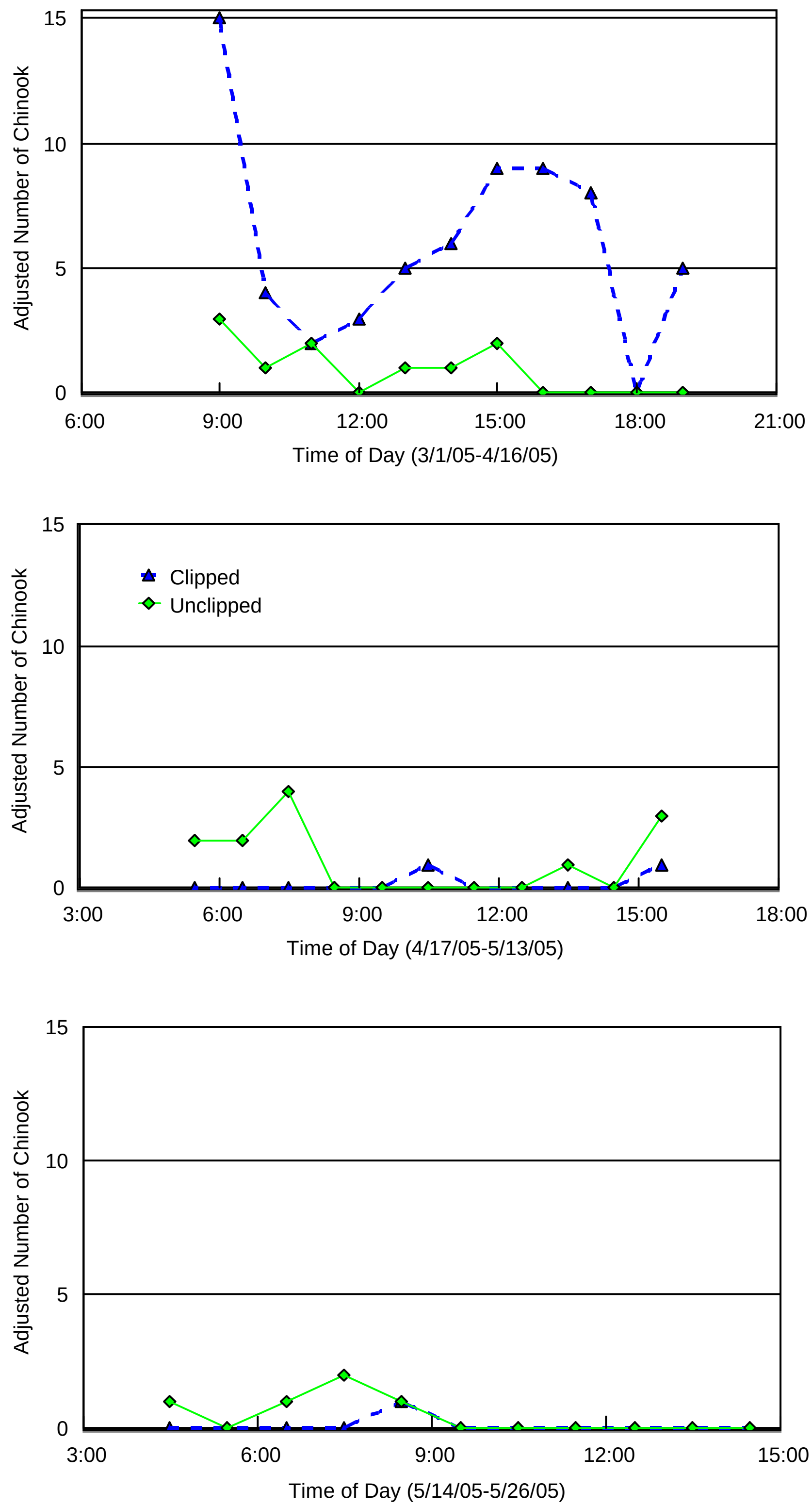

FIGURE 3.—Adjusted time-frequency distribution of Chinook caught in the Coleman National Fish Hatchery barrier weir trap in 2005. Three graphs represent three different start times. Start times were shifted to capture earlier passing Chinook. In addition, these earlier times coincided with lower water temperatures.

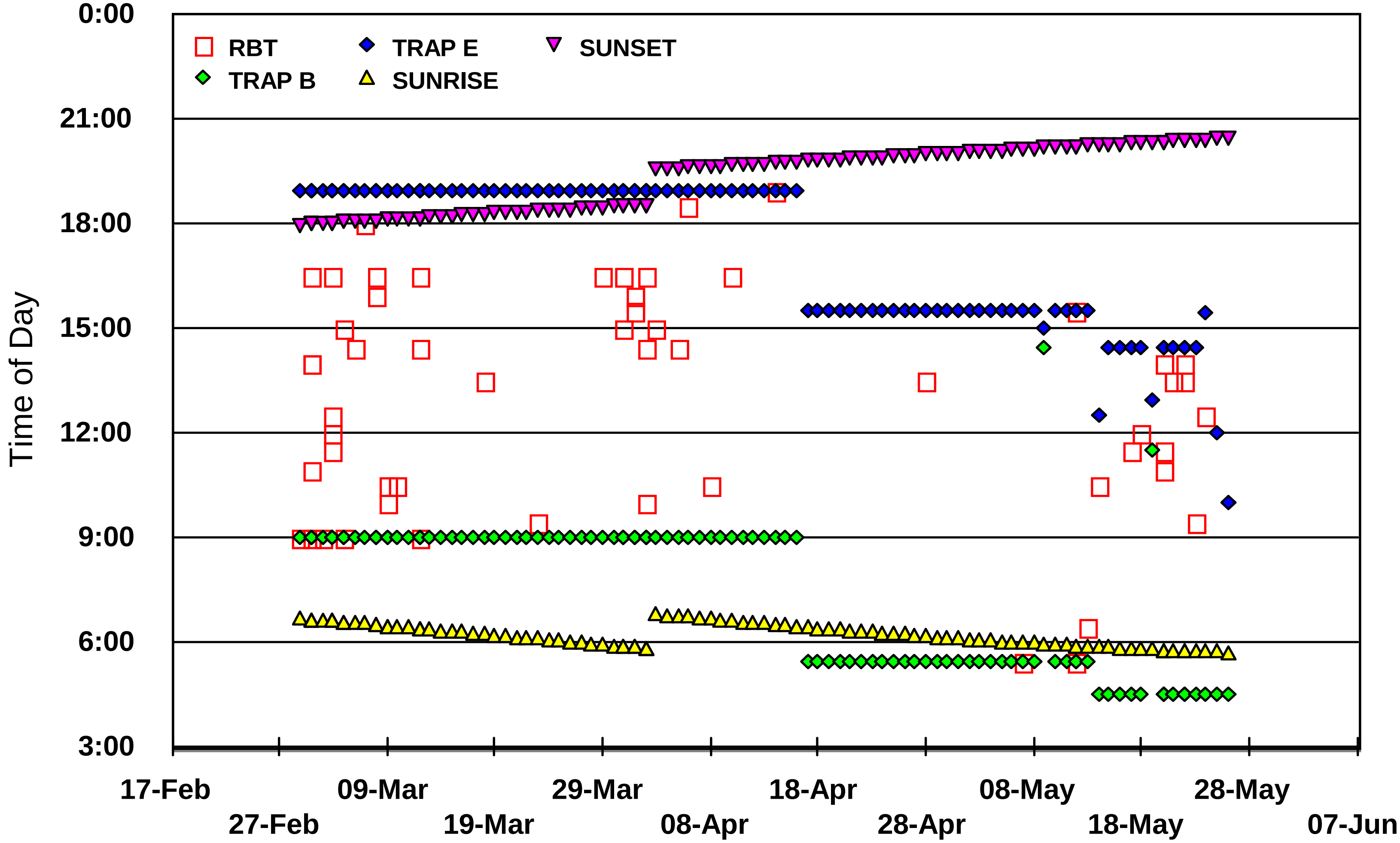

FIGURE 4.—Diel migration timing of rainbow trout/steelhead (RBT) caught in the Coleman National Fish Hatchery barrier weir trap in 2005. Also included are times of sunrise, sunset, beginning of trap operation (Trap B), and end of trap operation (Trap E).

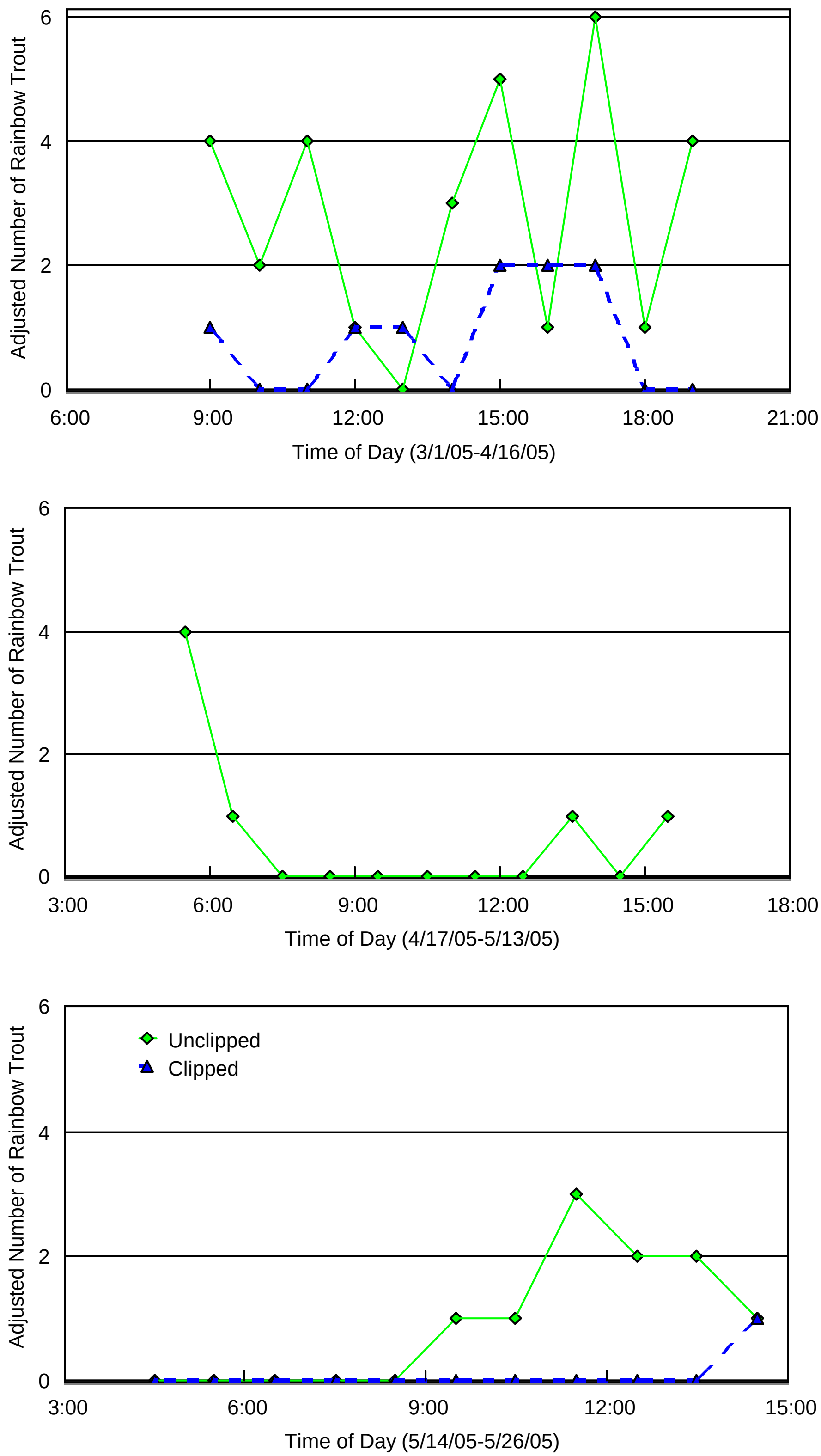

FIGURE 5.—Adjusted time-frequency distribution of rainbow trout/steelhead caught in the Coleman National Fish Hatchery barrier weir trap in 2005. Three graphs represent three different start times. These earlier times coincided with lower water temperatures.

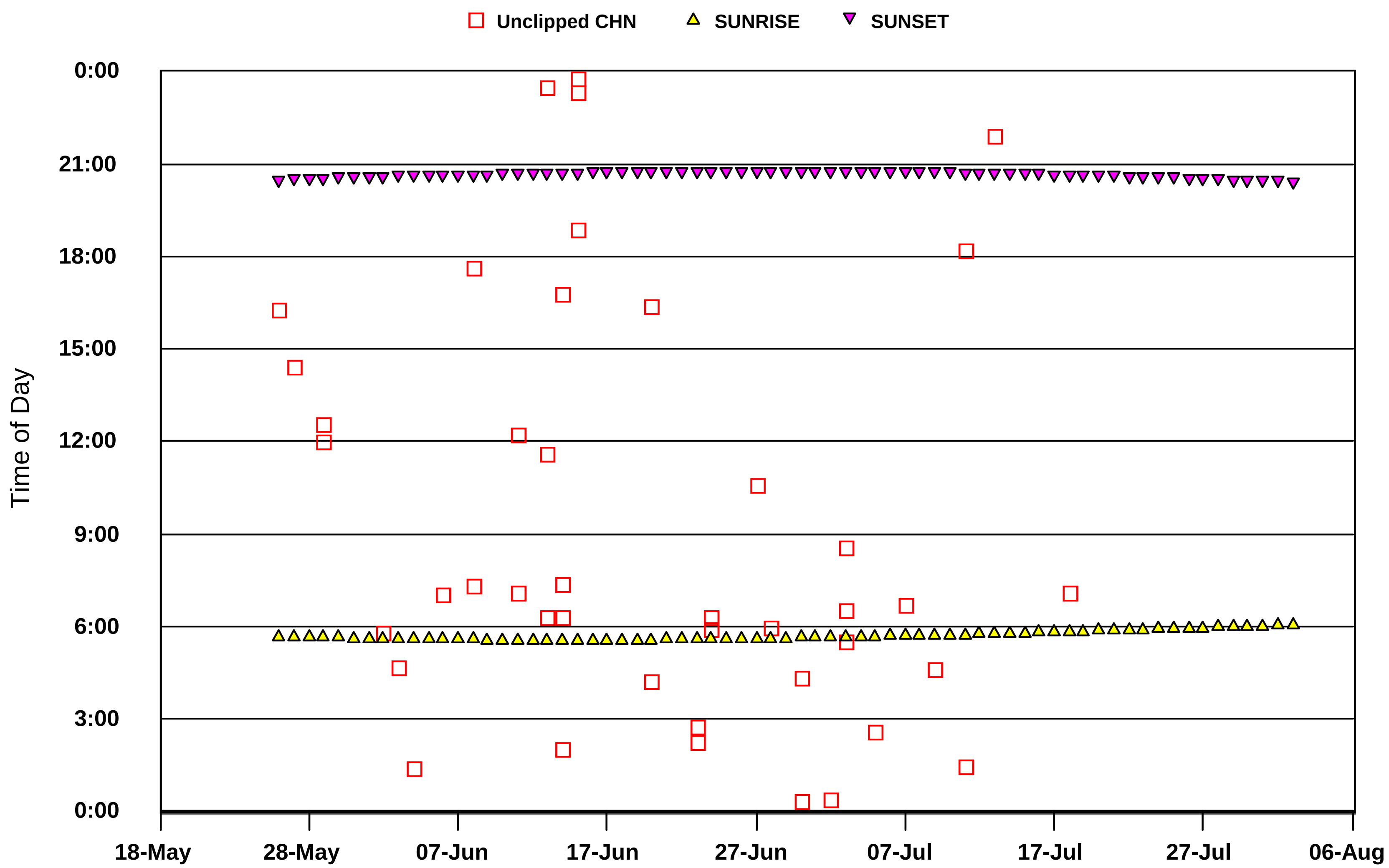

FIGURE 6.—Diel migration timing of Chinook (CHN) video taped passing the Coleman National Fish Hatchery barrier weir between May 26 and August 1, 2005.

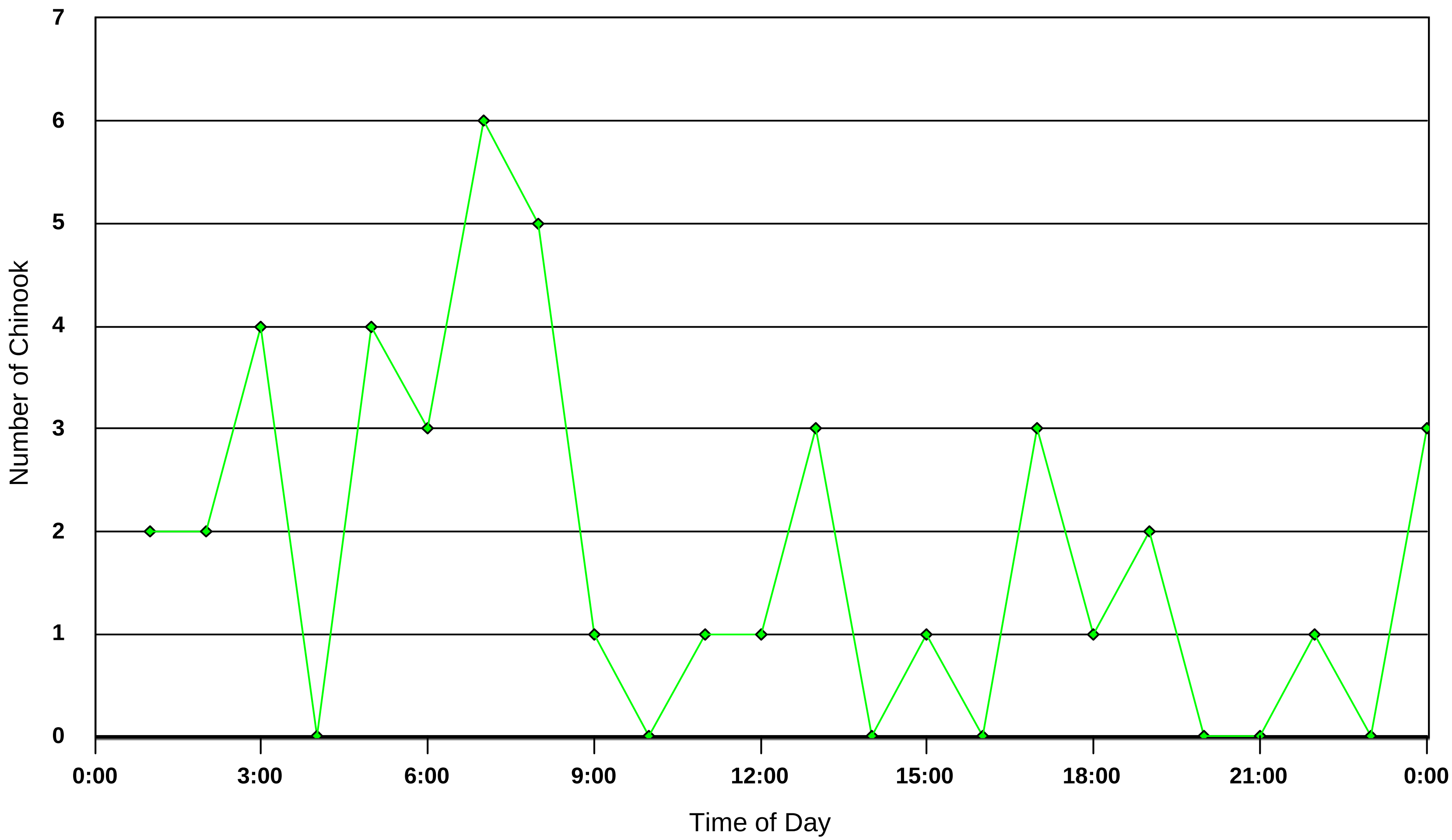

FIGURE 7.—Time-frequency distribution of Chinook video taped passing the Coleman National Fish Hatchery barrier weir between May 26 and August 1, 2005.

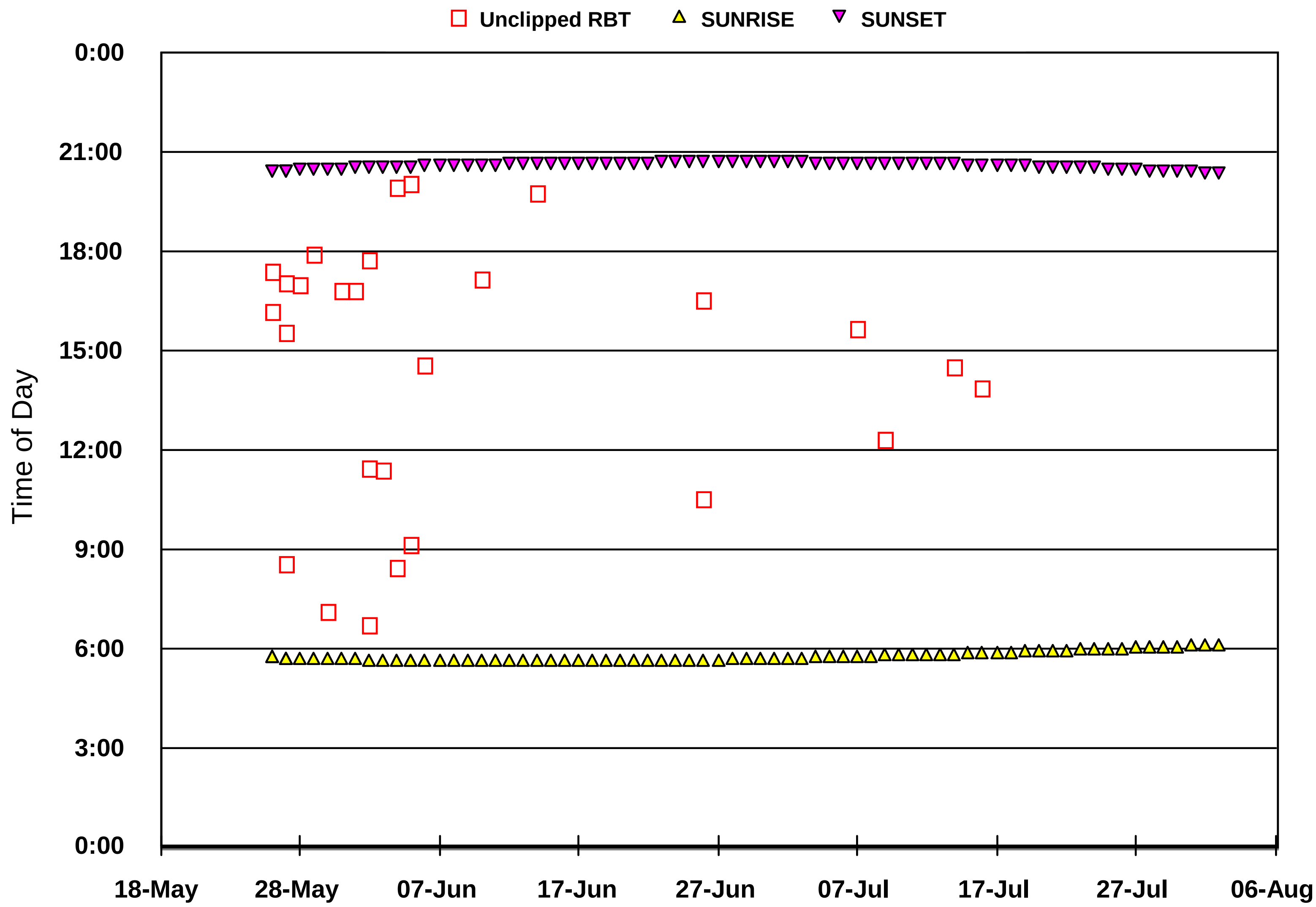

FIGURE 8.—Diel migration timing of rainbow trout/steelhead (RBT) video taped passing the Coleman National Fish Hatchery barrier weir between May 26 and August 1, 2005.

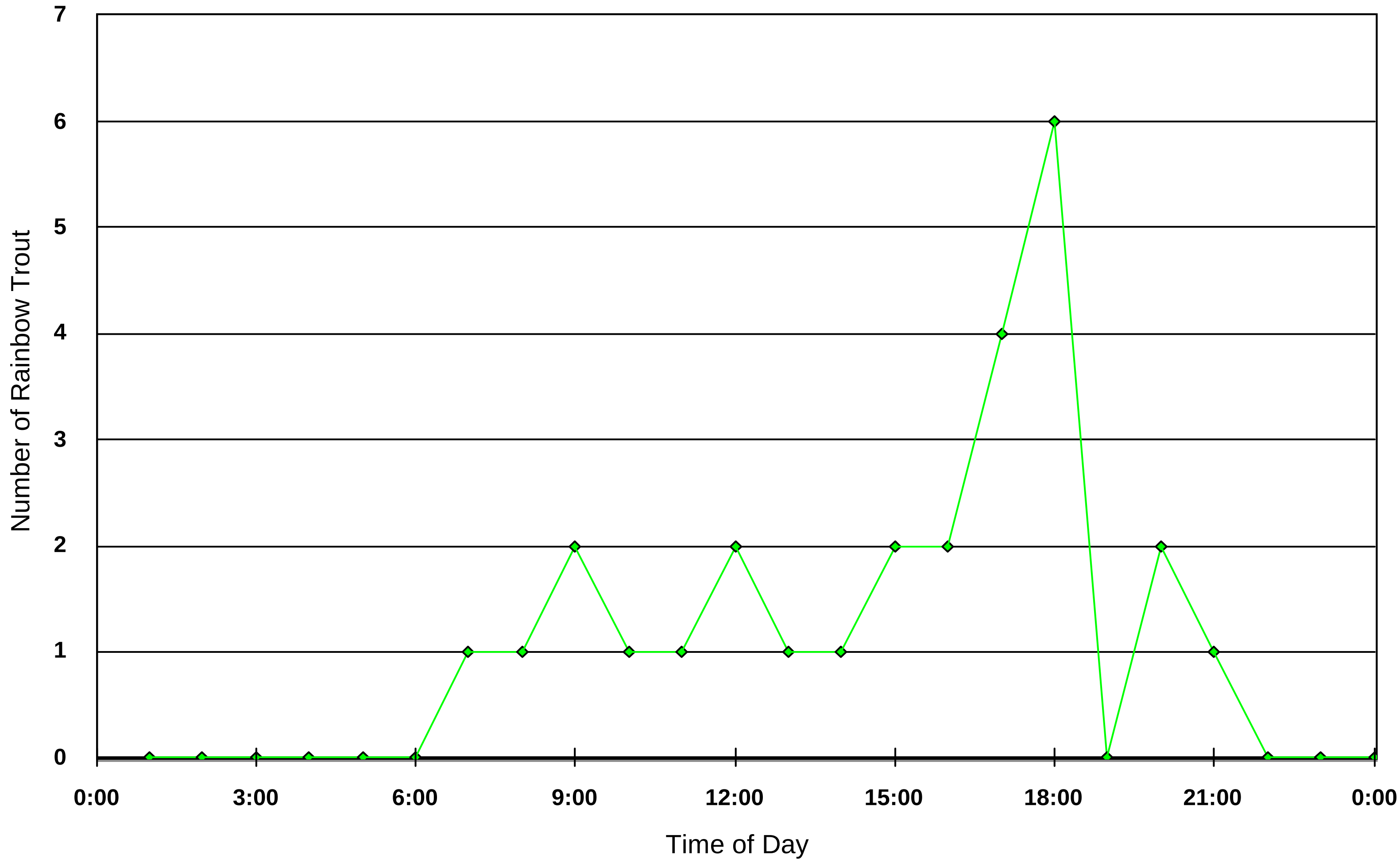

FIGURE 9.—Time-frequency distribution of rainbow trout/steelhead video taped passing the Coleman National Fish Hatchery barrier weir between May 26 and August 1, 2005.

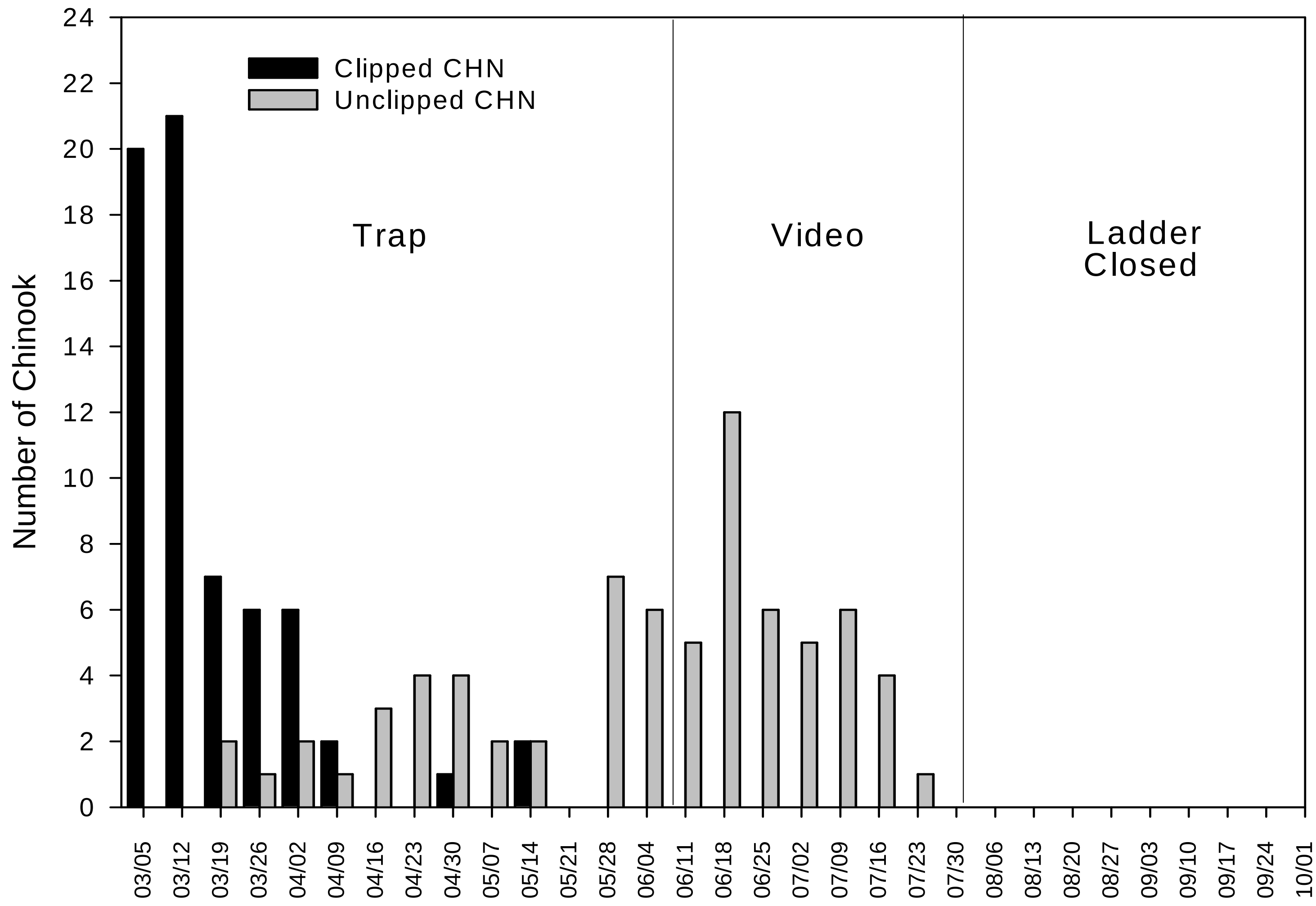

FIGURE 10.—Number of clipped and unclipped Chinook salmon (CHN) observed at the Coleman National Fish Hatchery barrier weir fish ladder in 2005, by week. Dates indicate the last day of the week.

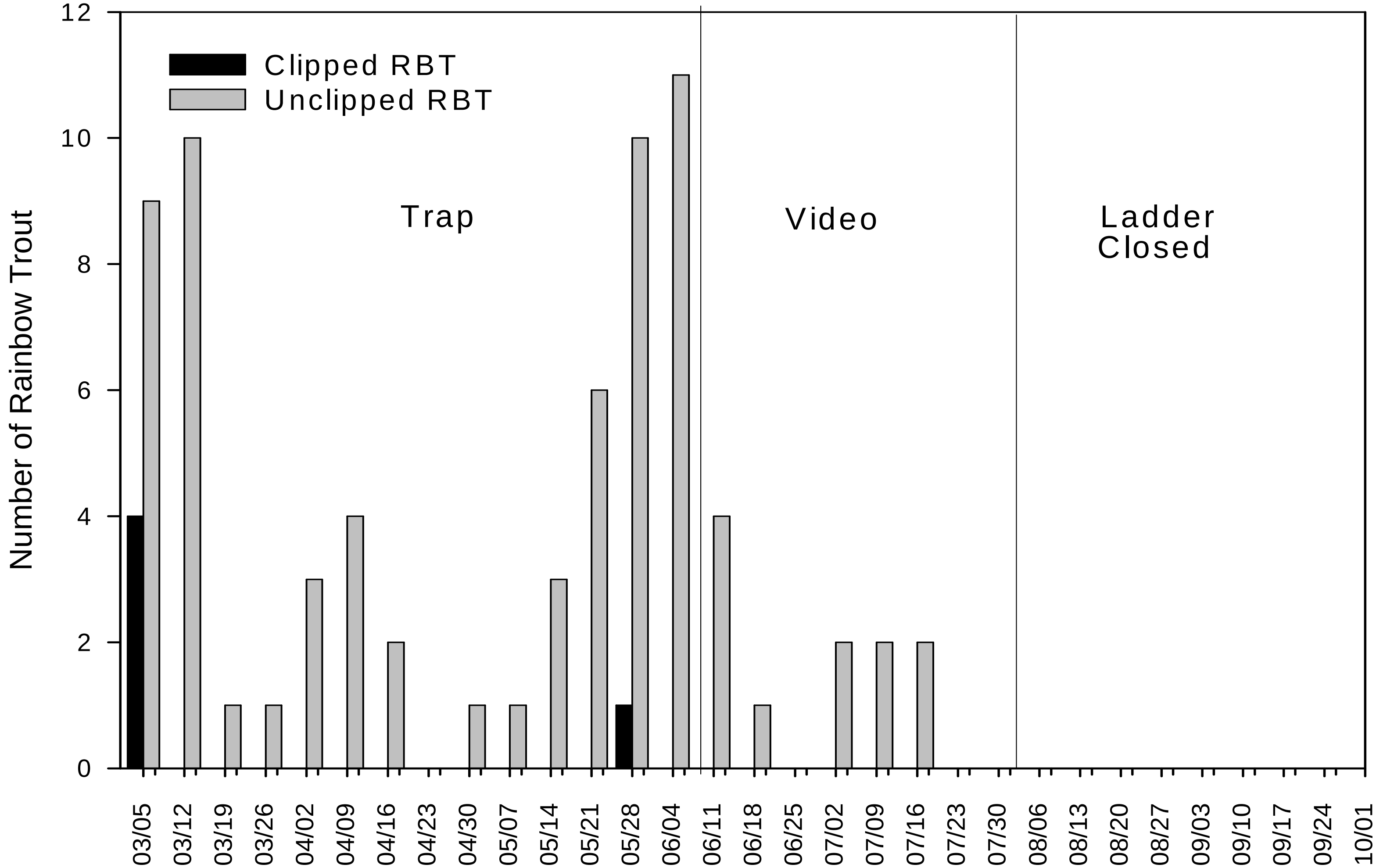

FIGURE 11.—Number of clipped and unclipped rainbow trout/steelhead (RBT) observed at the Coleman National Fish Hatchery barrier weir fish ladder in 2005, by week. Dates indicate the last day of the week.

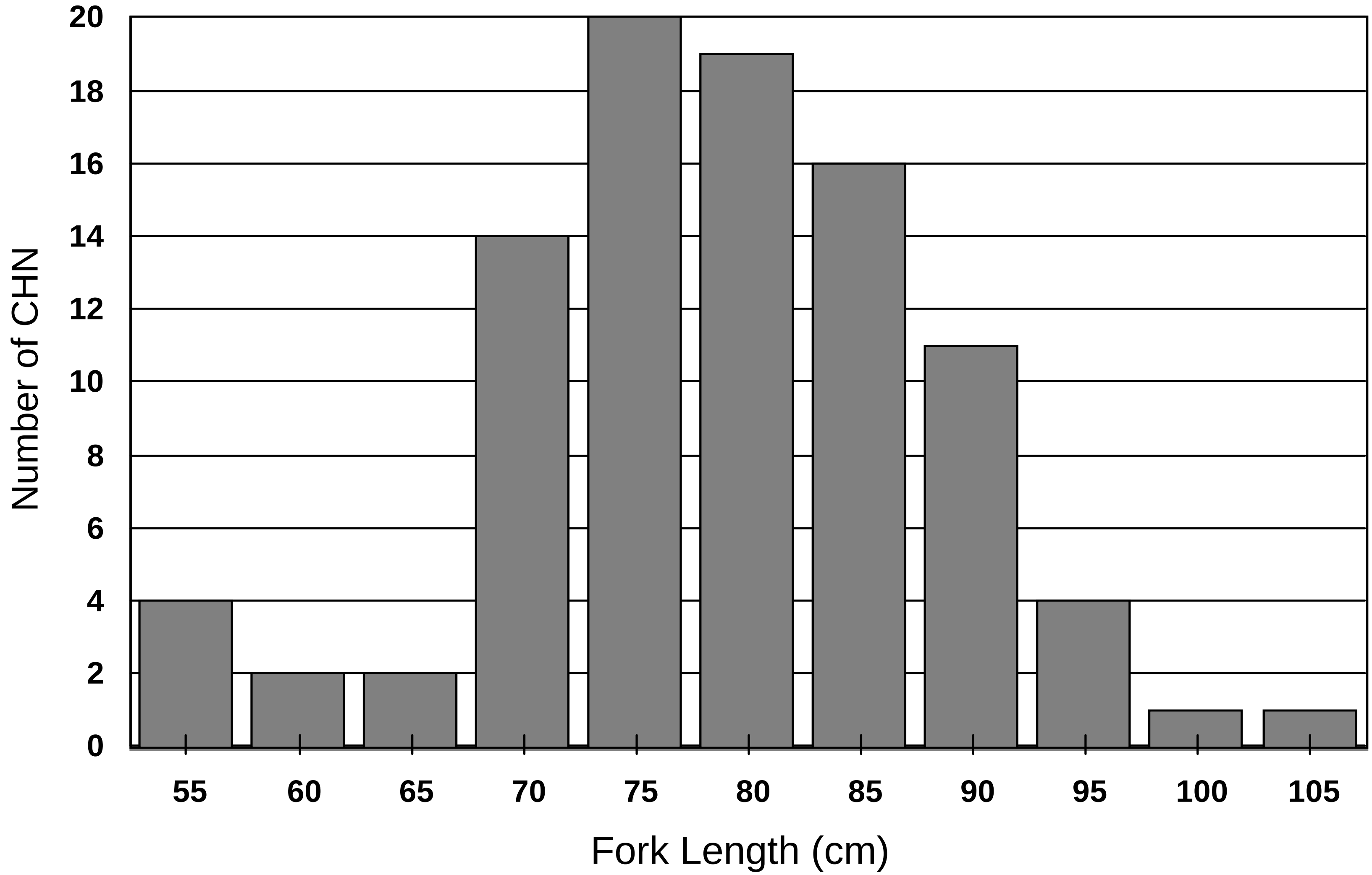

FIGURE 12.—Length-frequency distribution of Chinook (CHN) captured in the Coleman National Fish Hatchery barrier weir fish trap in 2005. Fork length labels are the upper end of the size category.

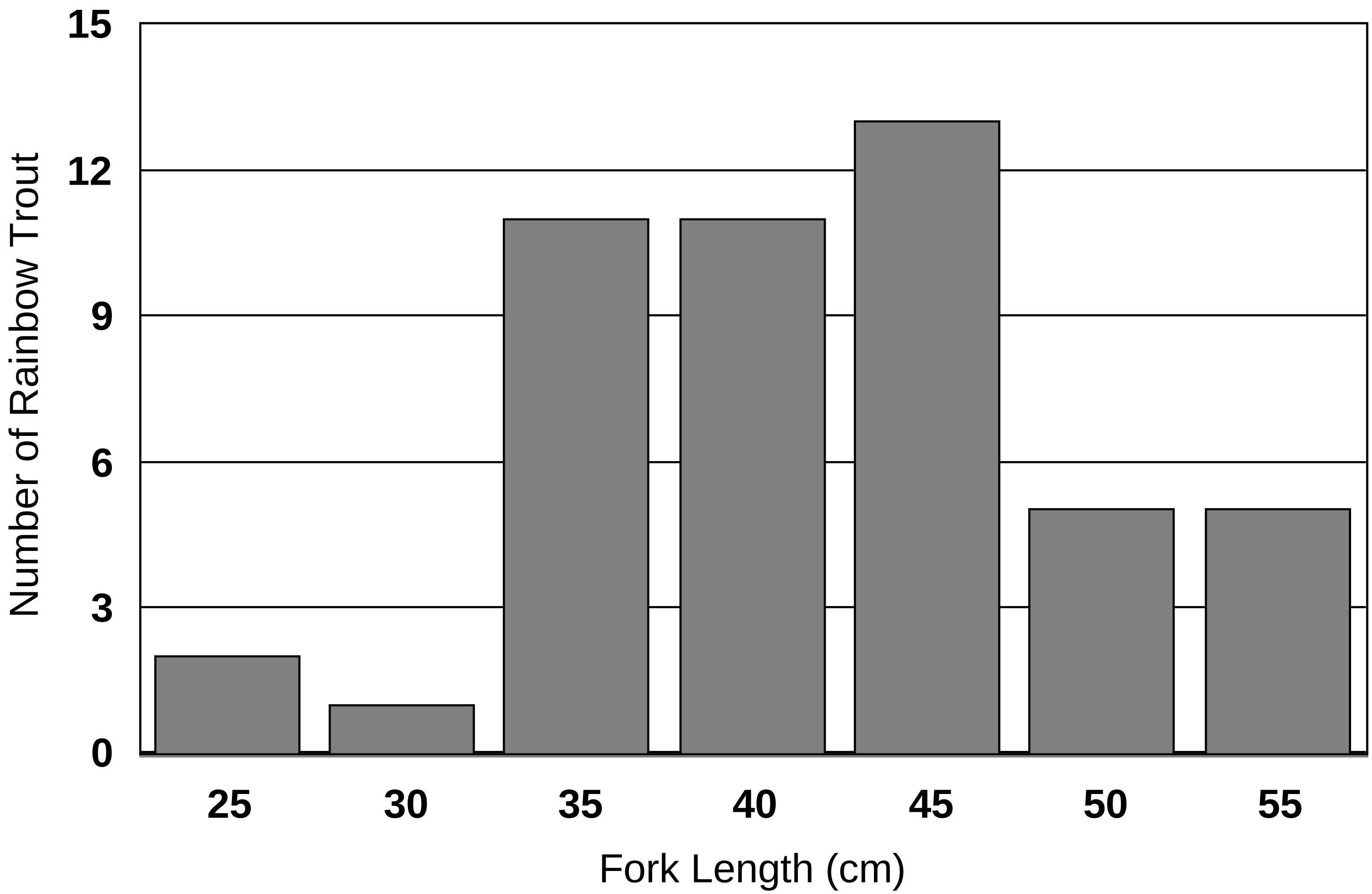

FIGURE 13.—Length-frequency distribution of rainbow trout/steelhead captured in the Coleman National Fish Hatchery barrier weir trap in 2005. Fork length labels are the upper end of the size category.

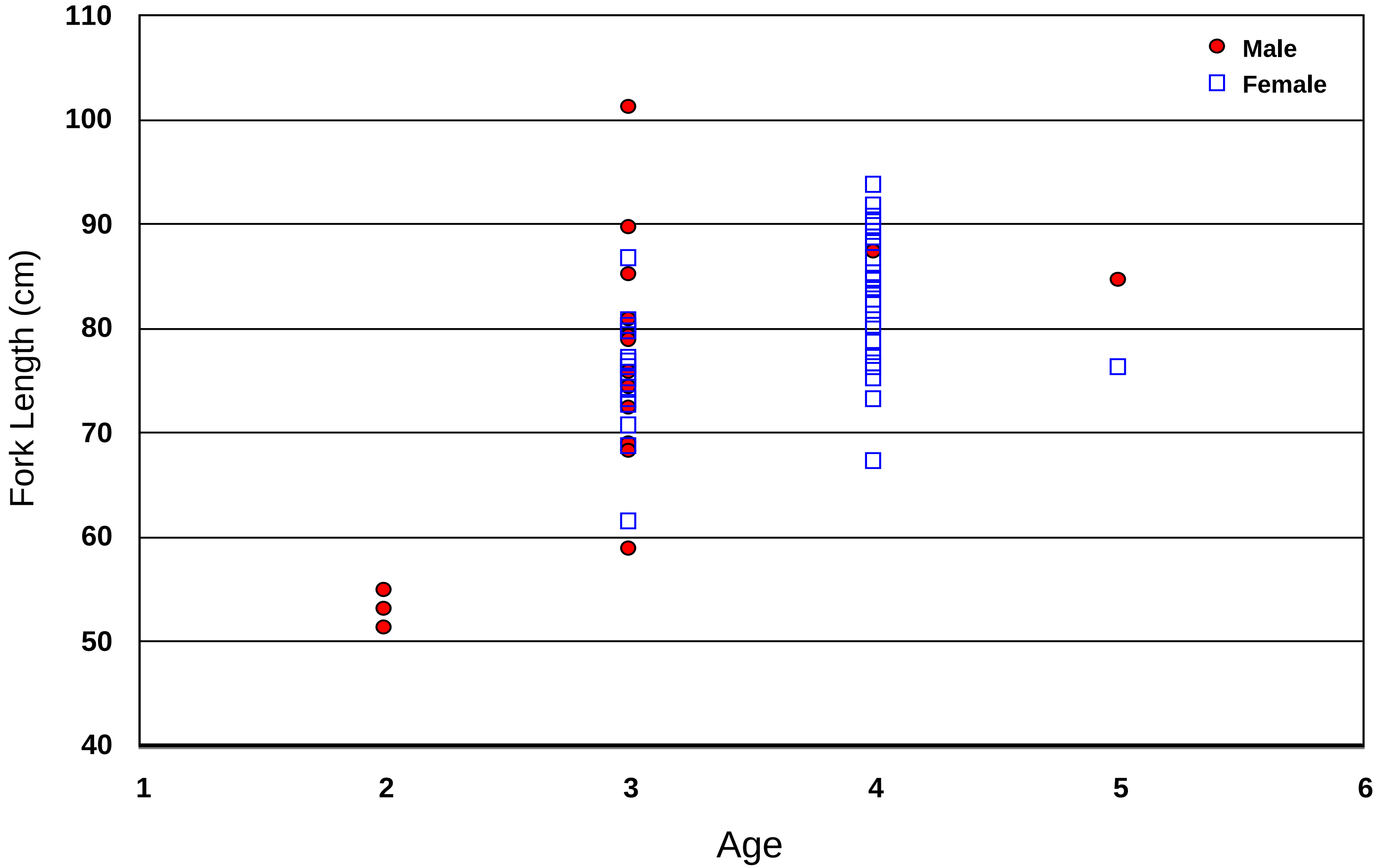

FIGURE 14.—Relationship between fork length and age for coded-wire tagged Chinook captured in the Coleman National Fish Hatchery barrier weir fish trap in 2005.

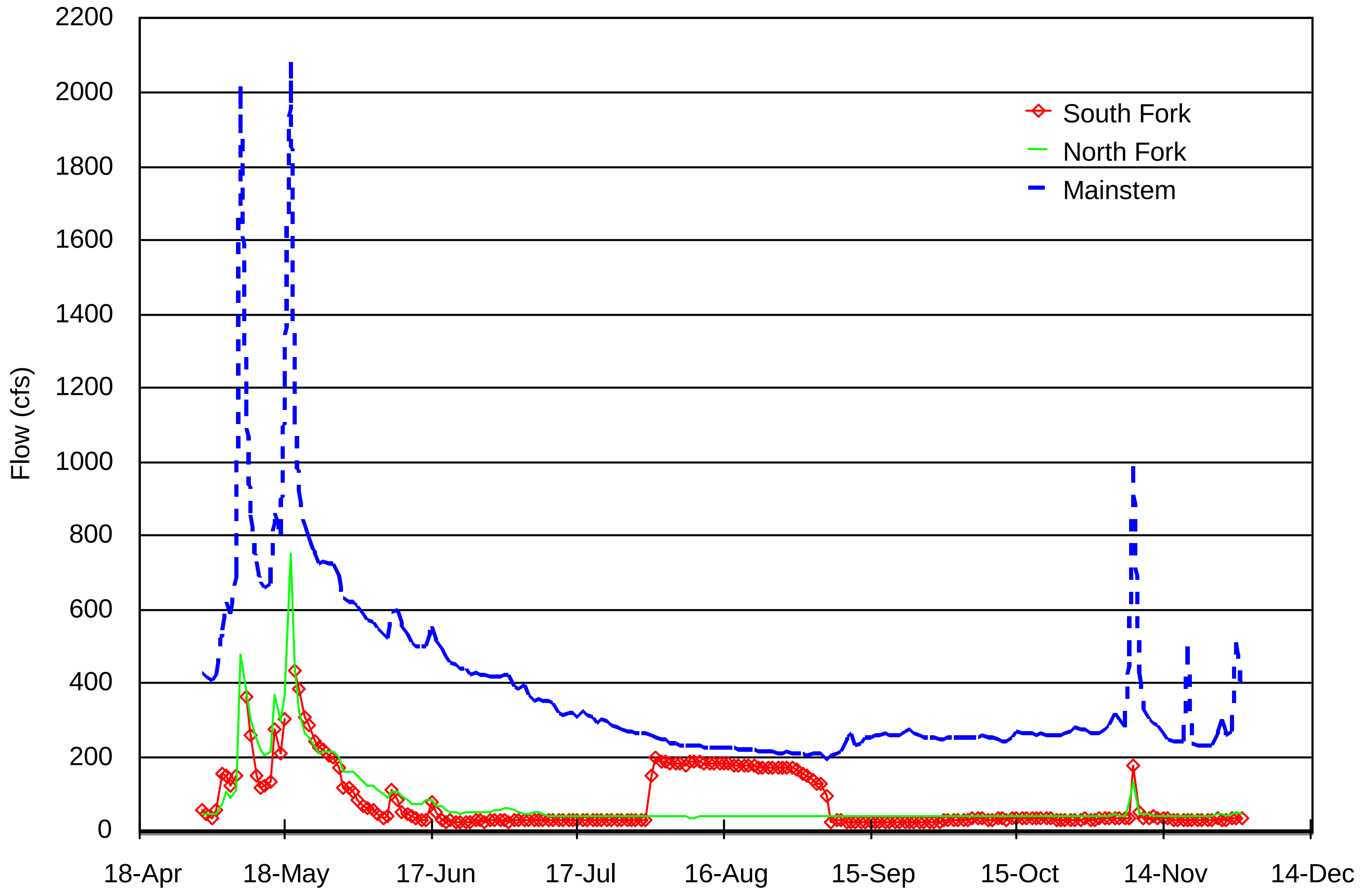

FIGURE 15.—Mean daily flows at the Coleman National Fish Hatchery barrier weir on the mainstem Battle Creek (rm 5.8), Wildcat Road Bridge on the North Fork (rm 0.9), and Manton Road Bridge on the South Fork (rm 1.7) in 2005.

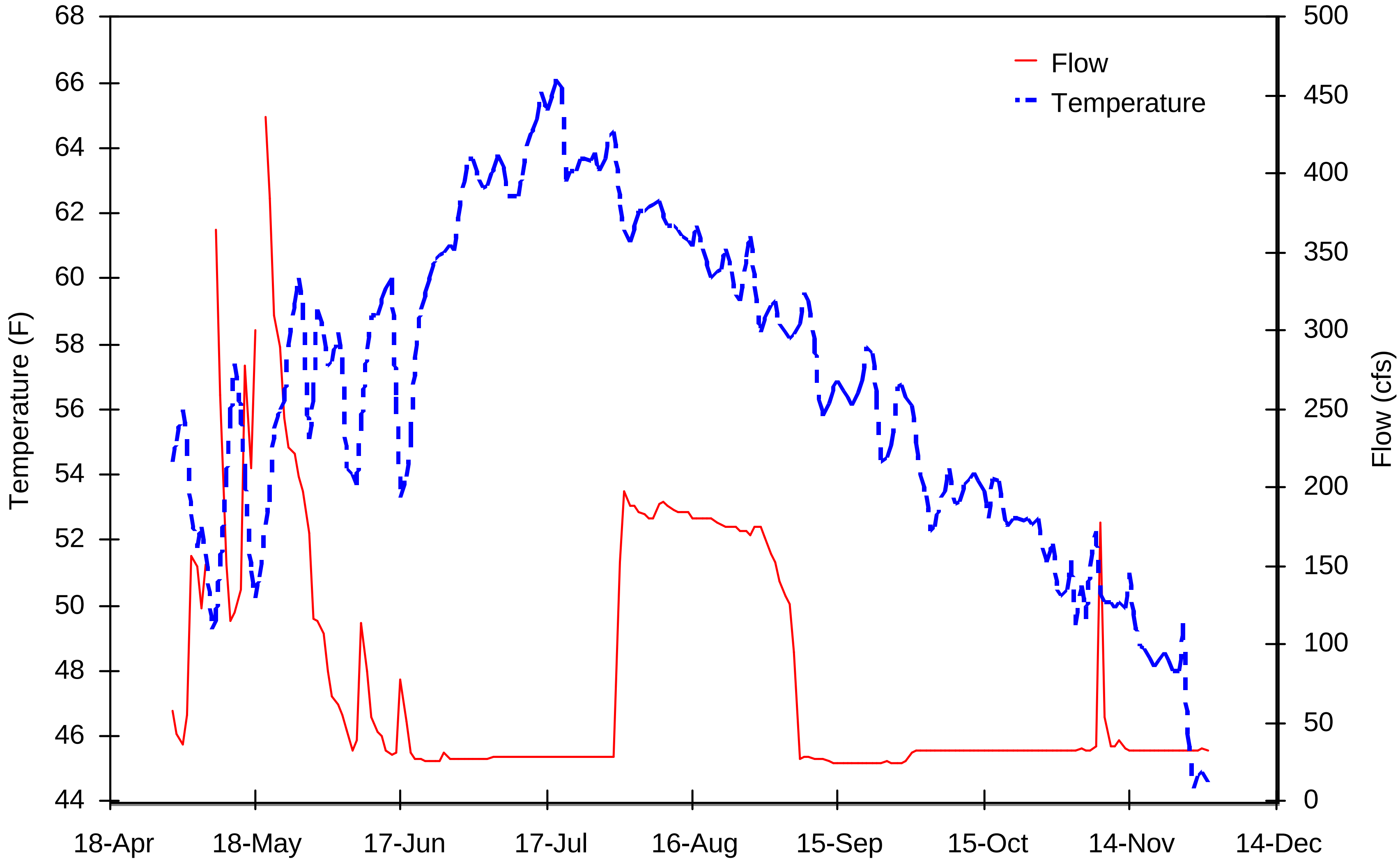

FIGURE 16.—South Fork Battle Creek Mean Daily Water Temperatures and Flows at Manton Road Bridge in 2005.

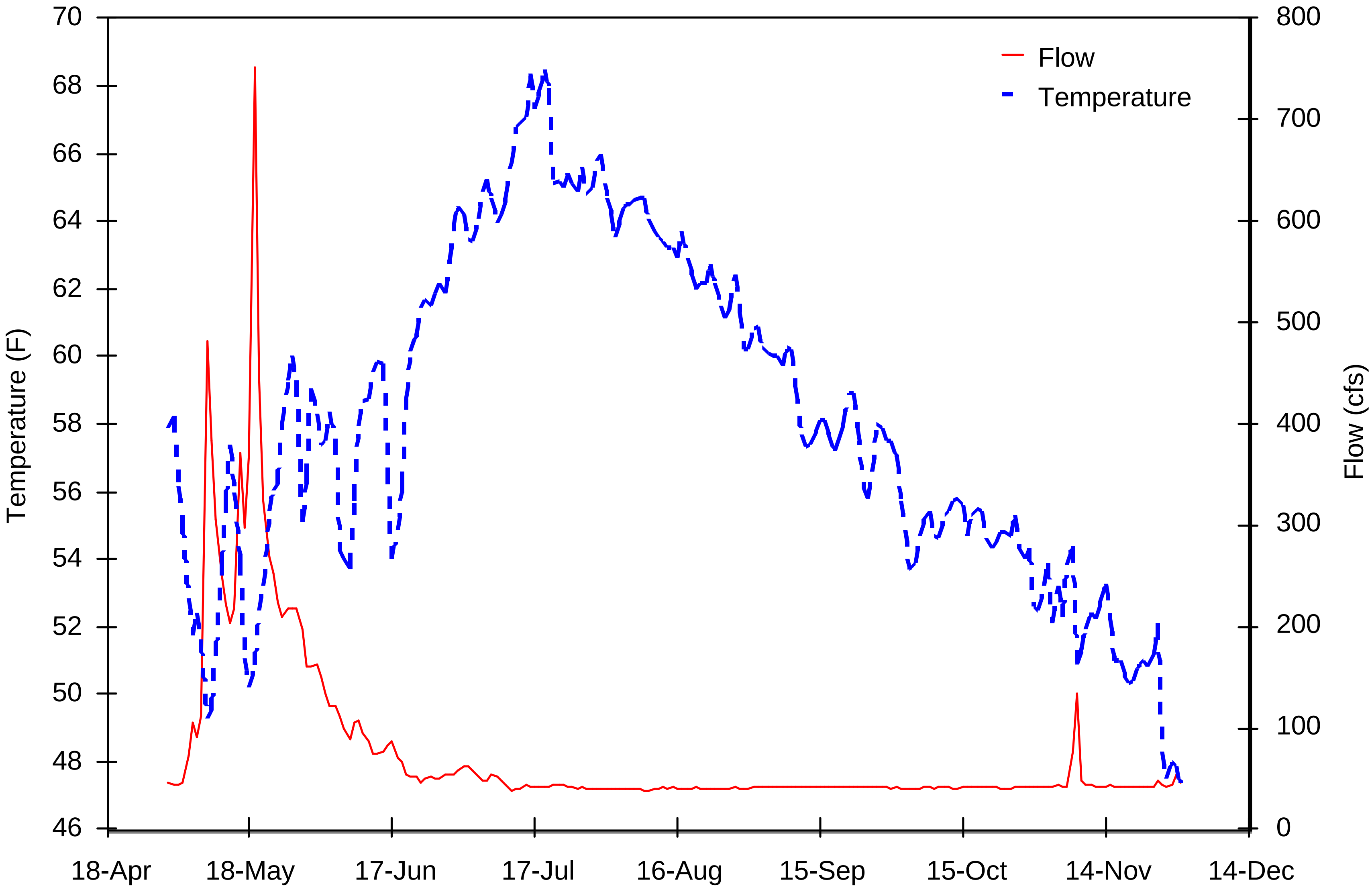

FIGURE 17.—North Fork Battle Creek Mean Daily Water Temperatures and Flows at Wildcat Road Bridge in 2005.

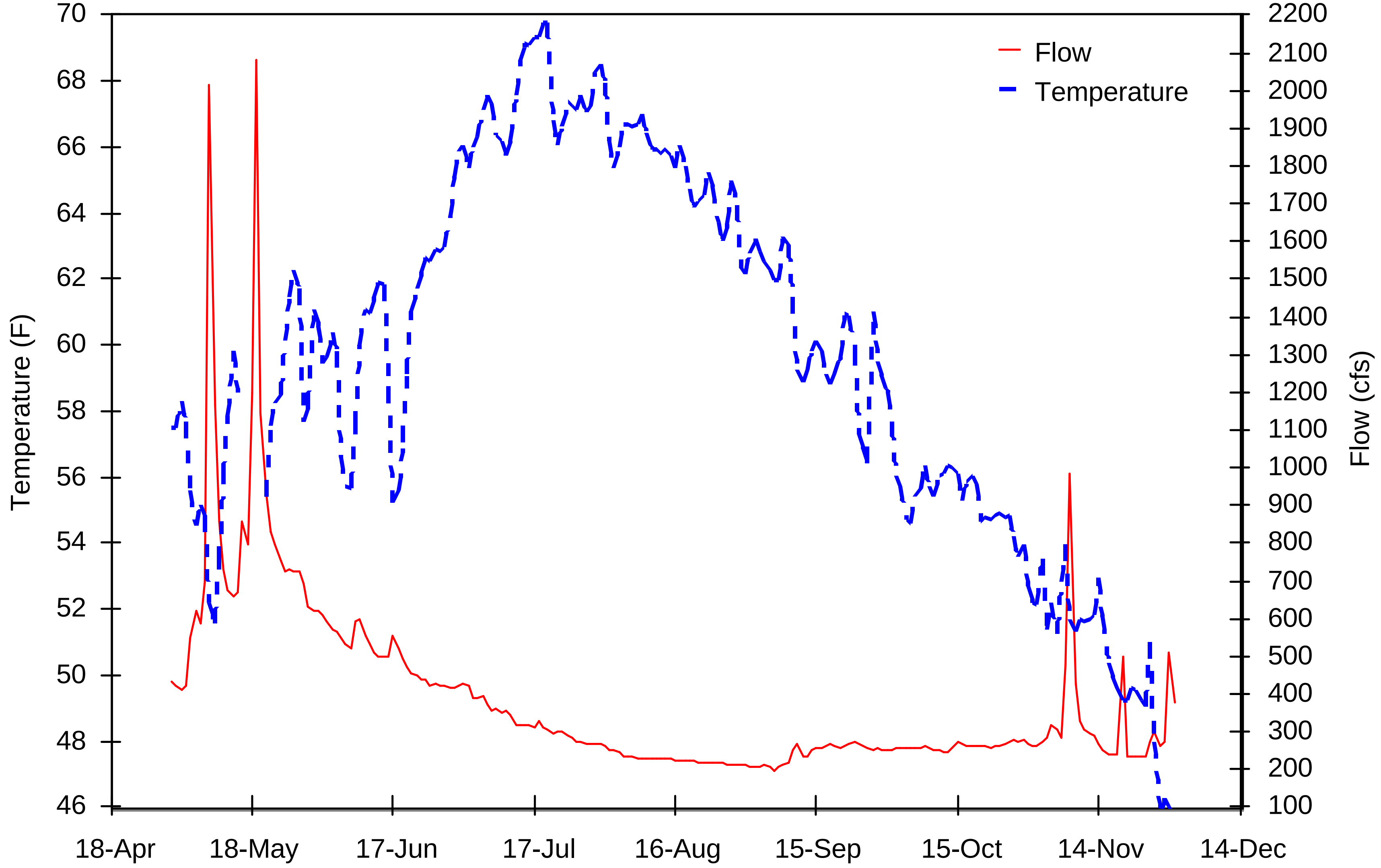

FIGURE 18.—Mainstem Battle Creek Mean Daily Water Temperatures and Flows at the Coleman National Fish Hatchery barrier weir in 2005.

Appendix

TABLE A.1.—Coded-wire tags recovered during Coleman National Fish Hatchery barrier weir trap monitoring in 2005.

Collection date	Collection location and method	Species	Sex	Fork length (cm)	Tag code	Hatchery or creek of origin	Run	Brood year
03/01/05	Barrier Weir Trap	Chinook	Female	73.5	05-10-92	CNFH	Late Fall	2002
03/01/05	Barrier Weir Trap	Chinook	Female	67.5	05-07-74	CNFH	Late Fall	2001
03/01/05	Barrier Weir Trap	Chinook	Unknown	91.0	05-10-91 or 05-07-75	CNFH	Late Fall	2002 or 2001
03/02/05	Barrier Weir Trap	Chinook	Female	80.0	05-10-93	CNFH	Late Fall	2002
03/02/05	Barrier Weir Trap	Chinook	Male	89.9	05-10-91	CNFH	Late Fall	2002
03/02/05	Barrier Weir Trap	Chinook	Female	85.5	05-07-74	CNFH	Late Fall	2001
03/02/05	Barrier Weir Trap	Chinook	Female	81.5	Lost Tag			
03/02/05	Barrier Weir Trap	Chinook	Male	84.9	05-04-66	CNFH	Late Fall	2000
03/02/05	Barrier Weir Trap	Chinook	Male	59.0	05-51-39	CNFH	Late Fall	2002
03/02/05	Barrier Weir Trap	Chinook	Male	72.5	05-10-95	CNFH	Late Fall	2002
03/02/05	Barrier Weir Trap	Chinook	Male	69.1	05-10-96	CNFH	Late Fall	2002
03/02/05	Barrier Weir Trap	Chinook	Female	76.5	05-04-69	CNFH	Late Fall	2000
03/02/05	Barrier Weir Trap	Chinook	Male	79.5	05-11-64	CNFH	Late Fall	2002
03/03/05	Barrier Weir Trap	Chinook	Female	81.5	05-51-35	CNFH	Late Fall	2001
03/03/05	Barrier Weir Trap	Chinook	Female	78.9	05-07-74	CNFH	Late Fall	2001
03/04/05	Barrier Weir Trap	Chinook	Female	75.4	05-10-91	CNFH	Late Fall	2002
03/04/05	Barrier Weir Trap	Chinook	Female	87.0	05-07-71	CNFH	Late Fall	2002
03/04/05	Barrier Weir Trap	Chinook	Female	66.0	05-11-65	CNFH	Late Fall	2001
03/04/05	Barrier Weir Trap	Chinook	Female	76.5	05-10-95	CNFH	Late Fall	2002
03/04/05	Barrier Weir Trap	Chinook	Female	76.0	05-10-95	CNFH	Late Fall	2002
03/04/05	Barrier Weir Trap	Chinook	Male	53.2	05-17-77	CNFH	Late Fall	2003
03/04/05	Barrier Weir Trap	Chinook	Female	69.0	05-10-95	CNFH	Late Fall	2002
03/04/05	Barrier Weir Trap	Chinook	Female	84.2	05-07-74	CNFH	Late Fall	2001
03/05/05	Barrier Weir Trap	Chinook	Female	92.0	05-07-69	CNFH	Late Fall	2001
03/06/05	Barrier Weir Trap	Chinook	Female	80.5	05-10-95	CNFH	Late Fall	2002
03/07/05	Barrier Weir Trap	Chinook	Male	51.5	05-17-66	CNFH	Late Fall	2003
03/07/05	Barrier Weir Trap	Chinook	Female	61.8	05-10-95	CNFH	Late Fall	2002

TABLE A.1.—Continued

Collection date	Collection location and method	Species	Sex	Fork length (cm)	Tag code	Hatchery or creek of origin	Run	Brood year
03/07/05	Barrier Weir Trap	Chinook	Male	87.5	05-51-35	CNFH	Late Fall	2001
03/08/05	Barrier Weir Trap	Chinook	Female	77.4	05-11-64	CNFH	Late Fall	2002
03/08/05	Barrier Weir Trap	Chinook	Female	80.0	05-10-96	CNFH	Late Fall	2002
03/08/05	Barrier Weir Trap	Chinook	Female	74.5	05-10-91	CNFH	Late Fall	2002
03/08/05	Barrier Weir Trap	Chinook	Female	87.0	05-07-66	CNFH	Late Fall	2001
03/08/05	Barrier Weir Trap	Chinook	Female	73.0	05-10-94	CNFH	Late Fall	2002
03/08/05	Barrier Weir Trap	Chinook	Female	83.0	05-07-66	CNFH	Late Fall	2001
03/08/05	Barrier Weir Trap	Chinook	Female	91.0	05-07-66	CNFH	Late Fall	2001
03/09/05	Barrier Weir Trap	Chinook	Female	76.9	05-07-66	CNFH	Late Fall	2001
03/09/05	Barrier Weir Trap	Chinook	Female	71.0	05-51-39	CNFH	Late Fall	2002
03/10/05	Barrier Weir Trap	Chinook	Male	68.5	05-10-96	CNFH	Late Fall	2002
03/10/05	Barrier Weir Trap	Chinook	Male	81.0	05-10-95	CNFH	Late Fall	2002
03/10/05	Barrier Weir Trap	Chinook	Female	80.5	05-07-74	CNFH	Late Fall	2001
03/10/05	Barrier Weir Trap	Chinook	Male	76.0	05-11-64	CNFH	Late Fall	2002
03/11/05	Barrier Weir Trap	Chinook	Female	85.0	05-07-69	CNFH	Late Fall	2001
03/11/05	Barrier Weir Trap	Chinook	Female	80.5	05-07-66	CNFH	Late Fall	2001
03/11/05	Barrier Weir Trap	Chinook	Female	76.5	05-07-66	CNFH	Late Fall	2001
03/12/05	Barrier Weir Trap	Chinook	Female	90.0	05-07-71	CNFH	Late Fall	2001
03/13/05	Barrier Weir Trap	Chinook	Female	72.5	Lost Tag			
03/14/05	Barrier Weir Trap	Chinook	Female	88.5	05-07-64	CNFH	Late Fall	2001
03/14/05	Barrier Weir Trap	Chinook	Female	77.7	05-07-74	CNFH	Late Fall	2001
03/15/05	Barrier Weir Trap	Chinook	Female	83.0	Lost Tag			
03/17/05	Barrier Weir Trap	Chinook	Female	73.5	05-07-70	CNFH	Late Fall	2001
03/17/05	Barrier Weir Trap	Chinook	Male	79.0	05-10-92	CNFH	Late Fall	2002
03/19/05	Barrier Weir Trap	Chinook	Female	82.5	05-07-74	CNFH	Late Fall	2001
03/20/05	Barrier Weir Trap	Chinook	Female	85.0	05-51-35	CNFH	Late Fall	2001
03/21/05	Barrier Weir Trap	Chinook	Female	90.5	05-07-66	CNFH	Late Fall	2001
03/22/05	Barrier Weir Trap	Chinook	Male	85.4	05-11-64	CNFH	Late Fall	2002
03/24/05	Barrier Weir Trap	Chinook	Male	101.5	05-49-39	CNFH	Late Fall	2002

TABLE A.1.—Continued

Collection date	Collection location and method	Species	Sex	Fork length (cm)	Tag code	Hatchery or creek of origin	Run	Brood year
03/25/05	Barrier Weir Trap	Chinook	Female	75.5	05-07-69	CNFH	Late Fall	2001
03/25/05	Barrier Weir Trap	Chinook	Female	84.0	05-07-70	CNFH	Late Fall	2001
03/28/05	Barrier Weir Trap	Chinook	Male	74.5	05-10-92	CNFH	Late Fall	2002
03/28/05	Barrier Weir Trap	Chinook	Female	84.9	05-07-70	CNFH	Late Fall	2001
03/28/05	Barrier Weir Trap	Chinook	Female	94.0	05-51-35	CNFH	Late Fall	2001
03/29/05	Barrier Weir Trap	Chinook	Female	81.0	05-10-91	CNFH	Late Fall	2002
03/31/05	Barrier Weir Trap	Chinook	Female	77.0	05-10-92	CNFH	Late Fall	2002
04/02/05	Barrier Weir Trap	Chinook	Female	89.5	05-07-66	CNFH	Late Fall	2001
04/04/05	Barrier Weir Trap	Chinook	Female	89.0	05-51-35	CNFH	Late Fall	2001
04/07/05	Barrier Weir Trap	Chinook	Male	55.0	05-17-66	CNFH	Late Fall	2003
04/28/05	Barrier Weir Trap	Chinook	Male	99.0	05-07-74	CNFH	Late Fall	2001
05/09/05	Barrier Weir Trap	Chinook	Female	87.5	05-07-74	CNFH	Late Fall	2001
05/14/05	Barrier Weir Trap	Chinook	Male	73.0	05-07-74	CNFH	Late Fall	2001
01/05/05	Snorkel	Chinook	Female	67.0	05-11-65	CNFH	Late Fall	2002
01/05/05	Snorkel	Chinook	Female	70.0	05-10-96	CNFH	Late Fall	2002
02/10/05	Snorkel	Chinook	Female	67.0	05-10-91	CNFH	Late Fall	2002
02/10/05	Snorkel	Chinook	Female	74.0	05-10-91	CNFH	Late Fall	2002
02/10/05	Snorkel	Chinook	Female	84.0	05-07-71	CNFH	Late Fall	2001
02/10/05	Snorkel	Chinook	Male	89.0	05-07-73	CNFH	Late Fall	2001
02/10/05	Snorkel	Chinook	Unknown	79.0	05-51-39	CNFH	Late Fall	2002

TABLE A.2.—Estimated number of days that egg incubation fell within the five water-temperature suitability categories for each spring Chinook redd in 2005. The incubation period was calculated using a cumulative total of 1,850 Daily Temperature Units (DTU).

Location	Reach	River mile	Date	Very poor	Poor	Fair	Good	Excell-ent	Total days
North Fork	2	0.71	9/14/2005	0	0	1	7	85	93
North Fork	2	1.98	9/28/2005	0	0	0	3	93	96
North Fork	2	1.98	9/28/2005	0	0	0	3	93	96
North Fork	2	1.02	9/28/2005	0	0	0	4	92	96
North Fork	2	1.02	9/28/2005	0	0	0	0	101	101
North Fork	2	0.61	9/28/2005	0	0	0	4	94	98
North Fork	2	1.63	10/12/2005	0	0	0	0	105	105
North Fork	2	1.48	10/12/2005	0	0	0	0	105	105
North Fork	2	1.41	10/12/2005	0	0	0	0	110	110
North Fork	2	1.40	10/12/2005	0	0	0	0	105	105
North Fork	2	1.38	10/12/2005	0	0	0	0	105	105
North Fork	2	1.38	10/12/2005	0	0	0	0	105	105
North Fork	2	1.28	10/12/2005	0	0	0	0	105	105
North Fork	2	1.28	10/12/2005	0	0	0	0	105	105
North Fork	2	1.28	10/12/2005	0	0	0	0	105	105
North Fork	2	1.00	10/12/2005	0	0	0	0	106	106
North Fork	2	0.87	10/12/2005	0	0	0	0	111	111
North Fork	2	0.78	10/12/2005	0	0	0	0	107	107
North Fork	2	0.77	10/12/2005	0	0	0	0	108	108
North Fork	2	0.60	10/12/2005	0	0	0	0	108	108
North Fork	2	0.47	10/12/2005	0	0	0	0	113	113
North Fork	2	0.39	10/12/2005	0	0	0	0	109	109
North Fork	2	0.99	10/25/2005	0	0	0	0	117	117
South Fork	3	2.19	9/28/2005	0	0	0	0	121	121
South Fork	3	1.93	9/28/2005	0	0	0	0	117	117
South Fork	3	1.95	10/12/2005	0	0	0	0	127	127
South Fork	3	1.95	10/12/2005	0	0	0	0	127	127
South Fork	3	1.13	10/12/2005	0	0	0	0	126	126
South Fork	3	2.12	10/26/2005	0	0	0	0	134	134
Mainstem	4	16.03	9/29/2005	0	0	0	0	112	112
Mainstem	4	16.00	9/29/2005	0	0	0	0	126	126
Mainstem	4	16.27	10/13/2005	0	0	0	0	117	117
Mainstem	4	15.86	10/13/2005	0	0	0	0	125	125
Mainstem	4	15.86	10/13/2005	0	0	0	0	125	125
Mainstem	4	15.74	10/13/2005	0	0	0	0	124	124

TABLE A.2.—Continued

Location	Reach	River mile	Date	Very poor	Poor	Fair	Good	Excell-ent	Total days
Mainstem	4	15.74	10/13/2005	0	0	0	0	124	124
Mainstem	4	14.35	10/13/2005	0	0	0	0	115	115
Mainstem	4	15.84	10/26/2005	0	0	0	0	134	134
Mainstem	4	16.06	11/14/2005	0	0	0	0	116	116
Mainstem	5	10.42	9/29/2005	0	0	3	10	86	99
Mainstem	5	11.92	10/13/2005	0	0	0	2	105	107
Mainstem	5	11.93	10/13/2005	0	0	0	2	105	107
Mainstem	5	11.76	10/13/2005	0	0	0	0	112	112
Mainstem	5	10.47	10/13/2005	0	0	0	5	101	106
Mainstem	5	10.44	10/13/2005	0	0	0	5	101	106
Mainstem	6	6.51	9/30/2005	0	0	0	7	95	102

TABLE A.3.—Chinook redd measurements taken during USFWS Battle Creek snorkel surveys in 2005.

Date	Reach	Max length (ft)	Max width (ft)	Area (ft^2)	Depth: pre-redd (ft)	Depth: pit (ft)	Depth: tailspill (ft)	Velocity (ft/s)	Substrate code [a]
9/14/2005	2	18.08	13.25	188.18	1.92	2.17	0.58	1.55	1
9/28/2005	2	18.33	7.08	101.99	1.17	1.67	1.08	1.72	1.3
9/28/2005	2	17.50	6.83	93.92	0.92	1.42	0.75	1.53	2.4
9/28/2005	2	14.17	6.25	69.54	1.92	2.08	0.58	0.34	1.2
9/28/2005	2	11.42	17.25	154.67	0.67	2.25	2.58	1.28	2.4
9/28/2005	2	24.00	9.33	175.93	1.00	1.63	0.83	1.71	1.2
9/28/2005	3	13.42	6.42	67.62	1.83	2.08	0.58	0.52	2.4
9/28/2005	3	11.08	11.83	103.01	0.75	1.33	0.67	2.15	1.3
9/29/2005	4	12.92	6.67	67.63	1.08	1.42	0.83	1.88	1.3
9/29/2005	4	17.50	10.00	137.44	1.33	1.67	0.75	1.48	1.3
9/29/2005	5	6.25	3.92	19.23	1.04	1.33	0.58	2.09	2.4
9/30/2005	6	14.50	10.25	116.73	1.17	1.67	0.83	1.96	2.4
10/12/2005	2	9.25	4.58	33.30	0.92	1.25	0.58	1.82	2.4
10/12/2005	2	8.42	7.00	46.27	1.75	1.92	1.00	1.64	1.3
10/12/2005	2	18.00	15.58	220.30	1.67	2.00	0.83	1.22	2.4
10/12/2005	2	7.67	5.67	34.12	1.50	2.17	0.75	2.20	2.4
10/12/2005	2	7.75	4.50	27.39	1.58	2.08	1.42	1.91	1.3
10/12/2005	2	13.42	4.00	42.15	1.58	2.08	1.25	1.98	2.4
10/12/2005	2	7.08	3.08	17.15	2.33	2.83	1.25	4.87	1.3
10/12/2005	2	7.42	5.50	32.04	1.08	1.75	0.75	3.74	2.4
10/12/2005	2	11.33	7.25	64.53	2.42	2.67	1.50	1.40	1.3
10/12/2005	2	13.08	8.67	89.06	1.83	2.17	1.17	1.34	2.4
10/12/2005	2	10.00	4.42	34.69	1.58	2.08	1.67	2.18	1.2
10/12/2005	2	18.42	19.50	282.06	2.25	2.50	0.92	1.07	1.3
10/12/2005	2	13.75	15.67	169.19	3.83	4.25	0.58	0.91	1.3
10/12/2005	2	4.83	7.83	29.74	1.17	1.92	0.75	1.97	2.4
10/12/2005	2	5.50	3.75	16.20	1.33	2.00	1.33	2.33	2.4
10/12/2005	2	11.00	6.67	57.60	1.08	1.83	0.83	1.67	1.2
10/12/2005	2	9.00	5.92	41.82	1.33	1.92	0.67	1.89	1.3
10/12/2005	3	24.33	11.42	218.19	0.92	2.00	0.54	0.57	1.3
10/12/2005	3	17.92	11.25	158.31	0.75	1.13	0.50	2.12	1.3
10/12/2005	3	16.92	9.58	127.33	1.42	1.58	0.50	1.49	2.4
10/13/2005	4	21.67	12.50	212.71	1.17	1.67	1.00	3.11	1.3
10/13/2005	4	20.42	6.67	106.90	1.00	1.33	0.92	3.20	2.4
10/13/2005	4	11.67	6.25	57.27	1.33	1.83	1.00	3.02	2.4
10/13/2005	4	20.83	10.83	177.26	1.67	2.17	0.92	1.64	1.3
10/13/2005	4	15.67	7.08	87.16	1.50	1.83	1.08	1.55	2.4
10/13/2005	4	15.00	7.50	88.36	2.17	2.33	1.75	1.72	2.4

TABLE A.3.—Continued

Date	Reach	Max length (ft)	Max width (ft)	Area (ft^2)	Depth: pre-redd (ft)	Depth: pit (ft)	Depth: tailspill (ft)	Velocity (ft/s)	Substrate code [a]
10/13/2005	5	22.33	12.67	222.18	1.25	2.33	0.42	0.97	1.2
10/13/2005	5	17.17	18.67	251.68	1.92	1.83	0.50	0.81	1.3
10/13/2005	5	15.83	12.50	155.44	1.25	1.67	0.83	1.45	2.4
10/13/2005	5	7.17	3.83	21.58	2.92	2.92	1.75	1.61	1.3
10/13/2005	5	16.17	4.58	58.20	1.92	2.17	1.25	2.63	1.2
10/25/2005	2	5.33	3.42	14.31	1.33	1.79	1.25	1.59	1.3
10/26/2005	3	26.17	12.00	246.62	1.00	1.17	0.38	1.03	2.4
10/26/2005	4	23.33	10.42	190.90	1.42	1.83	1.33	2.10	1.3
11/14/2005	4	8.00	5.58	35.08	1.75	2.17	1.33	1.60	1
Average		14.06	8.63	105.59	1.50	1.95	0.96	1.80	1.3[b]
Minimum		4.83	3.08	14.31	0.67	1.13	0.38	0.34	1
Maximum		26.17	19.50	282.06	3.83	4.25	2.58	4.87	2.4

[a] Dominant substrate codes are described by USFWS (2005) and are generally defined as follows; 1 = 1 in., 1.3 = 1-3 in., 2.4 = 2-4 in, etc.
[b] The median substrate code was used instead of an average.

TABLE A.4.—Rainbow trout/steelhead redd measurements taken during USFWS winter steelhead redd surveys on Battle Creek from December 15, 2004 through April 12, 2005.

Date	Reach	Max length (ft)	Max width (ft)	Area (ft^2)	Depth: pre-redd (ft)	Depth: pit (ft)	Depth: tailspill (ft)	Velocity (ft/s)	Substrate code [a]
12/17/2004	4	7.83	4.08	25.12	1.25	1.33	0.71	1.96	1
12/17/2004	4	12.92	8.00	81.16	1.33	1.58	0.83	1.24	1
12/17/2004	5	10.33	3.83	31.11	0.58	1.08	0.50	2.04	1
12/17/2004	5	12.83	5.08	51.24	2.25	2.42	1.25	0.99	2.4
1/6/2005	1	8.00	7.75	48.69	1.42	1.50	0.58	1.34	1
1/6/2005	1	7.92	3.75	23.32	1.75	1.58	0.67	0.73	1.2
1/6/2005	1	7.25	5.92	33.69	0.42	0.67	0.54	2.48	1.3
1/6/2005	1	6.67	3.83	20.07	1.17	1.58	0.67	1.10	1
1/6/2005	1	4.50	4.83	17.08	1.25	1.38	1.00	1.48	1.2
1/6/2005	1	7.42	4.75	27.67	1.25	1.42	0.33	1.82	1.3
1/6/2005	1	11.92	3.08	28.86	0.92	1.17	0.83	2.20	1.2
1/6/2005	1	11.00	3.42	29.52	1.33	1.50	0.83	2.42	2.4
1/6/2005	1	6.42	3.25	16.38	1.33	1.67	1.17	1.80	1
1/13/2005	3	10.00	4.58	36.00	0.67	0.96	0.54	0.81	1.2
1/13/2005	3	7.33	4.42	25.44	0.63	1.08	0.46	0.52	1
1/13/2005	3	9.00	4.75	33.58	0.83	1.00	0.42	0.77	1
1/13/2005	3	3.42	2.50	6.71	1.00	1.42	1.17	1.04	1
1/13/2005	3	9.33	6.58	48.26	0.75	1.08	0.58	1.98	1.3
1/13/2005	3	6.25	4.17	20.45	0.58	0.75	0.50	0.58	1
1/18/2005	2	9.17	6.42	46.20	1.54	1.75	0.92	2.42	1.2
1/18/2005	2	10.00	4.75	37.31	1.00	1.38	0.75	2.78	1.2
1/18/2005	2	5.92	4.17	19.36	1.00	1.50	1.25	2.24	1.2
1/18/2005	2	10.25	6.83	55.01	1.00	1.17	0.75	1.78	1.2
1/19/2005	2	9.00	2.75	19.44	1.08	1.42	0.83	1.41	1.3
1/19/2005	2	9.17	5.42	39.00	1.33	1.50	0.92	1.01	1
1/19/2005	2	9.08	7.17	51.13	1.08	1.50	0.83	1.90	1.3
1/19/2005	2	15.00	5.25	61.85	1.58	1.92	1.17	1.47	1.2
1/19/2005	2	9.75	5.92	45.31	1.17	1.83	1.17	2.63	1.2
1/19/2005	2	8.17	3.08	19.78	1.79	2.17	1.92	1.81	2.4
1/19/2005	2	6.33	3.17	15.75	1.50	1.75	1.33	0.92	1
1/19/2005	2	5.08	3.08	12.31	1.17	1.33	0.75	2.00	1.3
1/24/2005	1	7.33	4.25	24.48	1.42	1.92	1.25	1.97	1.2
1/24/2005	1	11.17	5.00	43.85	1.17	1.75	0.92	1.79	1.3
1/24/2005	1	5.08	2.92	11.64	1.92	2.17	1.58	1.59	1.2
1/25/2005	3	6.33	2.58	12.85	0.42	0.58	0.25	1.16	1.2
1/25/2005	3	11.50	4.75	42.90	0.83	1.13	0.58	0.98	1
1/25/2005	3	4.08	2.25	7.22	0.58	0.92	0.42	0.80	1
1/25/2005	3	5.92	3.00	13.94	0.58	0.75	0.33	0.39	1.2

TABLE A.4.—Continued

Date	Reach	Max length (ft)	Max width (ft)	Area (ft^2)	Depth: pre-redd (ft)	Depth: pit (ft)	Depth: tailspill (ft)	Velocity (ft/s)	Substrate code [a]
2/7/2005	1	10.50	4.50	37.11	0.75	0.92	0.54	1.74	1.2
2/7/2005	1	5.42	3.83	16.31	0.92	1.00	0.42	0.71	1
2/7/2005	1	5.67	3.50	15.58	1.50	1.75	0.92	1.92	1.2
2/7/2005	1	9.17	4.00	28.80	2.42	2.67	2.17	1.05	1
2/7/2005	1	7.92	3.25	20.21	0.50	0.67	0.17	0.95	1
2/7/2005	1	4.75	2.67	9.95	0.42	0.83	0.42	2.15	1.2
2/7/2005	1	9.08	3.42	24.37	0.58	0.92	0.33	1.50	1.2
2/7/2005	1	4.50	2.50	8.84	1.17	1.33	0.75	0.76	1
2/7/2005	1	6.92	3.42	18.56	1.42	1.67	0.92	1.50	1
2/7/2005	1	7.42	3.17	18.45	0.67	1.08	0.75	2.33	1
2/7/2005	1	11.58	4.50	40.94	0.75	1.17	0.50	2.41	1.2
2/7/2005	1	8.75	3.75	25.77	1.08	1.33	0.75	0.75	1.2
2/7/2005	1	16.33	8.33	106.90	0.58	1.25	0.42	1.37	1.2
2/7/2005	1	8.50	2.92	19.47	1.00	1.17	0.67	1.58	1
2/7/2005	1	7.42	5.42	31.55	1.58	1.75	0.83	0.72	1
2/7/2005	2	5.42	3.00	12.76	0.58	0.92	0.75	1.78	1.2
2/7/2005	2	3.33	3.42	8.94	2.17	2.58	2.33	1.39	1.3
2/7/2005	2	4.92	3.25	12.55	1.67	1.75	1.33	2.16	1.3
2/7/2005	2	5.17	1.17	4.73	1.58	1.71	1.00	1.01	1.2
2/7/2005	2	3.83	3.58	10.79	1.08	1.21	0.67	1.11	1.3
2/7/2005	2	6.92	2.58	14.03	2.83	2.83	2.17	0.88	2.3
2/7/2005	2	5.58	4.33	19.00	1.67	2.25	1.58	1.35	1.2
2/7/2005	2	8.25	2.92	18.90	0.42	0.83	0.29	0.89	1
2/7/2005	2	8.08	4.08	25.92	0.83	1.04	0.50	1.30	2.4
2/7/2005	2	7.08	3.08	17.15	1.50	1.54	1.08	1.85	1.3
2/7/2005	2	4.25	1.92	6.40	0.67	0.88	0.33	2.00	1
2/7/2005	2	2.75	1.33	2.88	1.04	1.17	0.79	1.69	1
2/8/2005	2	7.08	2.42	13.44	1.33	1.33	1.00	1.10	1.2
2/8/2005	2	7.25	2.75	15.66	0.92	1.08	0.50	2.73	1.3
2/8/2005	2	4.83	2.58	9.81	1.42	1.58	1.17	1.54	1.2
2/8/2005	2	8.83	3.67	25.44	2.46	2.75	1.67	1.21	1.2
2/8/2005	2	15.42	8.00	96.87	0.58	1.29	0.67	2.70	1.2
2/8/2005	2	4.25	2.08	6.95	1.17	1.54	1.08	2.96	1.2
2/8/2005	2	4.75	3.75	13.99	1.25	1.54	1.00	1.51	1.3
2/8/2005	2	5.33	2.92	12.22	0.75	0.92	0.63	1.74	1.2
2/8/2005	2	4.83	3.58	13.60	0.63	0.88	0.50	2.03	1.2
2/8/2005	2	7.67	3.75	22.58	2.08	2.17	1.33	1.32	1
2/8/2005	2	7.33	3.29	18.96	1.50	2.00	1.25	2.12	1
2/8/2005	2	6.17	4.17	20.18	0.67	0.92	0.42	0.86	1.3
2/8/2005	2	4.50	2.67	9.42	0.50	0.67	0.42	1.41	1

TABLE A.4.—Continued

Date	Reach	Max length (ft)	Max width (ft)	Area (ft²)	Depth: pre-redd (ft)	Depth: pit (ft)	Depth: tailspill (ft)	Velocity (ft/s)	Substrate code [a]
2/8/2005	3	6.00	3.25	15.32	0.92	1.42	0.67	0.74	1
2/8/2005	3	5.50	2.50	10.80	0.54	0.75	0.42	0.88	1
2/8/2005	3	7.75	3.00	18.26	0.50	0.75	0.33	1.04	1
2/8/2005	3	4.83	2.83	10.76	0.67	0.83	0.42	1.51	1
2/8/2005	3	6.58	5.00	25.85	1.00	1.21	0.38	0.95	1.2
2/8/2005	3	7.67	3.42	20.57	0.75	0.92	0.58	1.41	1.2
2/8/2005	3	3.75	1.75	5.15	0.58	0.83	0.50	1.60	1.2
2/9/2005	4	4.33	2.83	9.64	2.92	3.00	2.58	1.00	1
2/9/2005	4	5.75	5.42	24.46	2.58	2.75	2.08	1.23	1
2/9/2005	4	2.33	1.50	2.75	0.71	0.83	0.67	2.56	1.2
2/9/2005	4	6.42	2.25	11.34	1.17	1.33	0.58	1.11	1
2/9/2005	4	3.83	1.75	5.27	1.00	1.25	0.75	1.74	1.2
2/9/2005	4	5.08	3.08	12.31	1.50	1.67	1.42	1.92	1
2/9/2005	4	6.25	2.75	13.50	1.50	1.54	1.08	0.72	1
2/9/2005	4	6.67	2.83	14.84	0.75	0.92	0.50	1.02	1
2/9/2005	5	9.75	5.17	39.56	1.58	2.00	1.50	1.90	1
2/9/2005	5	4.50	4.83	17.08	1.25	1.67	0.83	1.20	1.3
2/9/2005	5	11.17	4.75	41.66	1.25	1.13	0.50	2.10	1.3
2/22/2005	1	5.42	2.92	12.41	3.00	3.25	2.67	1.49	1.3
2/22/2005	1	5.92	2.50	11.62	0.92	1.33	0.92	1.89	1.2
2/22/2005	1	5.33	2.00	8.38	1.50	1.67	1.08	1.78	1.2
2/22/2005	1	5.75	4.33	19.57	1.08	1.25	0.50	1.41	1.2
2/22/2005	1	4.25	2.67	8.90	1.08	1.17	0.50	1.21	1.2
2/22/2005	1	3.75	1.75	5.15	0.75	0.79	0.42	1.19	1
2/22/2005	1	4.67	3.75	13.74	0.58	0.83	0.46	1.91	1.2
2/22/2005	1	4.50	2.75	9.72	1.08	1.33	0.67	1.38	1
2/23/2005	2	8.25	3.75	24.30	1.08	1.42	1.00	2.55	1.2
2/23/2005	2	5.25	2.92	12.03	1.50	1.83	1.25	3.27	1.3
2/23/2005	2	2.08	1.58	2.59	0.83	0.92	0.50	2.09	1.2
2/23/2005	2	3.17	2.25	5.60	0.92	1.25	0.83	2.30	1.2
2/23/2005	2	5.17	2.00	8.12	1.00	1.17	1.00	2.08	1.2
2/23/2005	2	5.00	2.42	9.49	1.08	1.33	0.83	1.14	1.2
2/23/2005	2	4.25	2.50	8.34	1.42	1.75	1.25	1.88	1.2
2/23/2005	2	5.00	3.50	13.74	1.83	2.08	1.50	0.85	1.2
2/23/2005	2	4.25	3.33	11.13	0.92	1.17	0.67	2.07	2.4
2/23/2005	2	4.00	2.67	8.38	0.67	0.92	0.58	1.76	2.4
2/24/2005	3	4.50	2.08	7.36	1.42	1.58	1.25	1.04	1.2
2/24/2005	3	9.75	3.00	22.97	1.17	1.33	0.96	0.90	1.2
2/24/2005	4	4.42	3.42	11.85	1.17	1.42	1.08	3.14	1.2
2/24/2005	4	5.00	3.00	11.78	1.50	1.75	0.92	1.64	2.4

TABLE A.4.—Continued

Date	Reach	Max length (ft)	Max width (ft)	Area (ft^2)	Depth: pre-redd (ft)	Depth: pit (ft)	Depth: tailspill (ft)	Velocity (ft/s)	Substrate code [a]
2/24/2005	4	3.67	1.83	5.28	1.08	1.25	0.83	1.05	1.3
2/24/2005	4	3.08	1.75	4.24	1.58	1.75	1.63	2.20	1
2/25/2005	5	9.42	3.42	25.27	1.08	1.29	0.63	1.34	1.2
3/7/2005	1	3.50	2.67	7.33	1.63	1.63	1.33	0.72	1
3/7/2005	1	4.25	3.75	12.52	0.79	0.92	0.58	1.81	1
3/7/2005	1	9.83	6.83	52.77	1.67	1.88	1.17	1.75	1.3
3/7/2005	1	5.17	3.83	15.56	1.67	2.00	1.46	1.19	1.2
3/7/2005	1	4.92	1.25	4.83	0.58	0.83	0.58	1.38	1.2
3/8/2005	2	6.25	2.17	10.64	0.58	1.00	0.75	2.54	1
3/8/2005	2	4.75	1.58	5.91	0.75	1.00	0.67	1.56	1
3/8/2005	2	5.25	2.33	9.62	0.75	1.08	0.58	2.16	1.2
3/8/2005	2	6.00	2.33	11.00	1.00	1.25	1.17	2.59	1
3/8/2005	2	5.67	4.25	18.92	1.67	1.92	1.58	1.87	1
3/8/2005	2	6.42	4.42	22.26	0.58	1.00	0.75	3.20	1.2
3/8/2005	2	4.83	1.83	6.96	2.00	1.71	1.17	1.74	1.2
3/8/2005	2	5.08	2.25	8.98	1.71	1.75	1.04	1.76	1
3/8/2005	2	4.92	2.58	9.98	1.79	1.83	1.17	1.69	1
3/8/2005	2	3.33	2.67	6.98	0.71	0.96	0.58	1.38	1.2
3/9/2005	3	6.42	2.33	11.76	1.08	1.54	0.71	0.92	1.2
3/10/2005	4	3.25	2.17	5.53	1.00	1.25	1.08	1.49	1.2
3/10/2005	4	5.58	2.92	12.79	1.75	1.92	1.33	1.31	1.3
3/10/2005	4	2.08	3.25	5.32	0.83	1.08	0.75	1.04	1
4/5/2005	1	6.08	4.58	21.90	1.25	1.08	0.67	1.47	1
4/5/2005	1	6.17	4.67	22.60	1.83	1.75	0.75	1.14	1.2
4/5/2005	1	5.42	4.17	17.73	0.92	0.92	0.67	1.24	1.3
4/5/2005	1	7.50	3.92	23.07	0.92	1.17	0.33	1.27	1.2
4/5/2005	1	8.00	4.00	25.13	1.08	1.25	0.42	0.47	1.2
4/5/2005	1	6.75	2.17	11.49	1.33	1.50	1.00	2.32	1.3
4/12/2005	4	8.42	2.42	15.98	0.75	0.83	0.25	1.08	1
Average		6.64	3.53	20.40	1.17	1.40	0.88	1.56	1.2[b]
Minimum		2.08	1.17	2.59	0.42	0.58	0.17	0.39	1
Maximum		16.33	8.33	106.90	3.00	3.25	2.67	3.27	2.4

[a] Dominant substrate codes are described by USFWS (2005) and are generally defined as follows; 1 = 1 in., 1.3 = 1-3 in., 2.4 = 2-4 in, etc.
[b] The median substrate code was used instead of an average.