Evaluation of the Sacramento River winter chinook salmon (*Oncorhynchus tshawytscha*) propagation program in 1996.

USFWS Report

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ABSTRACT

This is part of an ongoing study to evaluate the effectiveness of a hatchery propagation (supplementation) program's ability to assist in the recovery of the endangered Sacramento River winter chinook salmon *(Oncorhynchus tshawytscha).* The propagation program was conducted at the U.S. Fish and Wildlife Service's (Service) Coleman National Fish Hatchery (NFH) located on Battle Creek, a tributary to the Sacramento River, California. We accomplished study objectives by estimating escapement and identifying homing and spawning locations of hatchery-origin winter chinook salmon through spawning ground surveys on the Sacramento River and Battle Creek, utilizing fish traps, and video recording fish passage at dams. An estimated 237 hatchery-origin winter chinook salmon returned to the Sacramento River drainage in 1996 and all appeared to have returned to Battle Creek. The estimated escapement represents a replacement level of better than 4: 1 as the majority of the hatchery-origin winter chinook salmon returning to the Sacramento River system in 1996 were assumed to be from brood years 1993 and 1994. Wild -origin winter chinook salmon experienced a replacement level of 2.5: 1 for the same time period. Actual age structure could not be determined due to the small sample size, but data suggest the 2 year old component made up at least one-half of the total return. Similar replacement levels and spawning locations were observed in 1995. Although the estimated returns suggest good survival of hatchery-origin winter chinook salmon, returns to Battle Creek do not supplement the wild population which spawn in the Sacramento River near Redding, California. Findings from this study support a current effort to develop an alternative method for rearing and releasing hatchery-origin winter chinook salmon so they imprint to the main stem Sacramento River near Redding. Additionally, management alternatives for the salmon returning to Battle Creek need to be developed. Suggested alternatives include: capturing adults and either relocating them to the Sacramento River near Redding or utilizing them in propagation programs; improving the habitat in Battle Creek to promote successful propagation, or; discounting them in restoration efforts.

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GOAL

The goal of this study was to continue evaluating the effectiveness of a hatchery supplementation program's ability to assist in the recovery of the endangered Sacramento River winter chinook salmon *(Oncorhynchus tshawytscha).* The objective was to determine if the propagation program increased the number of adults that returned to spawn in the main stem Sacramento River. We estimated escapement and identified homing and spawning locations of hatchery-origin winter chinook salmon to accomplish the study objective. Additionally, age, sex and spawning success was determined and tissue samples were collected from carcasses for genetic analysis.

INTRODUCTION

In 1988, the Service entered a mutual agreement with National Marine Fisheries Service (NMFS), U.S. Bureau of Reclamation and the California Department of Fish and Game (CDFG) to develop a winter chinook salmon hatchery propagation program at the Service's Coleman NFH, located on Battle Creek (Figures 1 and 2). The program was established to ensure the continued existence of Sacramento River winter chinook salmon. The goal of the propagation program is to supplement natural spawning while avoiding the development of an adult return to Coleman NFH.

An estimated 88 hatchery-origin winter chinook salmon returned to the Sacramento River and Battle Creek during 1995 and all hatchery-origin winter chinook salmon appeared to return to Battle Creek (USFWS 1996). The estimated 88 hatchery-origin winter chinook salmon represented a three fold increase over the 1992 founder population (i.e., 29 adults were collected for the propagation program in 1992 and resulted in a producing 88 adults that returned in 1995). Although the estimated returns suggest good survival of hatchery-origin winter chinook salmon, returns to Battle Creek do not represent achieving the goal of supplementing the wild population which spawn in the Sacramento River near Redding, California.

As a result of these findings, the winter chinook salmon hatchery propagation program at Coleman NFH was temporarily discontinued in 1996 until the imprinting problem is resolved. Concerns of hybridization of winter chinook salmon with individuals of other chinook salmon runs also had great influence on the temporary termination of the propagation program.

The Service outlined several potential options in attempt to provide a solution to the imprinting problem. These options included releasing juveniles at a different time or location; outplanting fertilized eggs; imprinting salmon to a chemo-attractant; relocating the hatchery facility; rearing the salmon in acclimation ponds; releasing the salmon in smaller groups; supplementing Coleman NFH with Sacramento River water; or, maintaining the current production program (Croci 1996). The Service has chosen to pursue development of a hatchery facility on the main stem Sacramento River, permitting hatchery-origin winter chinook salmon to be reared near the location where they are expected to return. The decision to pursue a main stem rearing facility for winter chinook salmon was supported by CDFG, NMFS and other interested agencies and groups (USFWS 1997).

Additionally, management alternatives for the salmon returning to Battle Creek need to be developed, particularly since the goal of the propagation program is not being met. Suggested alternatives include capturing the adults and either utilizing them in the propagation program or relocating them to the Sacramento River near Redding, California or modifying conditions in Battle Creek which would support successful reproduction of fish currently returning.

To continue to assess the success of the supplementation program, it is critical to: 1) estimate escapement of hatchery-origin winter chinook salmon to the Sacramento River including tributaries, (i.e., Battle Creek); 2) determine the location of spawning grounds of hatchery-origin winter chinook salmon; 3) determine the age and sex of returning adults; and, 4) monitor spawning success.

STUDY AREA

Surveys for adult winter chinook salmon occurred on the main stem Sacramento River from Red Bluff Diversion Dam (RBDD; river kilometer [RK] 388) to Keswick Dam (RK 483; Figure 1). Additionally, Battle Creek, a tributary of the Sacramento River, was monitored downstream of Eagle Canyon Dam on the north fork and downstream of Coleman Diversion Dam on the south fork (Figure 2).

Specific survey sites in the main stem Sacramento River include (Figure 1):

Red Bluff Diversion Dam	RK 388
spawning grounds	RK 438-483

Specific survey sites in Battle Creek include (Figure 2):

Coleman NFH's barrier dam		creek kilometer (CK) 10
spawning grounds	main stem:	from CK 5 to confluence of forks (approximate distance = 23 km)
	north fork:	confluence of forks to Eagle Canyon Dam (approximate distance = 7 km)
	south fork:	confluence of forks to Coleman Diversion Dam (approximate distance = 4 km)

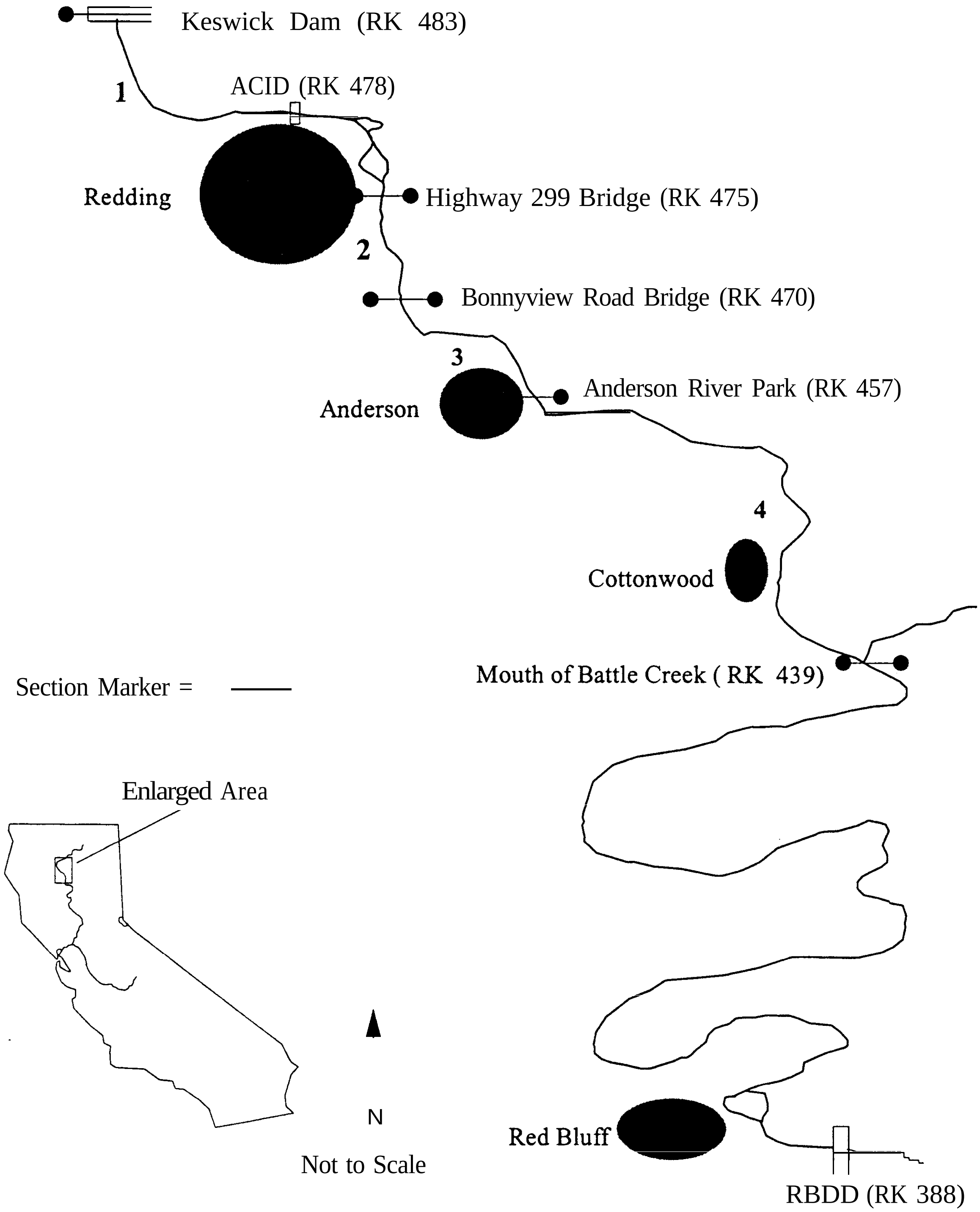

Figure 1 .-Location of 1996 winter chinook salmon spawning ground surveys in the Sacramento River. Maps include reach numbers, with starting and ending locations, and other identifying features such as Red Bluff Diversion Dam (RBDD), Red Bluff, Battle Creek, Anderson, Redding and Keswick Dam.

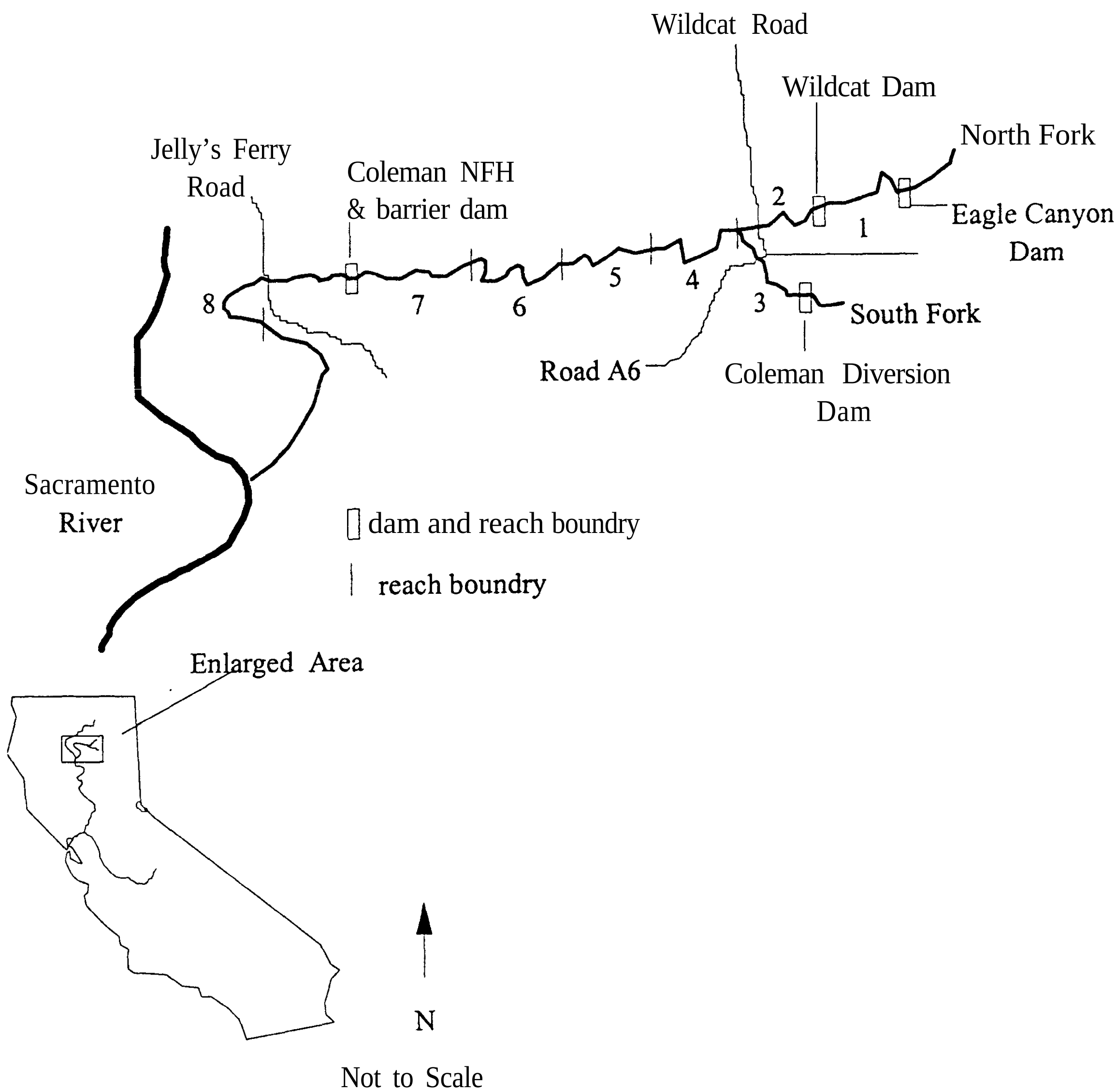

Figure 2.--Location of 1996 winter chinook salmon spawning ground surveys in the Battle Creek. Maps include reach numbers, with starting and ending locations, and other identifying features such as Coleman National Fish Hatchery (NFH) and the Coleman NFH's barrier darn, County Road A-6, Wildcat Road and Jelly's Ferry Road.

METHODS

Winter chinook salmon are raised to the pre-smolt stage at Coleman NFH and released into the Sacramento River near Redding, California (RK 476). It is hoped these juveniles imprint to the release location so that they eventually return as adults to spawn naturally with wild winter chinook salmon in the main stem Sacramento River. Prior to release, all winter chinook salmon juveniles are coded-wire tagged and adipose fin-clipped for future identification. Observations of adult chinook salmon were made at 4 survey locations as described in the study areas reach. To produce valid results, attempts were made to observe/sample 10% of the total 1996 winter chinook salmon run-size estimate. The annual run-size estimate is based on counts at the RBDD. Winter chinook salmon were distinguished from other runs (late-fall and spring) by run timing and physical characteristics (brightness, coloration, fin condition, and muscle tone). Hatchery-origin winter chinook salmon were identified by an adipose fin-clip, while wild winter chinook salmon were unmarked. When possible, coded-wire tag recovery was used for positive identification of run.

Survey *Sites*

Main Stem--Red Bluff Diversion Dam

Fish passage at RBDD was monitored during dam operation (15 May through 15 September). The Service made actual counts of fish passage through viewing facilities at the east and west ladders from 6:00 am to 8:00 pm daily. The total number of clipped and unclipped chinook salmon was recorded. At the center fish ladder, video recordings of fish passage occurred from 6:00 am to 8:00 pm each day. The tapes were reviewed to identify and count fish that had passed. Once a week, CDFG determined night passage at the east and west ladders through actual counts from 8:00 pm to 10:00 pm and then video recordings from 1O:OO pm to 6:00 am. The tapes were viewed to identify and count fish that had passed. This single night count was expanded to represent expected night passage for all other nights that week. CDFG also operated the fish trap located in the east fish ladder. The trap was usually operated 5 - 7 days a week from 6:00 am to 3:00 pm. Collected fish were identified to species or, if a salmon, to run. Fish were measured and checked for marks (hook scars, fin clips, etc). Combined day and night fish passage numbers for the various runs were apportioned out by run based on fish trap numbers. Data collected at RBDD was used to generate the winter chinook salmon run-size estimate. A separate estimate was determined for marked and unmarked winter chinook salmon.

Main Stem--Spawning Grounds

Boat surveys of winter chinook salmon spawning grounds in the Sacramento River were conducted to recover carcasses. Surveys were conducted four days each week from May through August. The river was broken down into four reaches that could be surveyed within a day (Table 1; Figure 1). Salmon carcasses collected during this period were assumed to be winter chinook salmon unless physical evidence suggested otherwise. Collected carcasses were measured (fork length in mm), sexed, checked for marks and expression of sex products. Tissue samples were collected for genetic analysis. A hole punch was used to obtain five small pieces of tissue (primarily fin) which were stored in a small vial containing tris-glycine buffer. Three samples (vials) were collected from each fish and then archived at the Northern Central Valley Fish and Wildlife Office (NCVFWO), Red Bluff, California. Scales were collected for ageing. Several aerial surveys were also conducted from May through August to identify/verify winter chinook salmon spawning grounds (redds) and carcasses. An attempt was made to recover carcasses identified during aerial surveys. Carcasses were observed for the presence of an adipose fin and the number of adipose fin-clipped salmon and unclipped salmon were noted.

Table 1 .-Reach number, upstream identification point and river kilometer (RK), downstream identification point and RK used during Sacramento River spawning grounds surveys for winter chinook salmon carcasses in 1996.

Reach	Upstream point	Upstream RK	Downstream point	Downstream RK
1	Keswick Dam	483	Highway 299	475
2	Highway 299	475	Bonnyview Boat Launch	470
3	Bonnyview Boat Launch	470	Anderson River Park	457
4	Anderson River Park	457	Mouth of Battle Creek	439

Battle Creek--Coleman National Fish Hatcher-v Barrier Dam

Operation of the Coleman NFH barrier dam prevented upstream passage of fish in Battle Creek from July through March. During October to March fish were directed into holding ponds at Coleman NFH where salmon and steelhead were used in propagation programs. Uninhibited passage upstream of the barrier was afforded from 26 March through 1 July 1996. An under-water video camera placed in a modified weir at the upstream end of the fish ladder was used to estimate escapement of chinook salmon which had passed the Coleman NFH barrier dam. Alternate lighting allowed 24 hour monitoring, and a time-lapse video recorder was used to reduce maintenance and viewing time. The time mode was set to 48 hours on a time lapse video cassette recorder and 120 minute 8 mm tapes were used. The time mode was switched to slower 24 hour recording mode to allow a sufficient number of frames to be captured for positive identification of marks. A time-date stamp was recorded. Tapes were viewed until a fish was observed, then reviewed at slow playback speed or "freeze frame" mode to assist in identification and mark detection. The certainty of the observation was either rated good, fair or poor.

Good signified complete confidence in determining species and presence or absence of an adipose fin; fair suggested confidence in determining species and presence or absence of an adipose fin but additional review was needed to classify the fish; and poor, suggested uncertainty in determining species and presence or absence of an adipose fin. The quality of the picture being observed was also rated as good, fair or poor. Good signified a clear picture throughout the day; fair suggested objects were discemable throughout the day but extra review was needed; and poor, suggested that objects were indistinguishable most of the day.

All salmon passing the barrier dam were recorded onto a file tape and reviewed by experienced personnel to confirm run and presence or absence of an adipose fin. The total number of clipped and unclipped salmon observed was recorded. Salmon were classified as unknown if the adipose fin was unidentifiable . Additionally, the hours of fish passage and the hours of video recorded fish passage were logged each day. Peak migration, date and time, for both adipose fin clipped and unclipped salmon in Battle Creek was determined. NCVFWO biologists conducted spot checks of video tapes to verify identification and counts.

Battle Creek--Spawning Grounds

Snorkel surveys were conducted each weekday on selected reaches (Table 2; Figure 2) of Battle Creek to locate winter chinook salmon spawning grounds (redds) and carcasses from 26 May through 30 August. Generally 2 of the 8 reaches were surveyed each day and all reaches were surveyed each week. When possible, recovered carcasses were measured, sexed, and checked for marks and expression of sex products. Fin tissue was collected for genetic analysis and archived at NCVFWO in Red Bluff, California. Scales were collected for ageing. Attempts to recover coded-wire tags occurred on adipose fin-clipped salmon and salmon of unknown origin (i.e., carcasses too severely decomposed to assess prior presence of an adipose fin). Redds were marked with flagging or some other visible marker (pile of rocks) to avoid counting twice. The total number of clipped and unclipped salmon observed or recovered were recorded.

Aerial surveys were also conducted from May through August to identify/verify winter chinook salmon spawning grounds (redds) and carcasses. An attempt was made to recover carcasses identified during aerial surveys.

Escapement Estimation

Two independent methods were used to estimate escapement of hatchery-origin winter chinook salmon. One method used data obtained at RBDD to remain consistent with the method used to estimate the winter chinook salmon run-size, however, this method was based on sampling only a portion of the run. A second method used data collected on Battle Creek to generate an escapement number and likely accounted for the complete run timing.

Table 2.-Reach number, upstream location and approximate creek kilometer (CK), and downstream location and approximate CK on Battle Creek where spawning grounds were surveyed for winter chinook salmon in 1996.

	Upstream		Downstream	
Reach	Location	CK	Location	CK
1 (north fork)	Eagle Canyon Dam	35	Wildcat Dam	32
2 (north fork)	Wildcat Dam	32	Confluence of forks	28
3 (south fork)	Coleman Diversion Dam	32	Confluence of forks	28
4	Confluence of forks	28	PG&E Pipeline	25
5	PG&E Pipeline	25	Mt. Valley Ranch	20
6	Mt. Valley Ranch	20	Ranch road	14.5
7	Ranch road	14.5	Coleman NFH barrier dam	10
8	Coleman NFH barrier dam	10	Refuge Boundary	5

Red Bluff Diversion Dam

The hatchery-origin winter chinook salmon escapement estimate made at the RBDD was derived from direct visual counts of fish passage. These direct visual counts were then expanded to reflect night passage and apportioned by run relative to data collected in the east fish ladder trap. Weekly data were then summed and expanded by the percentage of the historic run timing past the RBDD for the same sampling period. The methodology for this estimate was consistent with that used to generate the 1996 winter chinook salmon run-size estimate for unmarked fish (Appendix 1).

Battle Creek

Escapement to Battle Creek was estimated based on adult salmon collected at Coleman NFH, observations of video taped passage counts at the Coleman NFH's barrier dam and stream surveys. Winter chinook salmon were collected at Coleman NFH during adult collection for propagation programs of other runs of chinook salmon and steelhead. Video taped passage counts were only used in analysis to determine escapement for days with good to fair ratings. Stream surveys were used to document spawning location(s) and time, and to count redds. Carcasses provided a means to recover coded-wire tags allowing for positive identification of run and origin. Information from collected carcasses also verified origin of fin clipped salmon observed during video recordings.

For each week passage was recorded, escapement of clipped and unclipped salmon passing the Coleman NFH's barrier dam was estimated by expanding the total number of clipped and unclipped salmon observed by the percentage of passage that was recorded. Salmon with unknown clips were distributed between the clipped and unclipped categories based on the proportion of each category observed prior to expanding. Escapement for all weeks was generated with the following equation:

$$E = \sum_{i=1}^{15} \left(\left[\left(\frac{c_i}{(c_i + u_i)} \right) * unk_i \right] + c_i \right) * \left(\frac{P_i}{V_i} \right)$$

where:

E = Escapement estimation of hatchery-origin winter chinook salmon above the Coleman NFH barrier dam for 1996;

c = actual number of adipose fin-clipped chinook salmon observed passing the Coleman NFH barrier dam during the week;

u = actual number of unclipped chinook salmon observed passing the Coleman NFH barrier dam during the week;

unk = actual number of unknown clipped chinook salmon observed passing the Coleman NFH barrier dam during the week;

P = number of hours of unrestricted fish passage at the Coleman NFH barrier dam during the week; and,

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

Coded-wire tag recoveries identified various stocks (brood year or run) and the percentage of each. This percentage was then multiplied by the escapement estimate for clipped salmon and resulted in an estimated escapement for hatchery-origin winter chinook salmon. A separate estimate was generated for unclipped chinook salmon (Croci and Hamelberg 1997).

Typically, in a given week, the entire study area (27 kilometers above the Coleman NFH barrier dam and 7 kilometers below) was surveyed once. This sampling schedule equalized effort above and below the barrier dam allowing an estimate of the number of winter chinook salmon below the barrier dam to be as described below.

The nurnber of winter chinook salmon returning to Battle Creek below the Coleman NFH barrier dam was estimated by assuming the ratio of the estimated number of winter chinook salmon (WCS) to the number of carcasses collected was equal above and below the barrier dam.

$$\frac{\text{Estimated \# of WCS below Coleman NFH barrier dam}}{\text{\# WCS carcasses below Coleman NFH barrier dam}} = \frac{\text{Estimated \# of WCS above Coleman NFH barrier dam}}{\text{\# WCS carcasses above Coleman NFH barrier darn}}$$

For escapement estimate calculations, all carcasses collected in reach 8 less than 200 m downstream of the Coleman NFH barrier dam were considered to be recoveries in reach 7. It is assumed that salmon recovered within 200 m of the barrier dam had actually passed the barrier dam (and were counted), died and then drifted downstream over the barrier dam to be recovered in reach 8. This assumption was made because most carcasses likely drift downstream prior to settling out and a late-fall chinook salmon carcass was actually observed drifting over the Coleman NFH barrier dam (Vina Free, U.S. Fish and Wildlife Service, Northern Central Valley Fish and Wildlife Office, personal communication).

Additionally, all hatchery-origin winter chinook salmon recovered at Coleman NFH were added to the Battle Creek escapement number. These adult winter chinook salmon were captured during adult collections for propagation programs of other salmon runs and steelhead.

The final Battle Creek escapement estimation was divided by 96% to account for an assumed 4% stray rate. A 4% stray rate was applied to the Battle Creek estimate as this minimum stray rate has been noted for late-fall chinook released from Coleman NFH (USFWS 1996).

Spawning Location

Specific spawning locations for hatchery-origin winter chinook salmon were determined through river, stream and aerial surveys. Counts of clipped and unclipped winter chinook salmon observed at each location were recorded and the percent of hatchery-origin winter chinook salmon was determined. Comparing percent of hatchery-origin winter chinook salmon for each location and between the main stem Sacramento River and Battle Creek indicated homing tendencies. Observations of winter chinook salmon redds were also noted.

Age and sex ofreturning adults

Age of returning hatchery-origin winter chinook salmon was determined by: 1) recovering carcasses: 2) estimating fish lengths at the Coleman NFH barrier dam: and, 3) obtaining actual fish lengths at RBDD. Adipose fin-clipped salmon carcasses recovered were measured, sexed, and when possible, the snout and several scales were collected. Age was determined by recovering the coded wire-tag from the snout and reading growth rings on the scales from the salmon carcasses collected. Age was also determined from a length frequency distribution generated by estimating fish lengths of salmon that passed the video counting station at the Coleman NFH barrier dam. Estimated lengths were ascertained by calibrating the video system and then employing an advanced algorithm to the fish images contained on the file tape. The University of British Columbia, Canada was contracted to ascertain the video fish lengths (Royann Petrell, University of British Columbia, Canada, Bio-resource Engineering Department). Additionally, chinook salmon trapped at RBDD were measured and a length frequency distribution was developed to determine age structure.

The male to female ratio was determined through carcass recovery and trapping at RBDD No attempt was made to use video images at Coleman NFH barrier dam to determine sex ratio.

Spawning Success

Spawning success was assessed by: 1) monitoring water temperature in Battle Creek, particularly at redd locations; and, 2) observing newly emergent fry via snorkeling, beach seining and electro-fishing.

Temperature

Daily temperatures were recorded using mercury filled thermometers at approximately 9:00 am and 2:30 pm. Hobo® temperature recorders, programmed to record temperature at an hourly basis were at buried in the gravel near the location of observed salmon redds.

Fry sampling

Observations of newly emergent winter chinook salmon fry were made during daily snorkel surveys between late-May and mid-September. Approximate size of the fish observed was determined by comparing it to an object of known size (i.e., rock, hand, or stick) then measuring that object. In September, beach seining and electro-fishing were used to collect juvenile fish to obtain actual sizes. A small, lmm, fin-clip was obtained from captured juveniles and preserved in tris-glycine buffer, then archived at the NCVFWO.

RESULTS

Approximately 10% of the 1996 winter chinook salmon run size estimate was sampled in 1996 (Tables 3 and 4). A total of 128 winter chinook salmon carcasses were collected during surveys in the Sacramento River and Battle Creek (Table 3). An estimated run-size of 1,296 was obtained from the data collected at RBDD (Table 4). All carcasses were only sampled/counted once.

Escapement Estimation

Red Bluff Diversion Dam

The estimated winter chinook salmon run-size past RBDD in 1996 was 1,296 which includes estimates for both wild and hatchery salmon (Frank Fisher, CDFG, Inland Fisheries Branch, Red Bluff, personal communication; Table 4). Of the 1,296 estimated winter chinook salmon, 356 were determined to be of hatchery-origin and the remaining 940 were classified as wild-origin (Table 4). The estimate for hatchery-origin winter chinook salmon was determined by sampling 23 clipped winter chinook salmon at the RBDD fish trap from 15 May (gates down) through 10 August (end of historic winter chinook salmon migration past RBDD; Appendix 1).

Battle Creek

Data collected in Battle Creek suggest an estimated 237 hatchery-origin winter chinook salmon returned to the Sacramento River system in 1996 (Table 4). This finding was based on an estimate of 15 1 chinook salmon passing upstream of the Coleman NFH barrier dam from 26 March to 1 July 1996, one returning to Coleman NFH, and an estimated 76 returning below the Coleman NFH barrier dam. An assumed stray rate of 4% to the main stem Sacramento River contributed nine additional fish bringing the final estimate to 237.

The one hatchery-origin winter chinook salmon encountered at Coleman NFH while collecting for propagation programs (December through March) was found dead in a holding pond on 10 January 1996. This female salmon was 745 mm fork length and was determined to be from brood year 1992 (CWT recovery 0501010612).

An estimate of 15 1 hatchery-origin winter chinook salmon was determined by calculating estimates for each week and then summing weekly estimates for the entire study period (Table 5). Of the salmon video taped passing the barrier dam during good and fair picture quality, a total of 112 were clipped (2 were late-fall chinook), 27 were unclipped and 7 had unknown clips (Table 5). Many unknown clips (N=5) were observed during the first 3 weeks when the recorded time mode was set at 48 hours. The time mode was switched to a slower recording speed (24 hour) on 17 April. From 26 March to 1 July a total of 2,352 hours of passage was afforded at the Coleman NFH barrier darn. Eighty percent (1,871 hours) of the afforded passage was video recorded with a good or fair picture quality (Table 5). Poor video recordings resulted from highly turbid water or debris obstructing the view and were not considered in the percent of observed fish passage. On a few occasions, video recording was interrupted due to equipment failure.

Table 3.-Location, number of wild and hatchery winter chinook salmon observed, percent hatchery-origin and percent of the total estimated winter chinook salmon population sampled in the Sacramento River and Battle Creek during 1996. The thick line separates winter chinook salmon encountered in the main stem Sacramento River (above) and Battle Creek (below). Percent of total population sampled was based on California Department of Fish and Game's 1996 estimated escapement of 1,296 winter chinook salmon (marked and unmarked) to the Sacramento River (Frank Fisher, CDFG, Red Bluff, California, personal communication).

Location	Number wild	Number hatchery	Percent hatchery	Percent of total population sampled
Red Bluff Diversion Dam fish trap	63	23	27	7
Sacramento River spawning grounds	118	0	0	9
Coleman NFH's barrier dam fish ladder	0	110	100	9
Battle Creek spawning grounds	0	10*	100	1
Total	183	143		25

* Includes one hatchery-origin winter chinook salmon recovered on 10 January 1996 at Coleman NFH while collecting late-fall chinook salmon and steelhead for propagation programs.

Table 4.-Escapement estimates for hatchery and wild-origin winter chinook salmon as derived from data collected on Battle Creek and at the Red Bluff Diversion Dam in 1996. N/A indicates that an estimate was not made.

Method	Hatchery	Wild	Total
Battle Creek	237	N/A	N/A
Red Bluff Diversion Dam	356	940	1296

Table 5. -- Actual number of adipose fin-clipped hatchery-origin winter chinook salmon (clipped), unclipped chinook salmon and unknown clipped salmon observed during a given week and the expanded number of clipped salmon, hours of unrestricted passage and number of hours of video taped passage for good and fair video recordings at Coleman National Fish Hatchery's barrier dam from 26 March through 1 July 1996.

Week Ending	Actual Number Clipped	Actual Number Unclipped	Actual Number Unknown	Expanded Number Clipped*	Hours of Passage	Hours of Taped Passage
30 March	3	1	0	3	130	128
06 April	7	4	3	10	168	144
13 April	9	1	2	11	168	168
20 April	4	0	0	6	168	115
27 April	15	0	0	18	168	137
04 May	10	2	0	10	168	167
11 May	7	1	0	7	168	168
18 May	2	0	0	17	168	20
25 May	3	1	0	9	168	59
01 June	15	4	0	20	168	126
08 June	9	1	0	11	168	141
15 June	13	3	0	14	168	153
22 June	5	1	1	6	168	167
29 June	8	5	0	9	168	144
06 July	0	3	1	0	38	34
Total	110	27	7	151	3,352	1871

* Expanded number clipped= (((clipped/(clipped+unclipped) * unknown)+clipped) * (total hrs. passage/total hours of good and fair quality video taped passage))

A total of nine carcasses were recovered in Battle Creek during snorkel surveys, five were of hatchery-origin (adipose fin-clipped) and four were in a condition of decay that prevented origin identification (Table 6). Although no coded wire tags were recovered, all nine carcasses were assumed to be winter chinook salmon based on the time of the year the carcasses were recovered. Additionally, all were assumed to be of hatchery origin as all five salmon recovered which were discernable (i.e., hatchery/wild) were hatchery-origin (adipose fin-clipped).

Four of the carcasses were recovered below and five were recovered above the Coleman NFH barrier dam. One carcass was recovered less than 200 m below the Coleman NFH barrier dam (reach 8) and was assumed to have actually died above the dam (reach 7). Therefore, for escapement estimation calculations, we assumed that three carcasses were recovered below and six were recovered above the Coleman NFH barrier dam.

Assuming the sampling effort above and below the Coleman NFH barrier dam was equal, a ratio of three carcasses below to six above and a population of 15 1 salmon above, then an estimated 76 hatchery - origin winter chinook salmon returned to Battle Creek which did not pass the barrier dam.

An additional 4% of the Battle Creek escapement estimate, or nine salmon, were added to account for straying.

In summary, the estimated escapement of winter chinook salmon based on Battle Creek data is presented below:

Coleman NFH	1
Battle Creek above barrier dam	151
Battle Creek below barrier dam	+76
Sum for Battle Creek	228
Estimated 4% stray rate to the Sacramento River	+ 9
Final estimated escapement	237

Hatchery-origin winter chinook salmon were observed passing the Coleman NFH barrier dam every week the ladder was open through June (Table 5; Figure 3). (Unclipped chinook salmon will be considered in a separate report (Croci and Hamelberg 1997)). More salmon (59%) ascended the ladder during the dark hours (Figure 4). Other fish observed moving upstream while video recording at the Coleman NFH barrier dam include Sacramento squawfish *(Ptychocheilus grandis),* Sacramento sucker *(Catastomus occidentalis),* hardhead *(Mylopharodon conocephalus),* rainbow trout/steelhead (0. *mykiss* lamprey *(Lampetra* spp.), and black bass *(Micropterous* spp.).

Table 6.-Date, location (reach) of carcass, carcass condition, indication if tissue samples were collected, indication of the presence or absence of an adipose fin, coded wire-tag code (CWT), length, age and sex of adult chinook salmon carcasses recovered in Battle Creek during 1996 stream surveys. N/A indicates information was not available due to advanced decomposition of the carcass.

Date	Reach	Tissue Samples	Adipose fin-clip	CWT	Length (mm)	Age	Sex
10 Jan	CNFH	N/A	Yes	0501010612	745	4	female
28 May	8	Yes	Yes	no tag	850	3	female
4 June	6	Yes	Yes	no tag	540	2	male
2 July	6	Yes	Yes	no head	N/A	2	N/A
3 July	5	N/A	N/A	no tag	N/A	N/A	N/A
3 July	4	Yes	N/A	no head	N/A	2	male
17 July	4	Yes	N/A	no head	N/A	N/A	N/A
19 July	7*	Yes	Yes	no head	N/A	2	N/A
19 July	8	Yes	Yes	no head	N/A	2	N/A
24 July	8	N/A	N/A	no tag	N/A	N/A	N/A

* Actually recovered in reach 8, but for escapement estimation calculations this carcass was assumed to have been recovered in reach 7. This was done because it was recovered less than 200 m downstream of the Coleman NFH barrier dam and it was assumed to have drifted downstream from reach 7 into reach 8.

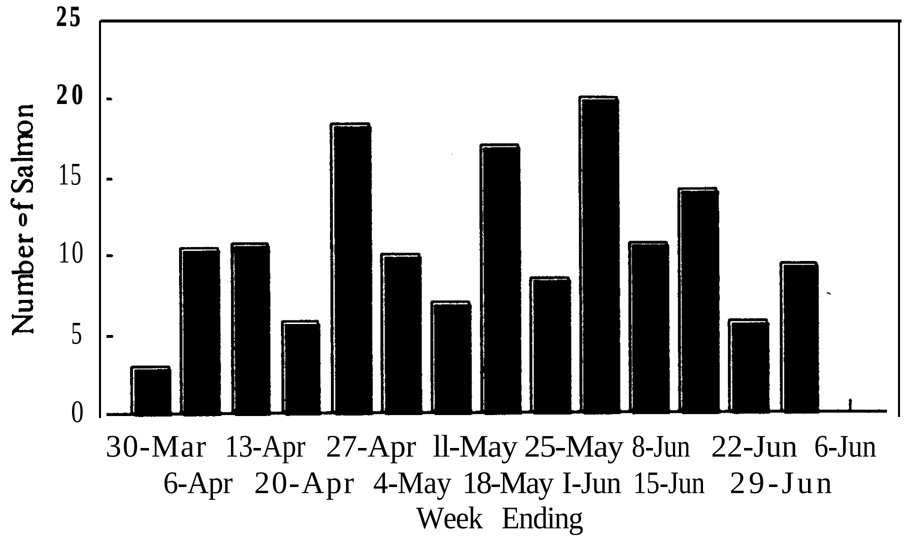

Figure 3 .-Estimated number and migration timing of hatchery-origin 'winter chinook salmon passing the Coleman National Fish Hatchery barrier dam for each week passage was recorded.

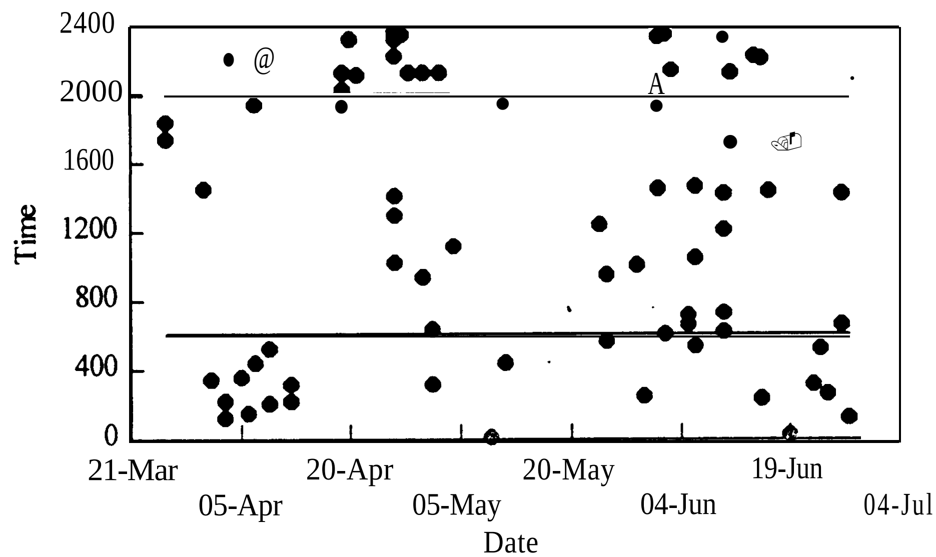

Figure 4.-Die1 migration timing of hatchery-origin winter chinook salmon in Battle Creek (N= 75). Daylight hours are between the lines. Only days when passage was recorded for 24 hours were used in analysis and displayed.

Spawning Location

Most or all hatchery-origin winter chinook salmon returned to Battle Creek (Table 3). No hatchery-origin winter chinook salmon were observed in the Sacramento River upstream of Battle Creek. Within Battle Creek, three carcasses were recovered below and six above the Coleman NFH barrier dam. Actually, four carcasses were recovered below and five above the Coleman NFH barrier dam, but because one carcass was recovered less than 200 m downstream of the Coleman NFH barrier dam, it was assumed to have drifted downstream over the dam from reach 7 into reach 8. Therefore, above the barrier dam 2 carcasses were recovered in reach 4, 1 in reach 5, 2 in reach 6, and 1 in reach 7 (Table 6).

Three winter chinook salmon redds were located in Battle Creek above the barrier dam, one in the north fork (reach 1) and two in the main stem near the outflow of Coleman Powerhouse (reach 7). Redds were not observed in the south fork of Battle Creek. A salmon per redd ratio above the Coleman NFH barrier dam was not made because so few redds were observed. Winter chinook salmon redds were not observed below the Coleman NFH barrier dam. However, two "practice" redds (an area of cleaned gravel that does not have the shape or size of a typical redd) were observed. Two practice redds were also observed above the Coleman NFH barrier dam (reaches 2 and 4). Additionally, no chinook salmon redds were observed during aerial surveys (Table 7).

Table 7.-Date, starting location, ending location and number of new redds observed during aerial flights of Battle Creek in 1996.

Date	Starting Location	Ending Location	Number of New Redds
3 June	mouth	Eagle Canyon Dam on north fork Coleman Diversion Dam on south fork	0
15 July	mouth	Coleman NFH barrier dam	0
23 July	mouth	Confluence of forks	0

Age and sex of returning adults

The age structure of returning hatchery-origin winter chinook salmon was estimated to be 82% jacks (two years old) and 18% adults (three or more years old; N= 80). The age structure determined by carcass recovery was 72% jack and 28% adult (N = 7; 14% three year old and 14% four year old salmon; only one coded-wire tag was recovered). The length frequency distribution by estimating fish lengths from video images also displayed a very strong age two component, 96% jacks and 4% adult (N= 50; 600 mm cut-off between jack and adult; Figure 5). Data also suggests that 56% of the hatchery-origin winter chinook salmon passing RBDD were jacks and 44% were adults (N = 23; 600 mm cut-off between jack and adult; Frank Fisher, Inland Fisheries Branch, CDFG, Red Bluff, CA, personal communication).

A sex ratio of 1 male to 1 female was observed for hatchery-origin winter chinook salmon returning to Battle Creek in 1996. This ratio was based on a sample size of four. Three of the salmon were collected during stream surveys and one was collected at Coleman NFH (Table 6). RBDD data suggests that 10.5 males returned to every 1 female (N = 23: Frank Fisher, Inland Fisheries Branch, CDFG, Red Bluff, CA, personal communication).

No adipose fin-clipped chinook salmon were collected in the main stem Sacramento River during spawning ground surveys. Therefore, sex ratio and age structure were not determined.

Spawning Success

Temperature

One temperature logger was placed at a redd located in reach 7 from 10 July through 21 August (Table 8). The logger was placed there almost 1 month after the redd was first observed. Average daily water temperature was 17.43°C. Water temperatures taken during daily surveys ranged from a minimum of 12.0°C on 27 June (a.m.) in Reach 3 to a maximum of 24.5°C on 30 July (p.m.) in Reach 7.

Table 8.- Location, reach, launch and recovery date, minimum recorded hourly water temperature °C, maximum recorded hourly water temperature °C, and average daily water temperature °C for a temperature logger deployed near a chinook salmon redd in Battle Creek during 1996.

Location	Reach	Launch Date	Recovery Date	Minimum Temperature °C	Maximum Temperature °C	Average Daily Mean °C
End of Coleman Powerhouse Canal	7	10 July	21 August	14.39	28.60	17.43

Juvenile monitoring

Recently emergent salmon were not observed during snorkel surveys or captured while beach seining or electro-fishing. Juvenile salmon were regularly observed during snorkel surveys with estimated fork lengths ranging from 50 - 130 mm in June, 60 - 170 mm in

July, 50 - 210 mm in August and 60 - 200 mm in September. Two distinct size groups were evident. Captured juvenile salmon during the first two weeks in September ranged in size from 60 - 158 mm. One ill salmon of 170 mm was collected by hand on 8 August. Smaller salmon were consistently more abundant.

DISCUSSION

Of the two methods used to estimate the escapement of hatchery-origin winter chinook salmon, the Battle Creek method appeared to be most accurate. Most or all hatchery-origin winter chinook salmon returned to Battle Creek and surveys on Battle Creek encompassed the entire migration and spawning period. Estimates based on RBDD data only accounted for approximately the last 15% of the winter chinook salmon migration period. Therefore, the estimated escapement for hatchery-origin winter chinook salmon in 1996 was 237 (Table 4), as derived by the method used for data collected on Battle Creek.
Considering the pre-season estimate for wild and hatchery-origin winter chinook salmon was about 400 fish, the estimate of 356 hatchery-origin winter chinook salmon alone, as derived from RBDD data, suggest the 1996 run was exceptional. It is believed that brood year 1994 winter chinook salmon likely benefitted from the wet winter of 1995 as suggested by the high percentage of jacks (age 2) 34.9% for unmarked and 52% for marked winter chinook salmon seen at RBDD.

The higher than anticipated escapement, as obtained from RBDD data, may also be a result of the migration period occurring later than the current method assumes. A later migration period would intuitively suggest that more hatchery-origin winter chinook salmon would be captured at RBDD and 23 hatchery-origin winter chinook salmon were sampled at the RBDD fish trap this year, the most since the supplementation program began. The delayed migration timing would overestimate the winter chinook salmon run-size for both the hatchery and wild components. A better method to estimate escapement for winter chinook salmon should be explored, one that accounts for the complete run timing.

The video monitoring of fish passage at the Coleman NFH barrier dam was quite reliable in 1996. Nearly 80% of controlled fish passage was video taped with good or fair picture quality, an improvement over 1995 when only 42% was recorded with good or fair picture quality. Better lighting, a more frequent maintenance schedule and familiarizing personnel with the equipment accounted for most of the improvement. Favorable environmental conditions (i.e., lack of high flow events) also factored heavily in the ability to monitor a larger percentage of time. The minor modification to the lighting system did not appear to affect movement of salmon or other fish species and improved the ability to monitor night passage. Additionally a high percentage of chinook salmon passed at night in 1996 (59%) than in 1995 (20%).

Although the method to estimate hatchery-origin winter chinook salmon abundance in Battle Creek appeared to be very accurate and reliable, potentially an under or overestimate of the population may have occurred. Undocumented fish passage at the Coleman NFH barrier dam may have underestimated the number of winter chinook salmon returning to Battle Creek. The Coleman NFH barrier dam was assumed to be 100% effective in preventing passage, however, fall chinook salmon have been observed ascending the dam in flows as low as 363 cfs. Nevertheless, passage at the ladder likely occurred at greater rate than at other points at the barrier dam.

Overestimate of hatchery-origin winter chinook salmon returning to Battle Creek may have occurred as a result of fallback of carcasses and live salmon. To account for "fallback," any carcass that was recovered within 200 m of the barrier dam was considered to be "recovered" above the barrier darn (reach 7). Carcasses recovered within 200 m of the barrier dam were assumed to have passed the barrier dam, died, and drifted downstream back over the barrier dam. It was necessary to account for "fallback" because carcasses tend to drift downstream after death and a late-fall chinook salmon carcass was actually observed drifting downstream over the Coleman NFH barrier dam previously. Live salmon may also have ascended the fish ladder, then "fellback" over the dam and ascended the ladder again. Essentially fish would be counted twice and result in a overestimate of the returning population. No attempt was made to account for "fallback" of live salmon because it has not been previously observed at this barrier.

In 1996 the estimate of winter chinook salmon returning to Battle Creek below the Coleman NFH barrier dam was accomplished by a different manner than in 1995. In 1995, the estimate below the barrier dam was based on redd counts. In 1996, the estimate was made using carcass recoveries. The change occurred because only three redds were observed in 1996 and all were above the Coleman NFH barrier dam. One reason so few redds were observed could have been the high water temperatures which may have disrupted spawning behavior of these fish. Additionally, salmon could have made it past the Coleman Diversion and Eagle Canyon dams and spawned further up in the system beyond where surveys were conducted. Finally, predators (otters, eagles) were regularly observed in Battle Creek during snorkel surveys and salmon may have fallen victim to predation prior to spawning. However, the actual reason for observing only a few redds remains unknown.

As in 1995, sufficient data was obtained to suggest most, or nearly all, hatchery-origin winter chinook salmon returned to Battle Creek. The return of winter chinook salmon to Battle Creek poses two concerns: 1) how to improve imprinting of hatchery-origin winter chinook salmon to the Sacramento River; and 2) how to best utilize winter chinook salmon returning to Battle Creek. Imprinting issues are discussed in the Service's "Alternate rearing and release strategies for winter chinook salmon *(Oncorhynchus tshawytscha)* raised at Coleman National Fish Hatchery" (Croci 1996). The Service consistently maintains that the goal of the propagation program is to supplement the natural spawning of winter chinook salmon in the main stem Sacramento River and does not desire to establish a hatchery-origin Battle Creek return to this end a new hatchery Livingston Stone National Fish Hatchery was constructed at the base of Shasta Dam.

Data collected at Battle Creek and RBDD suggest a very strong age 2 component of the 1996 return, likely greater than 50%. No attempt was made to differentiate age of adult salmon (age 2 plus) at RBDD or through video fish lengths. Because only seven samples were used to determine adult age structure of hatchery-origin winter chinook salmon in Battle Creek, the actual age structure is questionable.

Likewise, the accuracy and reliability used to determine the sex ratio of returning hatchery-origin winter chinook salmon to Battle Creek is very questionable due to the extremely small sample size (N = 4). The male to female ratio (10.5: 1 including 2 year old salmon) obtained at RBDD may be more appropriate. However, the RBDD fish trap only samples the last 15% of the winter chinook salmon migration timing. In any event, the Battle Creek sex ratio does not seem appropriate. Other means such as trapping or increasing effort on spawning ground surveys are needed if determining sex composition is important in future years.

The data suggest that production of juvenile winter chinook salmon in Battle Creek was very poor or nonexistent. Healey (1977) suggested water temperatures in excess of 14.2°C would result in temperature related egg and fry loss, and loss could approach 80% when temperature reached 16.1°C. Point temperatures taken twice daily suggest water temperature is unfavorable for egg survival in all of the surveyed areas. Additionally, no emergent chinook salmon fry were observed during snorkel surveys, and none were collected by beach seining or electro-fishing in early-September.

An attempt was made to determine the run of the juvenile salmon sampled in September and October. According to a daily length table’ generated from data collected in the upper Sacramento River and by comparing the size of the naturally produced salmon with those at Coleman NFH, the smaller group could be considered late-fall and the larger group could be considered fall chinook salmon. However, neither method is based on growth rates specific to Battle Creek. A better method needs to be developed to determine run of juvenile salmon in Battle Creek to document spawning success as a means to evaluate ongoing restoration activities.

Effort expended to conduct snorkel surveys on Battle Creek during 1996 more than doubled from the 1995 level (4 people per day from late-May through mid-October 1996 and 2 people per day from late -June through late-September 1995). This was an attempt to recover more carcasses, however, this did not occur. Predators or scavengers likely got

‘Generated by Sheila Greene, Department of Water Resources, Environmental Services Office, Sacramento (8 May 1992) from a table developed by Frank Fisher, California Department of Fish and Game, Inland Fisheries Branch, Red Bluff (revised 2 February 1992). Fork Lengths with overlapping run assignments are placed with the later spawning run.

to the carcasses first, as most recovered carcasses were only partial remains. More effort may be needed if carcass recovery remains a major objective of this project.

Based on our study, the Services feels that adult winter chinook salmon returning to Battle Creek should be collected and: 1) relocated, to the main stem Sacramento River near Redding or; 2) utilized in a propagation program. However, if natural spawning is allowed in Battle Creek, then monitoring efforts should be continued. In any event, the Service will continue to cooperate with CDFG, NMFS and other stakeholders for the management of hatchery-origin winter chinook salmon returning to Battle Creek.

If trapping adult salmon is not an option in 1997, then Coleman NFH barrier dam should be operated so that the entire winter and spring runs can access habitat above the dam. Passage should be allowed immediately after Coleman NFH stops collecting adult late-fall chinook salmon and steelhead (late-February/early-March) and continue into July. Additionally, any salmon collected at Coleman NFH during the course of spawning which is suspected of being a spring or winter chinook salmon should be provided access to suitable spawning habitat.

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Alternative methods need to be developed to more accurately determine escapement for hatchery-origin winter chinook salmon that return to the main stem Sacramento River and how to integrate these estimates with those from Battle Creek. Current data suggest hatchery-origin winter chinook salmon have imprinted on and returned to Battle Creek. However, if imprinting problems are corrected, then escapement estimates based solely on Battle Creek data will be inadequate. Additionally, estimating escapement of hatchery-origin and possibly wild winter chinook salmon from RBDD data may also be inadequate. Assuming the Battle Creek escapement estimates for 1995 and 1996 were accurate, then the relative error for escapement estimates in 1995 and 1996 for RBDD would be -64% and +50% respectively. In an effort to develop a more accurate means to estimate escapement in the main stem Sacramento River, mark and recapture of carcasses was attempted in 1996. However, the small recovery rate limited the applicability of this approach (Bob Reavis, CDFG, Environment Services, Sacramento, personal communication). If this method is to be used again in 1997 additional effort should be afforded to recover more carcasses.

Although only one coded-wire tag recovery was made in 1996, the majority of the hatchery-origin winter chinook salmon returning to the Sacramento River system in 1996 were assumed to be from brood years 1993 and 1994. The Coleman NFH propagation program retained 49 adults in those two years (20 in 1993 and 29 in 1994). Therefore, the estimated return number in 1996 represents a replacement level of approximately 4 to 1 despite experiencing 20% pre-spawn mortality in 1993 (4 fish) and 10% pre-spawn mortality in 1994 (3 fish; State Supervisor 1996). Likewise, the wild population experienced a replacement level of 2 to 1 for the time period. This was based on an estimated 32 1 adults returning in 1993 and 160 in 1994 which accounted for the 20 adults removed for the propagation program in 1993 and 29 in 1994 .

Additionally, the RBDD data suggest nearly 25% of the 1996 winter chinook salmon run-size estimate was of hatchery-origin. Hatchery-origin winter chinook salmon have experienced excellent survival and will likely aid in the recovery of the species if imprinting and genetic issues are resolved. However, monitoring the program must continue to determine its success.

RECOMMENDATIONS

Several recommendations to improve the Service's ability to estimate escapement and determine spawning location of hatchery-origin winter chinook salmon are listed below. Additionally, recommendations to improve the overall winter chinook salmon hatchery propagation program are described.

1) Implement alternative methods for rearing and releasing hatchery-origin winter chinook salmon aimed at improving imprinting on the main stem Sacramento River (Livingston Stone NFH).

2) Develop a management plan for winter chinook salmon returning to Battle Creek. Suggested options include: collecting adults for use in the propagation program; relocating captured adults; improving stream conditions to promote natural spawning; or, discounting hatchery-origin winter chinook salmon in recovery efforts.

3) Maintain current methods and increase the amount of effort used to obtain information relating to hatchery-origin winter chinook salmon homing tendencies, spawning locations, escapement estimation and spawning success.

4) Continue to seek alternative methods to improve escapement estimation of hatchery-origin winter chinook salmon, particularly in the Sacramento River and below Coleman NFH diversion dam. Methods should consider the small population size and attempt to standardize effort and findings between different locations.

5) Mark or tag (e.g., floy, radio tag) adult hatchery-origin winter chinook salmon to determine movement patterns and spawning locations particularly if salmon are

relocated from Battle Creek to the Sacramento River. Potential collection and marking / tagging sites include RBDD and Coleman NFH.

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