Ref ID 90979

Upper Sacramento River Winter Chinook Salmon Carcass Survey

2009 Annual Report

A U.S. Fish & Wildlife Service Report

U.S. Fish & Wildlife Service
Red Bluff Fish & Wildlife Office
Red Bluff, California 96080

TABLE OF CONTENTS

Figures and Tables

FIGURES

TABLES

Abstract

Since 1996, the U.S. Fish & Wildlife Service and the California Department of Fish and Game have cooperated on an annual survey of the principal spawning area for Sacramento River winter Chinook salmon. The U.S. Fish & Wildlife Service's objective in the survey is to collect data useful in evaluating the winter Chinook salmon supplementation program at the Livingston Stone National Fish Hatchery. Provided in this report is a summary of data from the 2009 Sacramento River winter Chinook carcass survey pertinent to evaluation of the supplementation program.

An estimated 4,537 winter Chinook returned in 2009 which was a significant increase over return years 2007 and 2008. An estimated 467 of the winter Chinook were of hatchery-origin, representing 10.3 percent of the total run. All hatchery-origin carcasses recovered in 2009 were age-3. The peak return of natural- and hatchery-origin fish was earlier than average but within the range previously observed. Spatial distributions of natural- and hatchery-origin winter Chinook were similar to each other but not to previous years. Turtle Bay was still a major collection area but there was also an increased carcass collection above the ACID dam for both natural- and hatchery-origin fish. The ratio of females to males was greater for hatchery-origin than natural-origin fish. The number of pre-spawn mortalities was small for both natural- and hatchery-origin females.

Introduction

The Sacramento River system supports four distinct "runs" of Chinook salmon (*Oncorhynchus tshawytscha*): fall, late-fall, spring, and winter. Winter Chinook salmon enter the Sacramento River from November through June in an immature reproductive state. They migrate into the upper reaches of the Sacramento River, hold in cool waters released from Shasta Dam, and spawn from May through August between the city of Red Bluff (river mile [RM] 245) and Keswick Dam (RM 302), the upstream limit of migration. Most winter Chinook salmon spawn at age three, with the remainder spawning at ages two and four (Hallock and Fisher 1985).

Winter Chinook salmon were listed as "threatened" under the Endangered Species Act in 1989 and their status was changed to "endangered" in 1994 (59 Federal Register 440). In 1989, the U.S. Fish and Wildlife Service (Service) began propagating winter Chinook salmon to supplement natural production. The winter Chinook salmon supplementation program was initially located at the Coleman National Fish Hatchery (NFH) on Battle Creek, a tributary of the Sacramento River. In 1998, the program was moved to the newly constructed Livingston Stone NFH, located at the base of Shasta Dam, to improve imprinting to natural spawning areas in the main stem Sacramento River.

A primary objective of the winter Chinook carcass survey is to estimate the abundance of returning winter Chinook. Precise estimates of winter Chinook abundance are necessary to meet the delisting requirements for the species, which are specified in the draft recovery plan for winter Chinook salmon (National Marine Fisheries Service 1997). The Service and the California Department of Fish and Game (CDFG) initiated the carcass survey in 1996 to improve the precision of population estimates, which had previously been based on extrapolation of fish counts at the Red Bluff Diversion Dam. Population estimates derived from the carcass survey are listed in the electronic CDFG GrandTab population file, and explained in further detail in a complementary report from the CDFG (Killam 2010).

Additional objectives of the carcass survey are to (1) collect information on several important life history attributes of winter Chinook, including: age and gender composition of the spawning population, pre-spawning mortality rate, and temporal and spatial distributions of spawning, and (2) collect data useful in evaluating the winter Chinook supplementation program. The following report was prepared by the Service to address these objectives.

Methods

Study Area & Sampling Protocol

The 2009 carcass survey was conducted on the Sacramento River, California and was designed to encompass the primary spawning areas of winter Chinook salmon. The survey area covered approximately 27 miles of the Sacramento River and was divided into four reaches (Figure 1): reach 1 extended from the Keswick Dam (RM 302) to the Anderson-Cottonwood Irrigation District (ACID) Diversion Dam (RM 298.5); reach 2 extended from the ACID Diversion Dam to the Highway 44 Bridge in Redding, California (RM 296); reach 3 extended from the Highway 44 Bridge to above Bourbon Island (RM 288.5), and reach 4 extended from above Bourbon Island to just downstream of Ash Creek Road Bridge (RM 276).

The carcass survey was designed to include the entire winter Chinook spawning period and was conducted daily in 3-day cycles: reach 4 on the first day, reach 3 on the second day, and reaches 2 and 1 on the third day. The order that reaches were sampled was consistent throughout the survey.

Typically, daily surveys were conducted with at least two boats, each having one observer and one operator. Each boat surveyed from a shoreline to the middle of the river. In 2009, due to scheduling conflicts and mechanical breakdowns, multiple daily surveys were conducted using just one boat with two observers. This one boat method was only used during periods or in locations when few carcasses were expected to be recovered. This single boat surveyed areas most likely to have carcasses based on observations made in previous survey cycles. Carcasses were recovered using a 4.9 meter pole with a five-pronged gig attached. Carcass condition was estimated as "fresh" or "non-fresh." A carcass was considered fresh if it had at least one clear eye, relatively firm body texture, or pink gills. Fresh carcasses were generally more intact than non–fresh carcasses and parameters such as length, gender, and spawn status could be determined more reliably. As a result, morphometric and other information in this report are based only on data from fresh carcasses unless otherwise noted.

Data gathered from carcasses included: date, location (reach, RM, and latitude / longitude), gender, spawn status (spawned, unspawned, and unknown), fork length, and adipose fin status (absent, present, and unknown). After data were collected, the carcass received an externally visible tag or was cut in half to ensure that the carcass was not resampled at a later date. Spawn status of females was defined as spawned (abdomen extremely flaccid or very few eggs remaining), unspawned (abdomen firm and swollen or many eggs remaining), or unknown (indeterminable spawn status, usually due to predation on the carcass). The spawn status of males was always categorized as unknown. Carcasses with an intact adipose fin were considered to be natural-origin and those with a missing adipose fin were considered to be hatchery-origin. The head was collected from all hatchery-origin carcasses so that the coded-wire tag (CWT) could be extracted and read at a later date (all hatchery-origin winter Chinook receive a CWT as juveniles prior to release). Additionally, the head was collected from carcasses with an adipose fin status of "unknown" so it could be examined for the presence of a CWT. These carcasses were counted as hatchery-origin if they contained a CWT; if they did not, their classification remained "unknown." The CDFG changed these to natural-origin for population estimate calculations (Killam 2009). Biological specimen collections consisted of a small piece of fin tissue from all fresh carcasses and skin patch (scales) from a sub-set of fresh carcasses for possible future genetic analysis and age determination, respectively. Preservation of specimens consisted of 100% ethanol for fin tissues and air desiccation of skin patches.

Data Analysis

Age two natural-origin carcasses were separated from age three and age four carcasses using length-frequency analysis (Ney 1993). The age of hatchery-origin carcasses was determined by decoding the CWT and identifying the brood year relative to the return year. Spatial and temporal distribution, age composition, gender composition, and pre-spawn mortality were compared between natural-origin and hatchery-origin carcasses. Longevity of natural-origin fish after spawning was assumed to be equal to that of hatchery-origin fish. This assumption allowed for the relative comparison of spawn timing between the two groups based on the timing of carcass recovery.

Run Size Estimate of Hatchery-origin Winter Chinook
The number of non-fresh hatchery-origin winter Chinook salmon carcasses was estimated based on the proportion of fresh adipose fin clipped carcass to the total fresh carcass recoveries (Appendix 1). The estimate of non-fresh hatchery-origin carcasses was added to the number of fresh hatchery-origin carcass recovered, and then expanded to include the unsampled fraction based on the Jolly-Seber mark-recapture method used by the CDFG (Killam 2010). Additional calculations were performed to adjust for carcasses for which "freshness" was not recorded, fish that did not receive an adequate fin clip when marked as juveniles (estimated from mark retention data), hatchery-origin fish that were removed from the natural spawning population for use as brood stock at Livingston Stone NFH, and straying into the survey area of non-winter Chinook hatchery fish.

Results

Carcass Recoveries
The survey was conducted from 4 May 2009 through 28 August 2009. A total of 1,904 carcasses was observed during the 2009 survey, representing 42% of the estimated run size (Table 1). This was among the lowest percent observed in recent survey years and likely due to the turbid condition of the Sacramento River in 2009 (Figure 2). Visibility was as shallow as two feet at times with the vast majority of the year at or below nine feet visibility (Secchi depth: average = 7.9 feet, maximum = 11.0 feet). A total of 802 fresh Chinook carcasses were recovered with 776 sampled for biological data and tissue samples (77 hatchery-origin, 685 natural-origin, and 14 of unknown origin). There was no information to indicate that hatchery-origin winter Chinook strayed within or outside of the upper Sacramento River basin. However, one winter Chinook was caught by an angler during the 2008 open salmon season in the Sacramento River[1].

Coded-Wire Tag Recoveries
Heads were collected from 151 fresh and non-fresh carcasses (125 hatchery-origin and 26 unknown-origin) and a readable CWT was recovered from 115 of the heads (tags were not detected in 35 heads and one tag was lost prior to being read; Appendix Table 1). Twelve of the unknown-origin carcasses contained a CWT. One hundred fourteen of the recovered tags were from winter Chinook released from the Livingston Stone NFH and one (code 062338) was a spring Chinook salmon reared at the CDFG Feather River Hatchery; data associated with this fish was removed from all analyses in this report unless otherwise noted.

Hatchery-origin Returns
An estimated 467 hatchery-origin winter Chinook returned in 2009, representing 10.3 percent of the total run. Age three fish (brood year 2006) were the only contributors to the 2009 return and all 18 CWT groups released from this brood year were represented (Table 2).

Temporal and Spatial Distribution

[1] This fish was observed during a creel survey conducted by the CDFG. Recovery data for this fish includes: 12/20/2008, RM92, female, 792mm FL, 7.75kg, CWT code 053473, BY2006.

The peak spawn date of June 29 for natural-origin carcasses was within the range observed in previous years; 2001-2008 average = July 7 and range = June 26 to July 14 (Figure 3). This natural peak spawn date was later than only 2008, which was the earliest observed during our survey (2001 – present). The peak spawn date of June 29 for hatchery-origin carcasses was within the range typically observed; 2001-2008 average = July 11and range = June 23 to July 23. This natural peak spawn date was later than only 2002, which was the earliest observed during our survey (2001 – present). The greater range of peak spawn dates for hatchery-origin carcasses is likely only an artifact of low sample sizes

The spatial distributions of natural- and hatchery-origin carcasses were considerably different in 2009 than in previous years (Figure 4). Similar to previous years, both natural- and hatchery-origin carcass recoveries generally increased as the RM increased with a major collection occurring at Turtle Bay (RM296.5). However, compared to previous years, natural-origin recoveries were decreased at Turtle Bay and had a noticeable increase at RM300 and 301. Hatchery-origin carcass recoveries had three major collection areas with the peak occurring at RM299. Similar to natural-origin recoveries, when compared to previous years, hatchery-origin recoveries were decreased at Turtle Bay and increased at RM301.

Age Composition and Length-at-Age

All recovered hatchery-origin fish were age-3 (Table 3). Carcasses of age three and age four natural-origin winter Chinook could not be distinguished using length-frequency analysis (Figure 5).

The frequency at length for all age-3 return year 2009 fresh carcass recoveries was generally consistent with the average for return years 2001 – 2008. The notable anomaly to the 2009 carcass recoveries was the near complete absence of all other age classes, particularly age-2 fish. The absence of well-defined modes in the length-frequency histogram precluded the ability to unambiguously distinguish between age three, four, and five fish. Comparison of length-at-age between natural-origin and hatchery-origin carcasses was not possible without knowing the age of natural-origin fish.

Gender Ratio

Considering all recoveries in 2009, substantially more female than male carcasses were recovered (Table 4). Among natural-origin fish observed in 2009, females outnumbered males 2.16 to 1 and among hatchery-origin fish, females outnumbered males 3.42 to 1.

Pre-spawning Mortality

In 2009, the overall percentage of female pre-spawn mortalities was small for both natural and hatchery fish. The percentage of hatchery-origin female carcasses categorized as “not fully spawned” was smaller than that of natural-origin carcasses; however, the sample size was low (Table 5).

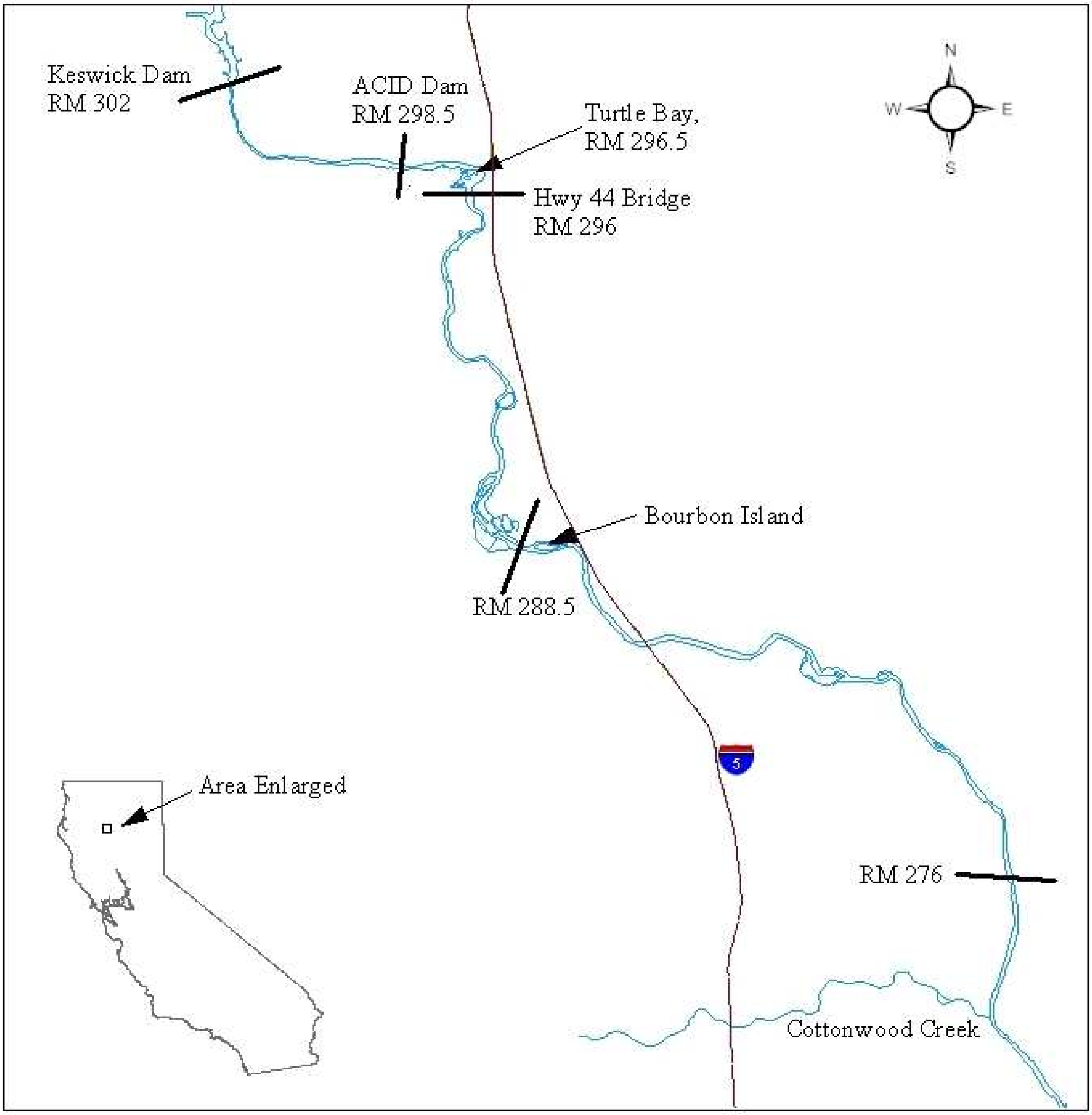

Figure 1. Sampling area of the Sacramento River winter Chinook salmon carcass survey for return year 2009. Reach 1 extended from the Keswick Dam (RM 302) to the Anderson-Cottonwood Irrigation District (ACID) Diversion Dam (RM 298.5); reach 2 extended from the ACID Diversion Dam to the Highway 44 Bridge in Redding, California (RM 296); reach 3 extended from the Highway 44 Bridge to above Bourbon Island (RM 288.5); and reach 4 extended from above Bourbon Island to just below Ash Creek Road bridge (RM 276). Turtle Bay (RM 296.5) is the primary carcass collection area.

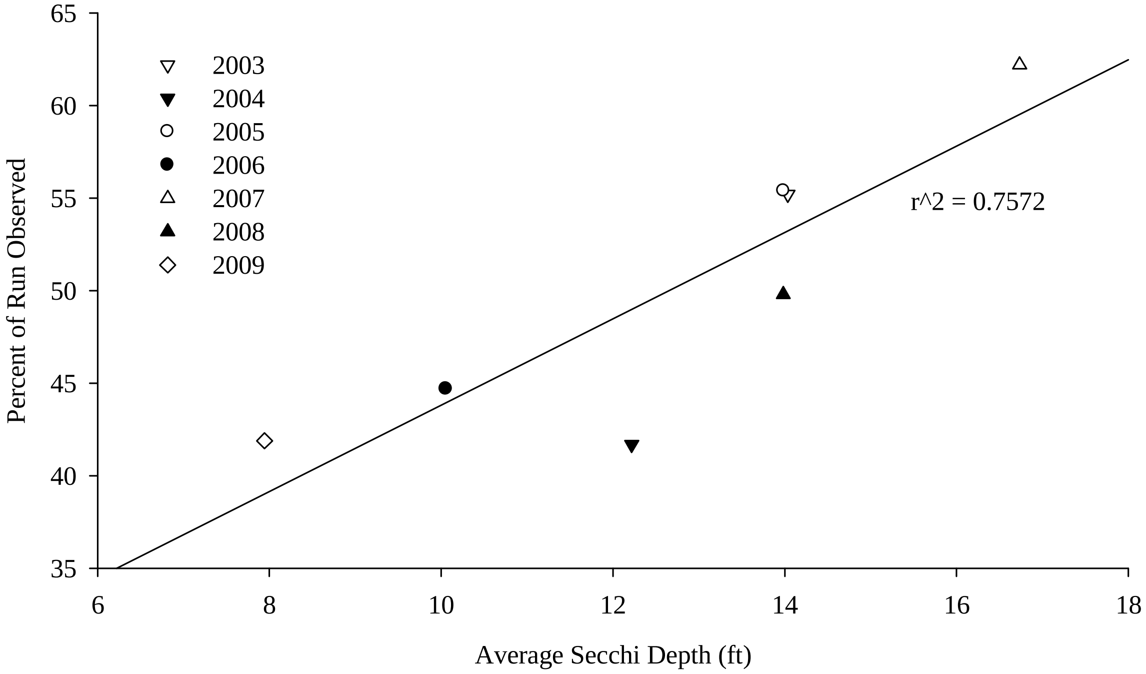

Figure 2. Correlation between average Secchi depth (feet) and percent of the run observed, 2003-2008. The linear regression line and statistic are also displayed.

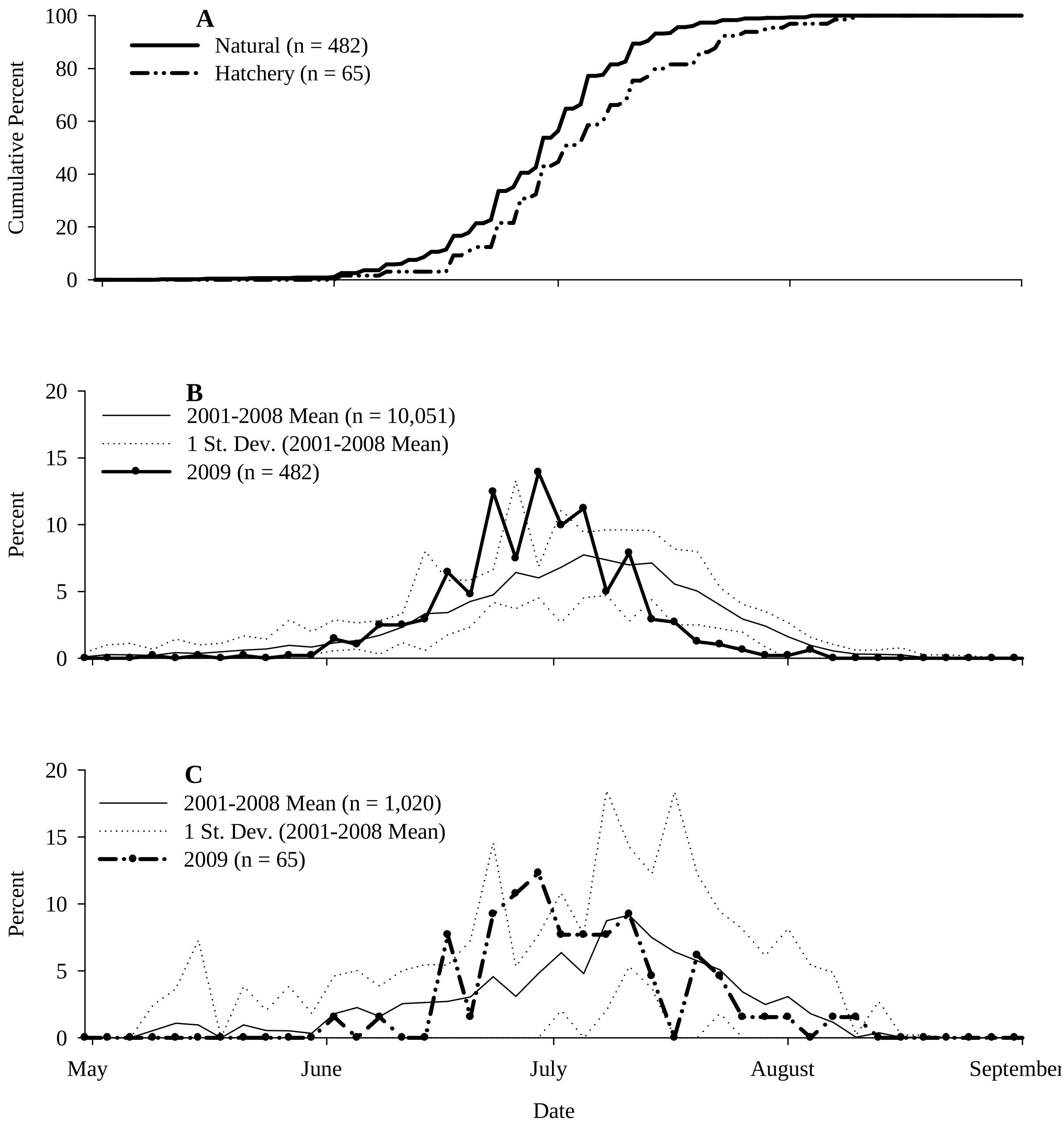

Figure 3. Temporal distribution of fresh female Sacramento River winter Chinook salmon carcass recoveries for return year 2009. Represented is (**A**) the cumulative percent of natural- and hatchery-origin winter Chinook salmon recovered by date for return year 2009 and a comparison of the total percent that returned by date with the mean observed for return years 2001 – 2008 for (**B**) natural- and (**C**) hatchery-origin fish.

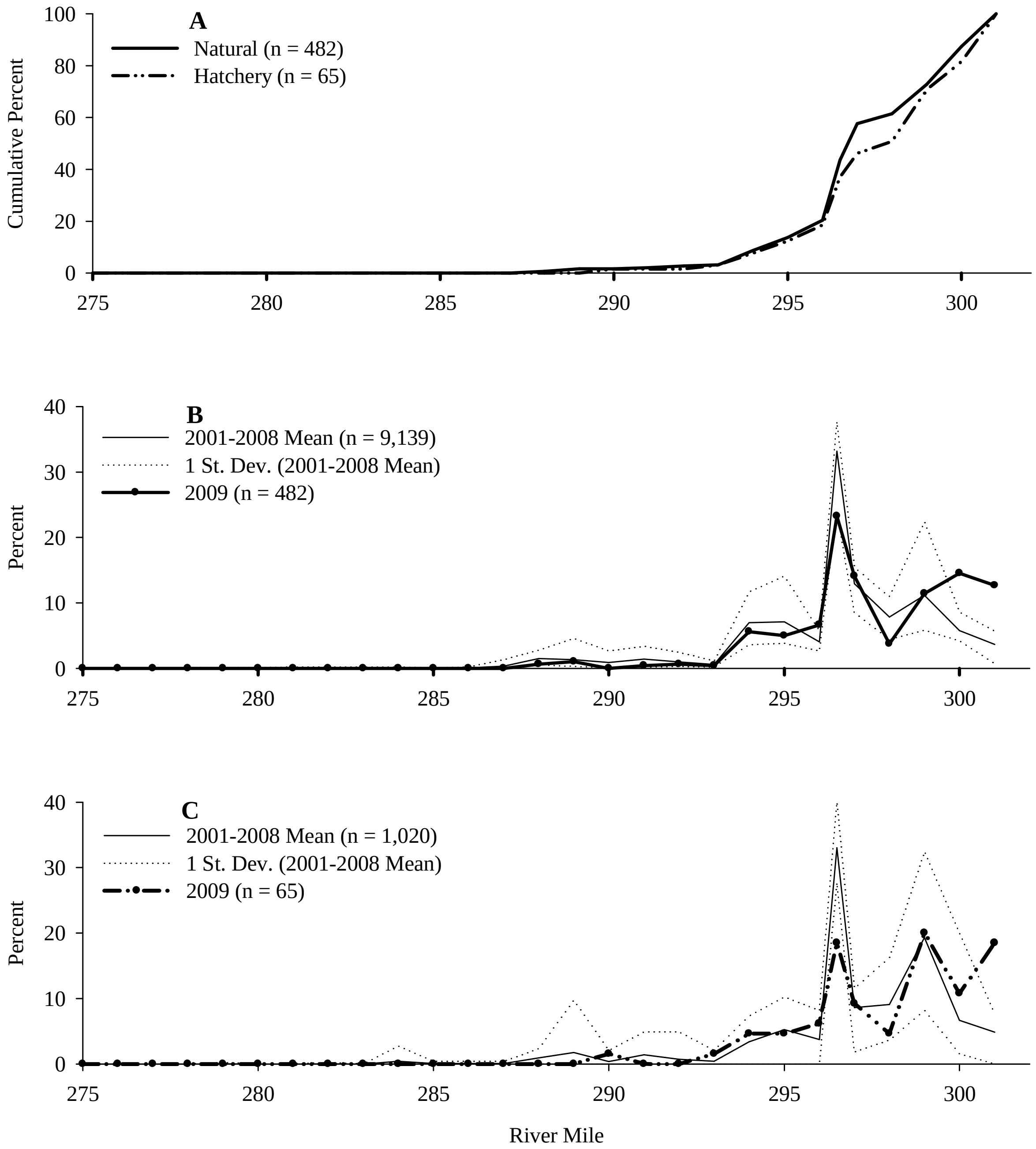

Figure 4. Spatial distribution of fresh female Sacramento River winter Chinook salmon carcass recoveries for return year 2009. Represented is (**A**) the cumulative percent of natural- and hatchery-origin winter Chinook salmon recovered by river mile for return year 2009 and a comparison of the total percent recovered by river mile with the mean observed for return years 2001 – 2008 for (**B**) natural- and (**C**) hatchery-origin fish.

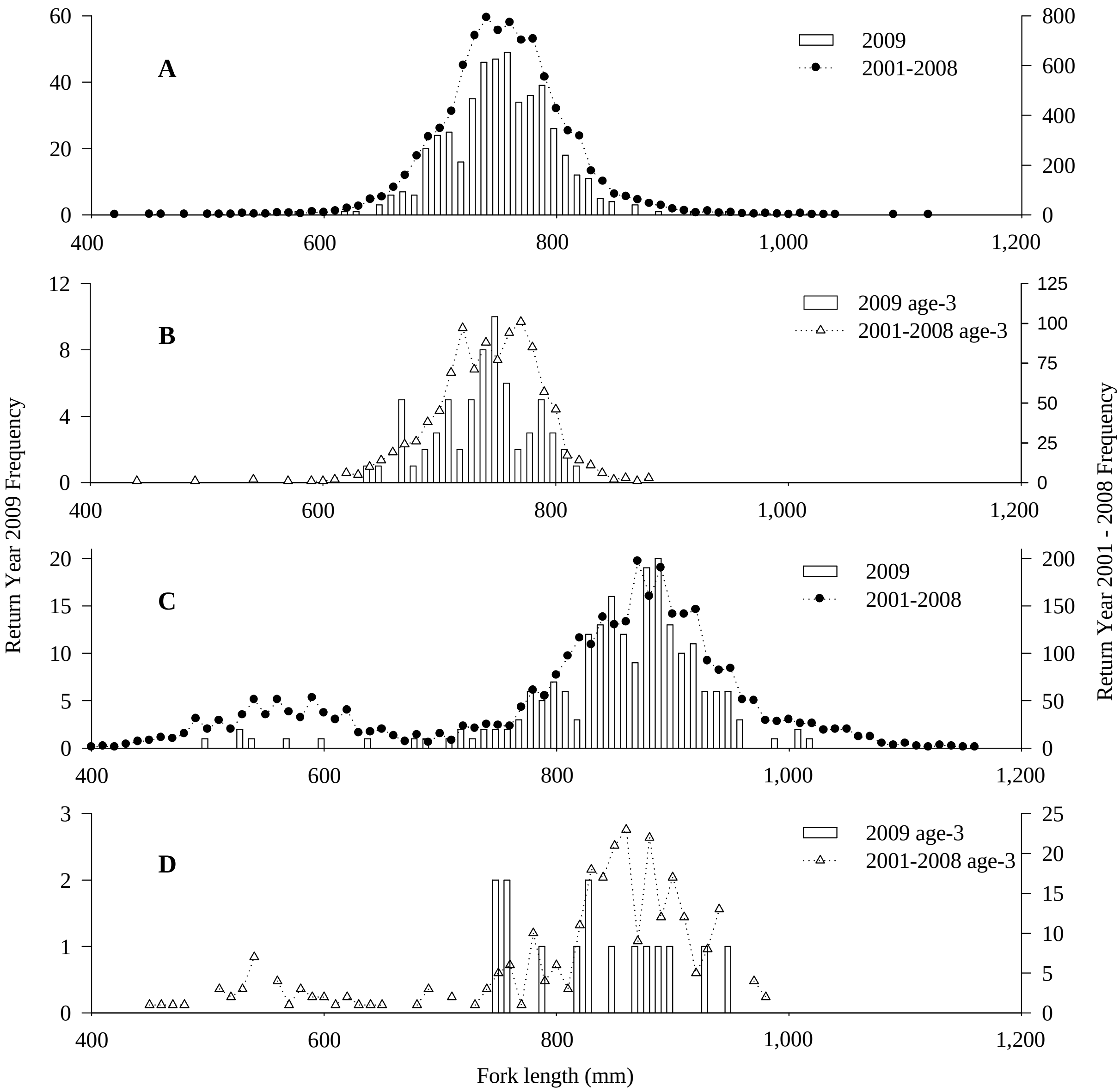

Figure 5. Winter Chinook salmon length-frequency distribution comparison of fresh carcass recoveries for return year 2009 and the mean from return years 2001 – 2008: (A) natural-origin females, (B) hatchery-origin females, (C) natural-origin males, and (D) hatchery-origin males.

Table 1. Sacramento River winter Chinook salmon estimated run size, carcasses observed, and percent at age by origin and gender, return years 2001 – 2009.

Total

Return Tear	Total Estimated Runsize[a]	Hatchery Origin Runsize	% of Run Hatchery Origin	Total Carcasses Observed	Percent of Run Observed	River miles Surveyed, From : To	Natural-origin, % at Age[b] Age 2	Natural-origin, % at Age[b] Ages 3 & 4	Hatchery-origin, % at Age[c] Age 2	Hatchery-origin, % at Age[c] Age 3	Hatchery-origin, % at Age[c] Age 4	Hatchery-origin, % at Age[c] Age 5
2001	8,224	513	6.2	5,145	62.6	288 : 302	9.0	91.0	23.0	77.0	0.0	0.0
2002	7,464	921	12.3	4,946	66.3	288 : 302	6.5	93.5	12.5	85.6	1.9	0.0
2003	8,218	474	5.8	4,536	55.2	286 : 302	2.7	97.3	8.5	90.6	0.9	0.0
2004	7,869	633	8.0	3,279	41.7	273 : 302	12.3	87.7	27.3	71.1	1.6	0.0
2005	15,839	3,092	19.5	8,772	55.4	273 : 302	4.4	95.6	4.9	95.0	0.1	0.0
2006	17,205	2,382	13.8	7,699	44.7	275 : 302	0.9	99.1	0.1	95.5	4.3	0.0
2007	2,542	189	7.4	1,581	62.2	276 : 302	4.0	96.0	0.0	74.6	25.4	0.0
2008	2,830	170	6.0	1,409	49.8	276 : 302	3.7	96.3	12.6	83.0	2.3	2.2
2009	4,537	467	10.3	1,902	41.9	276 : 302	1.0	99.0	0.0	100.0	0.0	0.0
Mean	8,303	982	11.8	4,363	52.5	.	5.1	94.9	5.7	91.7	2.6	0.0

Female

Return Year	Age 2	Ages 3 & 4	Age 2	Age 3	Age 4	Age 5
2001	0.2	99.8	3.2	96.8	0.0	0.0
2002	1.2	98.8	0.0	98.8	1.2	0.0
2003	0.2	99.8	0.0	98.9	1.1	0.0
2004	0.9	99.1	0.0	97.3	2.7	0.0
2005	0.3	99.7	0.0	100.0	0.0	0.0
2006	0.1	99.9	0.0	97.7	2.3	0.0
2007	0.6	99.4	0.0	76.1	23.9	0.0
2008	0.0	100.0	0.0	93.7	3.2	3.0
2009	0.0	100.0	0.0	100.0	0.0	0.0
Mean	0.4	99.6	0.1	97.8	2.0	0.1

Male

Return Year	Age 2	Ages 3 & 4	Age 2	Age 3	Age 4	Age 5
2001	25.4	74.6	47.1	52.9	0.0	0.0
2002	21.2	78.8	59.1	36.4	4.5	0.0
2003	15.9	84.1	43.5	56.5	0.0	0.0
2004	39.7	60.3	64.8	35.2	0.0	0.0
2005	15.8	84.2	19.5	80.0	0.5	0.0
2006	4.3	95.7	0.5	89.8	9.7	0.0
2007	13.7	86.3	0.0	63.1	36.9	0.0
2008	14.9	85.1	44.1	55.9	0.0	0.0
2009	3.3	96.7	0.0	100.0	0.0	0.0
Mean	18.4	81.6	21.0	74.9	4.1	0.0

[a] Run size was estimated by the California Department of Fish and Game and was reported by that agency as part of the Sacramento River winter Chinook salmon carcass survey effort (objective three).

[b] The number of age 2 natural-origin fish was estimated using length-frequency analysis. Age 2 fish were considered less than or equal to the following fork lengths (mm), by return year, females and males, respectively: 2001: 580, 690; 2002: 550, 680; 2003: 560, 670; 2004: 580, 690; 2005: 580, 670; 2006: 580, 670; 2007: 580, 680; 2008: 580, 680; 2009: 570, 670. Age of hatchery-origin carcasses was determined by coded-wire tag.

[c] Age of hatchery-origin carcasses was determined by coded-wire tags recovered at or above river mile 288 (consistency among years).

Table 2. Winter Chinook salmon returns by brood year, coded-wire tag (CWT) groups contributing to return, return rate, and returns at age for brood years 1999 – 2007. Adult returns in 2009 were from brood years 2005 (age four fish), 2006 (age three fish), and 2007 (age two fish).

Brood year[b]	No. of CWT grps. contributing to Release[c]	No. of CWT grps. contributing to Return	Avg. family grps. per CWT grp.	Number Released[d]	Total CWTs Recovered	Return Rate (%)[e]	CWT Returns at Age[a] Age 2[b]	Age 3[b]	Age 4[b]
1999	17	17	1.0	26,135	161	0.616	31	129	1
2000	27	27	3.0	146,477	138	0.094	17	119	2
2001	27	22	3.6	180,686	123	0.068	12	110	1
2002	32	32	2.7	154,920	1313	0.848	59	1221	33
2003	30	30	3.0	145,773	830	0.569	67	741	22
2004	16	16	4.5	124,861	52	0.042	1	50	1
2005	17	16	5.8	151,320	41	0.027	1	40	0
2006	19	NA[f]	6.6	149,040	124	NA[f]	10	114	NA[f]
2007	13	NA[f]	5.1	69,119	0	NA[f]	0	NA[f]	NA[f]

[a] Adult returns are based on all CWT returns including fresh and non-fresh carcasses from all sampling activities (including those other than the carcass survey).

[b] Fish return as: Age 2 (Brood year + 2 years), Age 3 (Brood year + 3 years), and Age 4 (Brood year + 4 years).

[c] Releases using captive broodstock or cryo-preserved sperm are not included.

[d] Number released reflects only those with a CWT and clipped adipose fin as estimated from tag retention data collected prior to release.

[e] Return rate (%) was calculated by dividing (number of CWTs recovered) by the (number of CWTs released), multiplied by 100.

[f] Return rate not final, returns not yet complete or not yet available.

Table 3. Fork length (mm) of fresh age two male Sacramento River winter Chinook salmon carcasses by origin, return years 2001 – 2009.

	Natural-origin[a]				Hatchery-origin			
Return Year	n	Mean	Min	Max	n	Mean	Min	Max
2001	162	563	400	690	24	539	390	650
2002	71	578	460	680	8	550	470	650
2003	56	521	410	650	10	518	420	580
2004	163	582	430	690	35	544	440	630
2005	132	554	410	660	38	550	450	650
2006	20	555	440	640	1[b]	-	540	540
2007	25	555	440	670	1	-	550	550
2008	18	535	420	650	5	511	440	570
2009	7	559	500	641	0	-	-	-

[a] The maximum length of natural-origin age two males was estimated through length-frequency analysis.

[b] Non-fresh carcass.

Table 4. Gender ratio of Sacramento River winter Chinook salmon carcasses by origin, return years 2001 – 2009.

	Natural-origin			Hatchery-origin		
Return Year	Female (F)	Male (M)	F:M	Female (F)	Male (M)	F:M
2001	1,179	639	1.85	61	51	1.20
2002	927	335	2.77	81	22	3.68
2003	1,899	352	5.39	98	23	4.26
2004	1,009	472	2.14	75	56	1.34
2005	2,452	885	2.77	600	203	2.96
2006	1,905	738	2.58	324	100	3.24
2007	534	204	2.62	36	5	7.20
2008	360	120	3.00	25	7	3.57
2009	486	225	2.16	65	19	3.42
Mean	1,195	441	2.71	152	54	2.81

Table 5. Pre-spawn mortality of female Sacramento River winter Chinook salmon by origin, return years 2001 – 2009.

Return year	Natural-origin			Hatchery-origin		
	Total carcasses	Number not fully spawned[1]	Percent not fully spawned[1]	Total carcasses	Number not fully spawned[1]	Percent not fully spawned[1]
2001	1,176	10	0.85	61	0	0.00
2002	925	19	2.05	81	3	3.70
2003	1,899	11	0.58	98	0	0.00
2004	988	7	0.71	75	4	5.33
2005	2,392	35	1.46	600	24	4.00
2006	1,905	25	1.31	324	23	7.10
2007	513	9	1.75	36	1	2.78
2008	360	6	1.67	25	0	0.00
2009	482	3	0.62	64	0	0.00
Mean	1,182	14	1.17	152	6	4.03

[1] "Not fully spawned" includes female carcasses classified as "unspawned" and "partially spawned".

Discussion

The winter Chinook salmon run size in 2009 (4,537) was moderately larger than recent years. Approximately 42 percent of the run was handled in 2009, which is among the lowest observed in recent survey years. This was likely due to the turbid condition of the Sacramento River. Hatchery-origin fish represented 10.3 percent of the total run (n = 467). The peak carcass recovery of natural-and hatchery-origin fish was 26 June and within the date range observed in previous years. However, the natural- and hatchery-origin return was the second earliest observed and only later than 2008 and 2002 respectively. Spatial distributions of natural- and hatchery-origin winter Chinook were slightly different than previous years. Turtle Bay was still a major carcass recovery area but the percent recovered was smaller compared to previous years and was larger above the ACID dam. Overall, substantially more female carcasses were recovered than males and the ratio of female to male was greater for hatchery-origin fish. Pre-spawning mortality was low for both natural- and hatchery-origin fish. No age-2 hatchery-origin fish were recovered for adult to grilse age comparisons among natural- and hatchery-origin fish. All adult hatchery-origin fish containing a CWT were age-3; however, age of adult natural-origin fish could not be determined with length-frequency analysis.

Literature Cited

Hallock, R.J. and F. W. Fisher. 1985. Status of winter-run Chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento River. California Department of Fish and Game, Anadromous Fisheries Branch, January 25, 1985 office report, 28 pp.

Killam, D. S. 2010. Chinook salmon populations for the upper Sacramento River basin in 2009. SRSSAP Tech. Report No. 10-1, 2010.

National Marine Fisheries Service. 1997. Proposed recovery plan for the Sacramento River winter-run Chinook salmon. National Marine Fisheries Service – Southwest Region Office, Long Beach, California.

Ney, J. J. 1993. Practical use of biological statistics. Pages 137-156 *in* C.C. Kohler and W. A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

USFWS. 2001. Winter Chinook salmon carcass survey annual report. USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

USFWS. 2002. Upper Sacramento River Winter Chinook salmon carcass survey 2002 annual report. USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

USFWS. 2003. Upper Sacramento River Winter Chinook salmon carcass survey 2003 annual report. USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

USFWS. 2004. Upper Sacramento River Winter Chinook salmon carcass survey 2004 annual report. USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

USFWS. 2005. Upper Sacramento River Winter Chinook salmon carcass survey 2005 annual report. USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

USFWS. 2006. Upper Sacramento River Winter Chinook salmon carcass survey 2006 annual report. USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

USFWS. 2007. Upper Sacramento River Winter Chinook salmon carcass survey 2007 annual report. USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Acknowledgements

Funding for this project was supplied from Central Valley Project Improvement Act, Comprehensive Assessment and Monitoring Program funds. Kevin Offill prepared this report and Kevin Niemela, Bob Null, and Doug Killam provided editorial review. Data were collected through a cooperative effort of U.S. Fish & Wildlife Service (Curtis Brownfield, Laura Mahoney, William McKinney, Kevin Offill, Mark Provencher, Mike Ricketts, and Julie Warden) and California Department of Fish and Game personnel (Matt Johnson, Doug Killam, Amber Leininger, Dale Morrison, Darin Olsen, Bret Rohrer, and Zach Sigler).

Appendix A-1. Estimated escapement of hatchery-origin winter Chinook salmon in the upper Sacramento River for 2009.

Methods and Equations

Total abundance of hatchery-origin winter Chinook salmon returning to the upper Sacramento River was estimated following a series of expansions to account for potential biases and difficulties in identifying hatchery-origin carcasses and recovering coded-wire tags. The number of hatchery-origin Chinook carcasses was expanded to: 1. account for unrecognized fin clips and undetected coded-wire tags in non-fresh carcasses, 2. include carcasses not observed during the survey, 3. account for fish taken into Livingston Stone NFH for use as brood stock, 4. to include hatchery-origin fish that did not have a clipped adipose fin, and 5. subtraction of non-winter Chinook strays. Descriptions of these expansions follow:

Non-fresh hatchery-origin carcasses were expanded for decreased coded-wire tag recovery and fin clip recognition based on the recovery rate of fresh hatchery-origin carcasses ($H_{NF\text{-}Exp}$):

$$H_{NF\text{-}Exp} = (H_{F\text{-}Obs} \times T_{NF\text{-}Obs}) / T_{F\text{-}Obs} \qquad (1)$$

where,
$H_{F\text{-}Obs}$ = number of fresh hatchery-origin carcasses,
$T_{NF\text{-}Obs}$ = total number of non-fresh hatchery- and natural-origin carcasses, and
$T_{F\text{-}Obs}$ = total number of fresh hatchery- and natural-origin carcasses recovered during the carcass survey. This includes fresh carcasses that were not sampled for biological data, other than freshness and gender, and tallied as "fresh chops" (indicating the carcass was compromised for biological data collection usually due to animal predation).

Expansions were made for adipose fin clipped hatchery-origin carcasses believed to be present in the upper Sacramento River, but not observed during the survey (H_{Sac}). This expansion was based on the proportion of hatchery-origin carcasses observed during the carcass survey to the total estimated escapement of winter Chinook salmon in the upper Sacramento River (this excludes fish retained as brood stock by the Livingston Stone NFH), based on the Jolly-Seber population estimate ($N_{J\text{-}S}$):

$$H_{Sac} = (H_{NF\text{-}Exp} + H_{F\text{-}Obs} + H_{Unk}) / T_{Obs} \times N_{J\text{-}S} \qquad (2)$$

where,
H_{Unk} = number of hatchery-origin carcasses with an unknown "freshness" and
T_{Obs} = the total number of carcasses observed during the carcass survey (including fresh and non-fresh and hatchery- and natural-origin carcasses).

Hatchery-origin fish captured for use as brood stock at Livingston Stone NFH ($LSNFH_H$) were accounted for by adding them to H_{Sac}. Addition of these fish yielded the total number of adipose fin clipped hatchery-origin fish present in the upper Sacramento River and at the Livingston Stone NFH (H_{Clip}):

$$H_{Clip} = H_{Sac} + LSNFH_{H} \quad (3)$$

To account for non-adipose fin clipped hatchery-origin fish, H_{Clip} was expanded based on mark retention rates measured prior to release of juveniles.

- H_{Clip} was apportioned among each recovered tag code (CWT_{App}):

  $$CWT_{App} = H_{Clip} \times (CWT_{Rec} / CWT_{T}) \quad (4)$$

  where,
  CWT_{Rec} = the number of coded-wire tags recovered for an individual tag code and
  CWT_{T} = the total number of all coded-wire tags recovered.

- CWT_{App} was expanded to include all hatchery-origin fish without an adipose fin clip (CWT_{Final}) based on tag retention rates measured prior to release of Chinook juveniles.

  $$CWT_{Final} = CWT_{App} / (J_{Clip} / J_{Obs}) \quad (5)$$

  where,
  J_{Clip} = the number of juveniles observed with an adipose fin clip during tag retention studies prior to release, by individual tag code and
  J_{Obs} = the total number of juveniles observed during tag retention studies prior to release, by individual tag code.

The total hatchery-origin Chinook salmon (H_{Total}) was obtained by summing CWT_{Final}:

$$H_{Total} = \Sigma\, CWT_{Total} \quad (6)$$

Lastly, CWT_{Final} estimated from hatchery strays ($CWT_{Final\text{-}Stray \text{ “listed by tag code”}}$) were removed to produce the final hatchery-origin winter Chinook estimate.

$$H_{Final} = H_{Total} - CWT_{Final\text{-}Stray} \quad (7)$$

<u>Data</u>

Appendix Table 1. Data obtained during the 2009 winter Chinook carcass survey and Keswick Trap operations.

84 =	$H_{F\text{-}Obs}$	=	Number of fresh hatchery carcass recoveries
1,102 =	$T_{NF\text{-}Obs}$	=	Number of non-fresh hatchery and natural carcass recoveries
802 =	$T_{F\text{-}Obs}$	=	Number of fresh hatchery and natural carcass recoveries
1,904 =	T_{Obs}	=	Total carcasses observed during the carcass survey
4,416 =	$N_{J\text{-}S}$	=	Total naturally reproducing winter Chinook salmon escapement
6 =	$LSNFH_H$	=	Hatchery fish retained for LSNFH broodstock
0 =	H_{Unk}	=	Total hatchery fish with unknown carcass condition

Appendix Table 2. Coded-wire tag codes recovered during the 2009 run year, by recovery location, with juvenile tag retention data. Recovery locations include the area surveyed during the winter Chinook carcass survey (Survey) and those collected for brood stock at the Livingston Stone National Fish Hatchery (LSNFH). For calculations using 'Juvenile Tag Retention Data': C = fish with an adipose fin clip, NC = fish with no adipose fin clip, T = fish with a coded-wire tag, NT = fish with no coded-wire tag.

Juvenile tag retention data

	CWT_{Rec}		Juvenile tag retention data			
CWTCode	Survey	LSNFH	T/C	NT/C	T/NC	NT/NC
051680	3	0	185	15	0	0
051682	3	0	189	8	3	0
051697	2	0	189	10	1	0
051698	14	0	186	13	1	0
052368	12	0	372	18	8	2
052490	6	0	162	38	0	0
052491	2	0	175	22	2	1
052492	6	0	185	15	0	0
052493	7	1	192	6	0	2
053399	3	0	168	29	2	1
053466	3	1	186	11	3	0
053467	2	0	190	10	0	0
053468	12	0	183	17	0	0
053469	10	2	195	4	1	0
053470	9	1	198	2	0	0
053471	5	0	174	26	0	0
053472	3	0	195	5	0	0
053473	9	1	190	10	0	0
053867	1	0	198	2	0	0
062338	1	0	198	2	0	0
	113	6				

Calculations

1. Non-fresh carcass expansion based on fresh carcass recovery rate

$$\left(\underset{H_{F\text{-}Obs}}{84} \times \underset{T_{NF\text{-}Obs}}{1{,}102} \right) / \underset{T_{F\text{-}Obs}}{802} = \underset{H_{NF\text{-}Exp}}{\mathbf{115}}$$

2. Expansion to include carcasses not observed

$$\left(\underset{H_{NF\text{-}Exp}}{115.4214} + \underset{H_{F\text{-}Obs}}{84} + \underset{H_{Unk}}{0} \right) / \underset{T_{Obs}}{1{,}904} \times \underset{N_{J\text{-}S}}{4{,}416} = \underset{H_{Sac}}{\mathbf{463}}$$

3. Addition of hatchery-origin fish retained for Livingston Stone NFH brood stock

$$\underset{H_{Sac}}{462.54} + \underset{LSNFH_H}{6} = \underset{H_{Clip}}{\mathbf{469}}$$

4. Estimated number of hatchery-origin Chinook salmon returning in 2009 by tag code, following expansions to account for coded-wire tag loss from non-fresh carcasses and carcasses present, but not observed.

CWTCode		H_{Clip}			CWT_{Rec}		CWT_T		CWT_{App}
051680	:	468.5429	×	(	3	/	119	) =	**11.8**
051682	:	468.5429	×	(	3	/	119	) =	**11.8**
051697	:	468.5429	×	(	2	/	119	) =	**7.9**
051698	:	468.5429	×	(	14	/	119	) =	**55.1**
052368	:	468.5429	×	(	12	/	119	) =	**47.2**
052490	:	468.5429	×	(	6	/	119	) =	**23.6**
052491	:	468.5429	×	(	2	/	119	) =	**7.9**
052492	:	468.5429	×	(	6	/	119	) =	**23.6**
052493	:	468.5429	×	(	8	/	119	) =	**31.5**
053399	:	468.5429	×	(	3	/	119	) =	**11.8**
053466	:	468.5429	×	(	4	/	119	) =	**15.7**
053467	:	468.5429	×	(	2	/	119	) =	**7.9**
053468	:	468.5429	×	(	12	/	119	) =	**47.2**
053469	:	468.5429	×	(	12	/	119	) =	**47.2**
053470	:	468.5429	×	(	10	/	119	) =	**39.4**
053471	:	468.5429	×	(	5	/	119	) =	**19.7**
053472	:	468.5429	×	(	3	/	119	) =	**11.8**
053473	:	468.5429	×	(	10	/	119	) =	**39.4**
053867	:	468.5429	×	(	1	/	119	) =	**3.9**
062338	:	468.5429	×	(	1	/	119	) =	**3.9**
									469

5 and 6. Estimated number of hatchery-origin Chinook salmon returning in 2009 by tag code, following the final expansion to account for hatchery-origin fish without an adipose fin clip.

CWTCode		CWT_{App}		J_{Clip}		J_{Obs}			CWT_{Final}
051680	:	11.8120	/ (	200	/	200	)	=	**11.8**
051682	:	11.8120	/ (	197	/	200	)	=	**12.0**
051697	:	7.8747	/ (	199	/	200	)	=	**7.9**
051698	:	55.1227	/ (	199	/	200	)	=	**55.4**
052368	:	47.2480	/ (	390	/	400	)	=	**48.5**
052490	:	23.6240	/ (	200	/	200	)	=	**23.6**
052491	:	7.8747	/ (	197	/	200	)	=	**8.0**
052492	:	23.6240	/ (	200	/	200	)	=	**23.6**
052493	:	31.4987	/ (	198	/	200	)	=	**31.8**
053399	:	11.8120	/ (	197	/	200	)	=	**12.0**
053466	:	15.7493	/ (	197	/	200	)	=	**16.0**
053467	:	7.8747	/ (	200	/	200	)	=	**7.9**
053468	:	47.2480	/ (	200	/	200	)	=	**47.2**
053469	:	47.2480	/ (	199	/	200	)	=	**47.5**
053470	:	39.3734	/ (	200	/	200	)	=	**39.4**
053471	:	19.6867	/ (	200	/	200	)	=	**19.7**
053472	:	11.8120	/ (	200	/	200	)	=	**11.8**
053473	:	39.3734	/ (	200	/	200	)	=	**39.4**
053867	:	3.9373	/ (	200	/	200	)	=	**3.9**
062338	:	3.9373	/ (	200	/	200	)	=	**3.9**
						H_{Total}		=	**471**

7. The estimated number of hatchery-origin winter Chinook salmon returning in 2009 following the removal of hatchery-origin non-winter fish.

H_{Total}		$CWT_{Final-062338}$		H_{Final}
471	-	4	=	**467**