Upper Sacramento River Winter Chinook Salmon Carcass Survey

2008 Annual Report

A U.S. Fish & Wildlife Service Report

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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 2008 Sacramento River winter Chinook carcass survey pertinent to evaluation of the supplementation program.

An estimated 2,830 winter Chinook returned in 2008 which is relatively small among the years the U.S. Fish & Wildlife Service has conducted the survey. An estimated 170 of the winter Chinook were of hatchery-origin, representing six percent of the total run. Very few hatchery-origin carcasses were recovered in 2008; however, the percentage of age two males was large relative to recent years and the percentage of age four males was small. Natural-origin fish returned approximately one week earlier than previously observed while peak return for hatchery-origin fish was within typically observed dates. Spatial distributions of natural- and hatchery-origin winter Chinook were similar to each other and to previous years. 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 2009).

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 2008 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 from May 1, 2008 through August 22, 2008 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.

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. 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). A small piece of fin tissue was taken from all fresh carcasses and preserved for future genetic analysis.

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 2009). 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 within the survey area of non-winter Chinook hatchery fish.

Results

Carcass Recoveries

A total of 1,409 carcasses was observed during the 2008 survey, representing approximately 50% of the estimated run size (Table 1). Five hundred thirteen fresh Chinook carcasses were sampled for biological data and tissue samples (32 hatchery-origin, 480 natural-origin, and 1 of unknown origin). There was no information to indicate that hatchery-origin winter Chinook strayed within or outside of the upper Sacramento River basin.

Coded-Wire Tag Recoveries

Heads were collected from 66 fresh and non-fresh carcasses (60 hatchery-origin and 6 unknown-origin) and a readable CWT was recovered from 46 of the heads (tags were not detected in 20 heads; Appendix Table 1). None of the unknown-origin carcasses contained a CWT. Forty-five of the recovered tags were from winter Chinook released from the Livingston Stone NFH and one (code 052864) was a late-fall Chinook salmon reared at the Service's Coleman NFH; data associated with this fish was removed from all analyses in this report unless otherwise noted.

Hatchery-origin Returns

An estimated 170 hatchery-origin winter Chinook returned in 2008, representing 6.0 percent of the total run. Age three fish (brood year 2005) were the primary contributors to the 2008 return, and 16 of the 18 CWT groups released from this brood year were represented (Table 2). One age-four and one age-five hatchery-origin winter Chinook was recovered during the survey. Seven age-two hatchery-origin carcass were recovered above RM286 in 2008, representing approximately 15.8 percent of the total hatchery return (Table 1). Only those carcasses recovered above RM286 where included in this analysis for consistency with previous data collections. The seven age-two hatchery origin carcasses were all male and represented approximately 51 percent of the total hatchery males collected.

Temporal and Spatial Distribution

The peak spawn date of June 26 for natural-origin carcasses was approximately one week earlier than observed in previous years; 2001-2007 average = July 9 and range = July 2 to July 14 (Figure 2). The peak spawn date of July 8 for hatchery-origin carcasses was within the range typically observed; 2001-2007 average = July 11and range = June 23 to July 23. 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-origin and hatchery-origin carcasses were similar in 2008 (Figure 3).

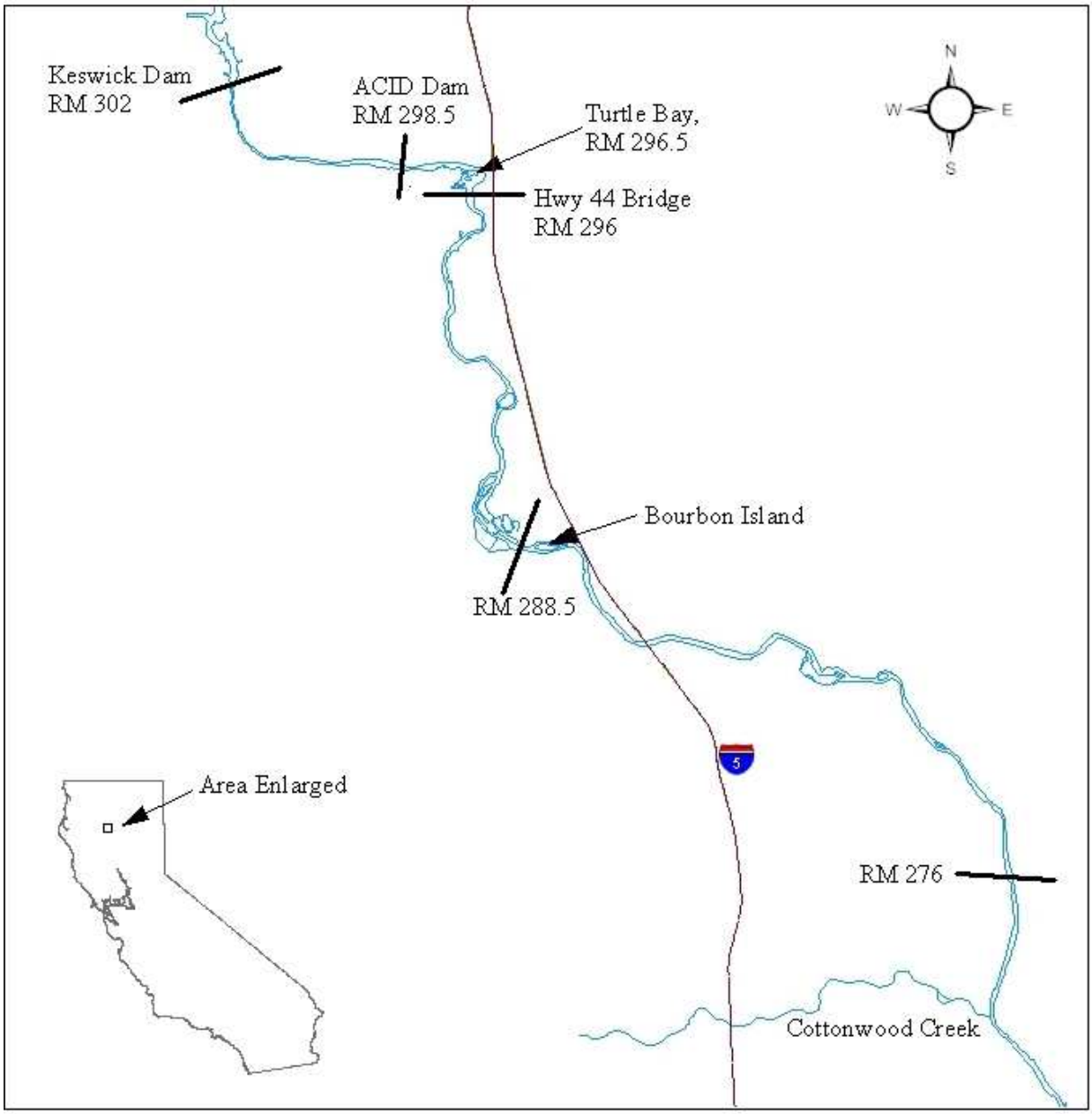

Figure 1. Sampling area of the Sacramento River winter Chinook salmon carcass survey for return year 2008. Reach 1 extended from the Keswick Dam (RM 302) to the Anderson-Cottonwood Irrigation District (ACID) Diversion Dam (RM 298.5); reach 2 extended from the ACID Diversion Dam to the Highway 44 Bridge 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.

Age Composition and Length-at-Age
A total of seven (5 fresh and 2 non-fresh) age two hatchery-origin carcass was recovered and all were a male (Table 3). Length-at-age comparisons using hatchery-origin fish could not be conducted due to the small sample sizes available. Age three fish accounted for most of the hatchery-origin returns of winter Chinook salmon (16% age-2, 80% age-3, 2% age-4, and 2% age-5). Carcasses of age three and age four natural-origin winter Chinook could not be distinguished using length-frequency analysis (Figure 4).

The frequency at length for return year 2008 fresh female natural-origin carcass recoveries was generally consistent with the average for return years 2001 – 2007. The same comparison with male data exhibited a definitive increase in the number of large fish (generally >950mm). The increased frequency of larger sized males observed in 2008 appears to have resulted from a relatively strong return of age-4 and age-5 fish; however, the absence of well-defined modes in the length-frequency histogram precluded the ability to unambiguously distinguish between age three and age 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 2008, substantially more female than male carcasses were recovered (Table 4). Among natural-origin fish observed in 2008, females outnumbered males 3.00 to 1 and among hatchery-origin fish, females outnumbered males 3.57 to 1.

Pre-spawning Mortality
In 2008, 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 lower than that of natural-origin carcasses; however, the sample size was low (Table 5).

Table 1. Sacramento River winter Chinook salmon estimated run size, carcasses observed, and percent at age by origin and gender, return years 2001 – 2008.

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]		Hatchery-origin, % at Age[c]			
							Age 2	Ages 3 & 4	Age 2	Age 3	Age 4	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	15.8	79.9	2.2	2.1
Mean	8,774	1,047	11.9	4,671	53.2	.	5.1	94.9	5.9	91.4	2.7	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
Mean	0.4	99.6	0.1	98.7	1.2	0.0

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	50.7	49.3	0.0	0.0
Mean	19.9	80.1	21.9	74.1	4.0	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. 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 – 2006. Adult returns in 2008 were from brood years 2004 (age four fish), 2005 (age three fish), and 2006 (age two fish).

Brood	No. of CWT grps. contributing to		Avg. family	Number	Total CWTs	Return	CWT Returns at Age[a]		
year[b]	Release[c]	Return	grps. per CWT grp.	Released[d]	Recovered	Rate (%)[e]	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	NA[f]	5.8	151,320	41	NA[f]	1	40	NA[f]
2006	19	NA[f]	6.6	149,040	10	NA[f]	10	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 – 2008.

	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	17	542	460	650	5	511	440	570

[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 – 2008.

	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
Mean	1,283	468	2.74	163	58	2.78

Table 5. Pre-spawn mortality of female Sacramento River winter Chinook salmon by origin, return years 2001 – 2008.

	Natural-origin			Hatchery-origin		
Return year	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
Mean	1,270	15	1.20	163	7	4.23

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

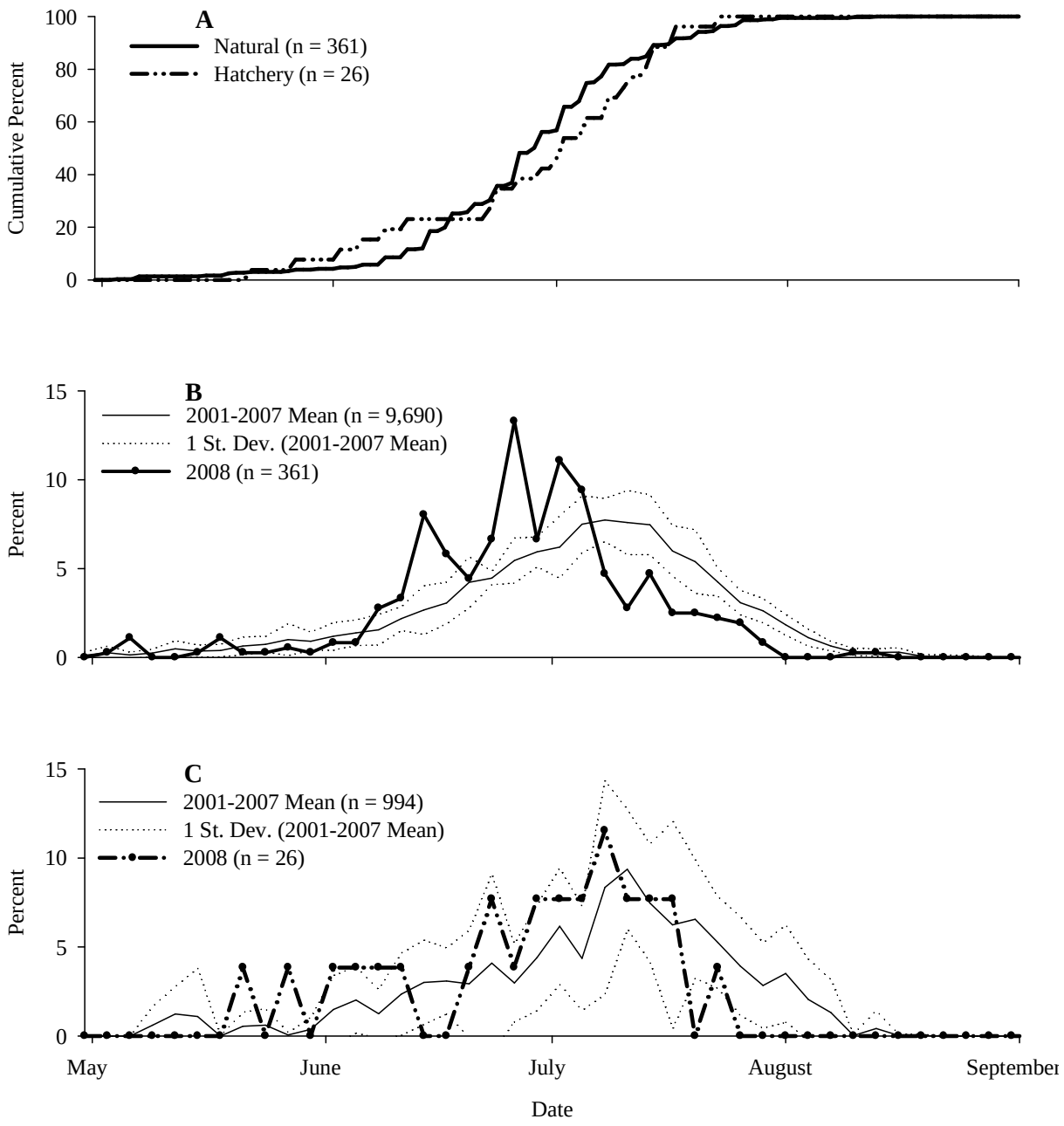

Figure 2. Temporal distribution of fresh female Sacramento River winter Chinook salmon carcass recoveries for return year 2008. Represented is (**A**) the cumulative percent of natural- and hatchery-origin winter Chinook salmon recovered by date for return year 2008 and a comparison of the total percent that returned by date with the mean observed for return years 2001 – 2007 for (**B**) natural- and (**C**) hatchery-origin fish.

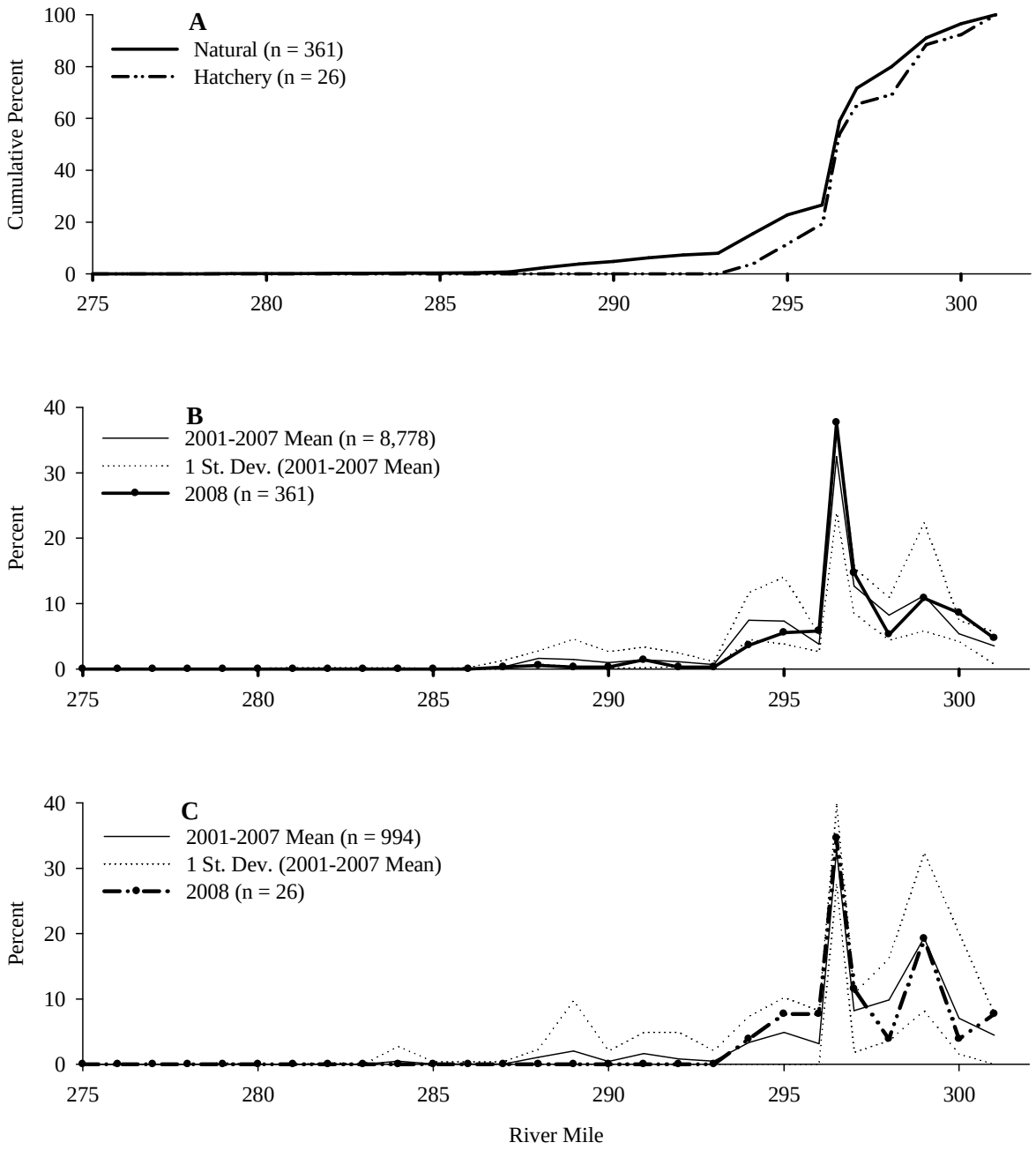

Figure 3. Spatial distribution of fresh female Sacramento River winter Chinook salmon carcass recoveries for return year 2008. Represented is (**A**) the cumulative percent of natural- and hatchery-origin winter Chinook salmon recovered by river mile for return year 2008 and a comparison of the total percent recovered by river mile with the mean observed for return years 2001 – 2007 for (**B**) natural- and (**C**) hatchery-origin fish.

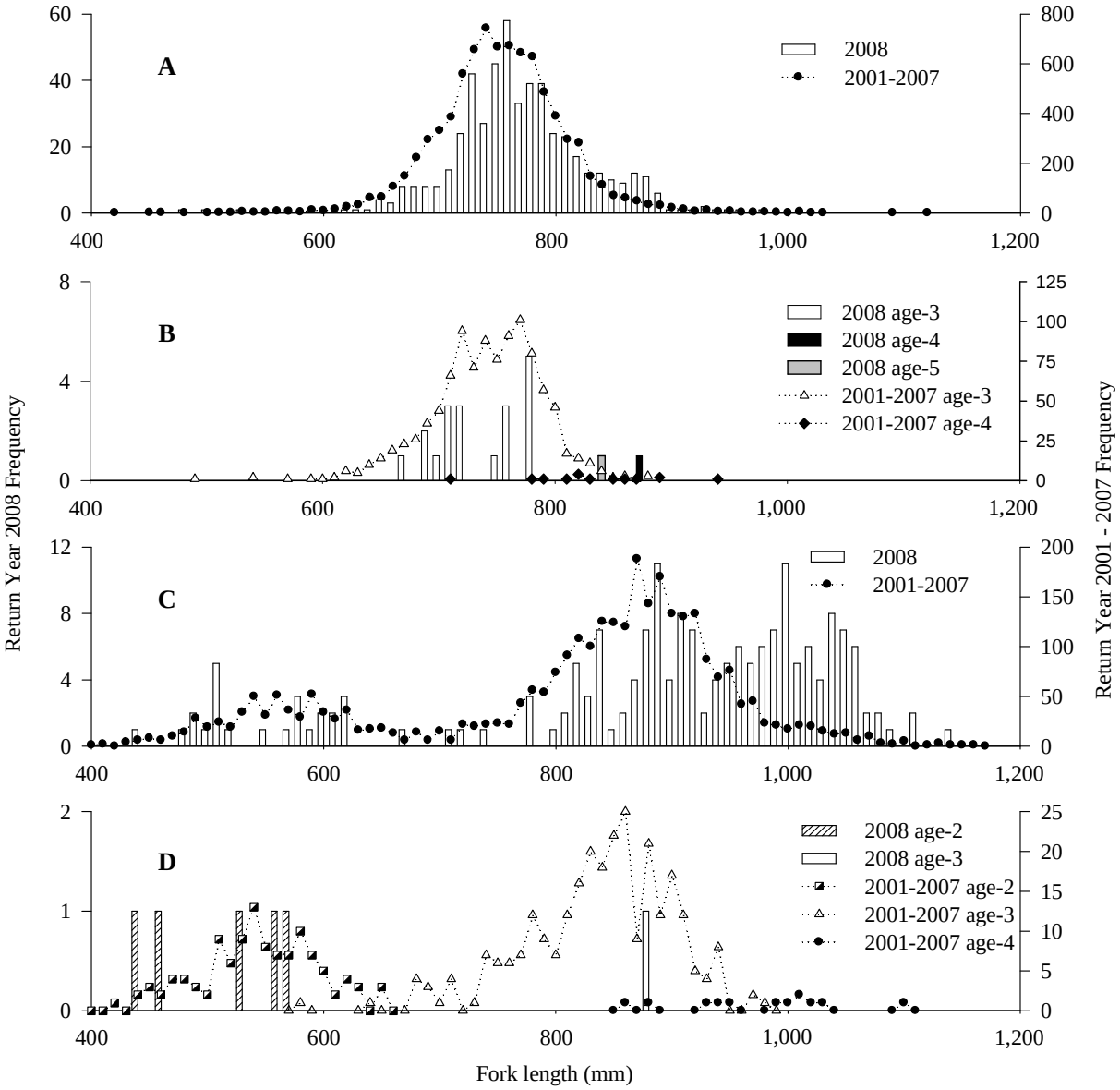

Figure 4. Winter Chinook salmon length-frequency distribution comparison of fresh carcass recoveries for return year 2008 and the mean from return years 2001 – 2007: (A) natural-origin females, (B) hatchery-origin females, (C) natural-origin males, and (D) hatchery-origin males.

Discussion

The winter Chinook salmon run size in 2008 (2,830) was only slightly larger than 2007; which was the smallest since 2000 (Killam 2009). Approximately 50 percent of the run was handled in 2008, which is similar to observations in recent survey years. Hatchery-origin fish represented 6.0 percent of the total run (n = 170). Natural-origin fish returned approximately one week earlier than previously observed while peak return for hatchery-origin fish was within typically observed dates. Spatial distributions of natural- and hatchery-origin winter Chinook were similar to previous years. 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. Too few hatchery-origin fish containing a CWT were recovered for any meaningful age analyses. Natural-origin males exhibited a definitive increase in large fish (>950mm) compared to recent years; likely due to strong age-4 and age-5 year classes.

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Appendix A-1. Estimated escapement of hatchery-origin winter Chinook salmon in the upper Sacramento River for 2008.

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.

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

Data

Appendix Table 1. Data obtained during the 2008 winter Chinook carcass survey and Keswick Trap operations.

33	=	$H_{F\text{-}Obs}$	= Number of fresh hatchery carcass recoveries
862	=	$T_{NF\text{-}Obs}$	= Number of non-fresh hatchery and natural carcass recoveries
547	=	$T_{F\text{-}Obs}$	= Number of fresh hatchery and natural carcass recoveries
1,409	=	T_{Obs}	= Total carcasses observed during the carcass survey
2,724	=	$N_{J\text{-}S}$	= Total naturally reproducing winter Chinook salmon escapement
8	=	$LSNFH_H$	= 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 2008 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.

	CWT_{Rec}		Juvenile tag retention data			
CWTCode	Survey	LSNFH	T/C	NT/C	T/NC	NT/NC
051680	1	1	185	15	0	0
051693	1		556	40	4	0
051979	1		200	0	0	0
052368	3	1	372	18	8	2
052478	2		195	5	0	0
052479	2		191	9	0	0
052480	3		181	19	0	0
052481	4		173	27	0	0
052482	3	1	184	16	0	0
052483	3		177	23	0	0
052484	1	1	189	11	0	0
052485	1	1	183	16	0	1
052487	2	1	190	10	0	0
052488	1		198	2	0	0
052774	2		197	3	0	0
052775	2		195	4	0	1
052776	2		197	3	0	0
052777	1		195	5	0	0
053072	1		196	4	0	0
053074	6		188	12	0	0
053399	1	1	168	29	2	1
053468	1		183	17	0	0
053473	1		190	10	0	0
052864	1		197	3	0	0
	46	7				

Calculations

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

$$\left(\frac{H_{F\text{-}Obs}}{33} \times \frac{T_{NF\text{-}Obs}}{862}\right) / \frac{T_{F\text{-}Obs}}{547} = \frac{H_{NF\text{-}Exp}}{\mathbf{52}}$$

2. Expansion to include carcasses not observed

$$\left(\frac{H_{NF\text{-}Exp}}{52.0037} + \frac{H_{F\text{-}Obs}}{33} + \frac{H_{Unk}}{0}\right) / \frac{T_{Obs}}{1{,}409} \times \frac{N_{J\text{-}S}}{2{,}724} = \frac{H_{Sac}}{\mathbf{164}}$$

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

$$\frac{H_{Sac}}{164.3251} + \frac{LSNFH_{H}}{8} = \frac{H_{Clip}}{\mathbf{172}}$$

4. Estimated number of hatchery-origin Chinook salmon returning in 2008 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	:	172.3251	×	(	2	/	53	)	=	**6.5**
051693	:	172.3251	×	(	1	/	53	)	=	**3.3**
051979	:	172.3251	×	(	1	/	53	)	=	**3.3**
052368	:	172.3251	×	(	4	/	53	)	=	**13.0**
052478	:	172.3251	×	(	2	/	53	)	=	**6.5**
052479	:	172.3251	×	(	2	/	53	)	=	**6.5**
052480	:	172.3251	×	(	3	/	53	)	=	**9.8**
052481	:	172.3251	×	(	4	/	53	)	=	**13.0**
052482	:	172.3251	×	(	4	/	53	)	=	**13.0**
052483	:	172.3251	×	(	3	/	53	)	=	**9.8**
052484	:	172.3251	×	(	2	/	53	)	=	**6.5**
052485	:	172.3251	×	(	2	/	53	)	=	**6.5**
052487	:	172.3251	×	(	3	/	53	)	=	**9.8**
052488	:	172.3251	×	(	1	/	53	)	=	**3.3**
052774	:	172.3251	×	(	2	/	53	)	=	**6.5**
052775	:	172.3251	×	(	2	/	53	)	=	**6.5**
052776	:	172.3251	×	(	2	/	53	)	=	**6.5**
052777	:	172.3251	×	(	1	/	53	)	=	**3.3**
053072	:	172.3251	×	(	1	/	53	)	=	**3.3**
053074	:	172.3251	×	(	6	/	53	)	=	**19.5**
053399	:	172.3251	×	(	2	/	53	)	=	**6.5**
053468	:	172.3251	×	(	1	/	53	)	=	**3.3**
053473	:	172.3251	×	(	1	/	53	)	=	**3.3**
052864	:	172.3251	×	(	1	/	53	)	=	**3.3**
										172

5 and 6. Estimated number of hatchery-origin Chinook salmon returning in 2008 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	:	6.5028	/ (	200	/	200	)	=	**6.5**
051693	:	3.2514	/ (	596	/	600	)	=	**3.3**
051979	:	3.2514	/ (	200	/	200	)	=	**3.3**
052368	:	13.0057	/ (	390	/	400	)	=	**13.3**
052478	:	6.5028	/ (	200	/	200	)	=	**6.5**
052479	:	6.5028	/ (	200	/	200	)	=	**6.5**
052480	:	9.7543	/ (	200	/	200	)	=	**9.8**
052481	:	13.0057	/ (	200	/	200	)	=	**13.0**
052482	:	13.0057	/ (	200	/	200	)	=	**13.0**
052483	:	9.7543	/ (	200	/	200	)	=	**9.8**
052484	:	6.5028	/ (	200	/	200	)	=	**6.5**
052485	:	6.5028	/ (	199	/	200	)	=	**6.5**
052487	:	9.7543	/ (	200	/	200	)	=	**9.8**
052488	:	3.2514	/ (	200	/	200	)	=	**3.3**
052774	:	6.5028	/ (	200	/	200	)	=	**6.5**
052775	:	6.5028	/ (	199	/	200	)	=	**6.5**
052776	:	6.5028	/ (	200	/	200	)	=	**6.5**
052777	:	3.2514	/ (	200	/	200	)	=	**3.3**
053072	:	3.2514	/ (	200	/	200	)	=	**3.3**
053074	:	19.5085	/ (	200	/	200	)	=	**19.5**
053399	:	6.5028	/ (	197	/	200	)	=	**6.6**
053468	:	3.2514	/ (	200	/	200	)	=	**3.3**
053473	:	3.2514	/ (	200	/	200	)	=	**3.3**
052864	:	3.2514	/ (	200	/	200	)	=	**3.3**
						H_{Total}		=	**173**

7. The estimated number of hatchery-origin winter Chinook salmon returning in 2008 following the removal of hatchery-origin non-winter fish.

H_{Total}		$CWT_{Final\text{-}052864}$		H_{Final}
173	-	3	=	**170**