U.S. Fish & Wildlife Service

Arcata Fisheries Data Series Report DS 2014-35

Fall Chinook Salmon Run Characteristics and Escapement for the Mainstem Klamath River, 2011

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April 2014

Funding to complete carcass surveys on the mainstem Klamath River during 2011 presented in this report was provided by a variety of sources, including the Bureau of Reclamation Klamath Fall Area Office, the U. S. Fish and Wildlife Service Yreka Fish and Wildlife Office, and the Klamath River Fish Habitat Assessment Program (Flow Study) of the U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office.

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Key words: carcass, Chinook salmon, egg production, escapement, Klamath, mark-recapture, Petersen, pre-spawn mortality, tag recovery, salmon, spawner

The correct citation for this report is:

Gough, S.A. 2014. Fall Chinook Salmon Run Characteristics and Escapement for the Mainstem Klamath River, 2011. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata Fisheries Data Series Report DS 2014-35, Arcata, California.

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Abstract. Adult fall Chinook salmon (*Oncorhynchus tshawytscha*) carcasses were surveyed on the mid-Klamath River during the 2011 spawning season to estimate escapement using postmortem tag-recovery statistical methods and to characterize the age and sex composition and spawning success of the run. The study area consisted of eight consecutive mainstem reaches extending from Iron Gate Dam downriver to the Shasta River confluence. Based on Kimura-adjusted scale readings and unstratified Petersen escapement estimates, the adult estimate for 2011 was made up of 1,133 age-3 (3-year old) spawners (23.2%), 1,511 age-4 spawners (31.0%), and 6 age-5 spawners (0.1%). Jacks (age-2 fish) represented 45.7% ($\widehat{N}_{jacks}$ = 2,229) of the total annual escapement. This was by far the largest jack proportion and escapement estimated in the 11-year history of this project. An estimated 40.9% of the fish that spawned in the surveyed area were of hatchery origin. The adult female–male ratio was 1.29:1. Pre-spawn mortality of females was 9.2%. Estimated egg deposition by adult females in the study area was 4.9 million.

Introduction

The Klamath River Basin (Figure 1) historically supported large runs of Chinook salmon *Oncorhynchus tshawytscha*, coho salmon *O. kisutch*, and steelhead *O. mykiss* (Leidy and Leidy 1984). These species contribute to economically and culturally important subsistence, sport, and commercial fisheries. A drastic decline of anadromous fishes during the past century and a half has occurred in the Klamath River Basin as a result of a variety of flow- and non-flow-related factors (West Coast Chinook Salmon Biological Review Team 1997; Hardy and Addley 2001). These factors include water storage and transfer, environmental phenomena, disease, changed genetic integrity from hatchery origin fish straying into natural spawning areas, overharvest, and land-use practices causing habitat loss, blockages, and degradation.

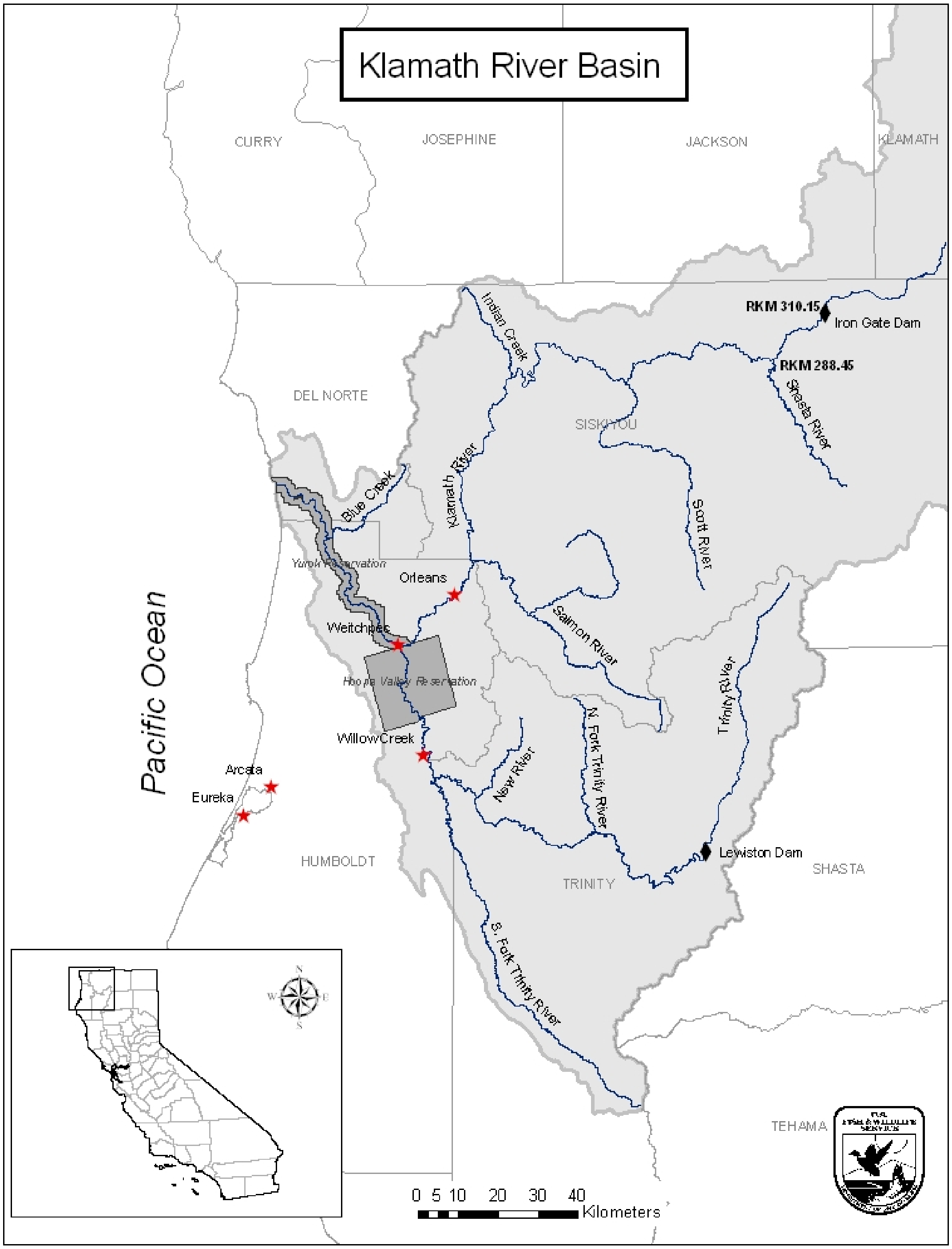

Figure 1. The mainstem Klamath River carcass survey study area extends from Iron Gate Dam to the Shasta River confluence in the Klamath River Basin, northern California.

The main purpose of this project was to provide the Klamath River Technical Team (KRTT) a fall Chinook salmon spawning escapement estimate for the mainstem Klamath River. KRTT depends on accurate escapement estimates of fall Chinook salmon throughout the Klamath River Basin to determine the total basin-wide natural escapement and age structure of the run. This information, along with age-structured hatchery escapement and inriver harvest estimates, is then used to project ocean stock abundance and assist in development of harvest management alternatives for the following year. Spawner estimates generated by the carcass tag-recovery survey conducted within the more densely used spawning reaches (i.e., above the Shasta River confluence) were summed with estimates derived from the redd survey for the less densely used spawning reaches to establish an estimate of escapement for the mainstem Klamath River (KRTT 2012). Accurate determination of the numbers of spawners within this reach is also needed for an ongoing outmigrant fry study (Chamberlain and Williamson 2006) and for calibration of the Chinook salmon production model, S^3 (Stream Salmonid Simulator). Additionally, carcass survey data are used to estimate annual age class proportions, jack–adult and adult female–male ratios, female spawning success/pre-spawn mortality, fork length distributions, proportions of naturally spawning hatchery-origin fish, and egg deposition.

Beginning in 1993, mainstem Klamath River fall Chinook salmon spawning escapement was estimated based on expanded redd counts (assumes each redd equals one adult female and one adult male; Magneson 2008). Redd surveys were conducted weekly on the 130-river kilometer (rkm) reach between Iron Gate Dam (IGD; rkm 310.15) and the confluence of Indian Creek (rkm 173.85) in Happy Camp, California (Figure 1). In 2001, we initiated a statistical-based carcass tag-recovery (i.e., mark-recapture) methodology with the objective of refining the escapement estimate in the heavily used spawning area between IGD and the Shasta River confluence (rkm 288.45). We conducted a postmortem tag-recovery study rather than the more common live tag–postmortem recovery or live mark–live recapture surveys since we had no opportunity to count, mark, or recover live fish (e.g., at a weir; Manly et al. 2005). From concurrent surveys in 2001 to 2004 and 2006, Petersen tag-recovery-based estimates of successfully spawned adult females and redd counts from IGD to the confluence of the Shasta River were compared. Estimates of successfully spawned females were 3.3 to 4.8 times higher than redd counts over this stretch of the river (Gough and Williamson 2012). We assumed Petersen estimates were the more accurate of the two methods and that redd counts underestimated escapement, presumably due to redd superimposition and difficulty in observing redds due to water clarity. Since 2007 only carcass surveys have been conducted in this section of the river.

Study Area

The survey area is the 21.20-rkm section of mainstem Klamath River between IGD (the upper limit of anadromy) and the Shasta River confluence divided into eight reaches (Figure 2; Table 1). Reaches were delineated based on previously mapped concentrations of redds and ended at distinguishable landmarks.

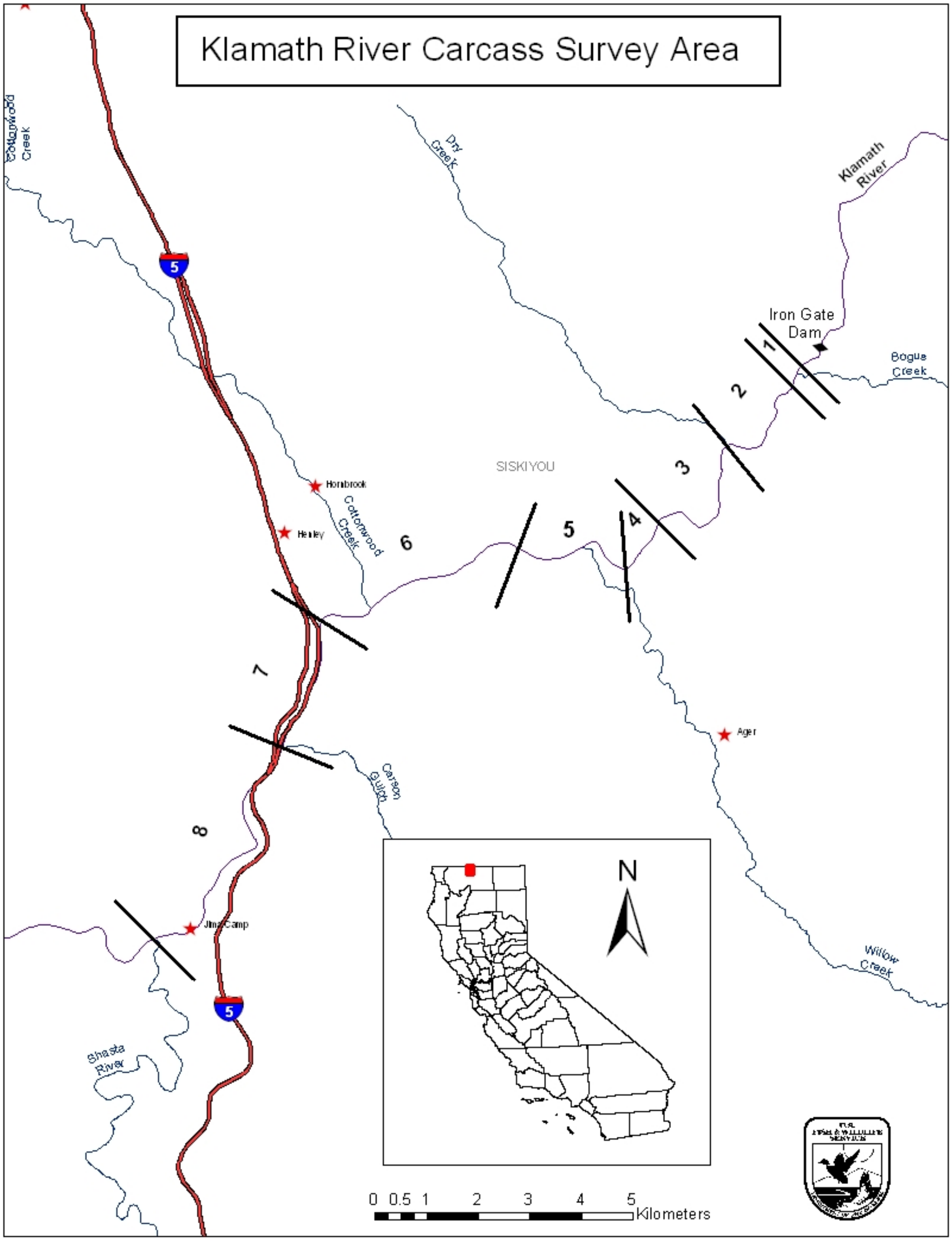

Figure 2. Klamath River carcass survey area from IGD to the Shasta River confluence with reaches delineated. Reach 1 begins at the first river access below IGD. Little to no spawning occurs between the dam and the access point.

Table 1. Reach boundaries and lengths in the Klamath River carcass survey study area. Downstream landmarks were the same as upstream landmarks of the next reach.

	Rkm		Length	
Reach	Upstream	Downstream	(rkm)	Upstream landmark
1	309.65	309.20	0.45	Boat ramp opposite Iron Gate Hatchery
2	309.20	307.10	2.10	Riffle below USGS Gaging Station
3	307.10	304.30	2.80	Dry Creek confluence
4	304.30	303.15	1.15	First wooden foot bridge
5	303.15	300.70	2.45	KRCE green wooden foot bridge
6	300.70	296.35	4.35	Copco-Ager (Klamathon) Bridge
7	296.35	293.70	2.65	Third (fallen) wooden foot bridge
8	293.70	288.45 [a]	5.25	Carson Creek confluence

[a] Shasta River confluence

Methods

Data were collected in a cooperative effort between U.S. Fish and Wildlife Service Arcata Fish and Wildlife Office (AFWO) and the Yurok Tribal Fisheries Program (YTFP). Weekly surveys were conducted from October 11 through November 30, 2011. Surveys were conducted by two three-person crews, one AFWO and one YTFP, oaring downstream in inflatable catarafts along opposite banks of the river. Each crew, consisting of a rower, a data recorder, and a carcass handler, searched the river for carcasses from their respective bank, AFWO on the left and YTFP on the right, to the center of the river. Each crew surveyed their same respective bank throughout the survey season. Side channels were walked or floated to look for carcasses. The following information was recorded for each survey: survey week, date, reach(es) surveyed, surveyors' names, predominant weather of the day, daily mean discharge at USGS Gage 11516530 below IGD, and weekly Secchi disk depth. We only recorded Secchi disk depth once per week since we have found only one location in the study area (in Reach 8) where the river is slow and deep enough to take a measurement.

Carcass Data

Each observed carcass not previously tagged (see *Tagging and Tag-Recovery* section below) was retrieved and the following data were recorded: reach, depth, location (lateral position in the channel), species, sex, fork length (FL), spawning condition, carcass condition (level of decay), presence or absence of an adipose fin, and scarring.

The depth at which carcasses were recovered was estimated and recorded using a scale of 0 to 3:

‘0’ = on the bank or floating at the surface;

‘1’ = subsurface to 3 ft deep;

‘2’ = 3 to 6 ft deep;

‘3’ = over 6 ft deep.

Lateral position was recorded as left bank (LB), right bank (RB), or mid-channel (MC):

LB = left third of the river channel width;

RB = right third of the river channel width;

MC = middle third of the river channel width.

Location of carcasses found in side channels were recorded as being on their respective bank and a comment was made on where in the side channel the carcass was encountered.

Carcass condition was categorized as fresh (F_1), partly decayed (D_2), or rotten (N):

F_1 = firm body, at least one clear eye, or pink or red gills,

D_2 = no F_1 characteristics, body has some firmness and little fungus or algae, and

N = rotten (decayed beyond D_2).

F_1-condition carcasses were believed to have expired within one week prior to capture, D_2-condition carcasses were believed to have expired one to two weeks prior to capture, and N-condition carcasses were believed to have expired more than two weeks prior to capture. Fork lengths were not recorded from N-condition carcasses.

Sex was distinguished for F_1- and D_2-condition carcasses only using morphological differences. Adult males are typically larger than adult females of the same age class, develop a more-pronounced kype, and may display red or reddish-purple color along their sides. Spawned females display ventrally eroded anal and caudal fins and an emptied abdomen. Carcasses were also cut open and sex was verified by gonad type or presence of eggs.

Positively identified male and female carcasses were assigned a spawning condition value based on a scale of 1 to 4 (Table 2). Spawning condition data were used to calculate spawning success and conversely, pre-spawn mortality, of female Chinook salmon each week and over the entire spawning season. F_1-condition carcasses were used to calculate weekly pre-spawn mortality. Female carcasses with spawning condition ‘1’ and ‘2’ were considered successful spawners. Carcasses with spawning condition ‘3’ were considered pre-spawn mortalities.

Table 2. Spawning condition scale used to assess spawning success in salmon carcasses

Condition	Female	Male
1	spawned out or less than one-third of eggs retained	flaccid strap-like gonads
2	partially spawned with one- to two-thirds of eggs retained	(not used)
3	unspawned or more than two-thirds of eggs retained	gonads solid and full
4	spawning condition could not be determined	spawning condition could not be determined

Throughout this report the term "jack" refers to age-2 (precocious) spawners, males (true jacks) and females (jills) inclusive. The size cut-off between adults and jacks was decided after the sampling season based on scale age proportions and length-frequency distributions compiled and analyzed by the KRTT (2012). The KRTT reviews data provided by various collaborators and jointly decides which method best represents the jack to adult proportions for each recovery area that should be used in the stock projection estimate.

Scale samples were collected to aid in calculating the age-structured estimates developed each year by the KRTT. Scales samples were collected from all F_1- and D_2-condition carcasses. A minimum of five scales were collected with large forceps from the preferred area of fish, described by Devries and Frie (1996) as the area laterally between the dorsal and anal fins above the lateral line. Scale samples were placed in individual envelopes with the following information: date, location, species, fork length, sex, and spawning condition. Scale samples were provided to the YTFP who coordinate the Klamath River portion of the KRTT age composition analysis (KRTT 2012).

Iron Gate Hatchery (IGH), located just below IGD and operated by the California Department of Fish and Wildlife (CDFW), produces fall Chinook salmon, coho salmon, and steelhead. The snouts of Chinook salmon carcasses with clipped adipose fins [ad clip; denoting a coded-wire-tagged (CWT) hatchery-origin fish] were removed and frozen in individual bags labeled with the following information: location recovered, sex, fork length, and spawning condition. These same data were also recorded on the survey form. CWTs were later removed from recovered snouts and read by USFWS personnel. CWT numbers are linked to the hatchery of origin, race, release type, and brood year of the individual fish.

Scars on the carcasses were recorded using the following codes:

C = clubbed gills, gill rot (*Flexibacter columnaris*), or columnaris disease (*Flavobacterium columnare*);

H = hook scar (indicated by hooks in the mouth or damage from fishing line to the maxillary);

L = lamprey bite;

N = net scar (indicated by line-like damage around the head, operculum, or in front of the dorsal fin);

S = scavenged (partially eaten by otters, bears, birds, etc.);

R = roe-stripped females (females that had roe removed and the carcass returned to the river).

Tagging and Tag–Recovery

All F_1- and D_2-condition carcasses were marked with uniquely numbered aluminum tags attached to a hog ring clamped around the lower jaw, allowing the fate of individual carcasses to be tracked over time and space. Tags were not applied to ad-clipped carcasses since removing the snout leaves the jaw poorly secured to the rest of the body. Tagged carcasses were replaced near the location and depth where they were found. N-condition carcasses were sampled, tallied, and cut in half to indicate that they had been sampled. Recaptured (previously tagged) carcasses were examined and the following data were recorded: reach, tag number, location, condition, and depth. Recaptured carcasses were then cut in half to negate the possibility of a second recapture.

Escapement Estimates

Tag-recovery data were analyzed using an unstratified (data summed from all survey weeks) Petersen population estimator (Seber 1982). The assumptions under which the Petersen method operates are (1) the population is closed, (2) all carcasses have equal capture probability in the first capture event, (3) marking individuals does not affect future catch probability, (4) marks are not lost between capture events, and (5) all recovered individuals are correctly identified and recorded (Krebs 1999). Although the study area is not a true closed system, the underlying purpose behind the closed system condition was not violated; we assume zero or negligible immigration or emigration occurred during each survey.

Escapement (*N*) was estimated without temporal or spatial stratification (unstratified) using the Petersen formula adjusted for bias (Krebs 1999):

$$\hat{N} = \frac{(M+1)(C+1)}{(R+1)} - 1,$$

where *M* = total number of carcasses tagged, *C* = total number of carcasses captured, and *R* = total recaptures of tagged carcasses.

For these data, 95% confidence limits were calculated by applying the normal distribution formula for standard error:

$$\hat{N} \pm 1.96\sqrt{\frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)}}.$$

Adult estimates were obtained by multiplying the total escapement estimate by the percentage of adult (ages 3 and up) spawners (P_{adult}) determined by the scale readings:

$$\hat{N}_{adult} = \hat{N} \cdot P_{adult}\ .$$

Individual age class escapement (N_x) was calculated likewise:

$$\hat{N}_x = \hat{N} \cdot P_x$$

where P_x is the percentage of age class 2, 3, 4, or 5.

Hatchery Contribution

IGH marks a proportion, varying with release group, of the juvenile Chinook salmon produced with both a CWT and ad-clip. An estimate of hatchery-origin Chinook salmon that spawned in the study area was calculated using the same methodology described in Harris et al. (2012) using only F_1- and D_2-condition carcasses as suggested by Mohr and Satterthwaite (unpublished). In this study all F_1- and D_2-condition carcasses captured were examined for ad clips. The number of CWT fish recovered for each code was estimated by multiplying the number of CWTs recovered by an expansion factor (*E*) which accounts for CWTs that were lost during dissection, unreadable tags, and missing snout samples (i.e., not collected from ad-clipped carcasses or lost prior to processing):

$$E = \left(\frac{AD_{obs}}{AD_{sample}}\right)\left(\frac{AD_{cwt}}{AD_{code}}\right),$$

where AD_{obs} = the number of ad-clipped Chinook salmon carcasses observed, AD_{sample} = the number of snout samples collected from ad-clipped carcasses, AD_{cwt} = the number of samples with a CWT, and AD_{code} = total number of CWTs recovered and decoded after processing samples.

To account for unmarked hatchery fish, the expanded estimates for each CWT code, *i*, were multiplied by a production multiplier ($PM_{code(i)}$) specific to each CWT code. Each $PM_{code(i)}$ was calculated from hatchery release data (Pacific States Marine Fisheries Commission 2011):

$$PM_{code(i)} = \frac{AD_{tag} + AD_{no-tag} + U}{AD_{tag}},$$

where AD_{tag} = the number of ad-clipped Chinook salmon released with a CWT, $AD_{no\text{-}tag}$ = the number of ad-clipped Chinook salmon without a tag, presumably because the tag had been shed, and U = the number of unmarked Chinook salmon in a release group.

The total contribution of hatchery Chinook salmon (N_H) is estimated by summing estimated contributions attributable to a specific CWT code ($H_{code(i)}$):

$$\hat{N}_H = \sum \hat{H}_{code(i)} = \sum \left(AD_{code(i)} \cdot E \cdot PM_{code(i)} \right),$$

where $AD_{code(i)}$ = the number of CWTs recovered with code, i.

Egg Deposition

The estimate of adult females, attained by multiplying the unstratified Petersen estimate by the proportion of adults from scale analyses and the proportion of females from the adult female–male ratio, was multiplied by predicted egg production to derive total egg deposition (N_e) in the study area. Chinook salmon females deposit multiple pockets of eggs in a single redd (Healey 1991). Successful deposition of eggs by partially spawned females was assumed to average half that of a fully spawned female. Allen and Hassler (1986) determined an average production (n_e) of 3,634 eggs by adult female Chinook salmon in the Klamath River. Escapement estimates of fully spawned females (F_{fs}) multiplied by 3,634 (n_e) were added to escapement estimates of partially spawned females (F_{ps}) multiplied by 1,817 (one-half of n_e) to yield total egg deposition in the study area:

$$\hat{N}_e = n_e \cdot \hat{F}_{fs} + \frac{1}{2} \cdot n_e \cdot \hat{F}_{ps}.$$

Results and Discussion

Temporal and Spatial Distribution of Carcasses

The season total of newly observed carcasses captured was 2,403 in 2011, adults and jacks included (Table 3; Appendix A). New carcass observations peaked in calendar week 46 with a close second highest capture in calendar week 47. Peak capture in previous years occurred in calendar weeks 44 to 46. Carcass density was highest in the uppermost reach of the survey area and declined steadily downstream (Figure 3).

Length Distribution

The 2011 jack–adult size cut-off (63 cm FL) was determined after the sampling season by the KRTT (2012; Figure 4; Table 4). Of the 319 measured fish less than or equal to 63 cm FL, 15 were female. Mean fork lengths of adult females, adult males, and jacks were 76.6 cm, 84.2 cm, and 56.6 cm, respectively (Table 4).

Table 3. Number of Chinook salmon carcasses captured by calendar week, Klamath River surveys 2001 to 2011. Annual peak counts are in bold font. Dashes indicate no survey conducted.

Calendar week	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
41	-	-	-	-	3	40	10	-	-	-	-
42	50	52	39	-	59	71	37	62	22	19	27
43	355	363	142	458	151	252	57	164	86	31	78
44	600	2,505	1,072	613	**440**	**538**	204	535	399	102	224
45	692	**2,638**	**2,022**	**670**	311	502	411	**895**	728	281	431
46	**868**	1,803	1,067	512	99	220	**907**	651	**776**	**496**	**696**
47	-	627	779	202	28	72	512	247	330	265	668
48	285	107	140	50	-	-	519	96	158	82	234
49	-	-	-	-	-	-	194	-	73	35	45
50	-	-	-	-	-	-	140	-	-	-	-
Total	2,850	8,095	5,261	2,505	1,091	1,695	2,991	2,650	2,572	1,311	2,403

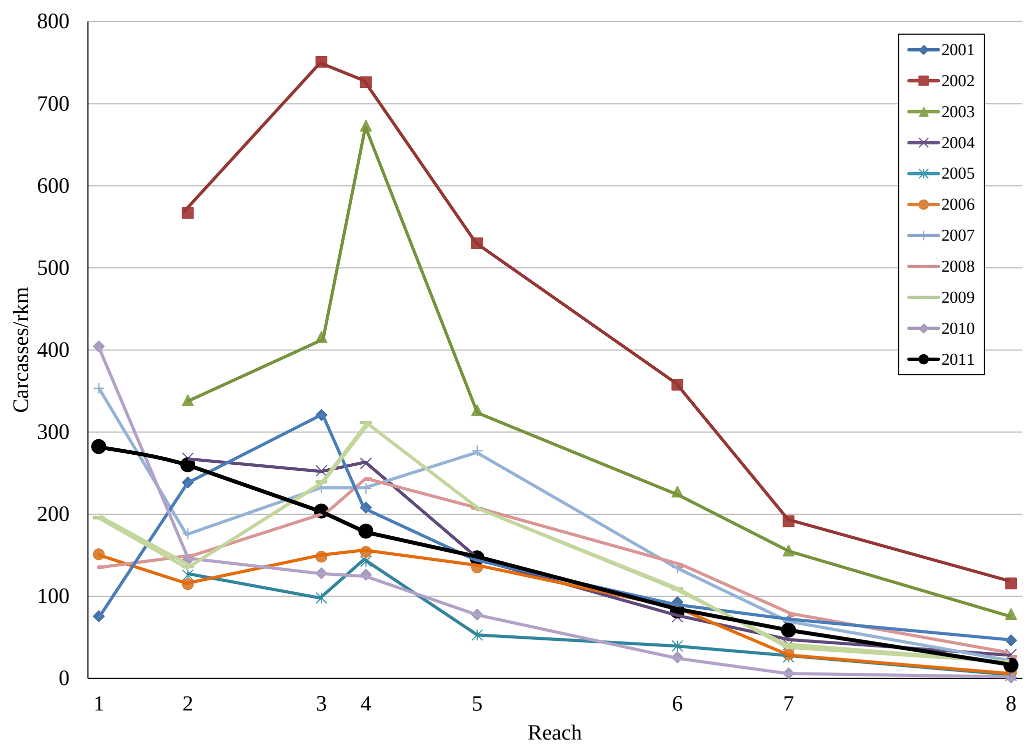

Figure 3. Chinook salmon carcass density (carcasses/rkm) by reach, Klamath River surveys 2001 to 2011. Reach 1 was not surveyed in 2002 to 2005.

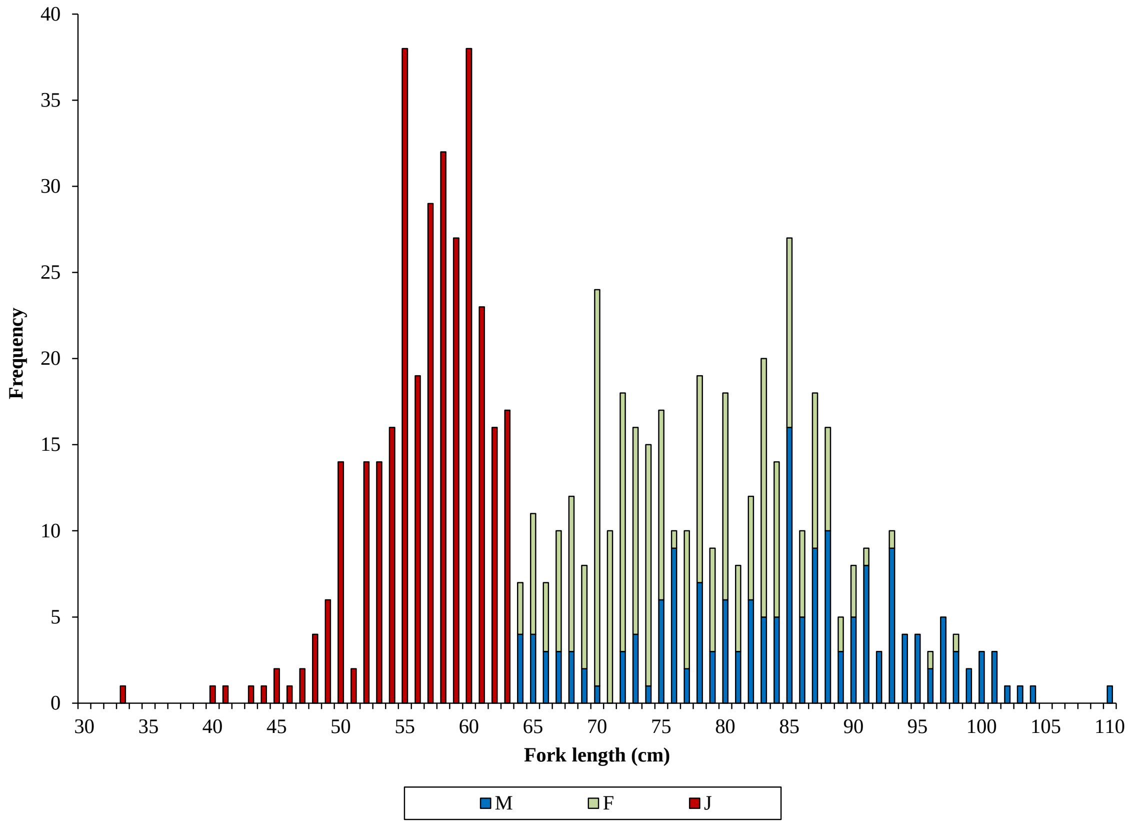

Figure 4. Length-frequency graph of F_1- and D_2-condition Chinook salmon spawners from the mainstem Klamath River survey 2011 [n = 732 (n_F = 235; n_M = 178; n_J = 319)].

Table 4. Mean fork lengths by year of mainstem Klamath River Chinook salmon carcasses, 2001 to 2011.

Year	Jack–adult FL (cm) cut-off (jacks ≤)	Adult females n	Adult females FL (cm) mean	Adult females FL (cm) s.d.	Adult males n	Adult males FL (cm) mean	Adult males FL (cm) s.d.	Jacks n	Jacks FL (cm) mean	Jacks FL (cm) s.d.
2001	63	571	76.3	6.3	486	85.4	9.6	75	53.8	6.3
2002	63	1,133	75.8	6.9	1,063	82.7	9.2	166	56.0	6.6
2003	55	985	76.9	7.8	667	87.0	10.2	24	48.0	5.4
2004	57	446	78.9	7.3	400	87.3	9.7	52	50.7	5.4
2005	52	247	73.7	7.6	219	83.3	9.7	5	47.0	4.3
2006	60	438	74.5	6.9	432	84.0	9.8	242	52.6	5.7
2007	51	918	66.6	5.3	402	77.2	10.0	26	46.5	3.5
2008	59	595	76.8	6.4	433	84.0	12.0	272	53.4	4.9
2009	58	729	73.2	5.7	381	83.0	8.4	74	51.6	4.1
2010	61	255	78.9	6.3	186	85.4	9.2	61	55.8	4.5
2011	63	235	76.6	7.2	178	84.2	9.9	319	56.6	4.4

Adult Female–Male Ratio

The percentage of females among handled adult carcasses was 56.4% in 2011 (adult female–male ratio = 1.29:1; Figure 5). The percentage of females has ranged from 51.8% (adult female–male ratio = 1.07:1; in 2002) to 72.9% (adult female–male ratio = 2.69:1; in 2007).

Pre-spawn Mortality

Pre-spawn mortality was 9.2% in 2011 (Figure 6). Prespawning mortality in previous years' surveys ranged from 1.0% (in 2009) to 22.1% (in 2005). Fully spawned individuals made up 88.7% of F_1- and D_2-condition female adult carcasses. Partially spawned individuals made up 2.1% of F_1- and D_2-condition female adult carcasses. Consistent with the trend revealed in previous years, pre-spawn mortality decreased to zero as the season advanced (Figures 7 and 8).

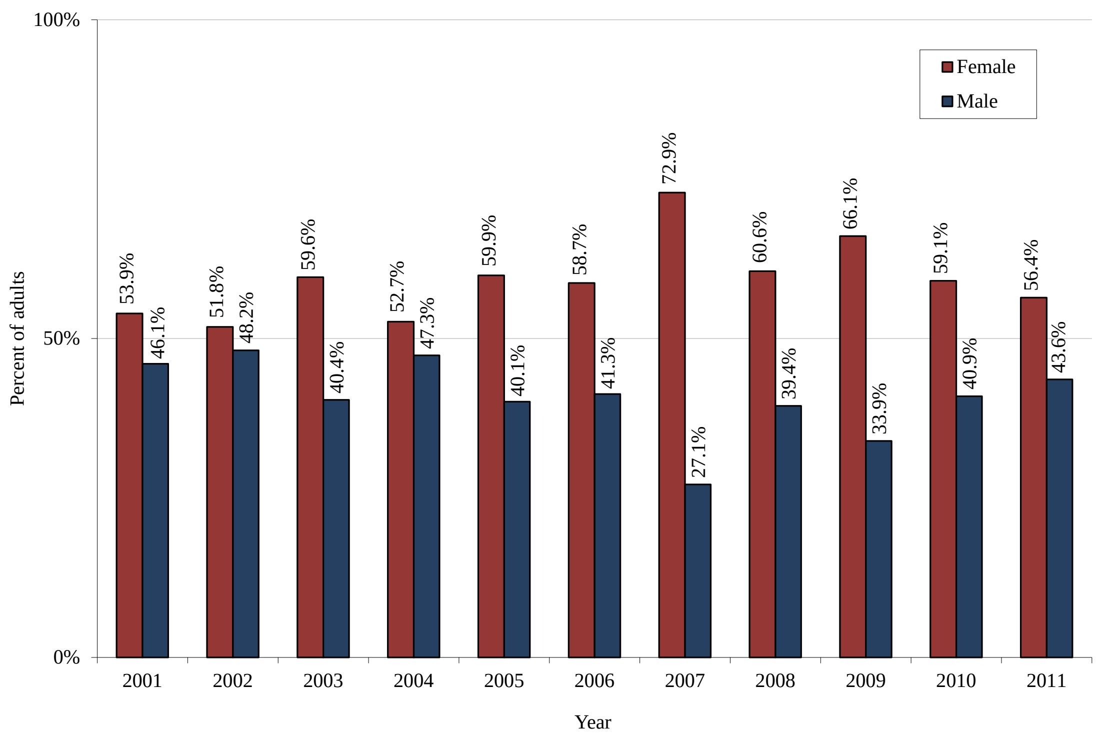

Figure 5. Female and male proportions of adult Chinook salmon carcasses in the mainstem Klamath River 2001 to 2011.

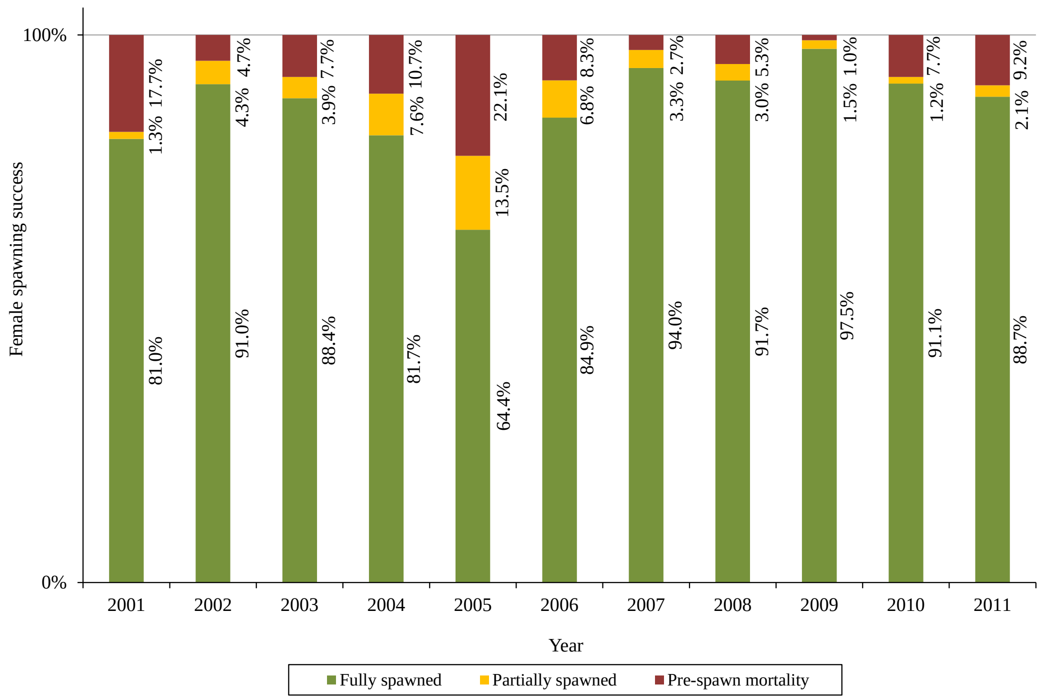

Figure 6. Spawning success female Chinook salmon based on F_1- and D_2-condition carcasses, Klamath River surveys 2001 to 2011.

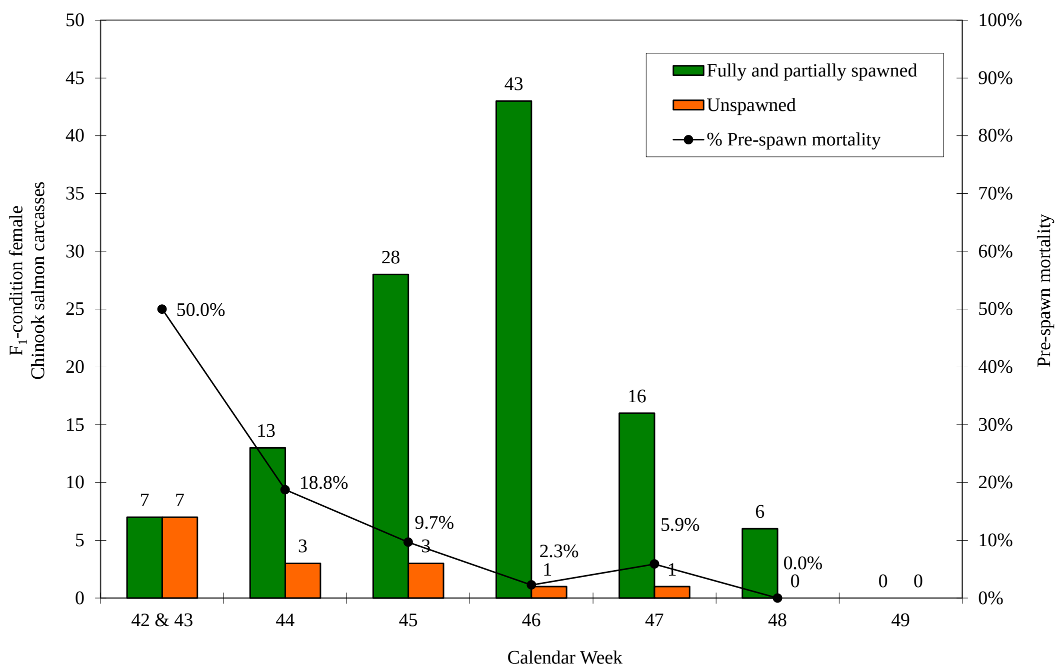

Figure 7. Weekly pre-spawn mortality from F_1-condition female carcasses, Klamath River survey 2011. Only F_1-condition carcasses were included since we can assume only those fish expired the week they were found. Calendar weeks 42 and 43 were combined since calendar week 42 had only a sample size of one.

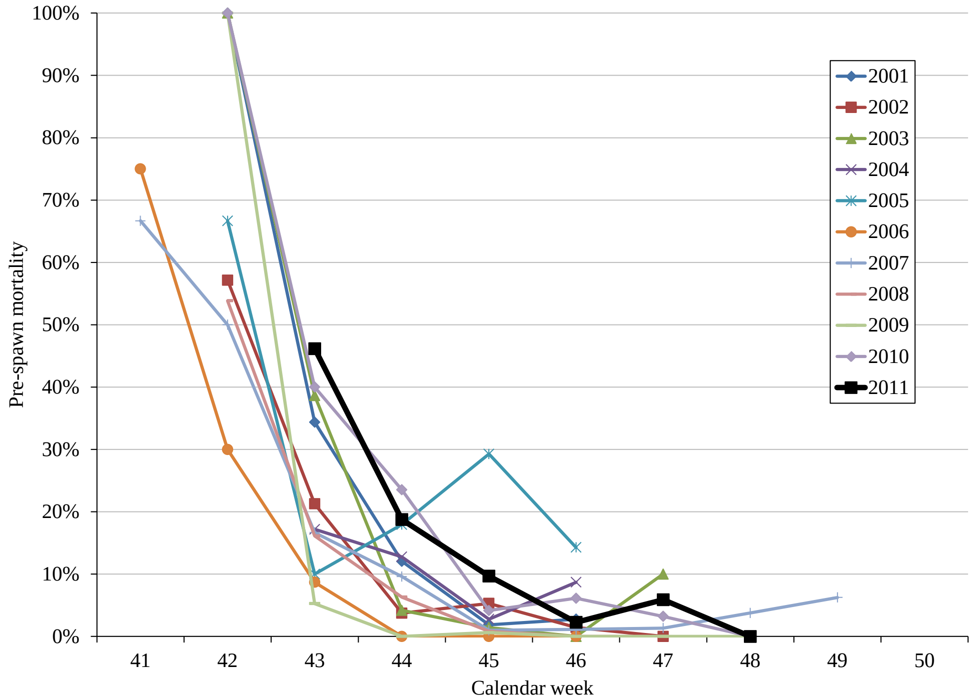

Figure 8. Weekly pre-spawn mortality from F_1-condition female Chinook salmon carcasses, Klamath River surveys 2001 to 2011. Only data points with sample sizes greater than or equal to five are included.

Escapement Estimates and Age Composition

The unstratified Petersen escapement estimate was 4,880 in 2011 (Table 5). Large sample sizes (C = 2,403; M = 736) and high overall recapture rate (49.2%) are indicators of high accuracy and precision of the population estimate (Williams et al. 2001). Also, sufficient numbers of carcasses were tagged and examined for tags for a population of this size were obtained, as recommended for research by Robson and Regier (1964).

Five hundred eighty scale samples were collected from carcasses and analyzed in 2011 to estimate the age composition of the mainstem spawning escapement. Spawning escapement, dominated by age-3 and age-4 fish in previous years, this year was dominated by 2-year olds. Based on Kimura-adjusted scale readings and the unstratified Petersen escapement estimate, jacks represented 45.7% ($\widehat{N}_{jacks}$ = 2,229) of the total escapement (Figure 9; Table 6). This was by far the largest jack escapement estimated in the 11-year history of this project; the largest jack run between 2001 and 2010 occurred in 2008 ($\widehat{N}_{jacks}$ = 836; $\hat{P}_{jacks}$ = 17.1%). The 2011 adult escapement, however, was estimated to be the second lowest since 2001. The adult estimate was made up of 1,133 3-year olds (23.2%), 1,511 4-year olds (31.0%), and 6 5-year olds (0.13%). The proportion of fish designated as jacks by the fork length cut-off was 2.1% lower than that estimated to be 2-year olds by scale aging. High jack numbers in 2011 are indicative of expected high returns of age-3 adults in 2012 and age-4 adults in 2013.

Table 5. Unstratified Petersen fall Chinook salmon escapement estimates and tag-recovery data, Klamath River surveys 2001 to 2011.

	Carcasses					Escapement	95% confidence limits	
Year	Captured	Tagged	Recovered	Tagging rate	Recovery rate	estimate	Lower	Upper
2001	2,850	1,070	389	37.5%	36.4%	7,828	7,253	8,403
2002[a]	8,095	2,335	1,334	28.8%	57.1%	14,394	13,934	14,855
2003[a]	5,261	1,661	686	31.6%	41.3%	12,958	12,274	13,642
2004[a]	2,505	896	500	35.8%	55.8%	4,715	4,469	4,960
2005[a]	1,091	378	94	34.6%	24.9%	4,585	3,860	5,309
2006	1,695	547	258	32.3%	47.2%	3,587	3,296	3,879
2007	2,991	1,225	663	41.0%	54.1%	5,523	5,273	5,774
2008	2,650	1,022	553	38.6%	54.1%	4,894	4,649	5,140
2009	2,572	1,133	658	44.1%	58.1%	4,427	4,238	4,615
2010	1,311	452	230	34.5%	50.9%	2,572	2,362	2,782
2011	2,403	736	362	30.6%	49.2%	4,880	4,551	5,209

[a] Reach 1 not surveyed. Mean Reach 1 escapement estimate (229) from 2001 and 2006–2010 added to Petersen calculation.

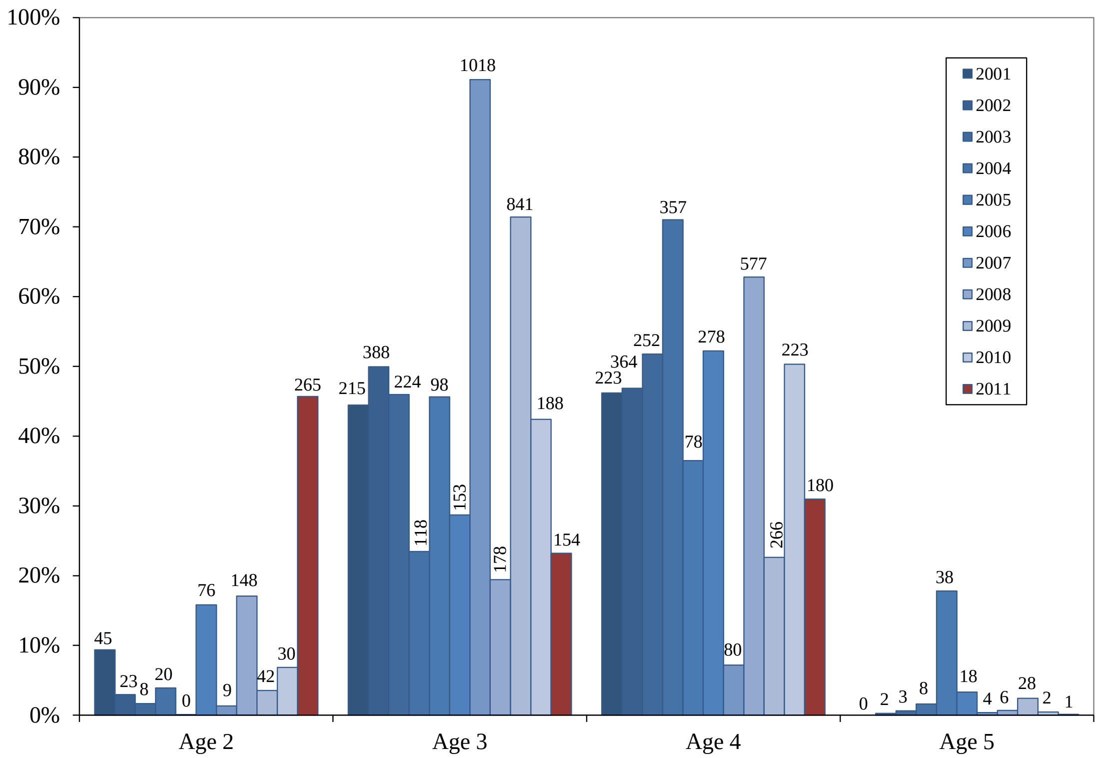

Figure 9. Fall Chinook salmon age composition percentages based on scale readings, Klamath River 2001 to 2011. Sample sizes by age are presented at the top of each bar.

Table 6. Fall Chinook salmon spawning escapement estimates (and percent of total run) for each age class, Klamath River surveys 2001 to 2011 (age compositions from Figure 9). *Note: Adults are ages 3 through 5.*

	Age				
Year	2 [a]	3	4	5	Adults [b]
2001	734 (9.4%)	3,479 (44.4%)	3,616 (46.2%)	0 (0.0%)	7,095
2002	424 (2.9%)	7,189 (49.9%)	6,743 (46.8%)	37 (0.3%)	13,970
2003	215 (1.7%)	5,957 (46.0%)	6,706 (51.8%)	80 (0.6%)	12,743
2004	184 (3.9%)	1,107 (23.5%)	3,349 (71.0%)	75 (1.6%)	4,531
2005	4 (0.1%)	2,092 (45.6%)	1,673 (36.5%)	816 (17.8%)	4,581
2006	567 (15.8%)	1,030 (28.7%)	1,873 (52.2%)	118 (3.3%)	3,021
2007	73 (1.3%)	5,032 (91.1%)	397 (7.2%)	21 (0.4%)	5,450
2008	836 (17.1%)	950 (19.4%)	3,075 (62.8%)	33 (0.7%)	4,058
2009	157 (3.6%)	3,162 (71.4%)	1,001 (22.6%)	107 (2.4%)	4,270
2010	176 (6.8%)	1,091 (42.4%)	1,294 (50.3%)	12 (0.5%)	2,398
2011	2,229 (45.7%)	1,133 (23.2%)	1,511 (31.0%)	6 (0.13%)	2,651

[a] age 2 same as jacks

[b] sum of ages 3 to 5 may be one less than the adult total due to rounding to whole numbers

Chinook salmon adult spawners in the mainstem Klamath River between IGD and the Shasta River confluence accounted for 67.7% of natural adult spawners in the mainstem Klamath River above Indian Creek, 14.8% of natural adult spawners in the Klamath River Basin above the Trinity River, and 5.7% of natural adult spawners in the entire Klamath River Basin in 2011 (Table 7). In the entire Klamath River Basin, Chinook salmon adult spawners in the mainstem Klamath River between IGD and the Shasta River confluence accounted for 3.8% of total adult escapement (hatchery and natural spawners) and 2.6% of the total adult inriver run (hatchery and natural spawners plus inriver harvest) in 2011.

Hatchery Fish Contribution

From the 77 F_1-and D_2-condition ad-clipped carcasses encountered in 2011, 75 snout samples were collected and CWTs recovered, of which 69 were decoded (Appendix B). Production multipliers from known CWT numbers ranged from 4.01 (24.9% tag rate; from Brood Year 2009) to 4.17 (24.0% tag rate; also from Brood Year 2009). The estimated proportion of hatchery-origin spawners in the study area was 40.9% (n = 1,994) in 2011 (Table 8; Appendix B). The estimated proportions of hatchery-origin spawners ranged from 1.2% to 14.2% in 2001 to 2004 and from 22.7% to 48.1% in 2005 to 2010.

Table 7. Proportions of Chinook salmon adult spawners in the mainstem Klamath River from Iron Gate Dam to the Shasta River confluence within different scales of the Klamath River Basin, 2001 to 2011. Data compiled from Magneson (2008) and KRTT (KRTAT 2003a, 2003b, 2004, 2005, 2006, 2007, 2008, 2009; KRTT 2010, 2011, 2012).

Year	Mainstem Klamath R. natural spawners IGD to Indian Cr.	Klamath Basin natural spawners above Trinity R.	Klamath Basin natural spawners (includes Trinity Basin)	Klamath Basin escapement (hatchery + natural)	Klamath Basin in-river run [a] TOTAL
2001	72.6%	17.4%	9.1%	5.3%	3.8%
2002	73.3%	27.2%	22.2%	15.5%	8.9%
2003	77.7%	23.7%	14.8%	8.6%	6.7%
2004	84.9%	40.2%	18.5%	9.5%	5.7%
2005	89.5%	32.6%	16.5%	8.3%	7.0%
2006	67.3%	21.3%	10.0%	6.1%	4.9%
2007	79.3%	25.6%	9.0%	5.7%	4.1%
2008	69.6%	21.3%	13.2%	9.1%	5.8%
2009	53.7%	15.4%	9.6%	6.7%	4.2%
2010	65.0%	15.8%	6.4%	4.3%	2.6%
2011	67.7%	14.8%	5.7%	3.8%	2.6%

[a] includes natural spawners, hatchery spawners, and in-river harvest

Table 8. Hatchery composition of fall of Chinook salmon in the mainstem Klamath River, IGD to the Shasta River confluence, based on carcass surveys, 2001 to 2011. *Note: Data only from F_1- and D_2-condition carcasses used.*

Year	Estimated hatchery-origin proportion	Escapement estimate: Total	Escapement estimate: Hatchery only
2001	11.8%	7,828	925
2002	14.2%	14,394	2,043
2003	3.8%	12,958	489
2004	1.2%	4,715	58
2005	26.6%	4,585	122
2006	22.7%	3,587	815
2007	39.8%	5,523	2,201
2008	37.0%	4,894	1,810
2009	25.1%	4,427	1,112
2010	48.1%	2,572	1,238
2011	40.9%	4,880	1,994

Egg Deposition

Egg deposition in the study area was estimated to be 4.9 million from 1,357 females in 2011 (Table 9). This is the second lowest estimate for egg deposition since 2001. Annual survival of these eggs during incubation depends on a variety of factors, including redd superimposition, temperature, dissolved oxygen, predation by invertebrates, fine sediment infiltration into the redd, periphyton biomass, and flow. (McNeil 1964; Nelson et al. 2012).

Table 9. Egg deposition (N_e) of Chinook salmon based on unstratified Petersen estimates from Klamath River carcass surveys 2001 to 2011. Note that F_{fs} and F_{ps} are estimates of fully and partially spawned females, respectively.

Year	$\hat{F}_{fs}$	$\hat{F}_{ps}$	$\hat{N}_e$
2001	3,100	49	11,400,000
2002	6,589	310	24,500,000
2003	6,718	296	25,000,000
2004	1,948	181	7,400,000
2005	1,767	371	7,100,000
2006	1,506	120	5,700,000
2007	3,732	131	13,800,000
2008	2,255	74	8,300,000
2009	2,743	42	10,000,000
2010	1,291	17	4,700,000
2011	1,326	31	4,900,000

Acknowledgements

We particularly thank the Yurok Tribal Fishery Program for their annual participation in the carcass survey. Field data were collected under the direction of Steve Gough. Data were collected by AFWO personnel: Sarah Burstein, Andrew Goodman, Jordan Green, Leanne Knutson, Keenan Smith, and Matt Smith-Caggiano. Data were collected by YTFP personnel: Jamie Holt, Rocky Erickson, and Troy Fletcher Jr.. Scales were prepared by the Klamath office of the Yurok Tribe and read by Steve Gough of AFWO and Arney Nova of YTFP.

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Appendix A. Summary of Chinook salmon carcasses observed, Klamath River surveys 2011. Jacks enumerated on the basis of postseason KRTT length criteria.

		New carcass captures								Recoveries from Survey Week:													
Survey	Survey	Tagged				Not tagged				1		2		3		4		5		6		7	
Week	Dates	M	F	U	J	M	F	U	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J
1	Oct 11-12	3	3	0	12	0	0	9	0														
2	Oct 18-19	11	19	0	12	1	1	33	1	0	1												
3	Oct 25-26	41	31	0	33	2	4	111	2	1	0	9	0										
4	Nov 1-2	54	56	2	83	5	4	220	7	0	0	1	1	16	5								
5	Nov 8-10	50	76	1	124	10	11	414	10	0	0	0	0	15	1	46	20						
6	Nov 15-16	17	40	0	50	14	10	518	19	0	0	0	0	4	2	18	13	62	45				
7	Nov 21-23	3	10	0	5	1	2	207	6	0	0	0	1	0	1	8	4	11	10	28	18		
8	Nov 29-30					1	0	44	0	0	0	0	0	0	0	1	1	3	2	1	4	1	1
Total		179	235	3	319	34	32	1,556	45	1	1	10	2	35	9	73	38	76	57	29	22	1	1

A = Adults
M = Male adults
F = Female adults
U = Unknown sex adults
J = Jacks

Appendix B. Hatchery composition of fall Chinook salmon in the mainstem Klamath River, IGD to the Shasta River confluence, based on carcass surveys, 2001 to 2011.

Data for 2001 to 2010 does not match what was reported in Gough and Williamson (2012). Only data from F_1- and D_2-condition carcasses were used in this table whereas data from carcasses of all conditions were used in the mentioned report. As a result hatchery proportion estimates below are 1.0 to 2.8 times greater (difference: 0.2% lower to 19.5% higher). The adjustment was made for a better comparison with 2011 results. Data from 2011 is presented in a separate table since a different methodology was used to calculate hatchery composition.

Year	Total carcass capture	Ad-clip carcass capture [a]	Proportion of hatchery-produced fish with ad-clip at IGH	Estimated capture of hatchery-origin carcasses	Estimated hatchery-origin proportion [b]	Escapement estimate: Total	Escapement estimate: Hatchery only
	C	AD_{obs}	$P(AD\|H)_{IGH}$	$\hat{H}$	$\hat{P}(H)$	$\hat{N}$	$\hat{N}_H$
2001	1125	5	3.76%	133	11.8%	7,828	925
2002	2343	13	3.98%	333	14.2%	14,394	2,043
2003	1664	4	5.73%	63	3.8%	12,958	489
2004	897	1	9.01%	11	1.2%	4,715	58
2005	386	8	7.78%	103	26.6%	4,585	1,222
2006	551	8	6.27%	125	22.7%	3,587	815
2007	1237	23	4.66%	493	39.8%	5,523	2,201
2008	1046	24	6.20%	387	37.0%	4,894	1,810
2009	1153	20	6.90%	290	25.1%	4,427	1,112
2010	472	20	8.80%	227	48.1%	2,572	1,238

[a] In 2002, 2003, 2006, and 2007 there were high discrepencies between banks in ad-clip detections. For these years AD_{obs} was predicted by expanding ad-clipped carcass capture from the bank with the higher number proportionately by the capture of all carcasses on each bank.

[b] $\hat{P}(H) = \hat{H}/C$

Year	Total carcass capture	Ad-clip carcass capture	Snout samples from ad-clip carcasses	CWTs recovered	CWTs decoded	Estimated capture of hatchery-origin carcasses	Estimated hatchery-origin proportion	Escapement estimate: Total	Escapement estimate: Hatchery only
	C	AD_{obs}	AD_{sample}	AD_{cwt}	AD_{code}	$\hat{H}$	$\hat{P}(H)$	$\hat{N}$	$\hat{N}_H$
2011	761	77	75	75	69	311	40.9%	4,880	1,994