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Fall Chinook Salmon Run Characteristics and Escapement for the Mainstem Klamath River, 2013-2015

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Table of Contents

page

List of Tables

List of Figures

List of Appendices

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Abstract.— Adult fall Chinook Salmon *Oncorhynchus tshawytscha* carcasses were surveyed on the mainstem Klamath River, from Iron Gate Dam to the confluence with the Shasta River, during the 2013, 2014, and 2015 spawning seasons to estimate annual escapement and characterize the age and sex composition and spawning success of the run. These are the 13th–15th years that this annual survey has been conducted. Using postmortem mark–recapture methods and an area-under-the-curve estimator, estimated spawning escapement for this section of the mainstem Klamath River was 7,358 fish in 2013, 16,720 in 2014, and 2,507 in 2015. Based on this estimate and age composition data from scale samples, spawning escapement by year class was 393 (5.3%) jacks (age-2 fish), 2,951 (40.1%) age-3 spawners, 4,015 (54.6%) age-4 spawners, and no (0.0%) age-5 spawners in 2013. In 2014, the estimates were 1,271 (7.6%) jacks, 6,477 (38.7%) age-3 spawners, 8,862 (53.0%) age-4 spawners, and 110 (0.7%) age-5 spawners. In 2015, the estimates were 85 (3.4%) jacks, 1,036 (41.3%) age-3 spawners, 1,264 (50.4%) age-4 spawners, and 122 (4.9%) age-5 spawners. An estimated 31.7% of the fish that spawned in the surveyed reach were of hatchery origin in 2013, 24.5% in 2014, and 26.2% in 2015. The annual adult female–male ratios were 1.9:1, 1.6:1, and 1.7:1 and annual pre-spawn mortality rates of females were 4.0, 10.3, and 6.3% in 2013, 2014, and 2015, respectively. Estimated annual egg deposition by adult females in the study area were 14.5, 27.5, and 3.9 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

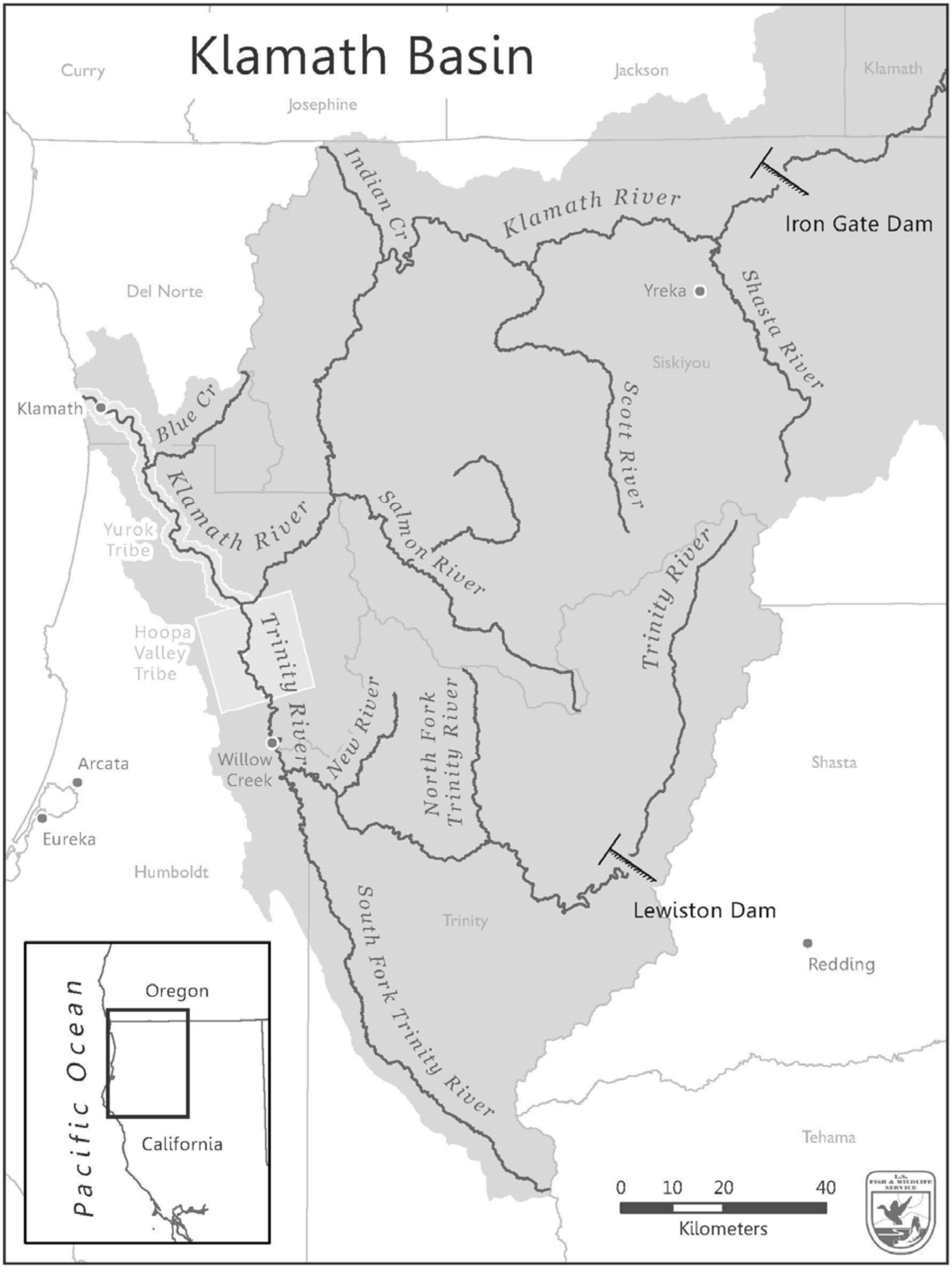

Figure 1. Klamath River Basin, northern California. The mainstem Klamath River carcass survey study area extends from Iron Gate Dam to the Shasta River confluence.

phenomena, disease, changed genetic integrity from hatchery-origin fish straying into natural spawning areas, over-harvest, and land-use practices causing habitat loss due to blockages and degradation.

Beginning in 1993, the U.S. Fish and Wildlife Service's Arcata Fish and Wildlife Office (AFWO) initiated the mainstem Klamath River fall Chinook Salmon spawning escapement assessment. In this program, escapement estimates were generated by expanding redd counts under the assumption that each redd equals one adult female and one adult male (Magneson and Colombano 2014). This effort was initiated to supplement fall Chinook Salmon spawning escapement and harvest monitoring that had been initiated in the Klamath River Basin in 1978 (CDFW 2013). In 2001, we initiated a carcass tag-recovery (i.e., mark–recapture) methodology with the objective of refining the escapement estimate in the heavily used spawning area between Iron Gate Dam [IGD; river kilometer (rkm) 310.15] 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). Petersen tag-recovery-based estimates and redd counts from concurrent surveys from IGD to the confluence of the Shasta River from 2001 to 2004 and 2006 were compared. Estimates of successfully spawned adult females were 3.3–4.8 times higher than redd counts over this stretch of 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 for this reason.

In 2012, a large run of fall Chinook Salmon was predicted to enter the Klamath Basin, the largest since comprehensive monitoring and harvest management activities were initiated in 1978 (O'Farrell 2012; PFMC 2012). The survey effort required to complete the mark–recapture protocol given the projected run size would have been unfeasible due to staffing, equipment, and time constraints. In response, we developed a methodology and protocol for an area-under-the-curve (AUC) escapement estimate (Gough and Som 2015). This new methodology allows the ability to complete weekly surveys regardless of run size by incorporating weekly systematic sampling rates, when necessary, based on the anticipated number of carcasses. This AUC methodology was continued in 2013–2015, though 2014 was the only year with a large enough run to require systematic sampling in some weeks.

The primary purpose of this project was to provide the Klamath River Technical Team (KRTT) with fall Chinook Salmon spawning escapement estimates 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 in-river 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 survey conducted within the more densely used spawning reaches (i.e., above the Shasta River confluence) are summed with estimates derived from the redd survey below the Shasta River confluence to establish an estimate of escapement for the mainstem Klamath River (KRTT 2012). Accurately determining the number of spawners within this reach is also needed for an ongoing outmigrant fry study

(Gough et al. 2015) and for calibrating the Chinook Salmon production model, Stream Salmonid Simulator. Additionally, carcass survey data are used to estimate annual age-class proportions, adult female–male ratios, female spawning success/pre-spawn mortality, fork length distributions, proportions of naturally spawning hatchery-origin fish, and egg deposition.

Study Area

The survey area consists of the 21.2-km section of mainstem Klamath River between IGD (the upper limit of anadromy) and the Shasta River confluence, and is divided into eight reaches (Table 1; Figure 2). Reach delineation is based on previously mapped concentrations of redds with boundaries at distinguishable landmarks.

Methods

Data were collected in a cooperative effort between AFWO and the Yurok Tribal Fisheries Program (YTFP). Weekly surveys were conducted from October 8 through December 4 in 2013, October 7 through December 3 in 2014, and October 7 through December 1 in 2015. Two crews, one AFWO and one YTFP, each comprised of three members, rowed downstream in inflatable catarafts on opposite banks of the river. Each crew, consisting of a rower, a data recorder, and a carcass handler, searched the river for carcasses on their respective bank, from the river's edge to the mid-channel. The crews switched banks every week. Side channels were surveyed for carcasses either by foot or by cataraft. 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 depth. We only recorded Secchi depth once per week because only one location in the study area (in Reach 8) was consistently slow and deep enough for this water transparency measurement.

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	(km)	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

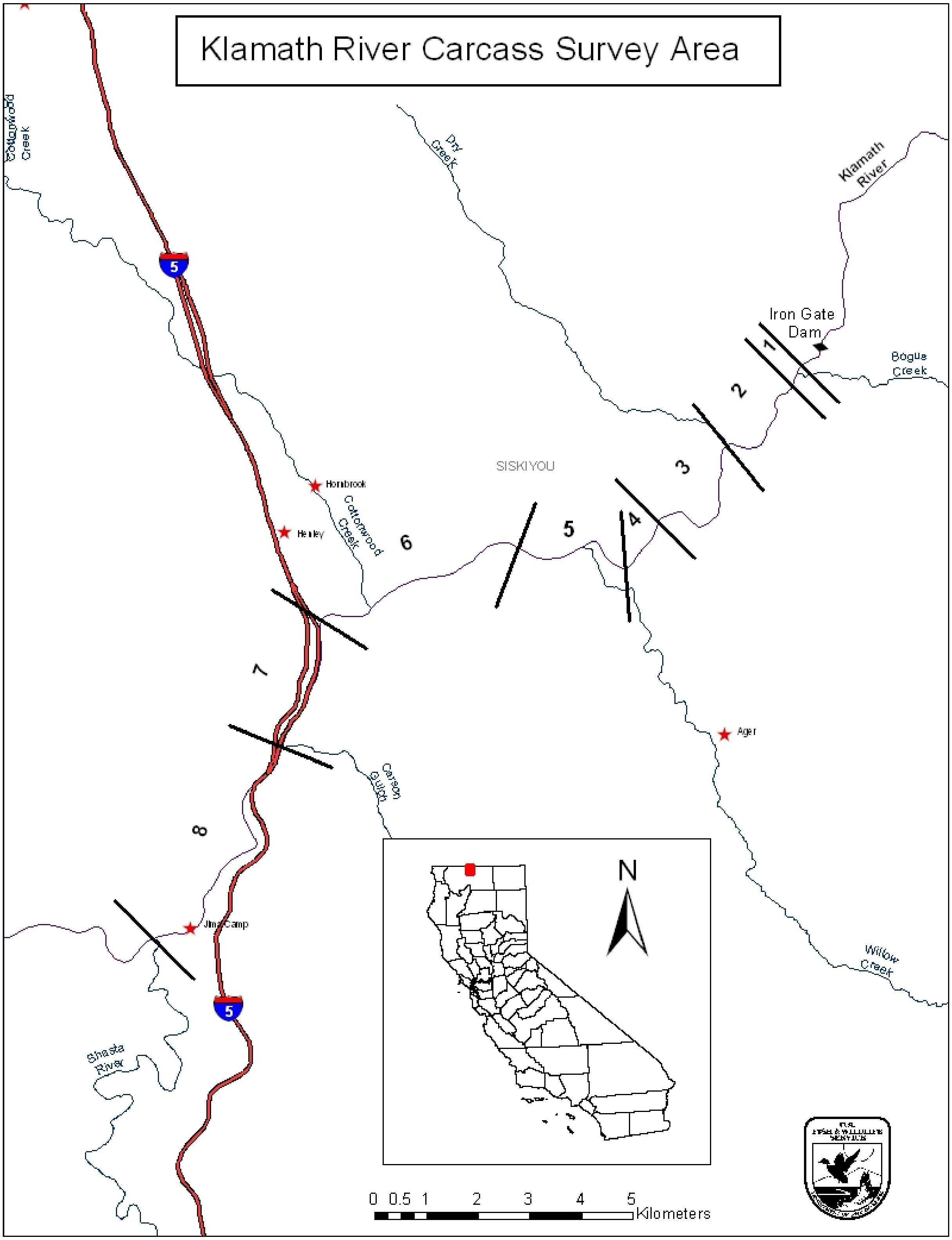

Figure 2. Klamath River carcass survey area from IGD (rkm 310.15) to the Shasta River confluence (rkm 288.45) with reaches delineated. Reach 1 begins at the first river access below IGD (rkm 309.65). Little to no spawning occurs between the dam and the access point.

Carcass Data

Each observed carcass not previously tagged (see Escapement Estimate section below) was retrieved and the following data were recorded: reach, 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.

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 denoting where in the side channel the carcass was encountered.

Carcass condition was categorized as fresh (F_1), partly decayed (D_2), or one of three stages of rotten (N_3, N_4, or N_5) according to the following indications:

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

D_2 = decayed beyond F_1 but body still has some firmness and little fungus;

N_3 = rotten (decayed beyond D_2; covered with fungus and flesh softening);

N_4 = very rotten (decayed beyond N_3; flesh liquefying);

N_5 = exceedingly rotten (decayed beyond N_4; deteriorated to the point that skin is sloughing off and the carcass is almost skeletal).

F_1-condition carcasses were believed to have expired less than one week prior to capture, D_2-condition carcasses were believed to have expired about one week prior to capture, and N_x-condition carcasses were believed to have expired more than one week prior to capture. Fork lengths were not recorded from N_x-condition carcasses.

Sex was distinguished using morphological differences for F_1- and D_2-condition carcasses only. Adult males are typically larger than adult females of the same age class, develop a more-pronounced kype, and may display reddish coloration 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 F_1- and D_2-condition female carcasses were assigned a spawning condition code from 1 to 4:

1 = spawned out or less than one-third of eggs retained;

2 = partially spawned with one- to two-thirds of eggs retained;

3 = unspawned or more than two-thirds of eggs retained;

4 = spawning condition not determined.

Spawning condition data were used to calculate spawning success and, conversely, pre-spawn mortality of female Chinook Salmon. Female carcasses with spawning condition ‘1’ and ‘2’ were considered successful spawners. Carcasses with spawning condition ‘3’ were considered pre-spawn mortalities. F_1- and D_2-condition carcasses with spawning condition '1', '2', and '3' were used to assess the overall spawning success for the entire spawning season. Only F_1-condition carcasses were used to estimate weekly pre-spawn mortality because we assume that only those fish expired the week they were sampled. Measurements of pre-spawn mortality are limited to occurrence within the space and time of the surveys. Pre-spawn mortality occurring in the lower Klamath River or prior to these surveys are not reflected in our data and analyses.

Throughout this report the term 'jack' refers to age-2 (precocious) spawners, including males (true jacks) and females (jills). The size cut-off between adults and jacks was decided after the sampling season based on scale-age data and length-frequency distributions compiled and analyzed by the KRTT (2014–2016). The KRTT reviews data from throughout the basin provided by various collaborators and jointly decides which method best represents the jack to adult proportions for each monitoring 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 were collected from all sampled F_1- and D_2-condition carcasses. A minimum of five scales were collected from the preferred area of the 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 and provided to YTFP, who coordinate the Klamath River portion of the KRTT (2014–2016) age composition analysis.

Escapement Estimate

Counts of carcasses were conducted weekly over the entire study area throughout the active spawning period. Every carcass was counted as long as surveys could be completed within the survey week. When the number of carcasses became too high for the crews to complete the survey within the work week, systematic sampling was employed to ensure completion. Sampling rates were derived using historic records of carcass data collection and the adult return apportioned to the mainstem Klamath River was projected according to historic spawning distribution patterns (CDFW 2013). When systematic sampling was employed, all carcasses were counted but data (location, condition, etc.) were only taken on sampled carcasses. Systematic sampling was only necessary in survey weeks 6, 7, and 8 of 2014, and a rate of 1:2 was applied in each of those three weeks.

All sampled 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 adipose fin-clipped ('ad-clipped') carcasses since removing the snout (see Hatchery Contribution section below) 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_x-condition carcasses were not tagged but were sampled, tallied, and replaced. Recaptured (previously tagged) carcasses were examined and the following data were recorded: reach, tag number, and condition. Recaptured carcasses were replaced to allow the possibility of multiple recaptures.

An AUC estimator, a widely used method for estimating salmon escapement, was used to estimate escapement in the study area (Manske and Schwarz 2000; Gough and Som 2015).

We adopted an AUC methodology which allows great flexibility for handling systematically sampled carcasses in some weeks (due to the large predicted run-size estimate, as described above) and missed weekly samples due to weather, river discharge, or logistical constraints. The details and methods of our AUC methodology are described in Gough and Som (2015). In brief, our procedure relied on the weekly carcass counts and concurrent mark-recapture experiment. We used these data to estimate average carcass survey life (i.e., the amount of time until a fresh carcasses becomes no longer intact), and weekly carcass detection probabilities. In turn, these data and estimates were combined within a trapezoidal AUC framework (Millar et al. 2012) to construct estimates of mainstem carcasses in the targeted reaches. We computed estimates of carcass survey life and observer efficiency (i.e., error), and incorporated the uncertainty of these estimates into our escapement estimates via a bootstrap approach to generate confidence intervals (Manske and Schwarz 2000).

The assumptions of our estimation method include:

1. Carcass arrivals and departures occur between weekly surveys (not during), and carcass departures are permanent. Our trapezoidal AUC method further assumes that carcass arrivals between surveys occur uniformly.
2. Uniquely numbered tags are used to mark carcasses and recaptured tags are correctly identified.
3. Each fish that expires and becomes a carcass within the spatial domain of the survey is immediately available for capture.
4. Captures and departures are independent among carcasses and between surveys.
5. Mean carcass survey life was the same for both left and right river banks.
6. Mean carcass survey life was constant throughout the survey season.
7. Time wise, the survey length encompasses the entire arrival and departure period.

The last assumption can be relaxed for the trapezoidal AUC methodology by combining periods of zero observed carcasses with weeks directly before and after the period of data collection. In regard to the carcass survey life estimates, early carcasses that arrive well before the first survey (but remain detectable) or carcasses that remain in the system long after the survey period would have their carcass survey life underestimated, though the consequences of this in our data are minor for two reasons. First, the survey period encompasses the weeks when the vast majority of carcasses enter the system. Second, average carcass survey life is unlikely to be effected by the relatively small carcass counts at the tail ends of the survey period.

Age-Class Estimates

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

$$\widehat{N}_{adult} = \widehat{N} * P_{adult} \,.$$

Individual age class estimates were calculated likewise:

$$\widehat{N}_{x} = \widehat{N} * P_{x} \,,$$

where *x* is age class 2, 3, 4, or 5.

Hatchery Contribution

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. A proportion, varying with release group, of the juvenile Chinook Salmon produced at the hatchery are injected with a coded-wire tag (CWT) and ad-clipped. CWT codes are linked to the hatchery of origin, race, release type, and brood year of the individual fish. All F_1- and D_2-condition carcasses captured were examined for ad-clips. Only F_1- and D_2-condition carcasses were included in this analysis to avoid the misidentification of ad-clips in non-fresh carcasses (Mohr and Satterthwaite 2013). The snouts of ad-clipped carcasses were removed and frozen in individual bags. CWTs were later removed from recovered snouts and read by AFWO and CDFW personnel.

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). The number of CWT fish for each code was estimated by multiplying the number of CWTs recovered by a sample expansion factor (ϵ) for the season 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):

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

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. Those carcasses observed when systematic sampling was implemented were expanded by the sampling rate [e.g., under a 1:3 systematic sampling rate each sampled carcass represents three carcasses with its attributes (i.e., ad-clip, CWT number, etc.)].

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 (PSMFC 2016):

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

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) was estimated by summing estimated contributions attributable to a specific CWT code ($H_{code(i)}$):

$$\widehat{N}_H = \sum \widehat{H}_{code(i)} = \sum \left(AD_{code(i)} * \epsilon * PM_{code(i)}\right),$$

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

Egg Deposition

Total egg deposition (N_e) in the study area was estimated by multiplying predicted egg production (n_e) by the estimate of adult females ($\widehat{N}_{adult}$). 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. We used annual average egg production (n_e = 3,401 in 2013, 3,349 in 2014, and 2,749 in 2015) per female at IGH as a surrogate for mainstem spawning female Chinook Salmon (Pomeroy 2015). Escapement estimates of fully spawned females (F_{fs}) multiplied by n_e were added to escapement estimates of partially spawned females (F_{ps}) multiplied by one-half of n_e to yield total egg deposition in the study area:

$$\widehat{N}_e = \left(n_e * \widehat{F}_{fs}\right) + \left(\frac{1}{2} * n_e * \widehat{F}_{ps}\right).$$

Results and Discussion

Temporal and Spatial Distribution of Carcasses

A total of 1,188 F_1- and D_2-condition carcasses were counted during the 2013 surveys, of which 1,084 were marked with uniquely numbered jaw tags (Table 2). The peak of new carcass observations, which typically occurs in calendar weeks 44–46, occurred in calendar week 44. Carcass density was highest in the uppermost reach of the survey area and declined steadily downstream of Reach 4 (Figure 3).

Table 2. Number of F_1- and D_2-condition fall Chinook Salmon carcasses captured by calendar week, Klamath River surveys, 2001–2015. Annual peak counts are in bold font. Dashes (-) indicate no survey conducted.

	Calendar week										
Year	41	42	43	44	45	46	47	48	49	50	Total
2001	-	50	165	310	**336**	251	-	16	-	-	1,128
2002	-	39	251	**1,032**	655	348	40	2	-	-	2,367
2003	-	23	91	583	**740**	181	49	4	-	-	1,671
2004	-	-	237	**292**	260	93	20	2	-	-	904
2005	3	30	87	**182**	70	10	1	-	-	-	383
2006	14	36	169	**203**	94	34	1	-	-	-	551
2007	7	27	41	145	241	**385**	216	142	26	9	1,239
2008	-	40	103	335	**345**	173	35	7	-	-	1,038
2009	-	14	64	267	**386**	280	89	45	2	-	1,147
2010	-	8	15	50	149	**156**	69	14	1	-	462
2011	-	17	45	107	200	**262**	111	18	1	-	761
2012	31	49	159	418	**526**	238	63	7	-	-	1,491
2013	8	8	149	**514**	283	154	50	19	3	-	1,188
2014	5	24	173	715	**898**	566	124	46	4	-	2,555
2015	5	16	70	**203**	133	99	39	14	1	-	580

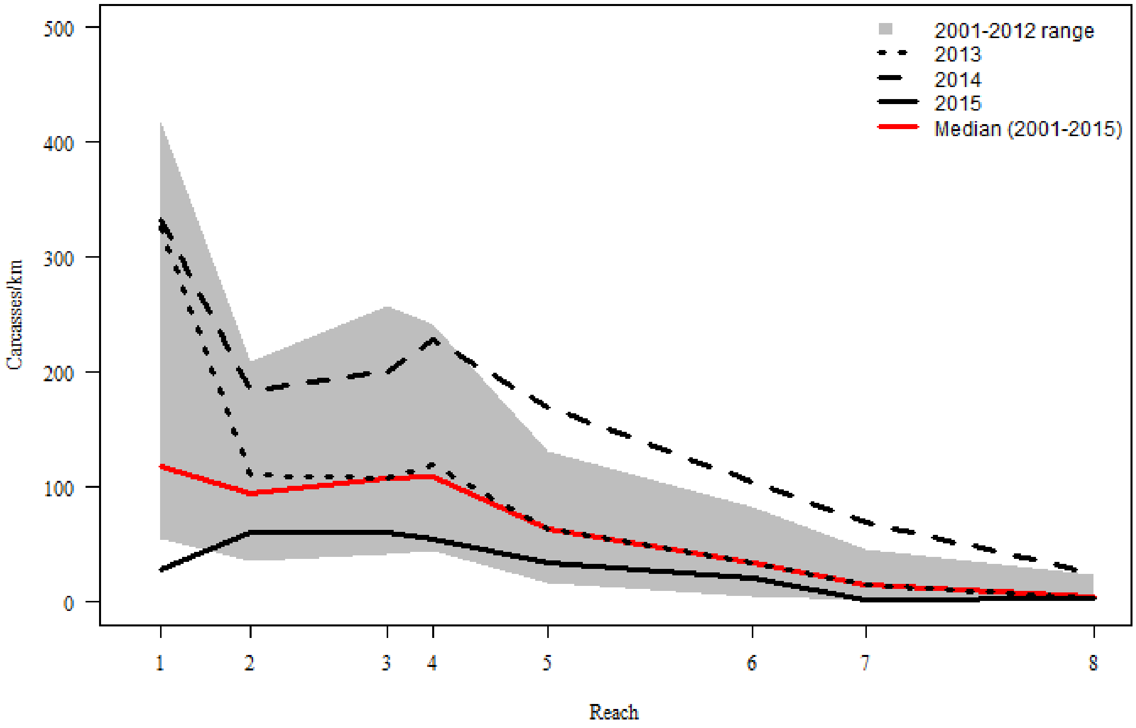

Figure 3. Fall Chinook Salmon carcass density (F1- and D2-condition only) by reach, Klamath River surveys, 2001–2015. Reach 1 was not surveyed from 2002 to 2005.

A total of 2,555 F1- and D2-condition carcasses were counted during the 2014 surveys, of which 2,070 were marked with uniquely numbered jaw tags (Table 2). The peak of new carcass observations occurred in calendar week 45. Carcass density was also highest in the uppermost reach of the survey area and declined steadily downstream of Reach 4 (Figure 3).

A total of 580 F1- and D2-condition carcasses were counted during the 2015 surveys, of which 540 were marked with uniquely numbered jaw tags (Table 2). The peak of new carcass observations occurred in calendar week 44. Carcass density was highest in Reach 2 and from there declined steadily downstream (Figure 3).

Length Distribution

The 2013 jack–adult size cut-off (57 cm FL) was determined after the sampling season by the KRTT (2014; Table 3; Appendix A). Of the 69 fish less than or equal to 57 cm FL, only one was female. Mean fork lengths of adult females, adult males, and jacks were 75.1, 81.4, and 51.4 cm, respectively.

The 2014 jack–adult size cut-off (60 cm FL) was determined after the sampling season by the KRTT (2015; Table 3; Appendix A). Of the 162 fish less than or equal to 60 cm FL, eight were female. Mean fork lengths of adult females, adult males, and jacks were 75.8, 83.1, and 54.1 cm, respectively.

The 2015 jack–adult size cut-off (54 cm FL) was determined after the sampling season by the KRTT (2016; Table 3; Appendix A). Of the 15 fish less than or equal to54 cm FL, only one was female. Mean fork lengths of adult females, adult males, and jacks were 71.3, 80.6, and 49.8 cm, respectively.

Table 3. Mean fork lengths by year of fall Chinook Salmon carcasses, Klamath River surveys, 2001–2015.

	Jack–adult	Adult females			Adult males			Jacks		
	FL (cm) cut-off		FL (cm)			FL (cm)			FL (cm)	
Year	(jacks ≤)	n	mean	s.d.	n	mean	s.d.	n	mean	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
2012	58	737	71.0	4.9	459	78.0	8.0	119	51.7	4.4
2013	57	725	75.1	6.7	387	81.4	9.9	69	51.4	4.3
2014	60	1,187	75.8	6.3	812	83.1	9.9	162	54.1	4.7
2015	54	352	71.3	6.0	207	80.6	9.2	15	49.8	3.7

Adult Female–Male Ratio

The percentage of females among handled adult carcasses was 65.1% (adult female–male ratio = 1.9:1) in 2013, 61.0% (1.6:1) in 2014, and 63.0% (1.7:1) in 2015 (Figure 4). The percentage of females ranged from 51.8% (adult female–male ratio = 1.1:1) to 72.9% (2.7:1) from 2001 to 2012. These ratios likely underestimate the proportion of males that spawned in the survey area. Female salmon tend to reside on their redds longer than males (Neilson and Geen 1981). Therefore, males were more likely to mobilize and leave the survey area after spawning. Though we were unable to measure how many males may have left the study area before dying, the mobilization of males is supported by our observed decrease in the female–male ratio moving downstream within the study area (Appendix B). Adult females were more abundant than males in Reaches 1–5, while males were generally more abundant in Reaches 6–8. Compared to adult Chinook Salmon annually returning to IGH, between 4.4 and 11.9% more females were observed among mainstem carcasses from 2013 to 2015 (Appendix C).

Pre-spawn Mortality

Annual pre-spawn mortality was 4.0, 10.3, and 6.3% in 2013, 2014, and 2015, respectively (Figure 5). Fully spawned individuals made up 92.2, 84.0, and 92.3% of F_1- and D_2-condition female adult carcasses. Pre-spawn mortality in previous years' surveys ranged from 1.0% (in 2009) to 22.1% (in 2005) with a mean of 9.0%. Consistent with the trend observed in previous years, pre-spawn mortality was generally highest at the beginning of the surveys and decreased as the season progressed (Figure 6; Appendix D). We only used natural pre-spawn mortality in this analysis. The survey crews also noted five F_1- and D_2-condition roe-stripped females in 2013 and one each in 2014 and 2015, presumably by fishermen, that we did not include in the evaluation of spawning success since their opportunity to spawn was prevented.

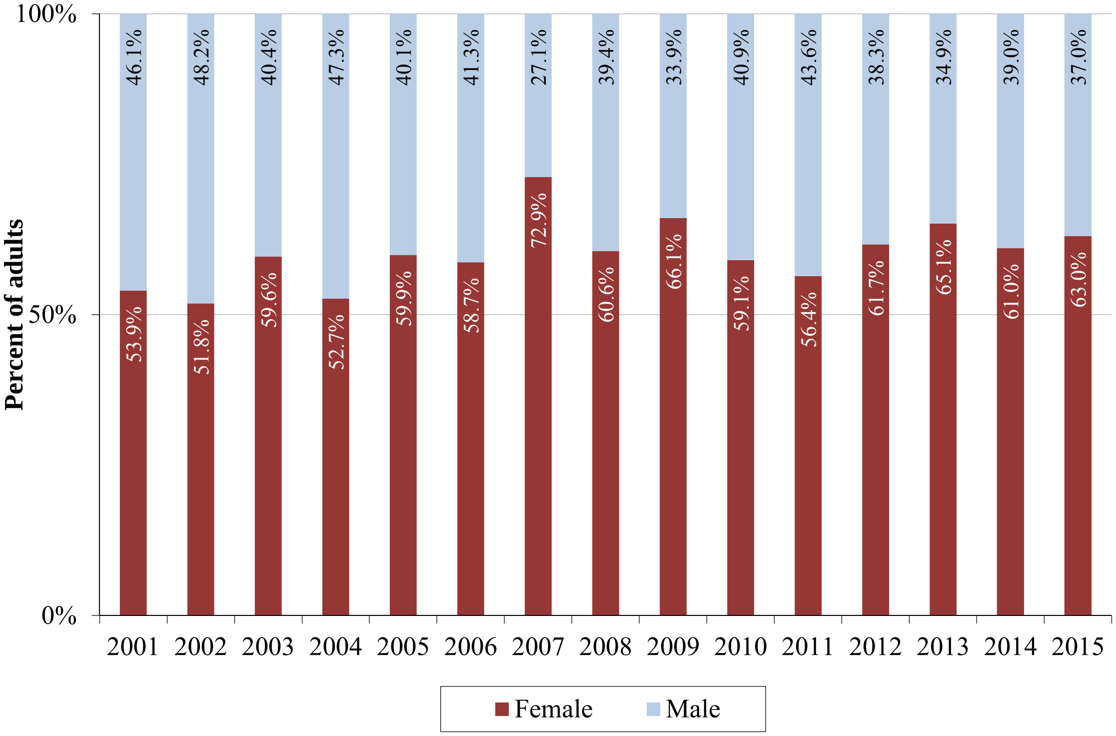

Figure 4. Female and male proportions of adult fall Chinook Salmon carcasses, Klamath River surveys, 2001–2015.

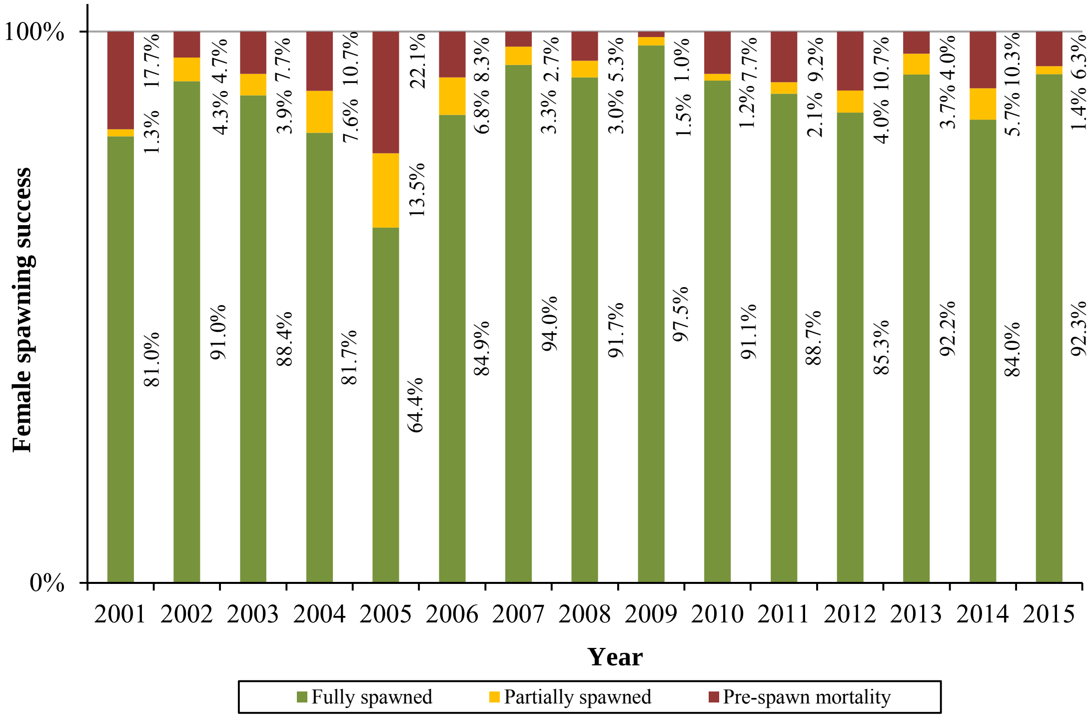

Figure 5. Spawning success of female fall Chinook Salmon based on F_1- and D_2-condition carcasses, Klamath River surveys, 2001–2015.

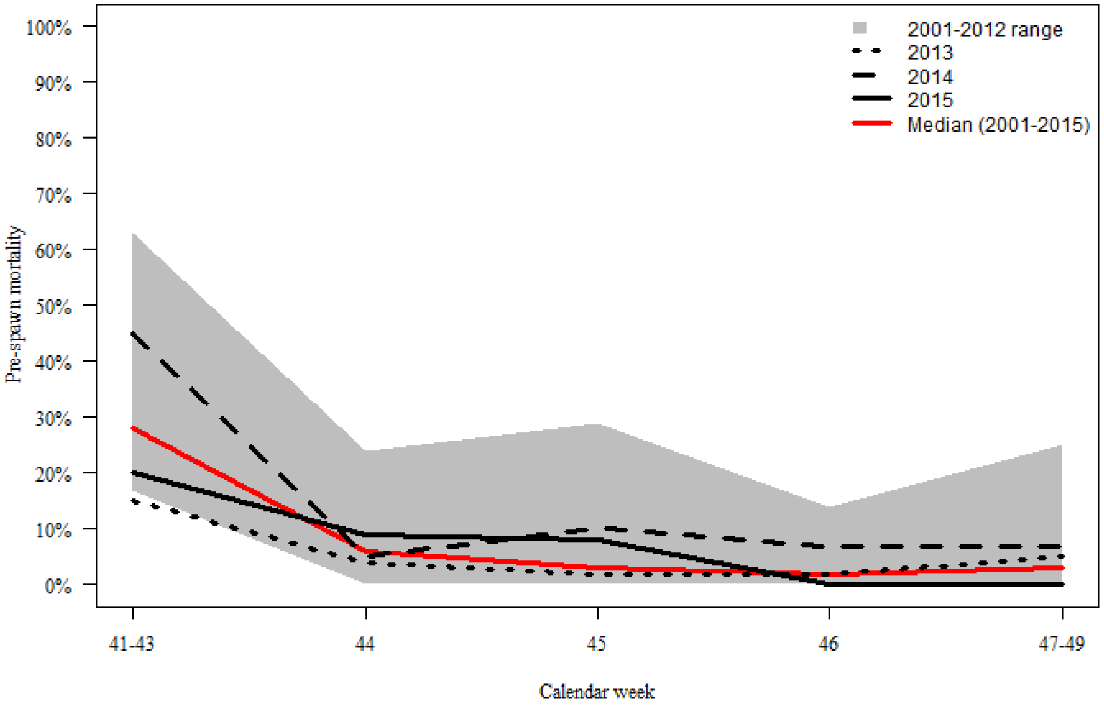

Figure 6. Weekly pre-spawn mortality from F1-condition female fall Chinook Salmon carcasses, Klamath River surveys, 2001–2015. Calendar weeks 41–43 and 47–50 were combined since sample sizes were typically low in calendar weeks 41, 42, 48, 49, and 50, if surveyed.

Escapement Estimates and Age Composition

The mainstem spawning escapement estimate in this study area for 2013 was 7,358 fish (95% CI: 5,902–21,161; Table 4). The estimated weekly recapture rates ranged from 0.21 to 0.53. The estimated carcass survey life was 2.9 weeks (95% CI: 1.2–3.9).

In 2014 the mainstem spawning escapement estimate in this study area was 16,720 fish (95% CI: 13,676–23,021), the highest estimate over the 15-year history of this survey (Table 4). The estimated weekly recapture rates ranged from 0.04 to 0.51. The estimated carcass survey life was 3.0 weeks (95% CI: 2.4–3.6).

In 2015 the mainstem spawning escapement estimate in this study area was 2,507 fish (95% CI: 1,883–3,305), the lowest estimated over the 15-year history of this survey (Table 4). The estimated weekly recapture rates ranged from 0.21 to 0.33. The estimated carcass survey life was 2.7 weeks (95% CI: 2.4–3.7).

After four years of AUC implementation, the behavior of the estimates warrants some discussion. Most obvious, is the general pattern of very diffuse estimates (i.e., large confidence interval widths). The AUC estimator relies on estimates of carcass survey life, and as a divisor in the AUC's equation, even moderate variance in this estimate propagates to larger variances in the carcass estimates. This was especially evident for the upper confidence limit of the 2013 estimate. The variance of the AUC estimates is also influenced by precision in weekly-stratified mark-recapture estimates of carcass capture probabilities. A common phenomenon in these carcass survey data is relatively sparse information for

Table 4. Fall Chinook Salmon escapement estimates, Klamath River surveys, 2001 to 2015.

Year	Escapement estimate	95% confidence limits		Estimator
		Lower	Upper	
2001	7,828	7,253	8,403	Petersen
2002	14,394	13,934	14,855	Petersen
2003	12,958	12,274	13,642	Petersen
2004	4,715	4,469	4,960	Petersen
2005	4,585	3,860	5,309	Petersen
2006	3,587	3,296	3,879	Petersen
2007	5,523	5,273	5,774	Petersen
2008	4,894	4,649	5,140	Petersen
2009	4,427	4,238	4,615	Petersen
2010	2,572	2,362	2,782	Petersen
2011	4,880	4,551	5,209	Petersen
2012	12,626	9,592	16,721	AUC
2013	7,358	5,902	21,161	AUC
2014	16,720	13,676	23,021	AUC
2015	2,507	1,883	3,305	AUC

estimating capture probabilities during the first few weeks of the survey season. Accordingly, imprecise estimates of early-season capture probabilities also contribute to the diffuse nature of the carcass estimates. Early season capture probabilities were particularly low in 2014 due to elevated flows affecting the first two survey weeks (Figure 7). With an aim to provide more precise carcass estimates, alternative estimators that do not rely on estimates of carcass survey life are being investigated, as well as alternative survey methodologies for estimating early-season carcass capture probabilities.

We assumed that males leaving the survey area after spawning (see Adult Female–Male Ratio section) did not significantly bias the escapement estimates. In 2013, 2014, and 2015, the majority (95.1, 87.5, and 95.7%, respectively) of carcasses were found in the first six survey reaches, indicating that most spawning activity occurred in the upper 13.3 km of the 21.2-km study area. Few, if any, of those male fish likely migrated or drifted downstream more than 7.9 km after spawning to leave the study area. Of the few males that spawned in the two downstream-most reaches, any that left the study area after spawning should have only minimally affected the escapement estimate.

Secchi depths ranged from 2.3 to 3.0 m in 2013, 1.5 to 2.7 m in 2014, and 2.1 to 4.3 m in 2015. The lowest visibility measurements in 2014 were only in survey weeks 7 (1.8 m) and 9 (1.5 m). We believe these ranges in visibility had only minimal influence on observation efficiency. With the exception of the first two surveys in 2014, steady flows contributed to consistent observation efficiency throughout each season. Flows below IGD were about 1,000 cfs throughout most of the survey seasons (Figure 7). In 2014, flows were about 1,700 cfs when the survey began and dropped to about 1,000 cfs on October 16.

Eight hundred twelve scale samples were collected from carcasses and analyzed in 2013 to estimate the age composition of the mainstem spawning escapement. Based on age-composition estimates (KRTT 2014) and the total escapement estimate, jacks represented 5.3% ($\widehat{N}_{jacks}$ = 393) of the total escapement and the majority of the adult component was made up of age-4 fish (Table 5). The proportion of fish designated as jacks by the fork length cut-off was 0.5% higher than that determined by scale aging.

Six hundred seventy-three scale samples were collected from carcasses and analyzed in 2014 to estimate the age composition of the mainstem spawning escapement. Based on age-composition estimates (KRTT 2015) and the total escapement estimate, jacks represented 7.6% ($\widehat{N}_{jacks}$ = 1,271) of the total escapement and the majority of the adult component was made up of age-4 fish (Table 5). The proportion of fish designated as jacks by the fork length cut-off was 0.1% lower than that determined by scale aging.

Five hundred seventeen scale samples were collected from carcasses and analyzed in 2015 to estimate the age composition of the mainstem spawning escapement. Based on age-composition estimates (KRTT 2016) and the total escapement estimate, jacks represented 3.4% ($\widehat{N}_{jacks}$ = 85) of the total escapement and the majority of the adult component was made up of age-4 fish (Table 5). The proportion of fish designated as jacks by the fork length cut-off was 0.8% lower than that determined by scale aging.

Adult Chinook Salmon spawners in the mainstem Klamath River between IGD and the Shasta River confluence accounted for 32.7–69.1% of natural-area adult spawners in the mainstem Klamath River above Indian Creek, 10.4–22.0% of natural adult spawners in the

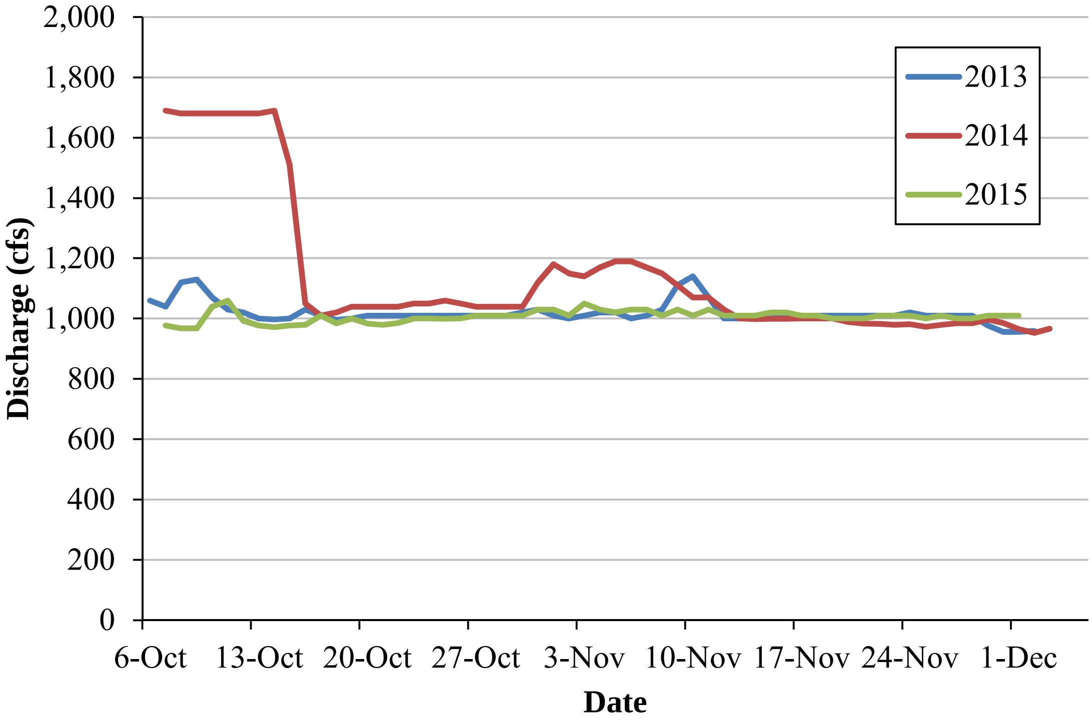

Figure 7. Mean daily discharge below Iron Gate Dam (USGS Gage 11516530) on the mainstem Klamath River during the 2013, 2014, and 2015 Chinook Salmon carcass surveys.

Table 5. Fall Chinook Salmon spawning escapement estimates (and percent of total run) for each age class, Klamath River surveys, 2001–2015 Note: Adults are ages 3–5.

	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 (0.1%)	2,651
2012	1,186 (9.4%)	10,382 (82.2%)	1,058 (8.4%)	0 (0.0%)	11,440
2013	393 (5.3%)	2,951 (40.1%)	4,015 (54.6%)	0 (0.0%)	6,965
2014	1,271 (7.6%)	6,477 (38.7%)	8,862 (53.0%)	110 (0.7%)	15,449
2015	85 (3.4%)	1,036 (41.3%)	1,264 (50.4%)	122 (4.9%)	2,422

[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

Klamath River Basin above the Trinity River, and 8.6–16.2% of natural adult spawners in the entire Klamath River Basin from 2013 to 2015 (Table 6). The proportion of adult spawners in the IGD–Shasta survey area relative to natural-area spawners above Indian Creek and the Trinity River in 2015 were the lowest in the 15-year history of these surveys. In the entire Klamath River Basin, fall Chinook Salmon adult spawners in the mainstem Klamath River between IGD and the Shasta River confluence accounted for 6.2–12.2% of total adult escapement (hatchery and natural spawners) and 3.1–9.6% of the total adult in-river run (hatchery and natural spawners plus in-river harvest) in 2013–2015. The proportion of natural spawners in the IGD–Shasta study area has trended downward over the 15-year history of these surveys at all these scales, but only significantly above Indian Creek ($p = 0.004$) and above the Trinity River ($p = 0.04$; Appendix E).

Hatchery Fish Contribution

From the 100 F_1- and D_2-condition ad-clipped carcasses encountered in 2013, 97 snouts were collected and 86 CWTs were recovered and decoded (Appendix F). Production multipliers from recovered CWTs ranged from 4.01 (24.9% tag rate; codes 068711, 068714, and 068716 from Brood Year 2009) to 12.17 (8.2% tag rate; code 068795 from Brood Year 2010).

Table 6. Proportions of fall Chinook Salmon adult spawners in the mainstem Klamath River from IGD to the Shasta River confluence within different scales of the Klamath River Basin, 2001–2015. Data compiled from KRTAT (2003–2004), KRTAT (2005–2009), and KRTT (2010–2016).

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%	21.2%	10.0%	6.1%	4.9%
2007	79.3%	25.6%	9.0%	5.7%	4.1%
2008	69.3%	21.3%	13.1%	9.1%	5.7%
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%	15.6%	5.8%	3.9%	2.6%
2012	62.8%	15.7%	9.4%	6.4%	3.9%
2013	57.2%	22.0%	11.8%	9.1%	4.2%
2014	69.1%	21.8%	16.2%	12.2%	9.6%
2015	32.7%	10.4%	8.6%	6.2%	3.1%

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

From the 111 F_1- and D_2-condition ad-clipped carcasses encountered in 2014, 107 snouts were collected, 101 CWTs were recovered, and 100 CWTs were decoded (Appendix F). Production multipliers from recovered CWTs ranged from 4.00 (25.0% tag rate; codes 060379 and 060422 from Brood Year 2011 and 068796 and 068797 from Brood Year 2012) to 12.17 (8.2% tag rate; code 068795 from Brood Year 2010).

From the 40 F_1- and D_2-condition ad-clipped carcasses encountered in 2015, 37 snouts were collected, 35 CWTs were recovered, and 32 CWTs were decoded (Appendix F). Production multipliers from recovered CWTs ranged from 4.00 (25.0% tag rate; codes 060379, 060421, and 060422 from Brood Year 2011 and 068796 and 068797 from Brood Year 2012) to 4.17 (24.0% tag rate; code 068793 from Brood Year 2010).

The estimated proportion of hatchery-origin spawners in the study area was 31.7% (n = 2,329) in 2013, 24.5% (n = 4,096) in 2014, and 26.2% (n = 657) in 2015 (Table 7). The estimated proportions of hatchery-origin spawners ranged from 1.2% to 14.2% between 2001 and 2004 and from 22.7% to 48.1% between 2005 and 2012.

Consistent with previous years, the reach-wise proportions of hatchery-origin Chinook Salmon in 2013, 2014, and 2015 were highest in Reach 1 (59.4, 46.0, and 87.7%, respectively; Figure 8). We expect annual in-river spawning by hatchery-origin fish to be concentrated in the uppermost reach due to its immediate proximity to IGH. As also exhibited in previous years, the proportion of hatchery-origin spawners gradually trended downward from Reach 2 to Reach 8, ranging between 0.0% and 45.4%.

Table 7. Hatchery composition of fall Chinook Salmon spawning escapement in the mainstem Klamath River from IGD to the Shasta River confluence, based on carcass surveys, 2001–2015. Note: Data only from F_1- and D_2-condition carcasses were used. See Appendix F for an explanation of the different methods used in estimating annual hatchery composition.

Year	Estimated hatchery-origin proportion	Escapement estimate	
		Total	Hatchery-origin
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	1,222
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	1,995
2012	45.3%	12,626	5,726
2013	31.7%	7,358	2,329
2014	24.5%	16,720	4,096
2015	26.2%	2,507	657
2016	28.1%	746	210

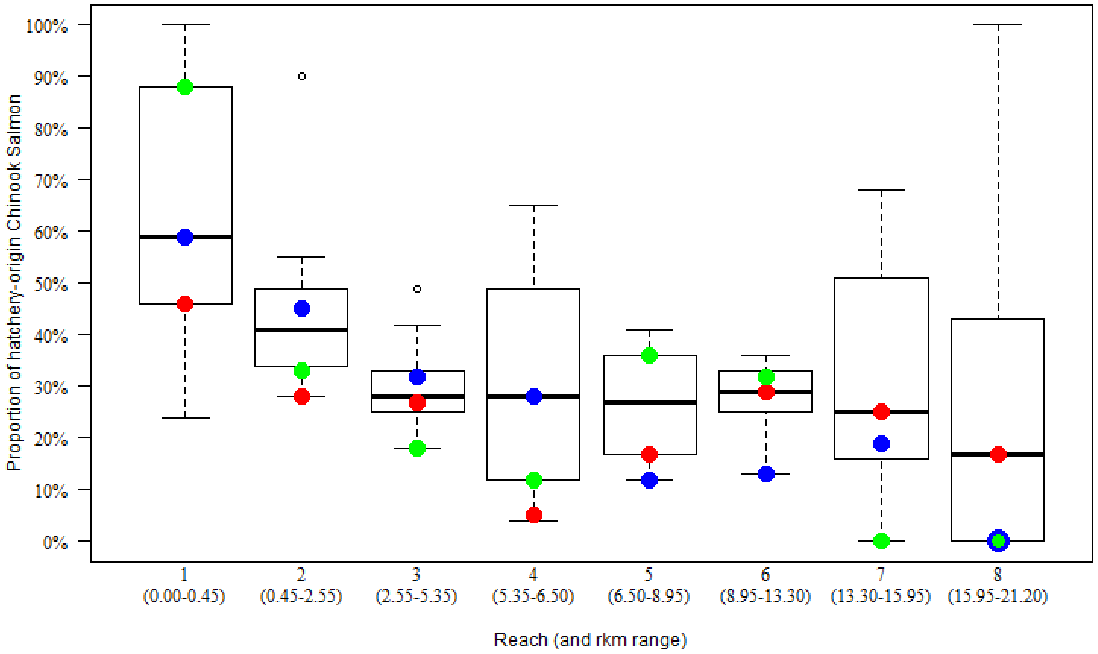

Figure 8. Box plot of proportions of hatchery-origin Chinook Salmon carcasses by reach, Klamath River surveys, 2007–2015. Data from 2013 are represented with blue circles, 2014 with red, and 2015 with green.

Egg Deposition

Egg deposition in the study area was estimated to be 14.5 million from 4,348 female Chinook Salmon in 2013, 27.5 million from 8,463 females in 2014, and 3.9 million from 1,430 females in 2015 (Table 8). Egg deposition in 2014 and 2015 were the highest and lowest (tied with 2010), respectively, in the 15-year history of these surveys. 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).

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Table 8. Egg deposition (N_e) by fall Chinook Salmon in the Klamath River from IGD to the Shasta River confluence, 2001–2015. F_{fs} and F_{ps} are escapement of fully and partially spawned females and n_e is the mean number of eggs produced per female at IGH. Data from 2001 to 2011 does not match what was reported in Gough and Williamson (2012) and Gough (2014). Annual female egg production as measured at IGH were used in this table whereas the mean egg production by adult female Chinook Salmon in the Klamath River (n_e = 3,634) as determined by Allen and Hassler (1986) was used in the mentioned reports. As a result egg deposition estimates below range from 22% lower to 4% higher than what was previously reported.

Year	$\hat{F}_{fs}$	$\hat{F}_{ps}$	n_e	$\hat{N}_e$
2001	3,100	49	3,776	11,800,000
2002	6,589	310	3,656	24,700,000
2003	6,718	296	3,333	23,000,000
2004	1,948	181	3,572	7,300,000
2005	1,767	371	2,890	5,600,000
2006	1,506	120	3,080	4,800,000
2007	3,732	131	2,834	10,800,000
2008	2,255	74	3,513	8,100,000
2009	2,743	42	3,030	8,400,000
2010	1,291	17	3,024	3,900,000
2011	1,326	31	3,550	4,800,000
2012	6,206	291	3,402	21,600,000
2013	4,181	168	3,401	14,500,000
2014	7,935	528	3,349	27,500,000
2015	1,408	21	2,749	3,900,000

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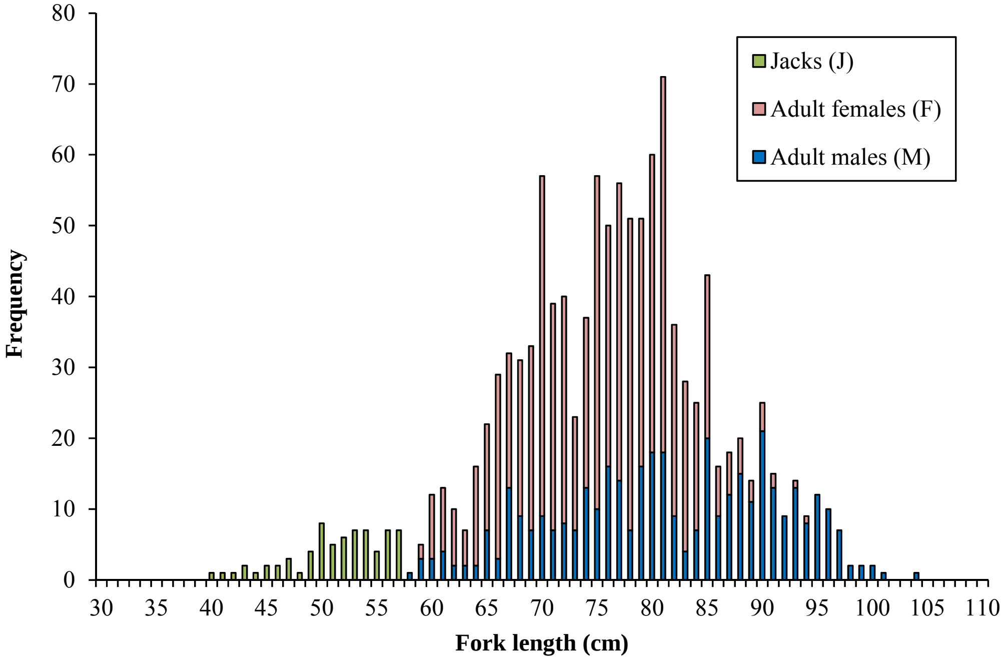
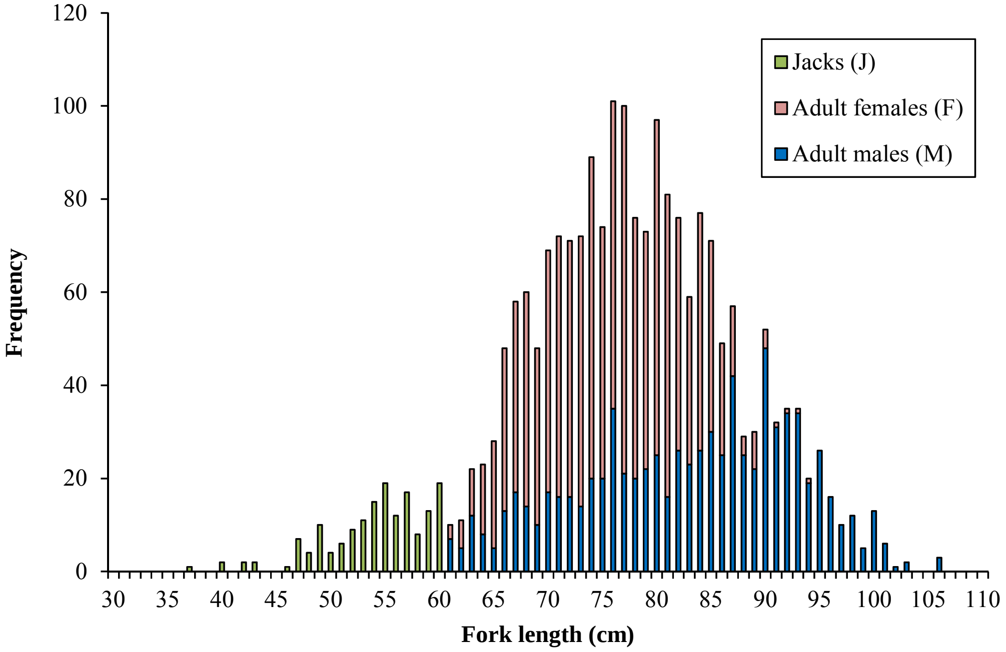
Appendices

Appendix A. Length-frequency of F1- and D2-condition fall Chinook Salmon carcasses, Klamath River surveys, 2013, 2014, and 2015.

2013 [n = 1,181 (n_F = 725; n_M = 387; n_J = 69)]

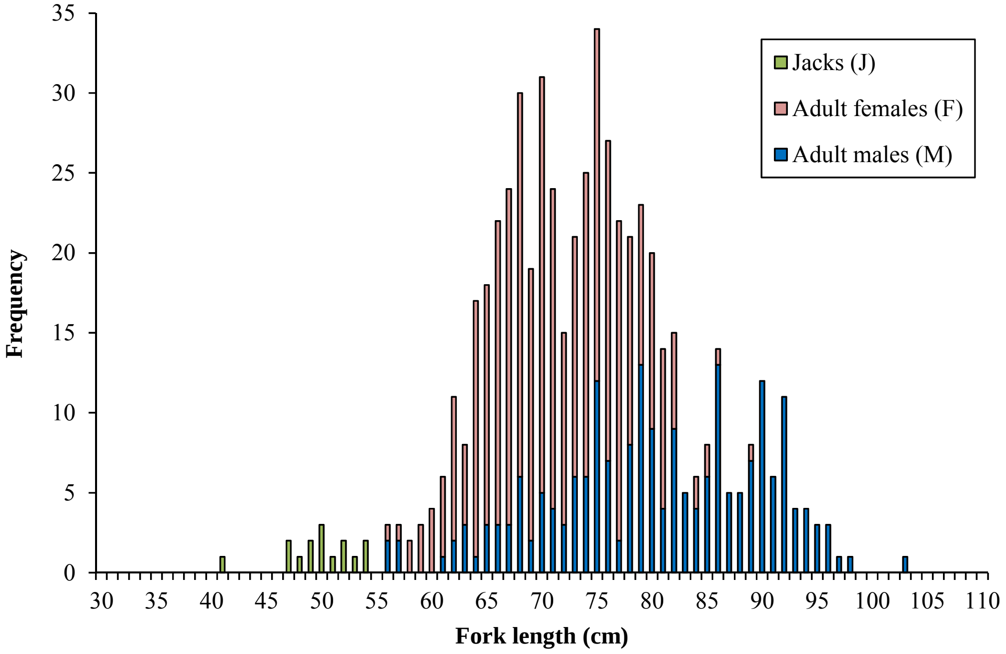


2014 [n = 2,161 (n_F = 1,187; n_M = 812; n_J = 162)]

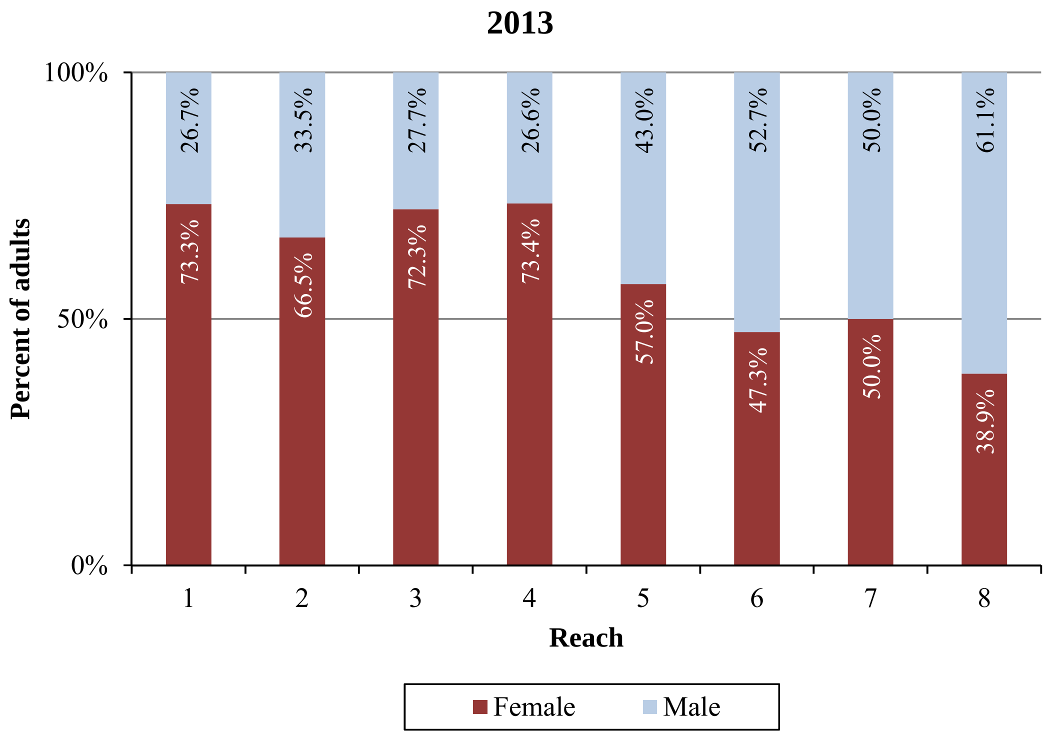


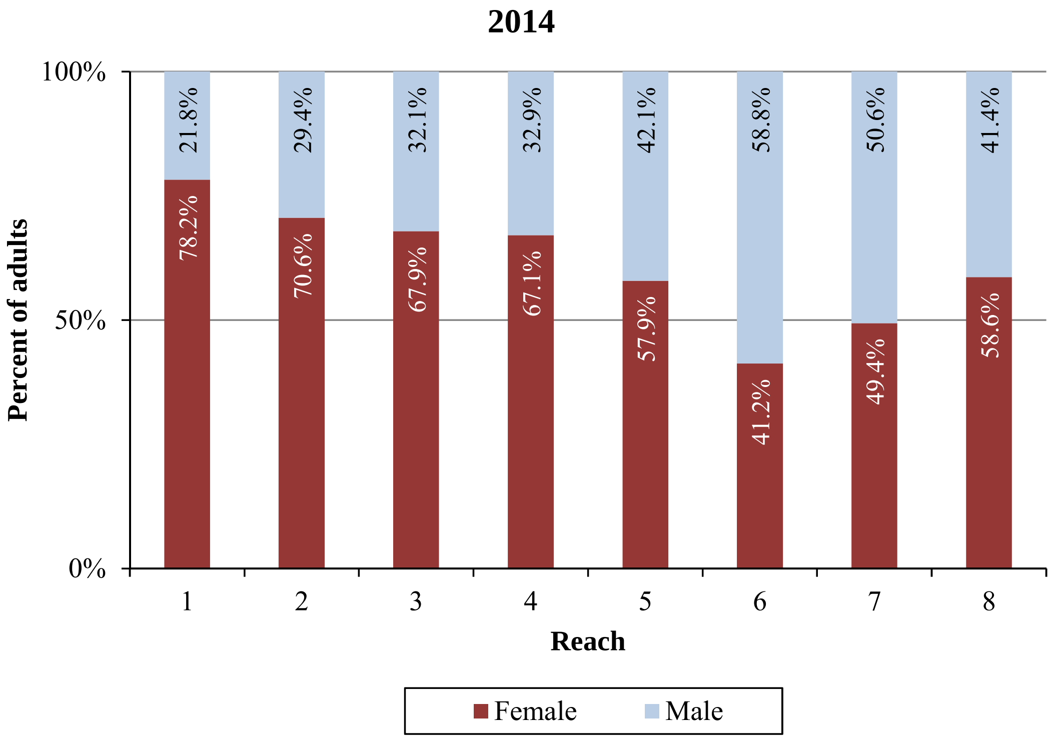
Appendix A (continued). Length-frequency of F_1- and D_2-condition fall Chinook Salmon carcasses, Klamath River surveys, 2013, 2014, and 2015.

2015 [n = 574 (n_F = 352; n_M = 207; n_J = 15)]

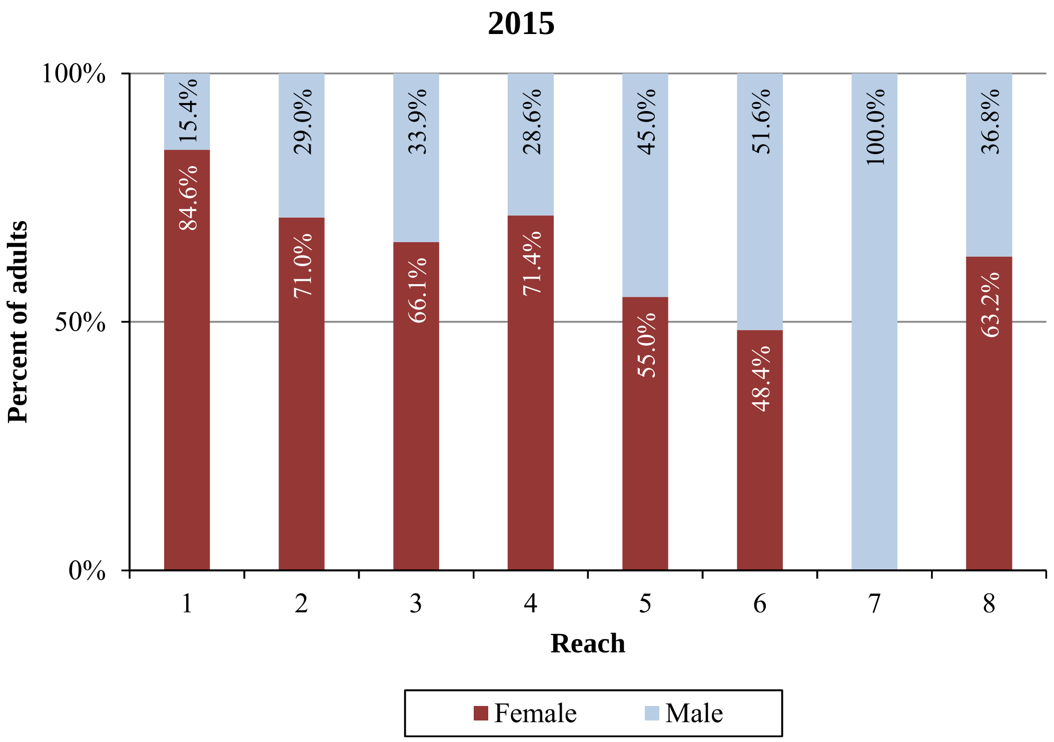


Appendix B. Proportions of adult male and female Chinook Salmon carcasses by reach, Klamath River surveys, 2013, 2014, and 2015.





Appendix B (continued). Proportions of adult male and female Chinook Salmon carcasses by reach, Klamath River surveys, 2013, 2014, and 2015.

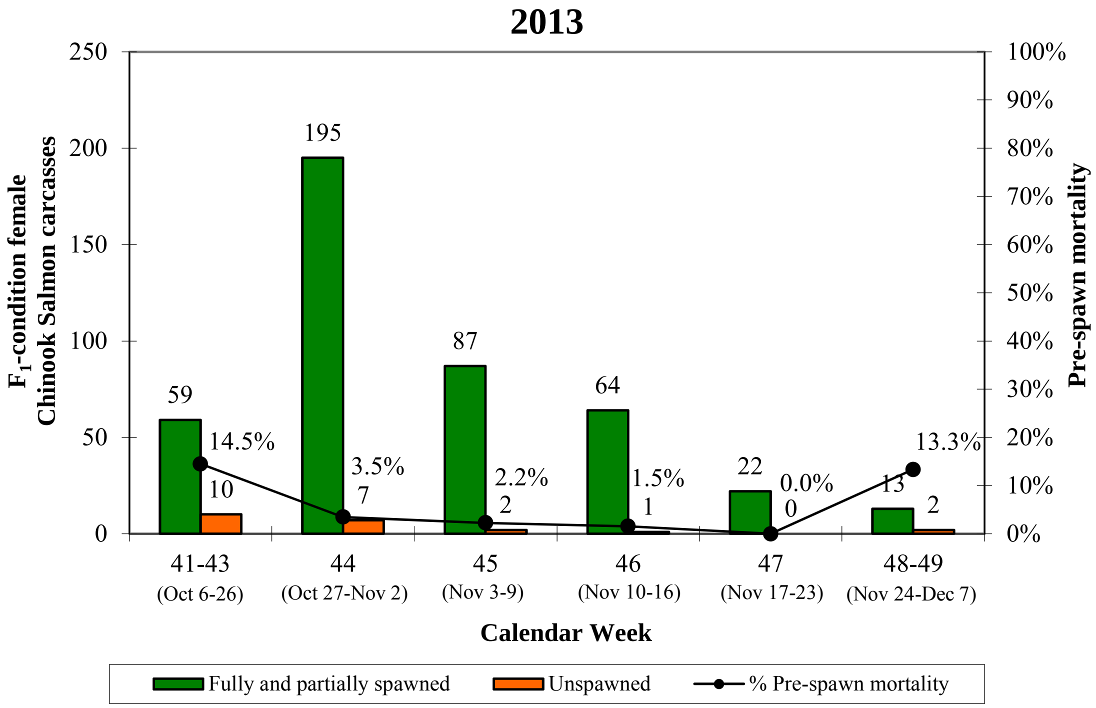


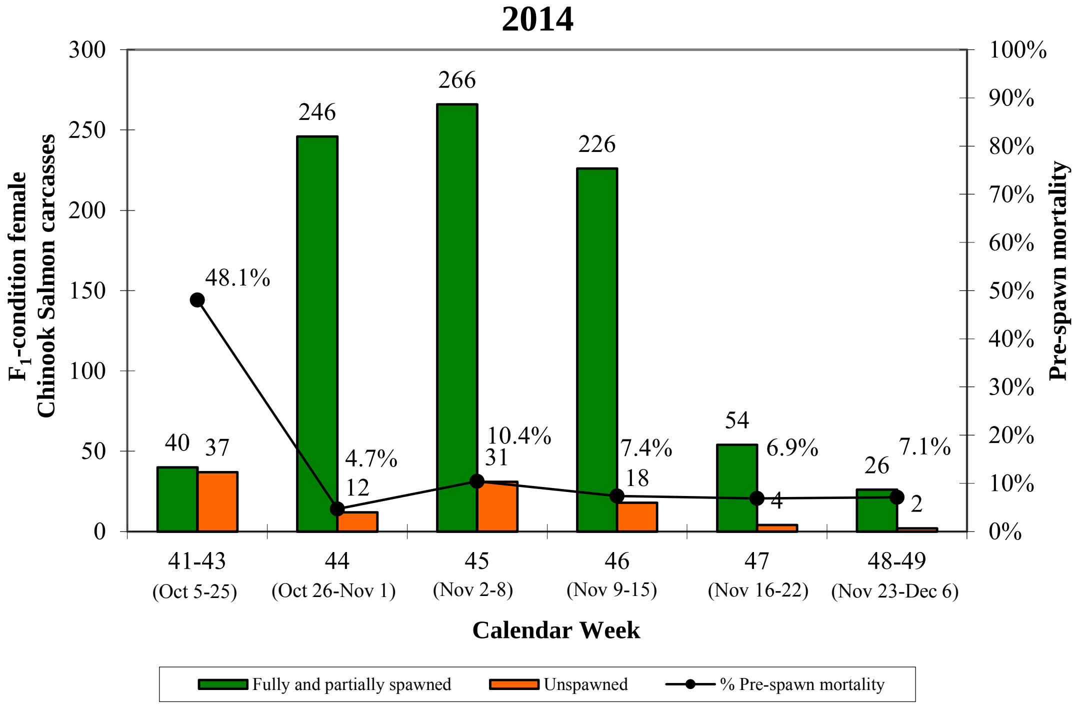
Appendix C. Proportions of female and male Chinook Salmon returning to IGH and the mainstem Klamath River, 2001–2015. IGH adult proportions were determined by first subtracting the jack percentage from the male percentage. Proportions of adult females and males were then recalculated from the remaining adult numbers. IGH data compiled from CDFG (2003), Hampton (2005), Richey (2006, 2007), Chesney (2007–2009), Chesney and Knechtle (2010–2016), and Pomeroy (2015).

	IGH returns					Mainstem carcasses	
	Overall [a]			Adults		Adults	
Year	Female	Male	Jacks	Female	Male	Female	Male
2001	49.1%	50.9%	2.1%	50.1%	49.9%	53.9%	46.1%
2002	48.9%	51.1%	5.2%	51.6%	48.4%	51.8%	48.2%
2003	51.3%	48.7%	0.9%	51.8%	48.2%	59.6%	40.4%
2004	46.0%	54.0%	8.8%	50.4%	49.6%	52.7%	47.3%
2005	50.4%	49.6%	0.3%	50.6%	49.4%	59.9%	40.1%
2006	44.0%	56.0%	16.8%	52.9%	47.1%	58.7%	41.3%
2007	60.9%	39.1%	0.9%	61.5%	38.5%	72.9%	27.1%
2008	42.3%	57.7%	21.5%	53.9%	46.1%	60.6%	39.4%
2009	53.9%	46.1%	8.4%	58.8%	41.2%	66.1%	33.9%
2010	50.2%	49.8%	9.4%	55.4%	44.6%	59.1%	40.9%
2011	26.5%	73.5%	52.9%	56.3%	43.7%	56.4%	43.6%
2012	52.5%	47.5%	3.8%	54.6%	45.4%	61.7%	38.3%
2013	48.5%	51.5%	8.9%	53.2%	46.8%	65.1%	34.9%
2014	49.0%	51.0%	4.1%	51.1%	48.9%	61.0%	39.0%
2015	57.0%	43.0%	2.7%	58.6%	41.4%	63.0%	37.0%

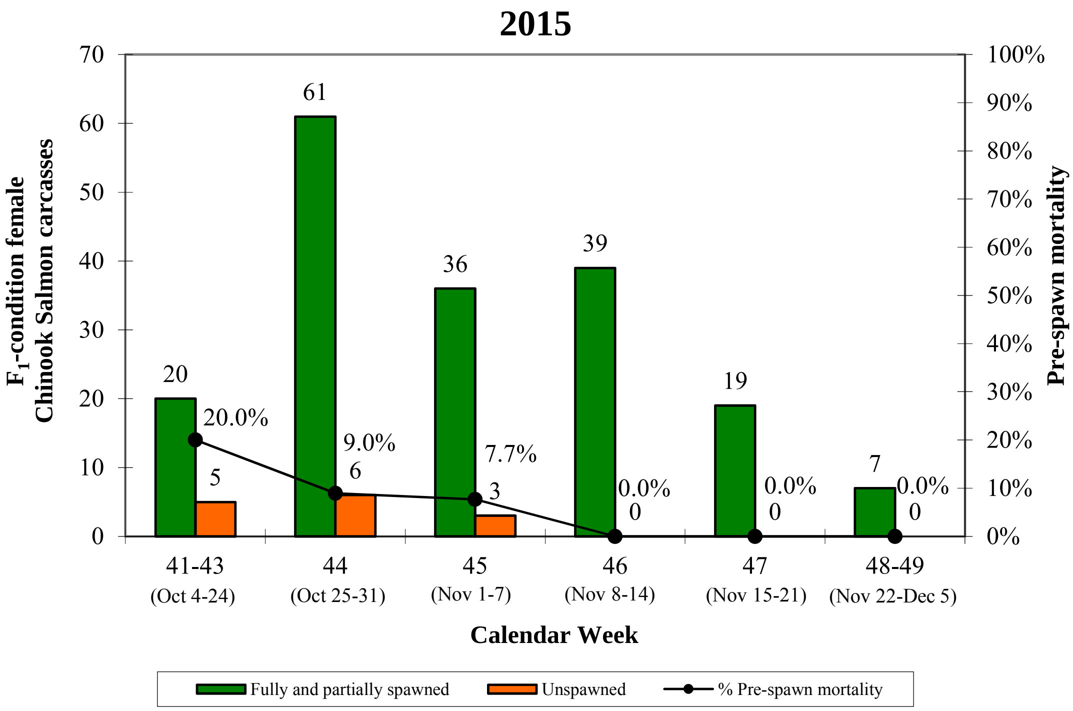
[a] Female and male proportions were calculated prior to distinguishing jacks and therefore total 100%

Appendix D. Weekly pre-spawn mortality from F_1-condition female fall Chinook Salmon carcasses, Klamath River surveys, 2013, 2014, and 2015. Only F_1-condition carcasses were included since we can assume only those fish expired the week they were found. Calendar weeks 41–43 and 48–49 were combined since sample sizes were low.

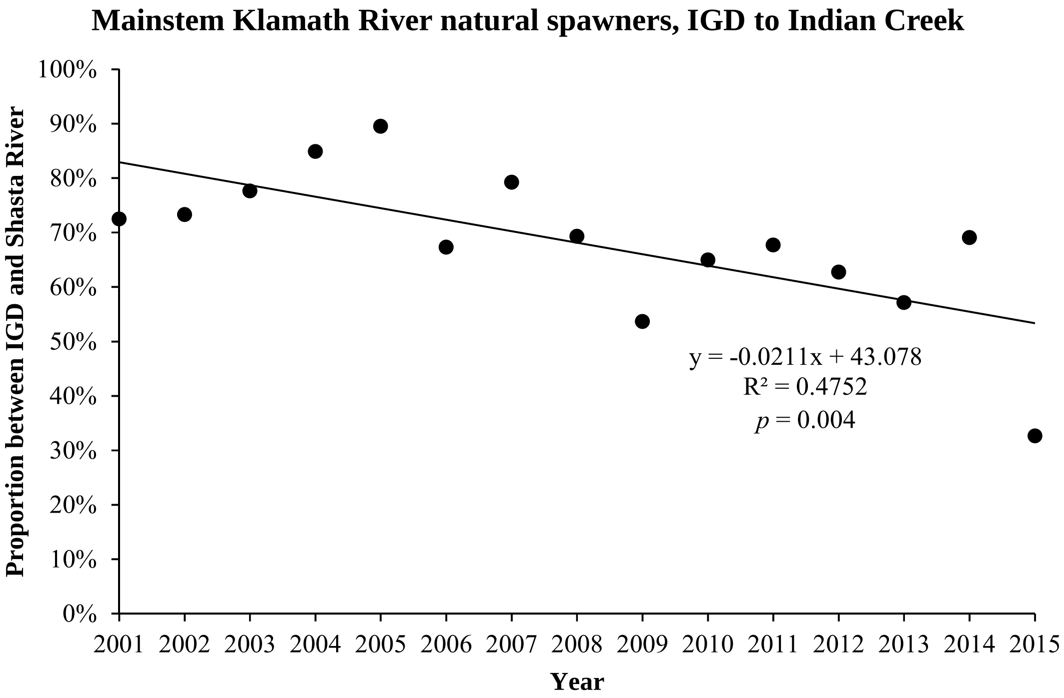


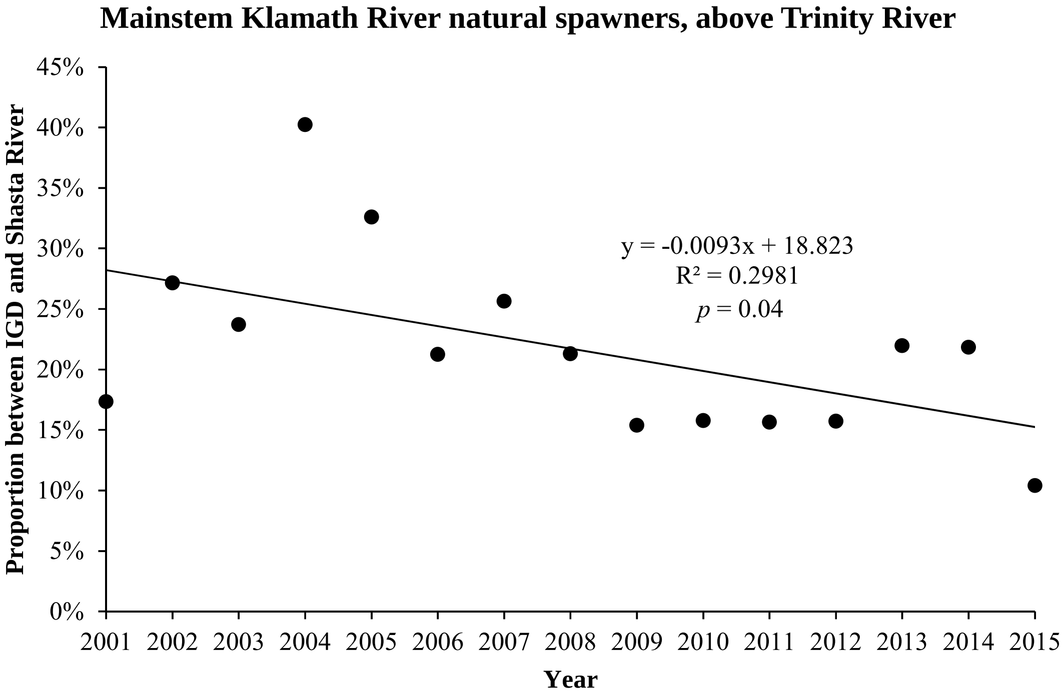


Appendix D (continued). Weekly pre-spawn mortality from F_1-condition female fall Chinook Salmon carcasses, Klamath River surveys, 2013, 2014, and 2015. Only F_1-condition carcasses were included since we can assume only those fish expired the week they were found. Calendar weeks 41–43 and 48–49 were combined since sample sizes were low.



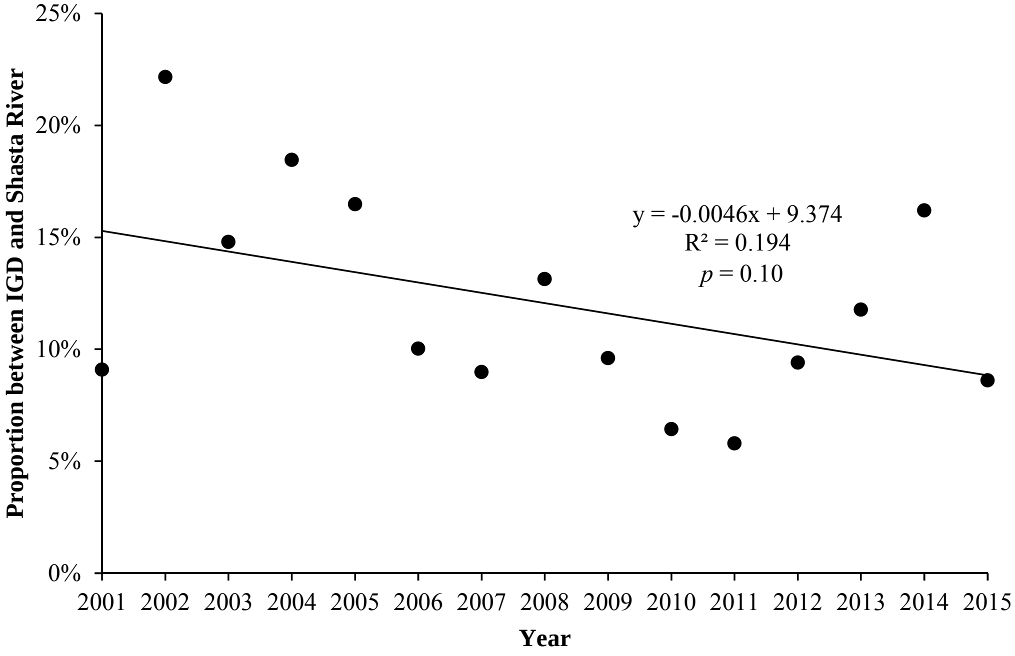
Appendix E. Proportions of fall Chinook Salmon adult spawners in the mainstem Klamath River from Iron Gate Dam to the Shasta River confluence within different scales of the Klamath River Basin, 2001–2015. Data compiled from KRTAT (2003–2004), KRTAT (2005–2009), and KRTT (2010–2016).



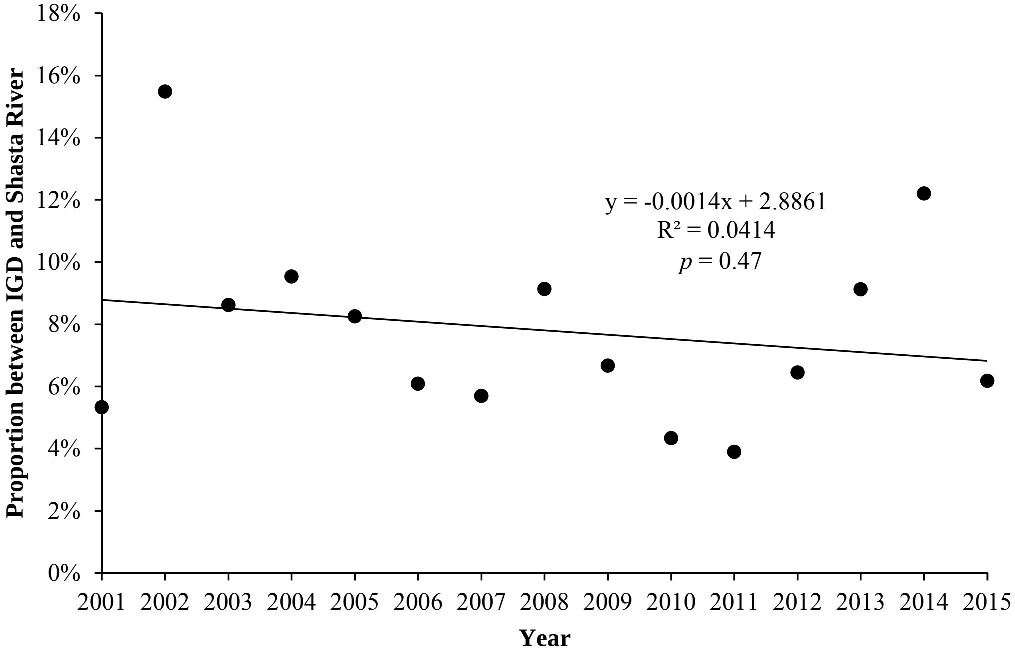


Appendix E (continued). Proportions of fall Chinook Salmon adult spawners in the mainstem Klamath River from Iron Gate Dam to the Shasta River confluence within different scales of the Klamath River Basin, 2001–2015. Data compiled from KRTAT (2003–2004), KRTAT (2005–2009), and KRTT (2010–2016).

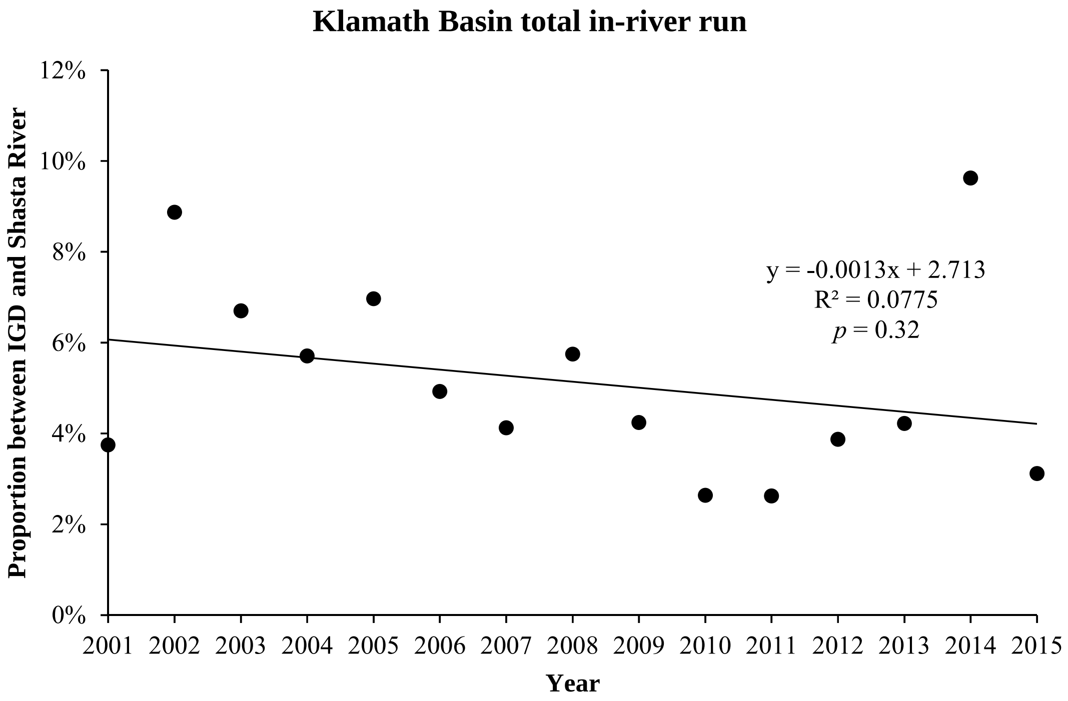
Klamath Basin natural spawners (including Trinity Basin)



Klamath Basin escapement (hatchery and natural)



Appendix E (continued). Proportions of fall 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, 2001–2015. Data compiled from KRTAT (2003–2004), KRTAT (2005–2009), and KRTT (2010–2016).



Appendix F. Hatchery composition of fall Chinook Salmon in the mainstem Klamath River, IGD to the Shasta River confluence, based on carcass surveys from 2001 to 2015. Data from 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 1.0–2.8 times greater (difference: 0.2% lower to 19.5% higher). The adjustment was made for a better comparison with 2011–2015 results. Data from 2011 to 2015 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	Hatchery only
	C	AD_{obs}	$P(AD\|H)_{IGH}$	$\hat{H}$	$\hat{P}(H)$	$\hat{N}$	$\hat{N}_H$
2001	1,125	5	3.76%	133	11.8%	7,828	925
2002	2,343	13	3.98%	333	14.2%	14,394	2,043
2003	1,664	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	1,237	23	4.66%	493	39.8%	5,523	2,201
2008	1,046	24	6.20%	387	37.0%	4,894	1,810
2009	1,153	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	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	1,995
2012 [c]	1,491	140	131	124	122	676	45.3%	12,626	5,726
2013	1,188	100	97	86	86	376	31.7%	7,358	2,329
2014 [c]	2,555	111	107	101	100	626	24.5%	16,720	4,096
2015	580	40	37	35	32	152	26.2%	2,507	657

[c] systematic sampling rates have not yet been applied to ad-clip and CWT values (AD_{obs}, AD_{sample}, AD_{cwt}, and AD_{code})