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Fall-Run Chinook Salmon Run Characteristics and Escapement in the Mainstem Klamath River below Iron Gate Dam, 2020-2023

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Abstract.— Adult fall-run Chinook Salmon *Oncorhynchus tshawytscha* carcasses and redds were surveyed on the mainstem Klamath River, California, from Iron Gate Dam to Wingate Bar during the 2020–2023 spawning seasons to estimate annual escapement and characterize the age and sex composition and spawning success of the run. Annual surveys were conducted over six to eight weeks in October and November. Using postmortem mark–recapture methods and a hierarchical latent variables model between Iron Gate Dam and the confluence with the Shasta River, the estimated spawning escapement for this 21.6-km section of the mainstem Klamath River ranged between 1,225 and 4,211 Chinook Salmon. Based on these estimates and age composition data from scale samples, spawning escapement by year class ranged between 2.2% and 16.4% age-2 (jacks), 24.9% and 88.8% age-3, 6.6% and 68.2% age-4, and 0.0% and 1.0% age-5 spawners. The estimated percentage of fish that spawned in the study area that were of hatchery origin ranged between 8.5% and 20.5%. The adult female–male ratio ranged between 1.2:1 and 2.0:1 and pre-spawn mortality rate of females ranged between 2.2% and 6.6%. Estimated egg deposition by females in the carcass study area ranged between 1.3 and 6.1 million. The redd count in the 125.7-km section of the mainstem river between the Shasta River confluence and Wingate Bar ranged between 772 and 1,192. Estimated egg deposition in the redd study area ranged between 1.8 and 3.0 million.

Introduction

Abundant runs of Chinook Salmon *Oncorhynchus tshawytscha* and steelhead *O. mykiss* and comparatively smaller runs of Coho Salmon *O. kisutch* were historically supported by the Klamath River Basin (Leidy and Leidy 1984; DOI et al. 2013; Figure 1.). 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 (Hardy and Addley 2001; Moyle et al. 2008; Thorsteinson et al. 2011; DOI et al. 2013). These factors include overharvest, habitat alterations and loss from various land-use practices (e.g., dam construction, agricultural development, timber harvest, mining, etc.), reduced genetic integrity from hatcheries, environmental phenomena, and disease.

In response to concerns over declining salmon abundance, the United States Congress enacted the Klamath River Fish and Wildlife Restoration Act (Public Law 99-552) in 1986 (USFWS 1991). Known as the 'Klamath Act', this legislation authorized the Secretary of the Interior to restore anadromous fish populations to optimum levels in the Klamath River Basin through the creation of the Klamath River Basin Conservation Area Restoration Program (KRBCARP). As part of the fishery resource monitoring program implemented under KRBCARP, the U.S. Fish and Wildlife Service (USFWS) Arcata Fish and Wildlife Office (AFWO) implemented redd surveys in 1993 to identify the distribution, abundance, and timing of fall-run Chinook Salmon spawning in the mainstem Klamath River between Iron Gate Dam [IGD; river kilometer (rkm) 310.1] and the confluence with Indian Creek (rkm 173.8), with the survey extended downstream to Wingate Bar (rkm162.6) in 2017. Escapement estimates were generated by expanding redd counts under the assumption that each redd represents one adult female and one adult male. This effort was initiated to supplement fall-run Chinook Salmon spawning escapement and harvest monitoring that had been initiated in the Klamath River Basin in 1978 (CDFW 2024).

In 2001, AFWO 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 IGD and the Shasta River confluence (rkm 288.5). A postmortem tag-recovery study was conducted rather than the more common live tag–postmortem recovery or live mark–live recapture surveys since the opportunity to count, mark, or recover live fish (e.g., at a weir; Manly et al. 2005) was not available. 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). Petersen estimates were assumed to be 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. Consequently, only carcass surveys have been conducted in this section of the river since 2007.

Since the inception of this survey, several changes have been made to the estimation methods to account for varying logistical challenges (Gough and Som 2015) along with improvements to statistical methodologies, including those leading to the currently implemented hierarchical latent variables model (Gough and Som 2017).

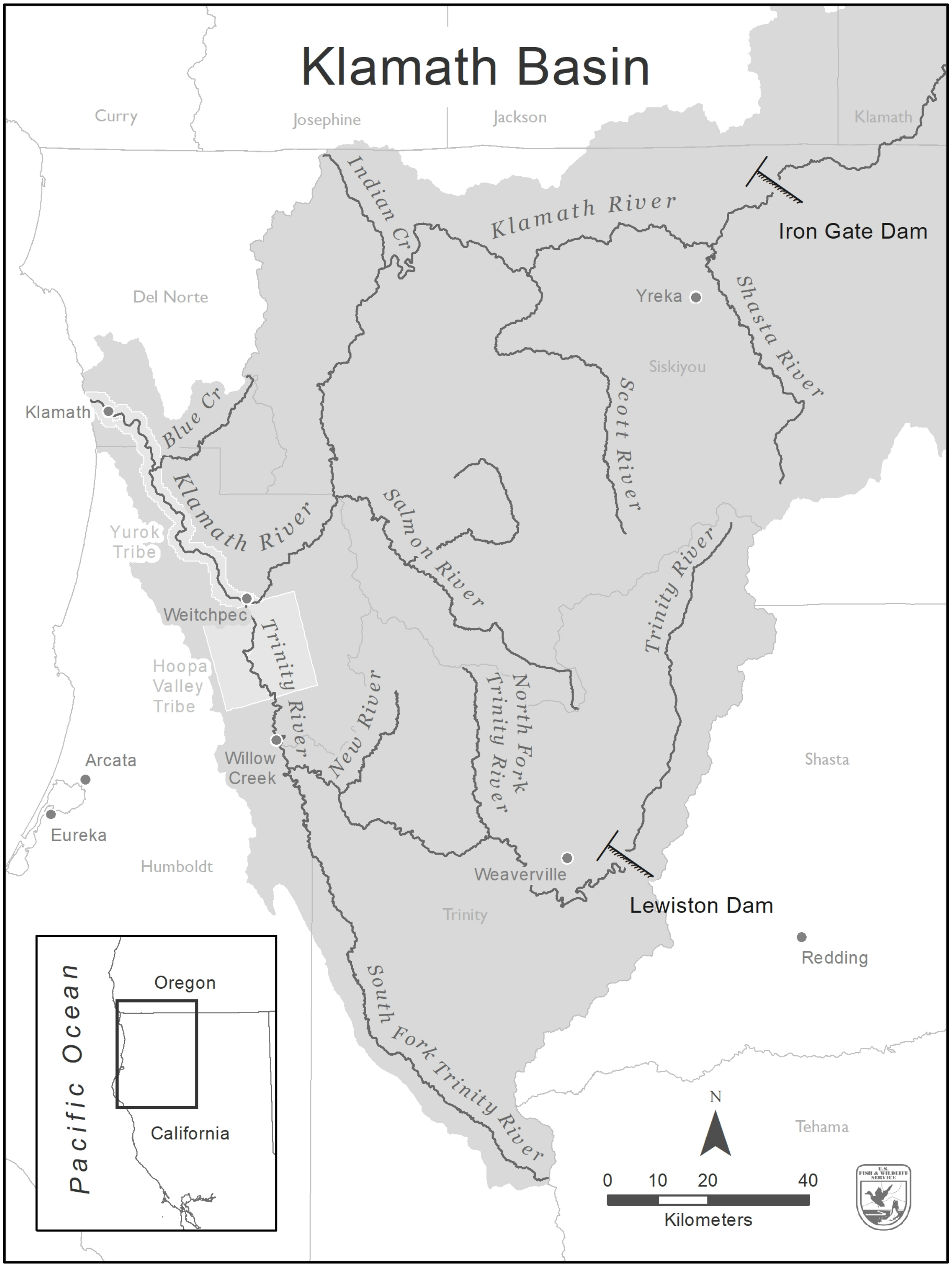

Figure 1. Klamath River Basin, northern California. The mainstem Klamath River carcass survey study area extends from Iron Gate Dam to the Shasta River confluence and the redd survey extends from the Shasta River to Wingate Bar, located 11.2 rkm downstream of Indian Creek.

The primary purpose of this project is to provide the Klamath River Technical Team (KRTT) with fall-run Chinook Salmon spawning escapement estimates for the mainstem Klamath River. 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 in the mainstem (KRTT 2024a). The KRTT depends on accurate escapement estimates of fall-run 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 developing harvest management alternatives for the following year (KRTT 2024b; PFMC 2024). Accurately determining the number of spawners within this reach is also needed for an ongoing outmigrant fry study (e.g., Wallin et al. 2023) and for calibrating the Stream Salmonid Simulator (S3), a Chinook Salmon production model (Perry et al. 2018). 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 mainstem Klamath River from IGD to Wingate Bar was divided into seven reaches (R1–R7) based on accessibility and distance that a single crew could survey for redds in a day (Figure 2; Table 1).

The carcass survey area (Reach R1) consists of the 21.2-km section of mainstem Klamath River between the boat ramp across the river from the Iron Gate Hatchery (IGH) and the Shasta River confluence, and is further divided into eight smaller reaches (C1–C8; Figure 3; Table 2). Reach delineation for the carcass survey is based on previously mapped concentrations of redds with boundaries at distinguishable landmarks. The 0.4 km above Reach C1, between IGD (the upper limit of anadromy) and IGH, was not surveyed because it is not accessible and little spawning activity occurs in this section of the river.

The redd survey area (Reaches R2–R7) extends 125.7 km between the confluence with the Shasta River and Wingate Bar. Reach R1 was only surveyed for redds from 1993 to 2004 and 2006. The upper 2.7 km in Reach R2, from the Shasta River to Ash Creek, was not surveyed because past surveys revealed little to no spawning activity in this section of the river. For this report we assumed no redds were constructed in this short stretch of the river. Prior to 2017, redd surveys went to the confluence with Indian Creek (Reach R6); Reach R7 was added to the redd survey in 2017 because an increasing number of Chinook Salmon appeared to be spawning below the carcass survey reaches and further downstream in the mainstem Klamath River.

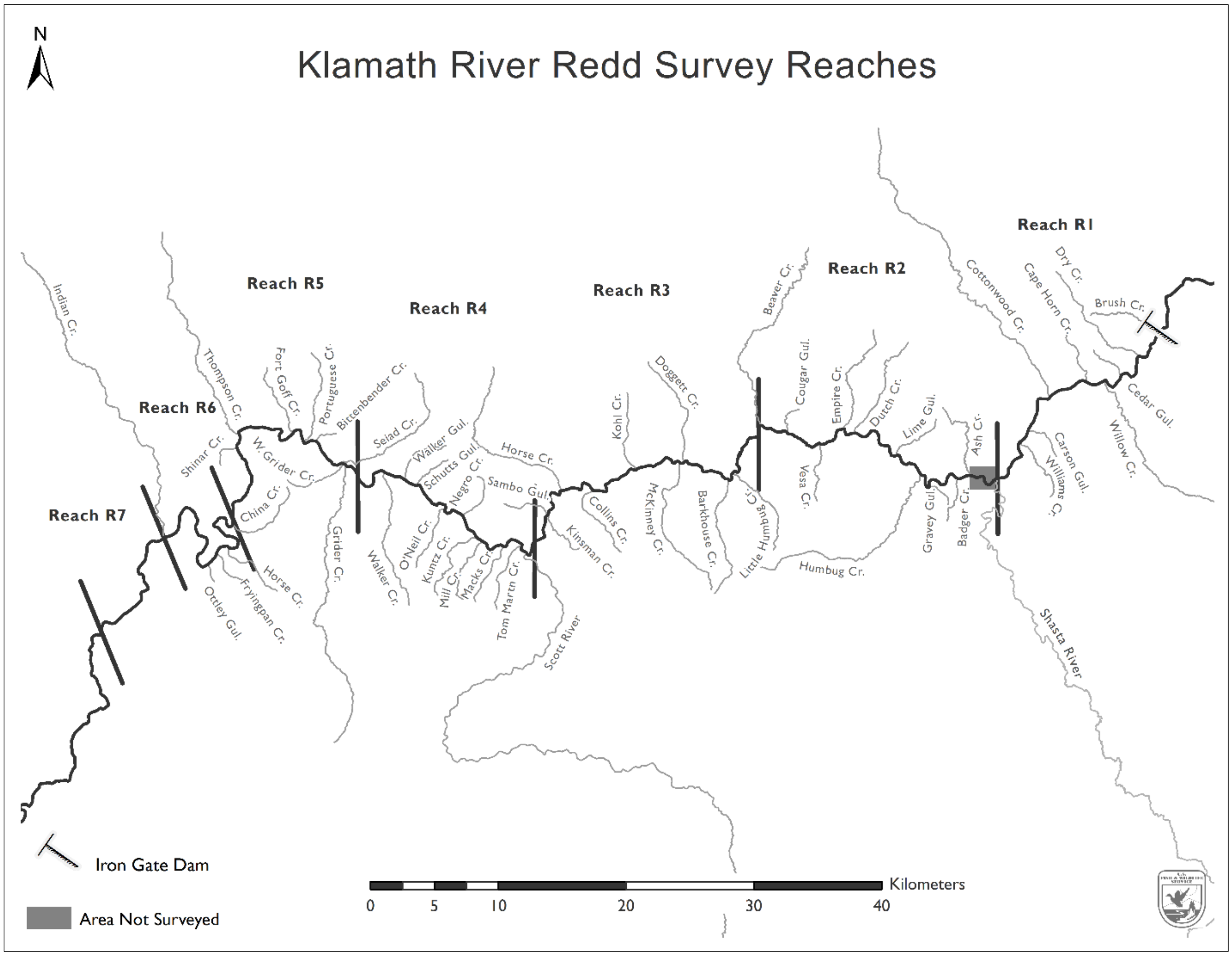

Figure 2. Mainstem Klamath River, California, fall-run Chinook Salmon redd survey reaches. *Note*: Escapement in Reach R1 (Iron Gate Dam–Shasta River) is estimated from carcass mark-recapture survey data. The 2.7-km section between the Shasta River and Ash Creek was not surveyed because past surveys revealed a lack of spawning activity in this stretch of river.

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

Reach	Rkm Upstream	Rkm Downstream	Length (km)	Upstream landmark
R1[a]	309.7	288.5	21.2	Boat ramp opposite Iron Gate Hatchery
R2[b]	288.5[e]	261.9	26.4	Shasta River confluence
R3[c]	261.9	234.3	27.6	Beaver Creek confluence
R4[b]	234.3	213.6	20.7	Blue Heron River Access
R5[c]	213.6	192.4	21.2	Seiad Bar
R6[d]	192.4	173.8	18.6	China Point River Access
R7[c]	173.8	162.6[f]	11.2	Indian Creek confluence

[a] redd surveys no longer conducted in Reach R1 (escapement in this reach estimated from carcass mark-recapture surveys by USFWS and the Yurok Tribe)

[b] surveyed by Karuk Tribe crew

[c] surveyed by USFWS crew

[d] Reach R6 was split at Gordon's Ferry (rkm 185.0) and surveyed by Karuk Tribe and USFWS

[e] the section of river between Shasta River and Ash Creek (rkm 285.7) was not surveyed because past surveys revealed little to no evidence of spawning activity in this area

[f] Wingate Bar River Access

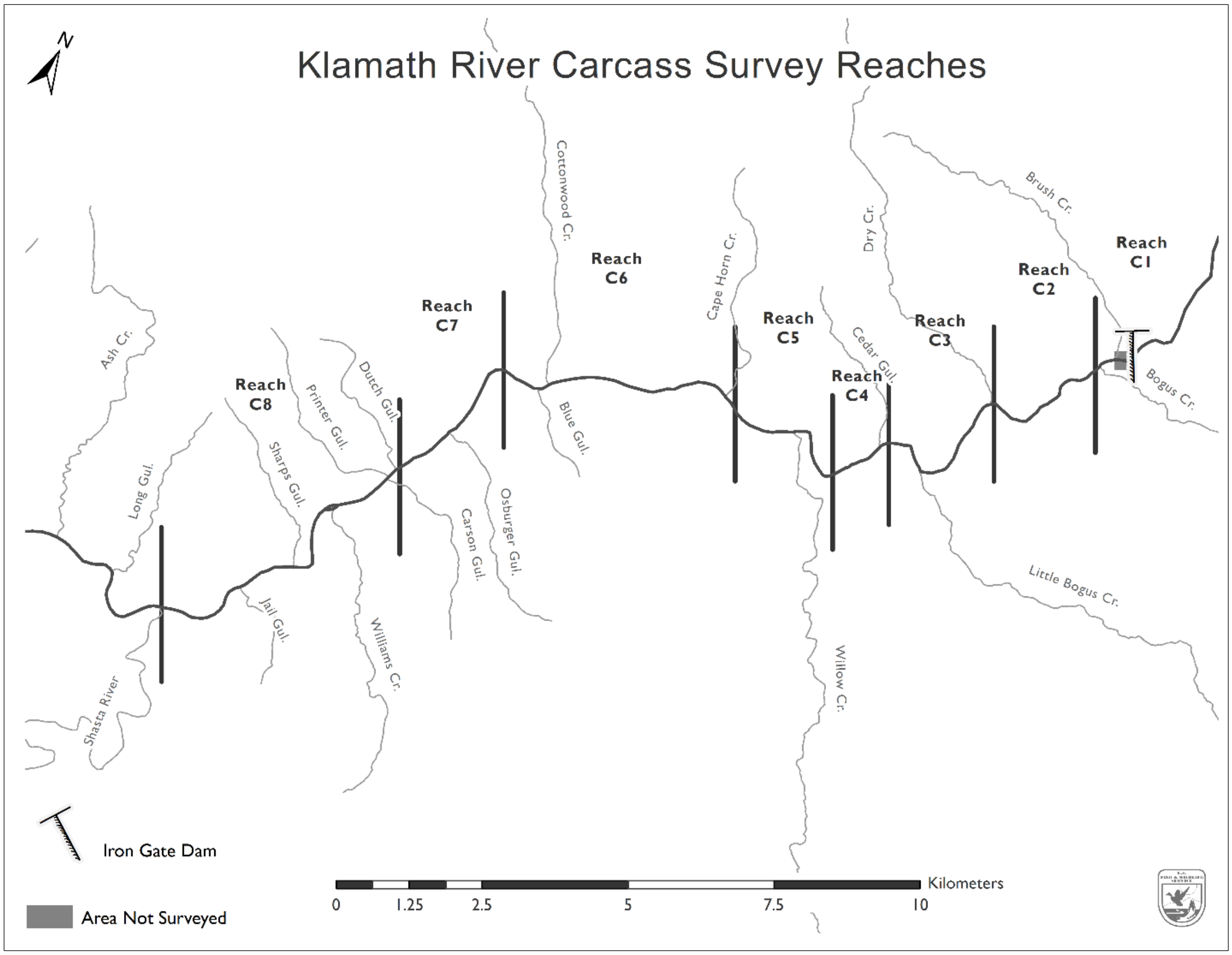

Figure 3. Klamath River, California, fall-run Chinook Salmon carcass survey area from IGD (rkm 310.1) to the Shasta River confluence (rkm 288.5) with reaches delineated. The survey begins in Reach C1 at the first river access below IGD (rkm 309.7). Little to no spawning occurs between the dam and the access point.

Table 2. Reach boundaries and lengths in the Klamath River carcass survey study area. Downstream landmarks were the same as upstream landmarks of the next reach.

Reach	Rkm		Length	
	Upstream	Downstream	(km)	Upstream landmark
C1	309.7[a]	309.2	0.5	Boat ramp opposite Iron Gate Hatchery
C2	309.2	307.0	2.2	Riffle below USGS Gaging Station
C3	307.0	304.3	2.7	Dry Creek confluence
C4	304.3	303.2	1.1	First wooden foot bridge
C5	303.2	300.7	2.5	KRCE green wooden foot bridge
C6	300.7	296.4	4.3	Copco-Ager (Klamathon) Bridge
C7	296.4	293.8	2.6	Third (fallen) wooden foot bridge
C8	293.8	288.5[b]	5.3	Carson Creek confluence

[a] The 0.4 km immediately downstream of Iron Gate Dam (rkm 310.1) is not surveyed.

[b] Confluence with the Shasta River

Methods

Carcass Survey – Iron Gate Dam to the Shasta River

Carcass data were collected in a cooperative effort between AFWO and the Yurok Tribal Fisheries Program (YTFP). Weekly surveys covering all reaches (C1–C8) in the study area were conducted from October 14 to November 18 in 2020, October 13 to December 1 in 2021, October 12 to November 30 in 2022, and October 11 to November 29 in 2023. In 2020, two more survey weeks were scheduled but cancelled due to an increase in Covid-19 cases and concerns. 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 disk depth. We only recorded Secchi disk depth once per week because only one location in the carcass study area (in Reach C8) was consistently slow and deep enough for this water transparency measurement.

Carcass Data

Each sampled 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.

Carcass condition was categorized as very fresh (F_1), partly decayed (D_2), or rotten (N) 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 = rotten (decayed beyond D_2; from covered with fungus and flesh softening to 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-condition carcasses were believed to have expired more than one week prior to capture. Throughout this report, both F_1- and D_2-condition carcasses are referred to as 'fresh'. Fork lengths from N-condition carcasses were not recorded.

Sex was distinguished for F_1- and D_2-condition carcasses using morphological differences and verified with an abdominal incision to check the gonad type or for the presence of eggs. 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.

Spawning conditions were assigned to F_1- and D_2-condition female carcasses using the following codes:

> 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 conditions '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 (2024a). The KRTT reviews data from throughout the basin provided by various collaborators and jointly decides which method best represents the jack–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 (e.g., KRTT 2024a). 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 age composition analysis.

Escapement Estimate

Counts of carcasses were conducted weekly over the entire study area. Every detected carcass was counted and every F_1- and D_2-condition carcass was evaluated during all survey weeks in 2020 and 2021, the first four and last two survey weeks in 2022, and the first four survey weeks in 2023. Systematic sampling rates were applied when the predicted number of carcasses would be too many for the crews to finish the survey. A systematic sampling rates of 1-in-5 was applied during the fifth survey weeks in 2022 and 2023 and 1-in-2 during the sixth survey week in 2022 and sixth through eighth survey weeks in 2023. F_1- and D_2-condition carcasses were marked with uniquely numbered aluminum tags attached to a hog ring clamped around the upper 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 their snouts were removed (see Hatchery Contribution section below). Tags were also not applied to carcasses that had been partially consumed by scavengers. Tagged carcasses were replaced near the location and depth where they were found. N-condition carcasses 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.

Carcass abundance estimates of fall-run Chinook Salmon in the mainstem Klamath River between Iron Gate Dam and the Shasta River confluence were generated via a hierarchical latent variables model (Gough and Som 2017). This model assumes a latent (unobservable) ecological process interacts with a detection process to produce the observed counts of carcasses (Kery and Schaub 2012). For this survey, the latent process is the true abundance of carcasses. As not all carcasses are observed (imperfect detection), a separate observation process links the unobserved latent process to the observed data.

The general model described above was executed with counts of fresh Chinook Salmon carcasses (i.e., those arriving since the prior survey) and weekly detection probabilities estimated from mark–recapture data. Weekly abundances are estimated by assuming that the weekly counts of fresh Chinook Salmon carcasses arise from a binomial distribution. Carcass counts in 2020 were extrapolated for the last two cancelled survey weeks by assuming a normal distribution for the arrival timing of all carcasses through the survey season. Graphical data summaries indicated this assumption was warranted. Details regarding the development and application of this model can be found in Gough and Som (2017). Additionally, numbers of carcasses available for detection probability are often sparse during the first and last weeks of the surveys. As such, an assumption is often made regarding a constant recapture rate within each period, and hence the numbers of marked and recaptured carcasses are pooled for estimation purposes.

Age-Class Estimates

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

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

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

In addition to fish spawning in the wild, fall-run Chinook Salmon and Coho Salmon are produced at the IGH under the operation of the California Department of Fish and Wildlife (CDFW). 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.

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 2024):

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

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 ($H_{code(i)}$):

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

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

Egg Deposition

Total egg deposition (N_e) in the carcass survey area was estimated by multiplying predicted egg production (n_e) by the estimate of adult females ($\hat{N}_{adult}$). 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. The annual mean egg production per female at IGH ($\bar{n}_e$) was used as a surrogate for mainstem spawning female Chinook Salmon. 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:

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

Redd Survey – Shasta River to Wingate Bar

Redd data were collected in a cooperative effort between AFWO and the Karuk Tribe. Weekly surveys in 2021 were conducted from October 13 to November 20 in 2020, October 13 to December 2 in 2021, October 12 to December 1 in 2022, and October 11 to November 17 in 2023. Two additional survey weeks were scheduled in 2020 but cancelled for this survey also because of Covid-19 concerns. Two crews, one AFWO and one Karuk, consisting of a rower and observer, surveyed the river by cataraft. Catarafts were maneuvered downstream in a zigzag pattern over spawning areas to count redds. Side channels were surveyed by foot and split channels by cataraft on alternating weeks. Crews surveyed the same reaches each week for consistency and familiarity with the river and to promote more accurate redd counts.

A GPS waypoint was taken at each lone redd or redd aggregation when observed for the first time during the season. The GPS waypoint, river kilometer, numbers of old and new redds, location of redd(s) in the channel, habitat type, and estimated age(s) of redd(s) were recorded on a data sheet each time a new redd or aggregation containing new redds was encountered. Only completed redds, identified by a pit and mound, were counted. Test redds (i.e., those without a completed pit and mound) were not included in the count. Only new redds (i.e., those observed for the first time) were summed across the survey weeks to produce the total redd count for the season.

Mean daily river discharge was obtained from USGS gaging stations 11516530, located in the Klamath River just downstream of IGD, and 11520500, located in the Klamath River near Seiad Valley.

Secchi disk depth was recorded each survey week in Reach R5 as measurement of water transparency, which can influence the observability of redds.

Adult and Age-2 Escapement Estimates

The total number of new redds from this survey was used to estimate the number of adult and jack (age-2 fish) fall-run Chinook Salmon that spawned in the mainstem Klamath River between the Shasta River and Wingate Bar. Assuming each redd represents one male and one female adult salmon, adult escapement (N_{adult}) was estimated by multiplying the total redd count (R) by two:

$$\widehat{N}_{adult} = 2R.$$

The age composition of mainstem Chinook Salmon from the IGD–Shasta River carcass survey (KRTT 2021, 2022, 2023, 2024a) was used as a surrogate for apportioning escapement by age class in the mainstem Klamath River below the Shasta River. In previous years, jack (age-2 fish) escapement (N_{jack}) was estimated in the following equation where P_{age2} is the jack proportion based on scale readings from the carcass survey:

$$\widehat{N}_{jack} = \frac{\widehat{N}_{adult}}{\left(1 - P_{age2}\right)} - \widehat{N}_{adult}\,.$$

Egg Deposition

Total egg deposition (N_e) in the redd survey area was estimated by multiplying predicted egg production (n_e) by the total redd count (R):

$$\widehat{N}_e = n_e * R\,.$$

The annual mean egg production per female at IGH was used as a surrogate for mainstem spawning female Chinook Salmon.

Results and Discussion

Survey Conditions

River Discharge

In 2020, mean daily discharge in the mainstem Klamath River below IGD was relatively stable throughout the entire survey period and ranged between 27.6 and 30.0 cm^3/s (Figure 4). Discharge near Seiad Valley ranged between 32.5 and 34.5 cm^3/s most of the survey season before a rain event in mid-November increased discharge here to as high as 43.6 cm^3/s.

Mean daily discharge in the mainstem Klamath River below IGD in 2021 was around 28 m^3/s below Iron Gate Dam for most of the season with higher flows (28.6–33.4 m^3/s) during the first two weeks in November (Figure 4). Mean daily discharge near Seiad Valley was around 33 m^3/s at the start of the survey period before rain events caused increased and variable flows that ranged between 34.0 and 52.1 m^3/s.

Mean daily discharge in the mainstem Klamath River below IGD in 2022 was relatively stable around 28 m^3/s through entire survey (Figure 4). Mean daily discharge near Seiad Valley was around 32 m^3/s at the start of the survey period, increased slightly to around 33 m^3/s in late October, briefly peaked at 37 m^3/s during a rain event in early November, and then stayed around 35 m^3/s for the remainder of the season with another brief peak to 38 m^3/s on December 1.

Mean daily discharge in the mainstem Klamath River below IGD in 2023 was relatively stable throughout the entire survey period and ranged between 28.1 and 30.6 cm^3/s (Figure 4). Mean daily discharge near Seiad Valley was around 36 to 38 m^3/s throughout the survey period except during a couple rain events that brought discharge up to 41.3 m^3/s on November 6 and 40.8 m^3/s on November 19.

Water Transparency

Secchi disk depth readings during the carcass surveys ranged between 1.8 and 2.5 m in 2020, 1.7 and 2.6 m in 2021, 2.0 and 3.6 m in 2022, and 2.6 and 3.2 m in 2023 (Figure 4). Conditions for the carcass mark-recapture survey were suitable within these visibility ranges.

Secchi disk depth readings during the redd surveys ranged between 1.5 and 2.1 m in 2020, 1.5 and 1.8 m in 2021, 0.8 and 1.5 m in 2022, and 0.5 and 1.5 m in 2023. Most redds were believed to have been observable within the ranges in visibility in 2020 and 2021. During the summer of 2022, the McKinney Fire burned over 60,000 acres of the Klamath National Forest in western Siskiyou County. Sediment input from tributaries in wildfire areas impaired visibility downstream of Vesa Creek in Reach R2 of the redd survey throughout 2022 and 2023 survey seasons. Visibility was less than the maximum depth at which redds may be constructed; therefore, redds were likely undercounted by an unknown amount.

Carcass Survey

Temporal and Spatial Distribution of Carcasses

A total of 408 F_1- and D_2-condition carcasses were observed during the 2020 surveys, 662 in 2021, 941 in 2022, and 1,179 in 2023 (Table 3). The peak of new carcass observations, which typically occurs in calendar weeks 44–46, occurred during calendar week 45 in 2020, 2021, and 2023 and calendar week 46 in 2022. Carcass densities in 2020 and 2022 were relatively low compared to previous years, but like previous years, was still highest in the upper reaches (Figure 5).

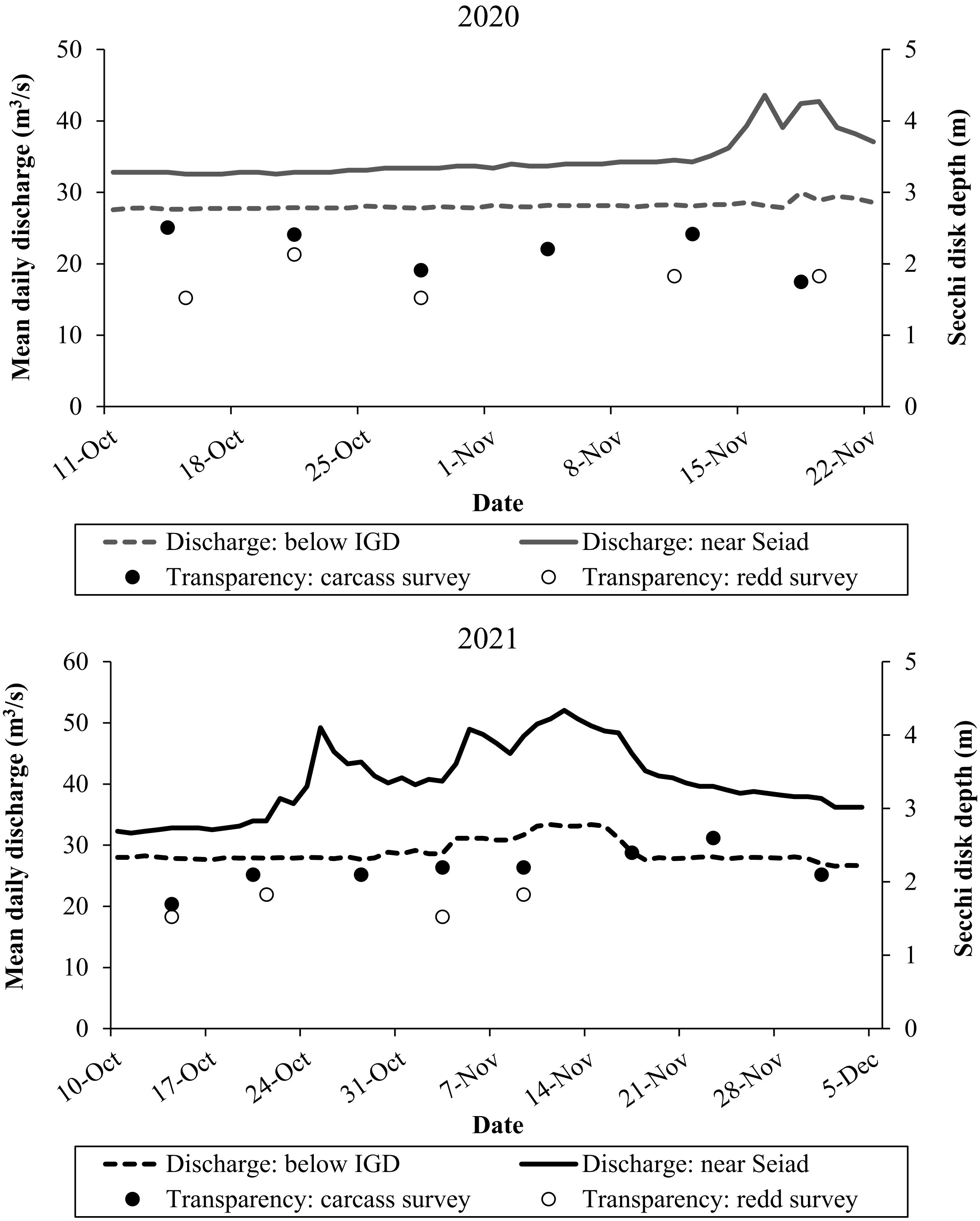

Figure 4. Mean daily discharge in the mainstem Klamath River below Iron Gate Dam (USGS gaging station 11516530) and near Seiad Valley (USGS gaging station 11520500) and weekly water transparency (Secchi disk depth) in Reaches C8 and R5 during Chinook Salmon spawning surveys, 2020–2023.

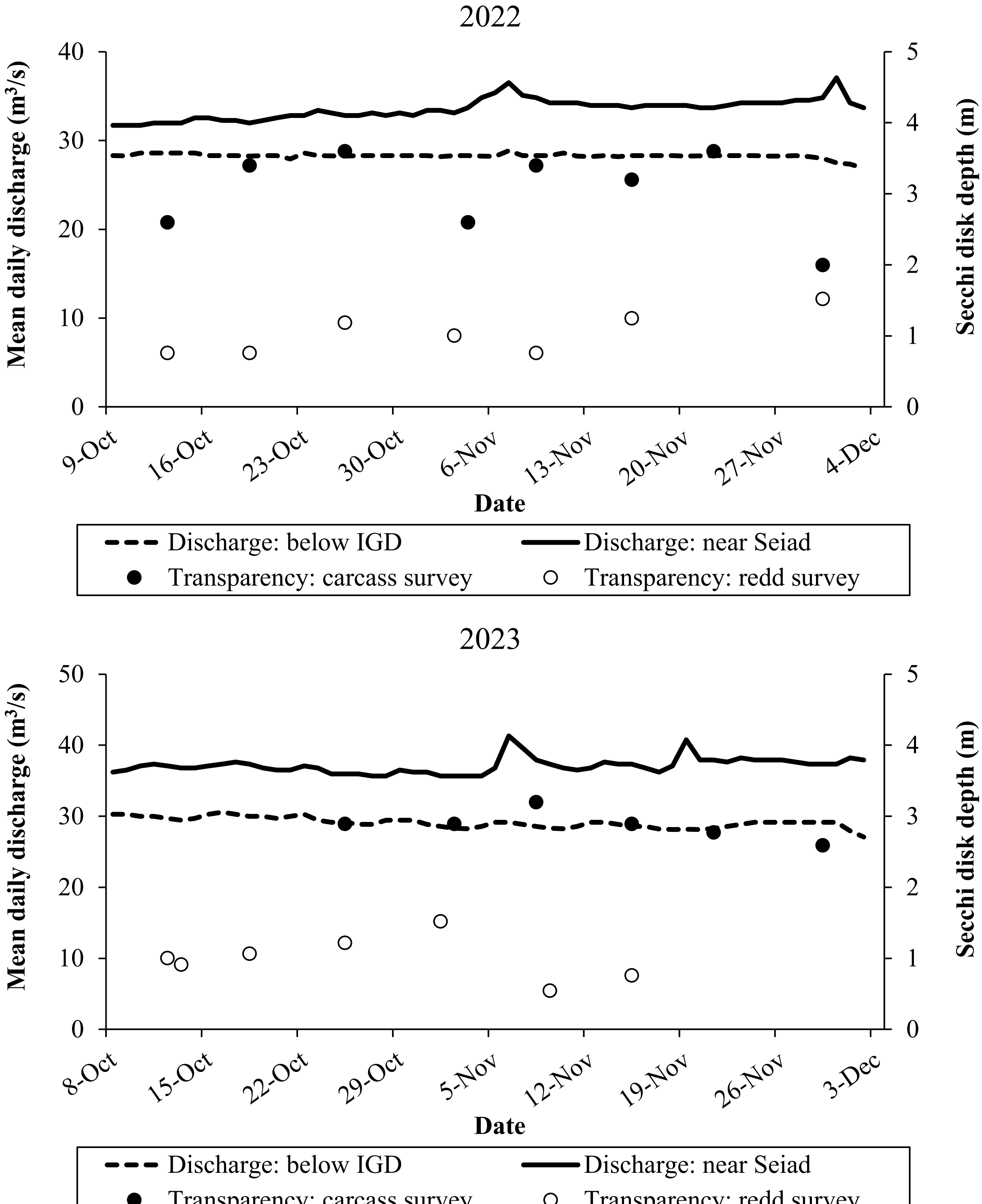

Figure 4 (continued). Mean daily discharge in the mainstem Klamath River below Iron Gate Dam (USGS gaging station 11516530) and near Seiad Valley (USGS gaging station 11520500) and weekly water transparency (Secchi disk depth) in Reaches C8 and R5 during Chinook Salmon spawning surveys, 2020–2023.

Table 3. Number of F_1- and D_2-condition fall-run Chinook Salmon carcasses observed by calendar week, Klamath River surveys, 2001–2023. Annual peak counts are in bold font. Shaded values are counts that have been expanded by a systematic sampling rate. Dashes (-) indicate no survey conducted. Note that the numbers presented here have not yet been expanded into escapement estimates.

	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
2016	1	7	45	**84**	**84**	14	9	10	3	-	257
2017	8	42	145	**404**	388	185	94	2	1	-	1,269
2018	14	42	230	605	**940**	545	170	30	-	-	2,576
2019	3	6	16	53	**85**	82	69	28[a]	4	-	346
2020	-	7	19	60	**123**	120	79	-	-	-	408
2021	-	3	25	180	**268**	158	24	4	0	-	662
2022	-	5	27	123	286	**395**	76	25	4	-	941
2023	-	10	58	231	**405**	375	82	18	0		1,179

[a] only Reaches C1–C5 surveyed

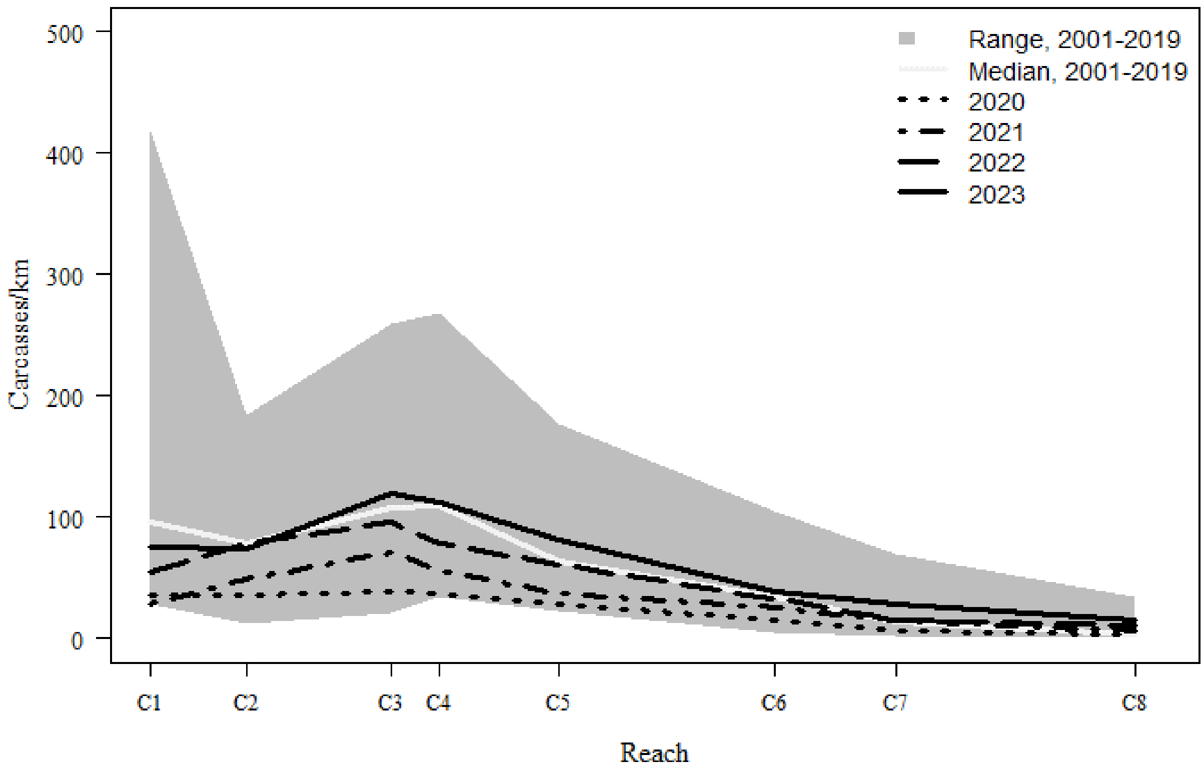

Figure 5. Fall-run Chinook Salmon carcass density (from *counts* of F_1- and D_2-condition carcasses only) by reach, Klamath River surveys, 2020–2023 compared to the range and median from 2001 to 2019. Reach C1 was not surveyed from 2002 to 2005.

Length Distribution

Mean fork lengths of adult females, adult males, and jacks were 64.0, 65.3, and 47.0 cm, respectively, in 2020 (Table 4; Appendix A). Mean fork lengths of adult females, adult males, and jacks were 67.5, 72.7, and 50.1 cm, respectively, in 2021 (Appendix B). Additionally, 17 age-2 female ('jill') carcasses were observed in 2021 with a mean fork length of 53.8 cm. Mean fork lengths of adult females, adult males, and jacks were 68.0, 75.1, and 48.1 cm, respectively, in 2022 (Appendix C). Mean fork lengths of adult females, adult males, and jacks were 75.1, 83.1, and 51.6 cm respectively, in 2023 (Appendix D). No jills were sampled in 2020. Three jills were observed in 2022 and four were observed in 2023, but no further analyses were done with those fish due to the small sample size.

The mean fork length of adult males in 2020 was the smallest of the 23-year data set while also displaying the largest variation and size overlap with jacks. Jacks ranged between 33 and 57 cm FL while age-3 males ranged between 43 and 92 cm FL with 32.9% of those fish measuring 57 cm FL and smaller. The unusual number of age-3 male Chinook Salmon that resembled jacks in size and scale pattern may be attributed to very little growth in 2019 when ocean conditions were poor.

Table 4. Mean fork lengths by year of fall-run Chinook Salmon carcasses, Klamath River surveys, 2001–2023. In all years except 2017, when age-2 females were few, the term 'jack' was used to refer to all age-2 fish, regardless of sex. Also, adults were distinguished from 'jacks' using annual fork-length size cutoffs from 2001 to 2016. Since 2017, adults and jacks (and jills in 2017 and 2021) were identified using scale ages.

Year	Jack–adult FL (cm) cut-off (jacks ≤)	Adult females FL (cm) mean	Adult females FL (cm) s.d.	Adult males FL (cm) mean	Adult males FL (cm) s.d.	Jacks FL (cm) mean	Jacks FL (cm) s.d.
2001	63	76.3	6.3	85.4	9.6	53.8	6.3
2002	63	75.8	6.9	82.7	9.2	56.0	6.6
2003	55	76.9	7.8	87.0	10.2	48.0	5.4
2004	57	78.9	7.3	87.3	9.7	50.7	5.4
2005	52	73.7	7.6	83.3	9.7	47.0	4.3
2006	60	74.5	6.9	84.0	9.8	52.6	5.7
2007	51	66.6	5.3	77.2	10.0	46.5	3.5
2008	59	76.8	6.4	84.0	12.0	53.4	4.9
2009	58	73.2	5.7	83.0	8.4	51.6	4.1
2010	61	78.9	6.3	85.4	9.2	55.8	4.5
2011	63	76.6	7.2	84.2	9.9	56.6	4.4
2012	58	71.0	4.9	78.0	8.0	51.7	4.4
2013	57	75.1	6.7	81.4	9.9	51.4	4.3
2014	60	75.8	6.3	83.1	9.9	54.1	4.7
2015	54	71.3	6.0	80.6	9.2	49.8	3.7
2016	55	73.0	6.3	79.4	10.4	49.5	5.1
2017	64[a],55[b]	66.8	6.0	76.5	7.6	53.1[a],54.0[b]	4.7[a],5.1[b]
2018	57	67.2	4.8	74.0	7.2	53.0	5.4
2019	54	63.1	6.2	66.4	8.9	47.3	4.7
2020	49	64.0	5.0	65.3	12.1	47.0	6.8
2021	60[a],55[b]	67.5	5.6	72.7	8.9	50.1[a],53.8[b]	6.3[a],8.6[b]
2022	58	68.0	6.1	75.1	10.3	48.1	6.1
2023	56	75.1	7.6	83.1	10.2	51.6	8.3

[a] true jacks (age-2 males)
[b] jills (age-2 females)

Adult Female–Male Ratio

The percentage of females among adult carcasses was 53.9% (adult female–male ratio = 1.2:1) in 2020, 65.6% (1.9:1) in 2021, 66.2% (2.0:1) in 2022, and 59.1% (1.5:1) in 2023 (Figure 6). Between 2001 and 2019 the percentage of females ranged from 51.8% (adult female–male ratio = 1.1:1) to 72.9% (2.7:1). 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 removal of males is supported by our observed decrease in the female–male ratio moving downstream within the study area (Appendix E). Compared to adult Chinook Salmon that returned to IGH, the percentage of returning adults that were female was 5.4%, 17.4%, 15.3%, and 8.3% higher in the mainstem Klamath River from 2020 to 2023, respectively (Appendix F).

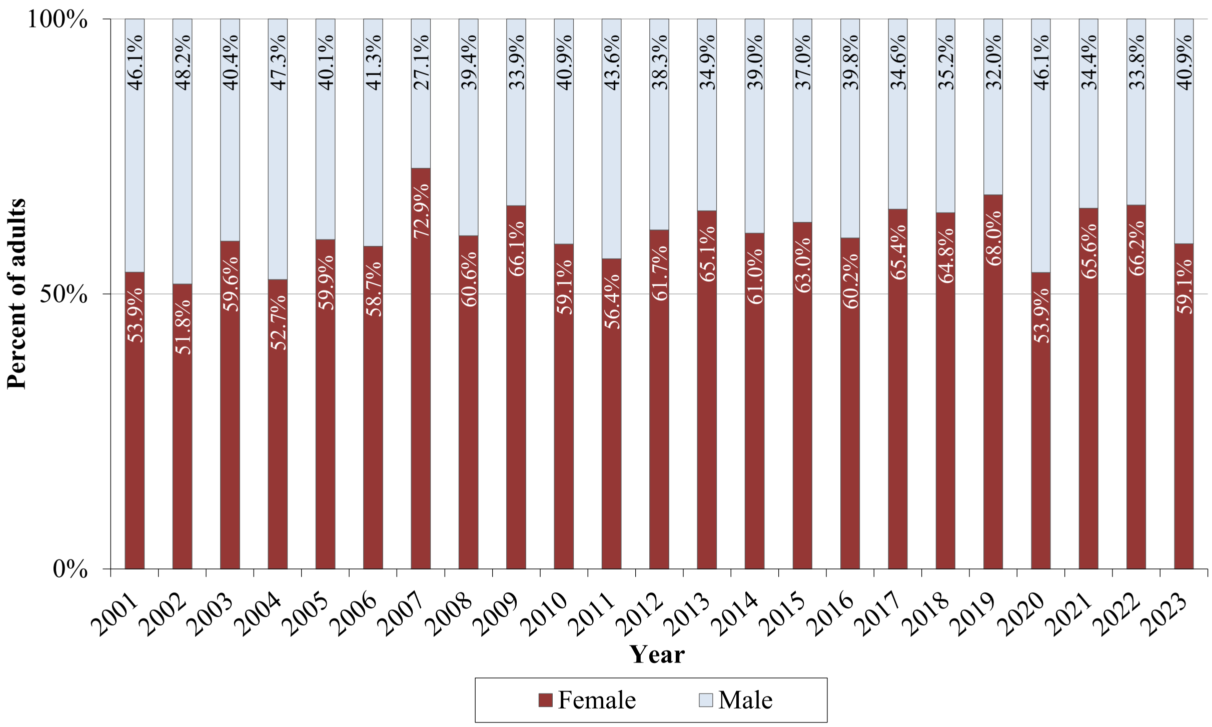

Figure 6. Female and male proportions of adult fall-run Chinook Salmon carcasses, Klamath River surveys, 2001–2023. Adults were distinguished from jacks using a fork length size cutoff in 2001–2016. Since 2017, adults were identified using a size cutoff in years when systematic sampling was used and scale ages during years when all observed carcasses were sampled.

Pre-spawn Mortality

Thirteen pre-spawn mortality female Chinook Salmon carcasses were sampled in 2020, 8 in 2021, 35 in 2022, and 41 in 2023 (Figure 7). Pre-spawn mortality rates for each season was 6.3%, 2.2%, 5.8%, and 6.6%, respectively. Fully spawned individuals made up 89.4%, 95.3%, 88.4%, and 90.9% of F_1- and D_2-condition female adult carcasses, respectively. Pre-spawn mortality in previous years ranged between 1.0% and 22.1% (mean = 7.0%). Consistent with most previous years, pre-spawn mortality observed from 2020 to 2023 was highest at the beginning of the survey seasons. (Figure 8; Appendix G).

Escapement Estimates and Age Composition

The fall-run Chinook Salmon spawning escapement estimate in this study area was 1,225 (95% CI: 1,036–1,455) in 2020, 2,105 (95% CI: 1,739–2,696) in 2021, 3,243 (95% CI: 2,660–4,063) in 2022, and 4,211 (95% CI:3,619–5,019) in 2023 (Table 5). Uniquely numbered jaw tags were applied to 395, 616, 551, and 731 carcasses during each of the four survey seasons, respectively. Weekly mark-recapture data were combined from the first two survey weeks in each of the four years, and from the final two survey weeks in 2021 and 2023. These data from early and late-season weeks were combined to achieve adequate sample sizes. As noted above, grouping consecutive weeks of mark–recapture data assumes constant detection probability within each grouped time block. The estimated weekly recapture rates for carcasses captured one week after tagging ranged between 0.08 and 0.42 in 2020, 0.15 and 0.34 in 2021, 0.04 and 0.40 in 2022, and 0.17 and 0.63 in 2023.

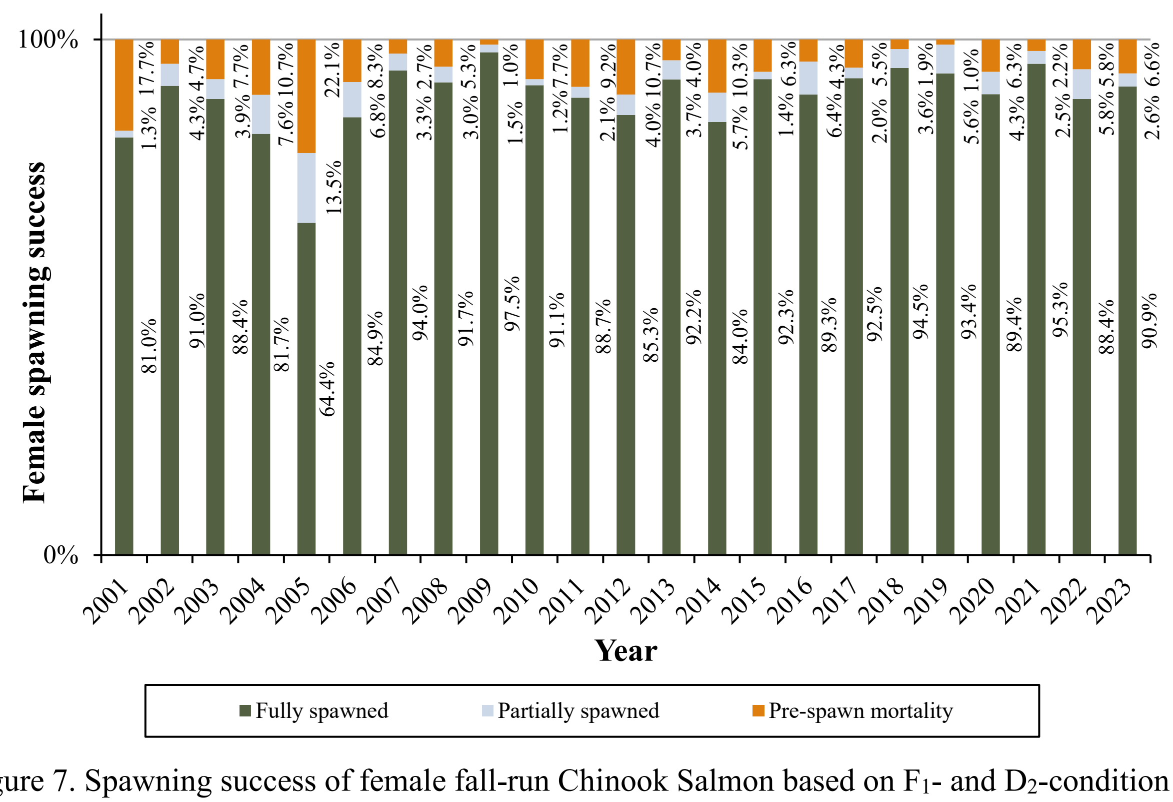

Figure 7. Spawning success of female fall-run Chinook Salmon based on F_1- and D_2-condition carcasses, Klamath River surveys, 2001–2023.

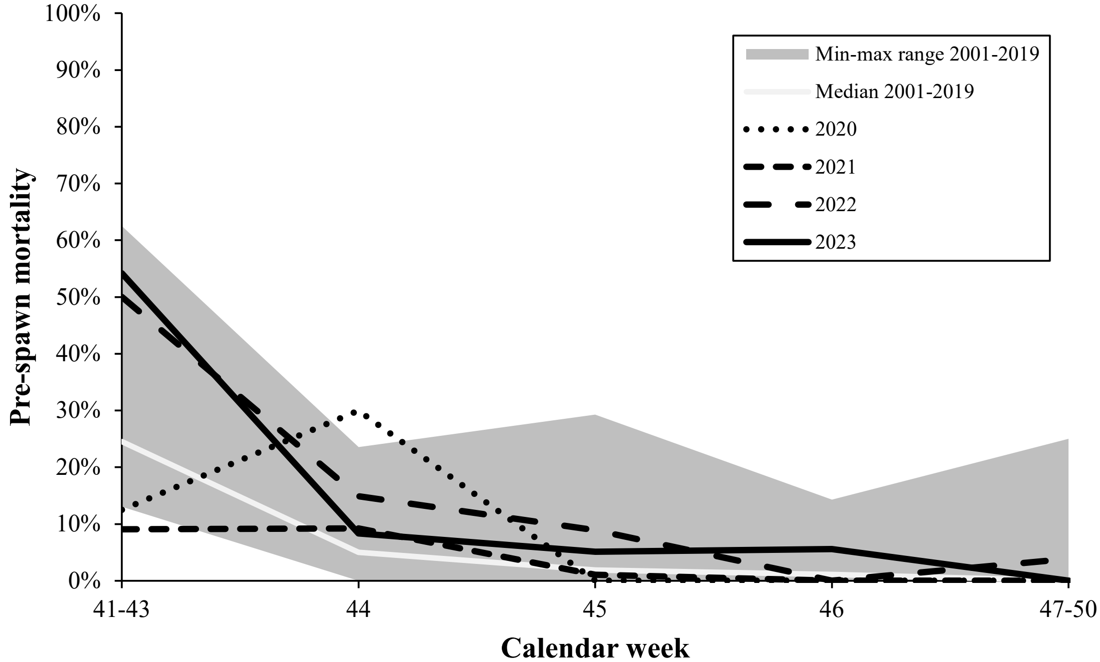

Figure 8. Weekly pre-spawn mortality from F_1-condition female fall-run Chinook Salmon carcasses, Klamath River surveys, 2020–2023, compared to the range and median from 2001 to 2019. Calendar weeks 41–43 and 47–50 were combined since sample sizes were typically low in calendar weeks 41, 42, 48, 49, and 50, if surveyed.

Males leaving the survey area after spawning (see Adult Female–Male Ratio section) were assumed to not greatly bias the escapement estimates. A large majority (87.0%–91.7%) of carcasses from 2020 to 2023 were found in the first six survey reaches (C1–C6), indicating that most spawning activity occurred in the upper 13.3 km of the 21.2 km of surveyed area. Few, if any, male fish likely migrated or drifted downstream more than 7.9 km after spawning and left 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.

Four hundred three, 633, 558, and 434 scale samples were collected from carcasses in 2020–2023, respectively, and analyzed to estimate the annual age composition of the mainstem spawning escapement. Based on age-composition estimates (KRTT 2021, 2022, 2023, 2024a) and the total escapement estimates, age-2 fish represented 4.5% ($\widehat{N}_2$ = 56) of the total escapement in 2020, 16.4% ($\widehat{N}_2$ = 345) in 2021, 2.2% ($\widehat{N}_2$ = 71) in 2022, and 5.9% ($\widehat{N}_2$ = 247) in 2023 (Table 6). The proportion of fish designated as jacks by the fork length cut-off were between 2.6% lower and 1.2% higher than that determined to be 2-year olds by scale aging. The most abundant age class returning to the study area were age-3 fish in 2020, 2021, and 2022 (88.8%, 44.9%, and 65.4%, respectively) and age-4 in 2023 (68.2%).

Table 5. Fall-run Chinook Salmon escapement estimates, Klamath River surveys, 2001–2023. AUC = area-under-the-curve; HLVM = hierarchical latent variables model.

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
2016	746	590	962	HLVM
2017	4,740	3,955	6,564	HLVM
2018	8,162	2,424	14,382	HLVM
2019	1,318	964	2,215	HLVM
2020	1,225	1,036	1,455	HLVM
2021	2,105	1,739	2,696	HLVM
2022	3,243	2,660	4,063	HLVM
2023	4,211	3,619	5,019	HLVM

Table 6. Fall-run Chinook Salmon spawning escapement estimates (and percent of total run) for each age class, Klamath River surveys, 2001–2023. Note: adults are ages 3–5.

	Escapement				
Year	Age-2	Age-3	Age-4	Age-5	Adults [a]
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
2016	39 (5.2%)	236 (31.6%)	471 (63.1%)	0 (0.0%)	707
2017	1,749 (36.9%)	2,376 (50.1%)	550 (11.6%)	65 (1.4%)	2,991
2018	454 (5.6%)	6,972 (85.4%)	736 (9.0%)	0 (0.0%)	7,708
2019	171 (13.0%)	876 (66.5%)	262 (19.9%)	9 (0.7%)	1,147
2020	56 (4.5%)	1,088 (88.8%)	81 (6.6%)	0 (0.0%)	1,169
2021	345 (16.4%)	945 (44.9%)	808 (38.4%)	7 (0.3%)	1,760
2022	71 (2.2%)	2,043 (65.4%)	1,112 (31.9%)	16 (0.5%)	3,172
2023	247 (5.9%)	1,049 (24.9%)	2,871 (68.2%)	44 (1.0%)	3,964

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

Adult fall-run Chinook Salmon spawners in the mainstem Klamath River between IGD and the Shasta River confluence accounted for 42.5%–67.3% of natural-area adult spawners in the mainstem Klamath River above Wingate Bar, 9.9%–21.5% in the Klamath River Basin above the Trinity River, and 4.5%–14.4% in the entire Klamath River Basin annually from 2020 to 2023 (Table 7). In the entire Klamath River Basin, fall-run Chinook Salmon adult spawners in the mainstem Klamath River between IGD and the Shasta River confluence accounted for 3.4%–9.0% of total adult escapement (hatchery and natural spawners), and 2.6%–6.9% of the total adult in-river run (hatchery and natural spawners plus in-river harvest) annually from 2020 to 2023. The proportion of natural spawners in the IGD–Shasta study area has trended downward from 2001 to 2023 above Indian Creek ($p = 0.005$) and above the Trinity River ($p = 0.008$), while a downward trend is suggestive but inconclusive in the entire Klamath Basin ($p = 0.09$; Appendix H). We hypothesize that the downward trends may be due to decreased survival in Chinook Salmon as juveniles since the survey area is a short distance upstream of a *C. shasta* infectious zone [River Mile 177–144 (rkm 285.5–232.3); Hallet and Bartholomew 2006; Fujiwara et al. 2011; Voss et al. 2024]. The spring release of juvenile Chinook Salmon from IGH typically occurs after most naturally produced fish have already migrated downstream and when infections can be most prominent. Therefore, if this hypothesis is true, we would expect to see a similar pattern for hatchery fish. Evidence supporting this hypothesis include significant downward trends in 1) the number of hatchery-origin Chinook Salmon that returned to IGH from 2001 to 2023 ($p = 0.009$)and 2) the proportion of Chinook Salmon that were estimated to be of hatchery origin that returned to both IGH ($p < 0.001$) and the IGD–Shasta River study area ($p < 0.001$) from 2007 to 2023 (Appendix I). Several larger-scale environmental factors may have also affected the population dynamics and determining the cause will require further investigations.

Table 7. Proportions of fall-run Chinook Salmon adult spawners in the mainstem Klamath River from IGD to the Shasta River confluence within different spatial scales of the Klamath River Basin, 2001–2023. Data compiled from KRTAT (2003a, 2003b, 2004), KRTAT (2005–2009), and KRTT (2010–2023, 2024a).

	Proportion of mainstem Klamath River adult spawners among:				
Year	Mainstem Klamath R. natural spawners from IGD to Indian Creek[a]	Klamath Basin natural spawners above Trinity River	Klamath Basin natural spawners (includes Trinity Basin)	Klamath Basin escapement (hatchery + natural)	Klamath Basin total in-river run [b]
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%
2016	24.4%	6.8%	5.1%	4.0%	2.9%
2017	76.5%	21.6%	16.2%	10.1%	9.4%
2018	67.3%	20.6%	14.4%	10.7%	8.4%
2019	35.6%	8.5%	5.7%	4.5%	3.1%
2020	42.5%	9.9%	4.5%	3.4%	2.6%
2021	42.5%	10.5%	5.9%	4.1%	3.3%
2022	67.3%	21.5%	14.4%	9.0%	6.8%
2023	65.0%	20.4%	12.1%	7.2%	6.9%

[a] IGD to Wingate Bar 2017–2023

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

Hatchery Fish Contribution

Snout samples were collected from 12 of the 13 F_1- and D_2-condition ad-clipped carcasses encountered in 2020, all 27 in 2021, 33 of 51 in 2022, and 89 of 160 in 2023. Of these, 8, 15, 29, and 77 coded-wire tags (CWT) were recovered and decoded, respectively (Appendix J). All CWTs recovered were from age-3 and -4 fish and with production multipliers that ranged between 4.00 and 4.10 in 2020 and 2021 and between 1.00 and 6.58 in 2022 and 2023. The estimated annual proportion of hatchery-origin spawners in the study area ranged between 8.5% and 20.5%% ($\widehat{N}_H$ range: 104–864; Table 8). The estimated proportion of hatchery-origin spawners ranged from 1.2% to 14.2% between 2001 and 2004 and from 8.5% to 48.1% between 2005 and 2019.

Like previous years, the proportion of hatchery-origin Chinook Salmon from 2020 to 2023 was highest in Reach C1 or C2 (Figure 9). Annual in-river spawning by hatchery-origin fish are expected to be concentrated in the uppermost reach due to its immediate proximity to IGH.

Table 8. Hatchery composition of fall-run Chinook Salmon spawning escapement in the mainstem Klamath River from IGD to the Shasta River confluence, 2001–2023. See Appendix J 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
2017	19.8%	4,740	939
2018	22.4%	8,162	1,828
2019	18.5%	1,318	244
2020	8.5%	1,225	104
2021	9.9%	2,105	208
2022	13.1%	3,243	424
2023	20.5%	4,211	864

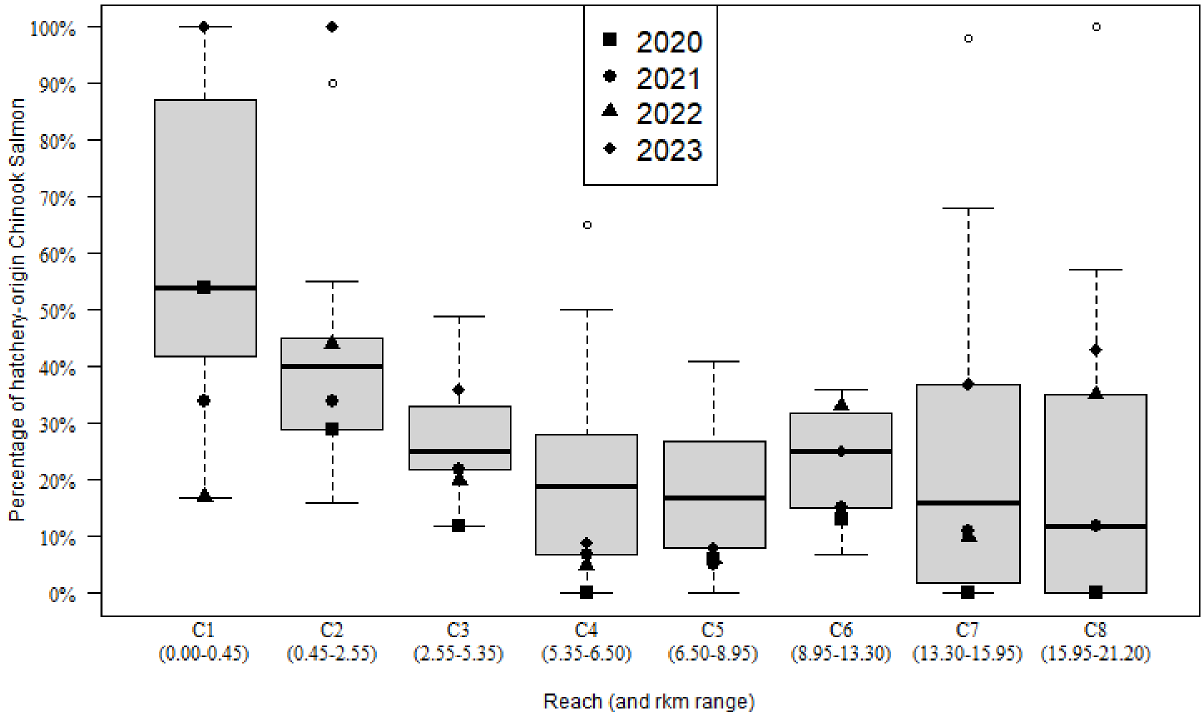

Figure 9. Box plot of percentages of hatchery-origin Chinook Salmon carcasses by reach, Klamath River surveys, 2007–2023, with data points from 2020–2023 also plotted individually.

Egg Deposition

The annual mean egg production per female at IGH was 2,269 in 2020, 2,334 in 2021, 2,564 in 2022, and 2,850 in 2023 (Brock and Sisk 2024). Egg deposition in the carcass survey study area was estimated to be 1.3 million from 590 female fall-run Chinook Salmon in 2020, 2.7 million from 1,165 females in 2021, 4.9 million from 1,978 females in 2022, and 6.1 million from 2,186 females in 2023 (Table 9). 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. Estimated egg deposition (N_e) by fall-run Chinook Salmon in the Klamath River between IGD and the Shasta River confluence, 2001–2023. F_{fs} and F_{ps} are escapement of fully and partially spawned females and $\bar{n}_e$ is the mean number of eggs produced per female at IGH.

Year	$\hat{F}_{fs}$	$\hat{F}_{ps}$	$\bar{n}_e$	$\hat{N}_e$
2001	3,100	49	3,776	11,800,000
2002	6,589	310	3,656	24,700,000
2003	6,718	296	3,331	22,900,000
2004	1,948	181	3,576	7,300,000
2005	1,767	371	2,893	5,600,000
2006	1,506	120	3,153	4,900,000
2007	3,732	131	2,489	9,500,000
2008	2,255	74	3,488	8,000,000
2009	2,743	42	3,332	9,200,000
2010	1,291	17	3,454	4,500,000
2011	1,326	31	3,422	4,600,000
2012	6,021	282	3,401	21,000,000
2013	4,181	168	3,432	14,600,000
2014	7,935	528	3,577	29,300,000
2015	1,408	21	2,746	3,900,000
2016	380	27	2,589	1,000,000
2017	1,916	41	2,551	4,900,000
2018	4,720	180	2,474	11,900,000
2019	728	44	2,089	1,600,000
2020	563	27	2,269	1,300,000
2021	1,135	30	2,334	2,700,000
2022	1,856	122	2,564	4,900,000
2023	2,125	61	2,850	6,100,000

Redd Redd Survey

Redd Counts and Escapement

Seven hundred eighty-four redds were counted (plus another 8 extrapolated for cancelled surveys) in 2021, 1,192 in 2021, 772 in 2022, and 1,068 in 2023, which represent 1,584, 2,384, 1,544, and 2,136 adult fall-run Chinook Salmon, respectively, between the Shasta River confluence and Wingate Bar (Reaches R2–R7; Tables 10–13). After the surrogate jack proportions from the IGD–Shasta River carcass survey were applied to the adult estimates, jack escapement to this area was estimated to be 38, 234, 17, and 66, respectively. The annual counts in Reaches R2–R6 from 2020 to 2023 were all below the previous 27-year mean (1,244; Figure 10; Figure 11; Appendix K). The highest count of new redds occurred during calendar week 45 in 2020 and 2021, calendar week 44 in 2022, and calendar week 43 in 2023 (Tables 10–13). Previous years' peak counts of new redds typically occurred in calendar week 43 or 44 (mid- to late October).

Distribution

Redd concentration by reach ranged between 2.1 and 11.0 redds/km in 2020, 3.0 18.7 redds/km in 2021, 1.9 and 9.3 redds/km in 2022, and 1.7 and 16.2 redds/km in 2023 (Tables 10–13). The lowest and highest annual redd densities were consistently in Reaches R7 and R6, respectively. Redds in all reaches were distributed mostly in aggregations of less than 30 redds in low-gradient riffles (Appendices L–O). The third largest redd aggregation (50 redds) of 2020 and largest redd aggregation from 2021 to 2023 (96, 75, and 131 redds, respectively) was about 2 km upstream of Horse Creek in Reach R6 on a wide low-gradient riffle. See Appendices L–O for maps of redd distribution by reach.

Table 10. Fall-run Chinook Salmon redd counts by week and reach, Klamath River surveys, 2020. NS = no survey.

Calender week	Survey dates	Reach						Total
		R2[a]	R3[b]	R4[a]	R5[b]	R6[c]	R7[b]	
42	Oct 13-16	0	1	1	0	1	0	3
43	Oct 20-23	47	38	47	35	25	6	198
44	Oct 27-30	29	10	76	19	77	2	213
45	Nov 3-6	36	40	23	32	72	13	216
46	Nov 10-13	10	37	19	17	17	2	102
47	Nov 17-20	0	22	11	8	11	0	52
48	-	No Survey (Thanksgiving week)						-
49	- [d]	0	3	2	1	2	0	8
Reach Total		122	151	179	112	205	23	792
Percent of Total		15.4%	19.1%	22.6%	14.1%	25.9%	2.9%	-
Redd Density		4.6/km	5.5/km	8.6/km	5.3/km	11.0/km	2.1/km	6.3/km

[a] surveyed by Karuk Tribe crew

[b] surveyed by USFWS crew

[c] reach split and surveyed by Karuk Tribe and USFWS crews

[d] no survey (cancelled due to Covid concerns); redd numbers projected from mean ratio of counts of last survey week to penultimate survey week using data from 2009 to 2019

Table 11. Fall-run Chinook Salmon redd counts by week and reach, Klamath River surveys, 2021. NS = no survey.

Calender	Survey	Reach						
week	dates	R2[a]	R3[b]	R4[a]	R5[b]	R6[c]	R7[b]	Total
42	Oct 13-16	0	4	0	2	21	0	27
43	Oct 19-22	15	48	68	69	95	12	307
44	Oct 26	57	104	- [d]	- [d]	- [d]	- [d]	161
45	Nov 2-4	13	137	73	55	76	- [d]	354
46	Nov 8-10	10	29	23	36	104	- [d]	202
47	Nov 16-19	6	31	12	18	49	22	138
48	-	No Survey (Thanksgiving week)						-
49	Nov 30 - Dec 3	1	0	0	0	2	0	3
Reach Total		102	353	176	180	347	34	1,192
Percent of Total		8.6%	29.6%	14.8%	15.1%	29.1%	2.9%	-
Redd Density		3.9/km	12.8/km	8.5/km	8.5/km	18.7/km	3.0/km	9.5/km

[a] surveyed by Karuk Tribe crew

[b] surveyed by USFWS crew

[c] reach split and surveyed by Karuk Tribe and USFWS crews

[d] not surveyed because of high turbidity following rain event

Table 12. Fall-run Chinook Salmon redd counts by week and reach, Klamath River surveys, 2022. NS = no survey.

Calender	Survey	Reach						
week	dates	R2[a]	R3[b]	R4[a]	R5[b]	R6[c]	R7[b]	Total
42	Oct 12-14	0	1	0	0	0	0	1
43	Oct 18-20	25	26	14	13	11	10	99
44	Oct 25-27	60	29	84	33	45	0	251
45	Nov 2-3	62	54	- [d]	38	50	- [d]	204
46	Nov 8-10	23	3	35	7	27	11	106
47	Nov 15-17	3	22	38	7	40	0	110
48	-	No survey (Thanksgiving week)						-
49	Nov 29 - Dec 1	0	1	0	0	0	0	1
Reach total		173	136	171	98	173	21	772
Percent of total		22.4%	17.6%	22.2%	12.7%	22.4%	2.7%	-
Redd density		6.5/km	4.9/km	8.3/km	4.6/km	9.3/km	1.9/km	6.1/km

[a] surveyed by Karuk Tribe crew

[b] surveyed by USFWS crew

[c] reach split and surveyed by Karuk Tribe and USFWS crews

[d] not surveyed because of adverse weather conditions

Table 13. Fall-run Chinook Salmon redd counts by week and reach, Klamath River surveys, 2023. NS = no survey.

Calender week	Survey dates	Reach R2[a]	R3[b]	R4[a]	R5[b]	R6[c]	R7[b]	Total
42	Oct 11-13	7	2	0	0	10	0	19
43	Oct 17-19	46	34	20	43	109	2	254
44	Oct 24-26	28	196	32	117	108	11	492
45	Nov 1-3	44	69	41	43	53	0	250
46	Nov 7-9	5	16	2	1	14	6	44
47	Nov 15-17	0	2	0	0	7	-	9
48	-	No survey (Thanksgiving week)						-
49	-	No survey						-
Reach total		130	319	95	204	301	19	1,068
Percent of total		12.2%	29.9%	8.9%	19.1%	28.2%	1.8%	-
Redd density		4.9/km	11.6/km	4.6/km	9.6/km	16.2/km	1.7/km	8.5/km

[a] surveyed by Karuk Tribe crew

[b] surveyed by USFWS crew

[c] reach split and surveyed by Karuk Tribe and USFWS crews

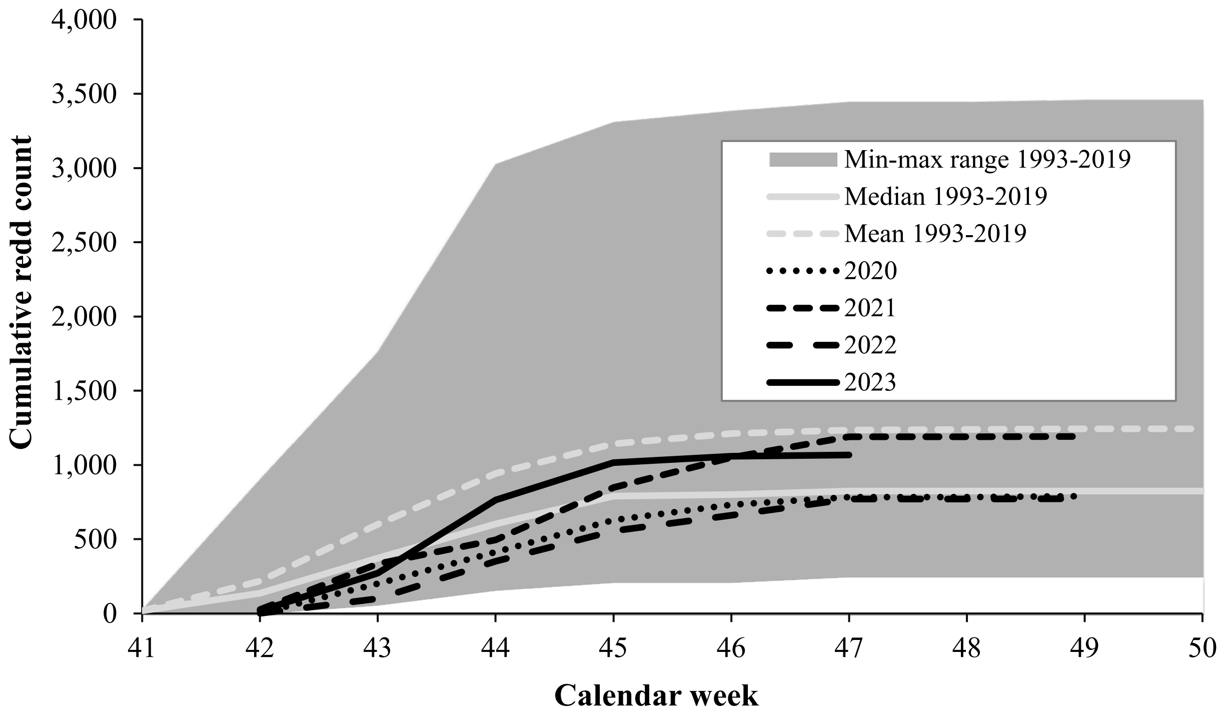

Figure 10. Cumulative counts of fall-run Chinook Salmon redds by calendar week, Klamath River surveys, 2020–2023, compared to the range and mean from 1993 to 2019.

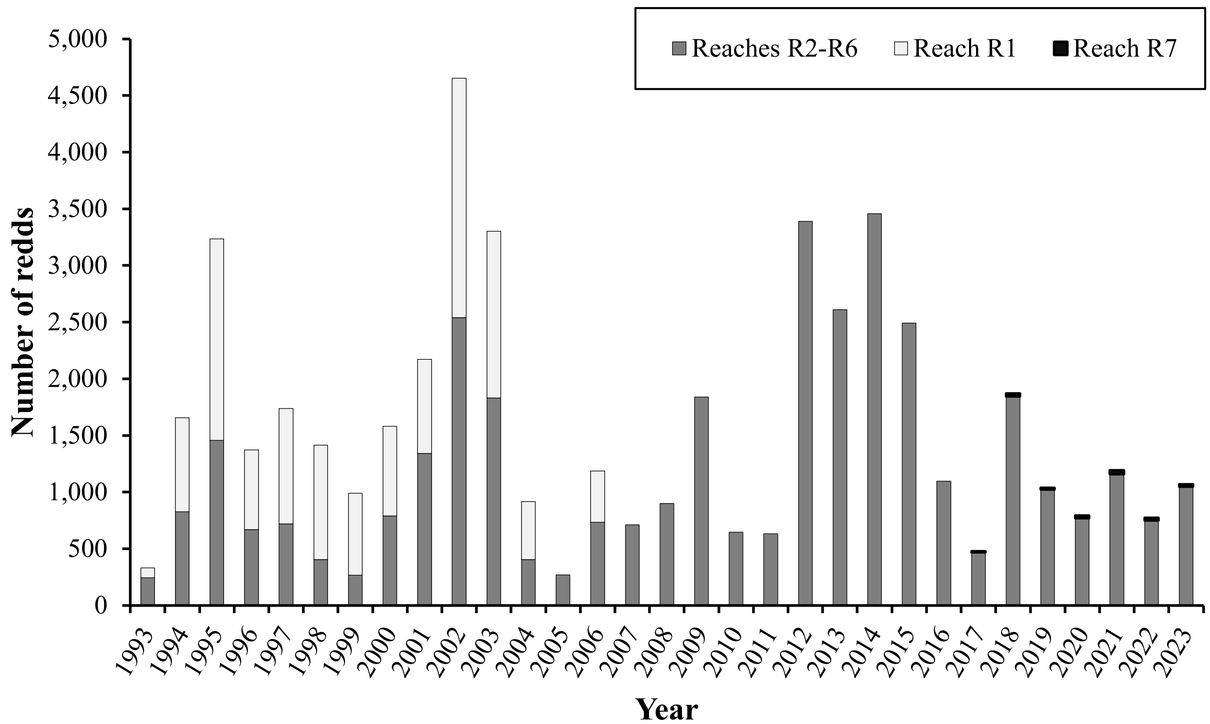

Figure 11. Annual fall-run Chinook Salmon redd counts, Klamath River surveys, 1993–2023. Reach R1 was surveyed from 1993 to 2004 and in 2006. Reach R7 has only been surveyed since 2017.

Egg Deposition

Egg deposition by female fall-run Chinook Salmon in the redd survey study area was estimated to be 1.8 million in 2020, 2.8 million in 2021, 2.0 million in 2022, and 3.0 million in 2023.

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We particularly thank the Karuk Tribe Department of Natural Resources and Yurok Tribal Fishery Program for their annual participation in this survey. Data were collected by Karuk Tribe personnel: Ken Brink, Alex Corum, Eric Fieberg, Ben Harrison, Chaas Hillman, Mike Polmateer, Beau Quinter, and Clayton Tuttle; by YTFP personnel: Rocky Erickson, Jamie Holt, Gilbert Myers, and Keenan O'Rourke; and by USFWS personnel: Samantha Adams, Olivia Black, Jackie Bridegum, Sierra Castro, Olyvia Childress, Nicholas Glaser, Aliah Guerrero, Aaron Masse-Bachelier, Reuben Smit, Clara Smith, Tyler Wallin, and Adam Wojtczak. We thank Nicholas Som of USGS for statistical support of population estimation methods. From AFWO, we also thank Olivia Black and Erik Kenas for cartographic support.

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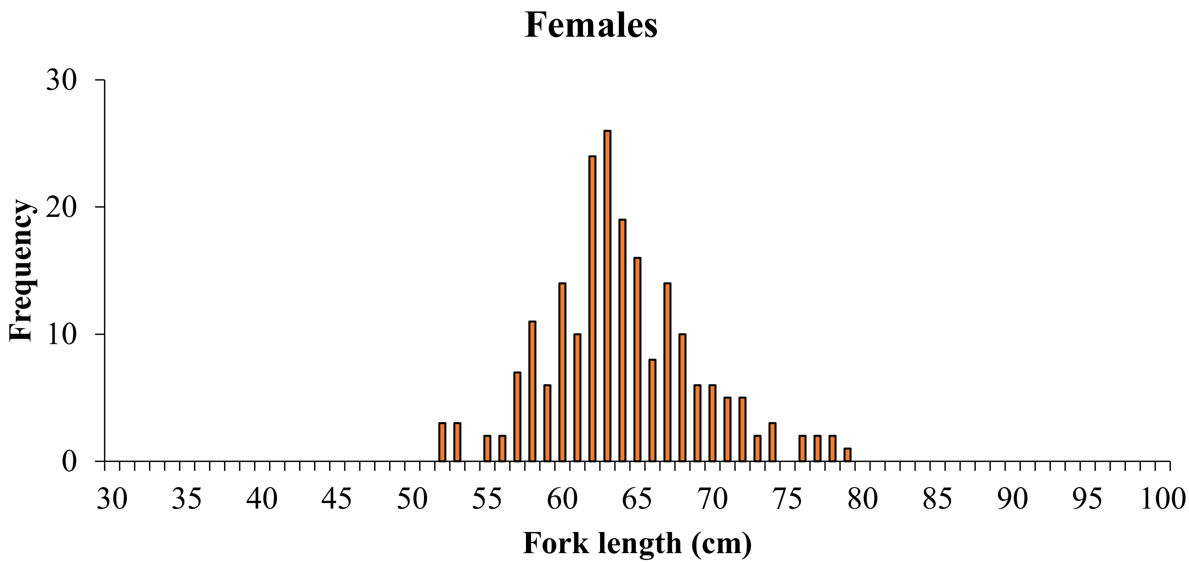
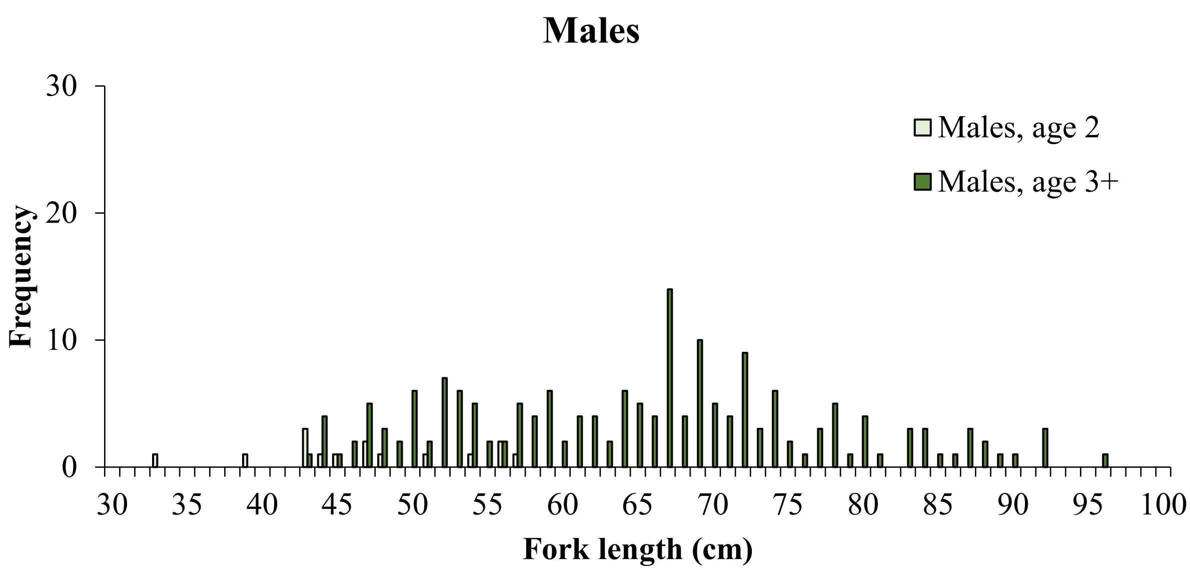
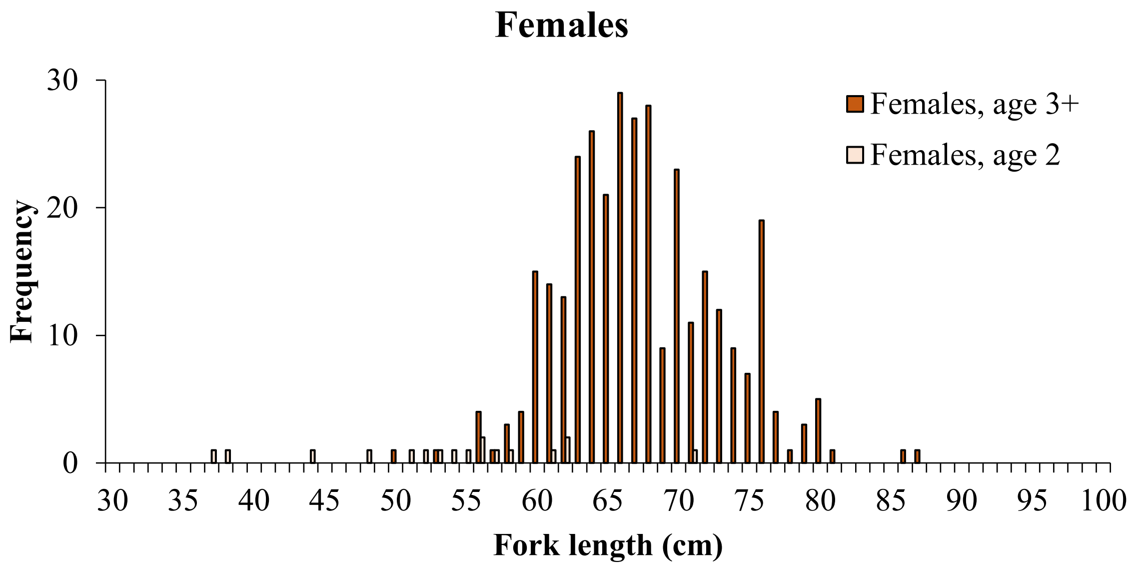
Appendices

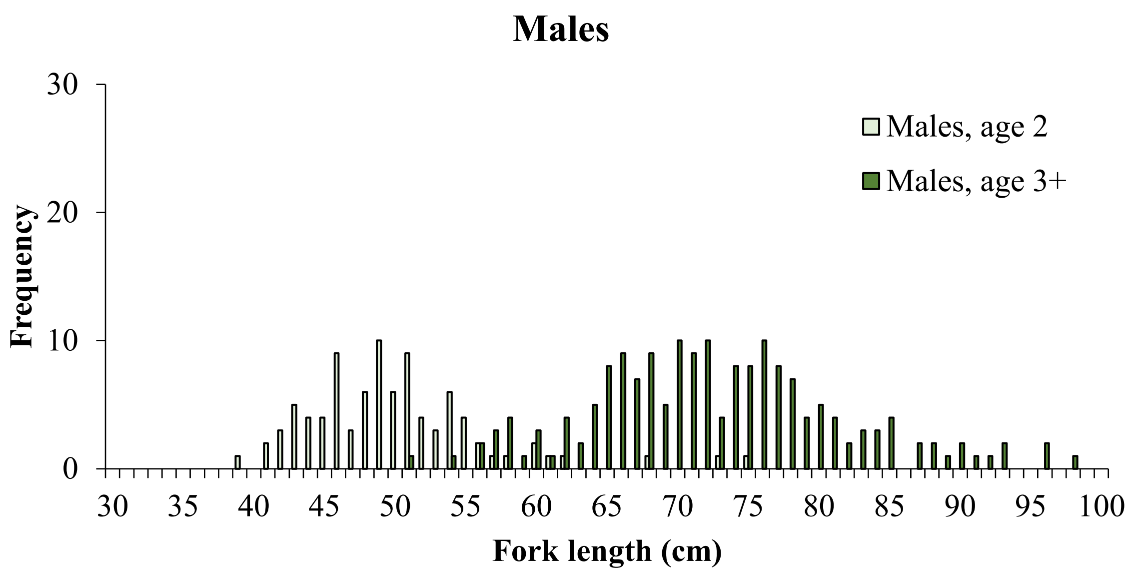
Appendix A. Length-frequency of F_1- and D_2-condition fall-run Chinook Salmon carcasses, Klamath River surveys, 2020. n = 397 (n_F = 206; n_M = 176; n_J = 15).



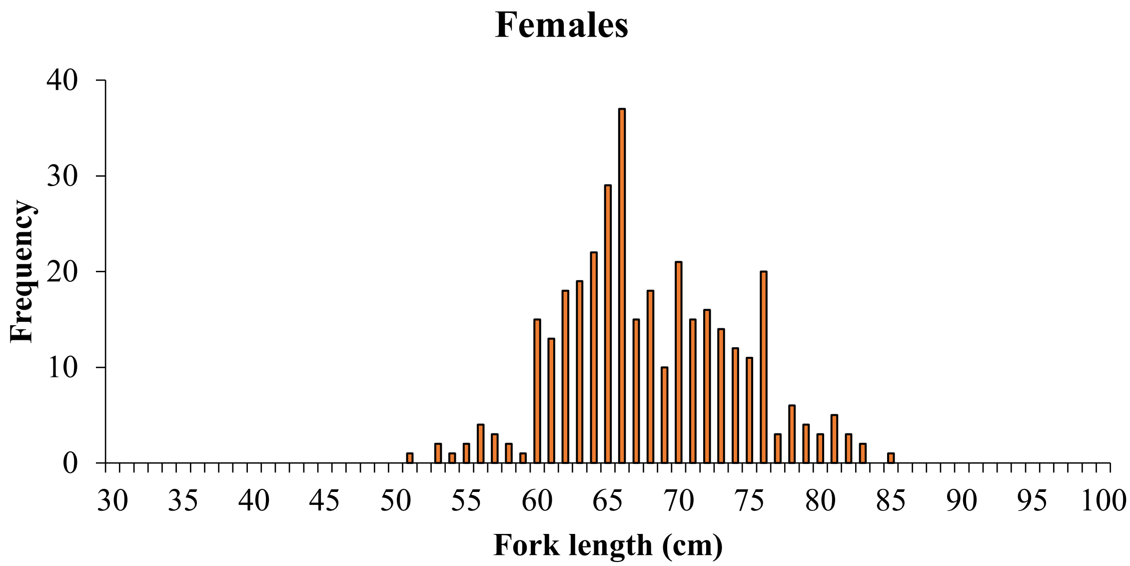


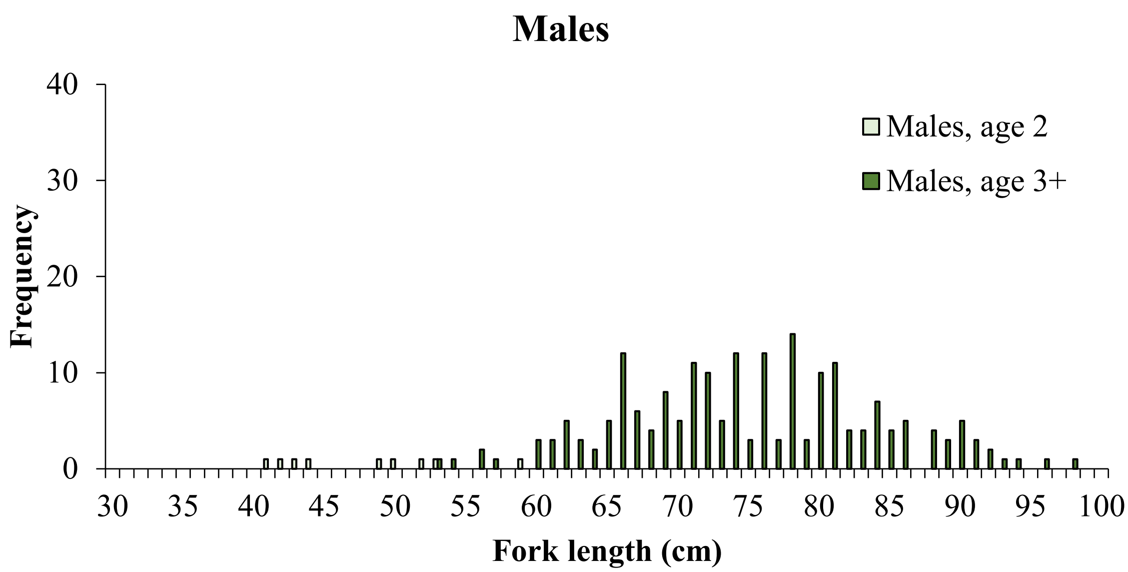
Appendix B. Length-frequency of F_1- and D_2-condition fall-run Chinook Salmon carcasses, Klamath River surveys, 2021. n = 617 (n_F = 332; n_{jill} = 17; n_M = 178; n_{jack} = 90).



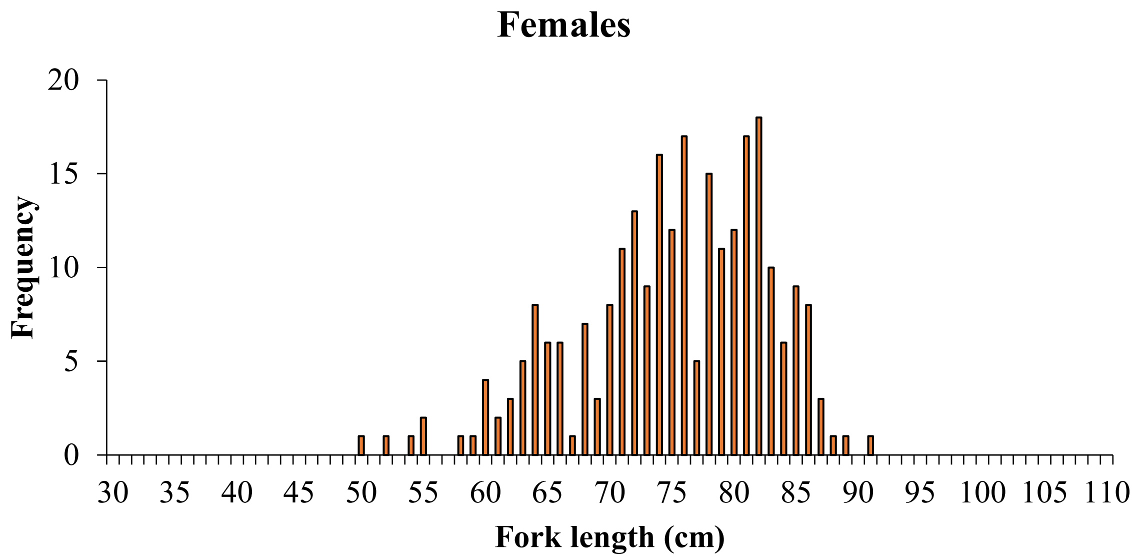


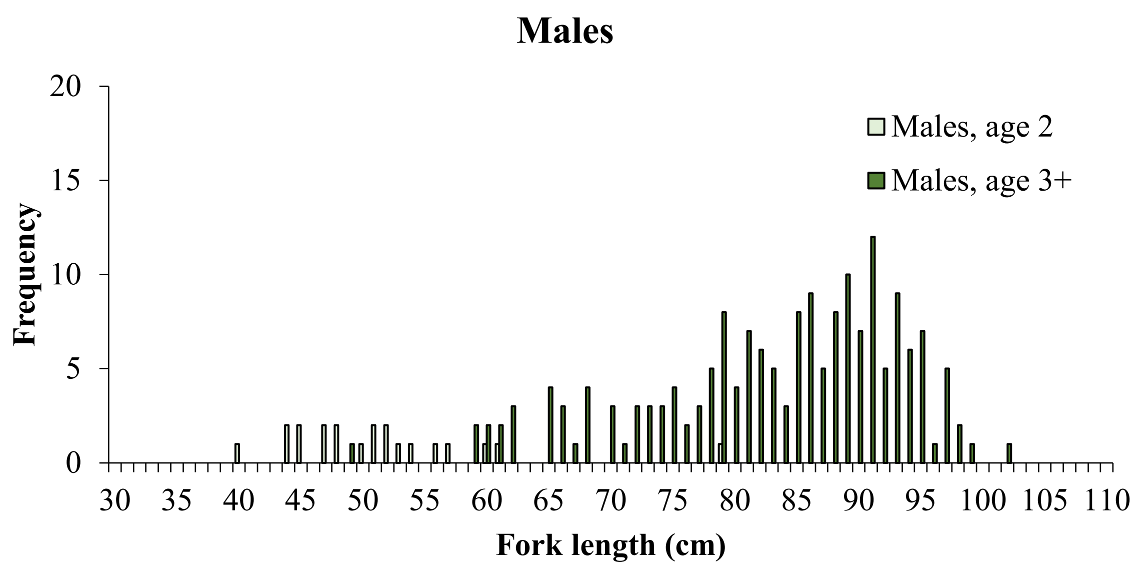
Appendix C. Length-frequency of F_1- and D_2-condition fall-run Chinook Salmon carcasses, Klamath River surveys, 2022. n = 557 (n_F = 348; n_M = 200; n_J = 9).



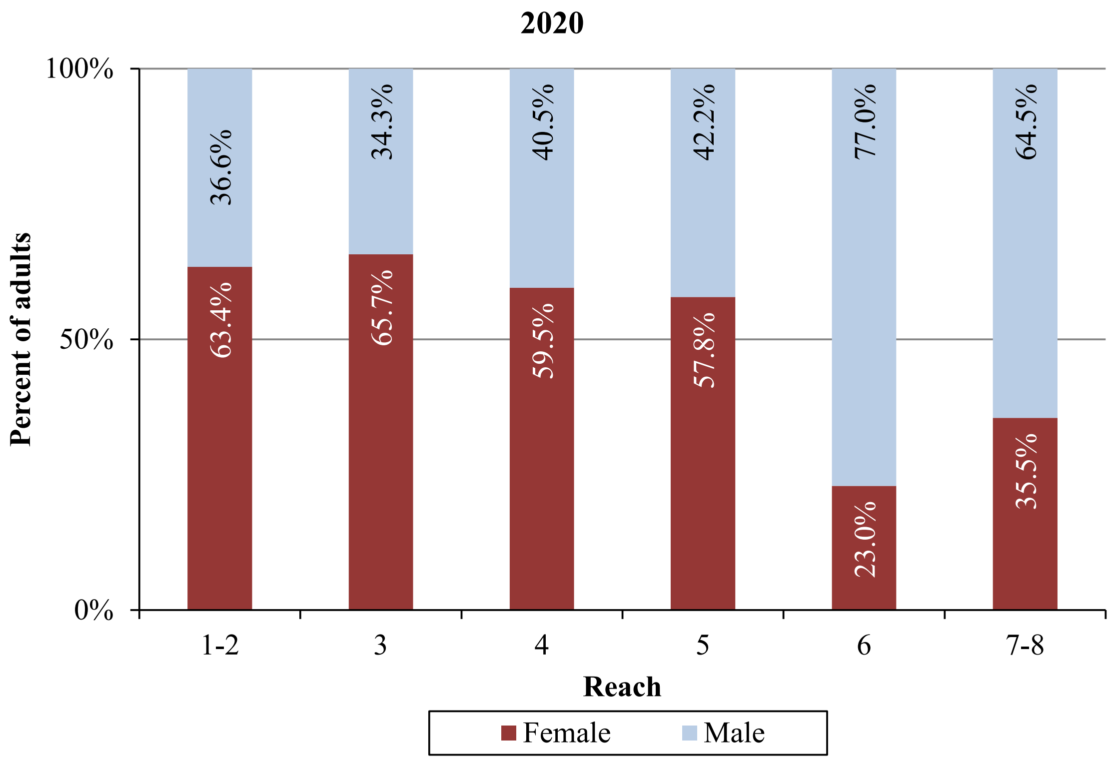


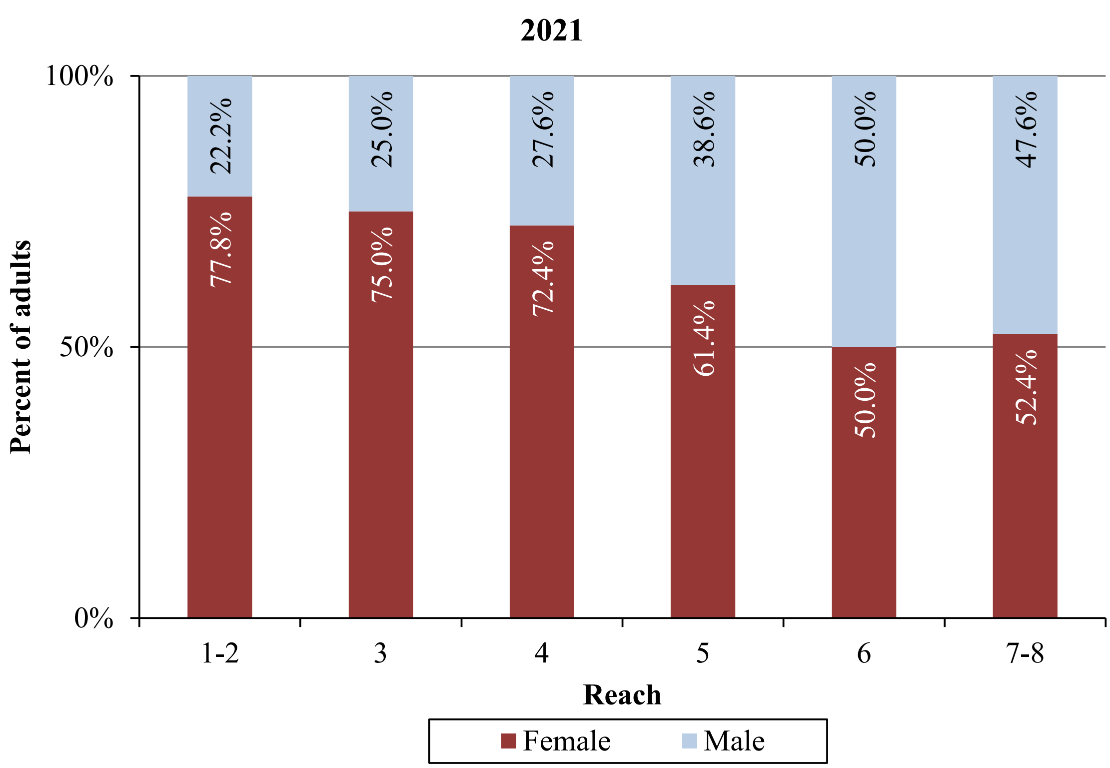
Appendix D. Length-frequency of F_1- and D_2-condition fall-run Chinook Salmon carcasses, Klamath River surveys, 2023. n = 454 (n_F = 55; n_M = 8; n_J = 21).



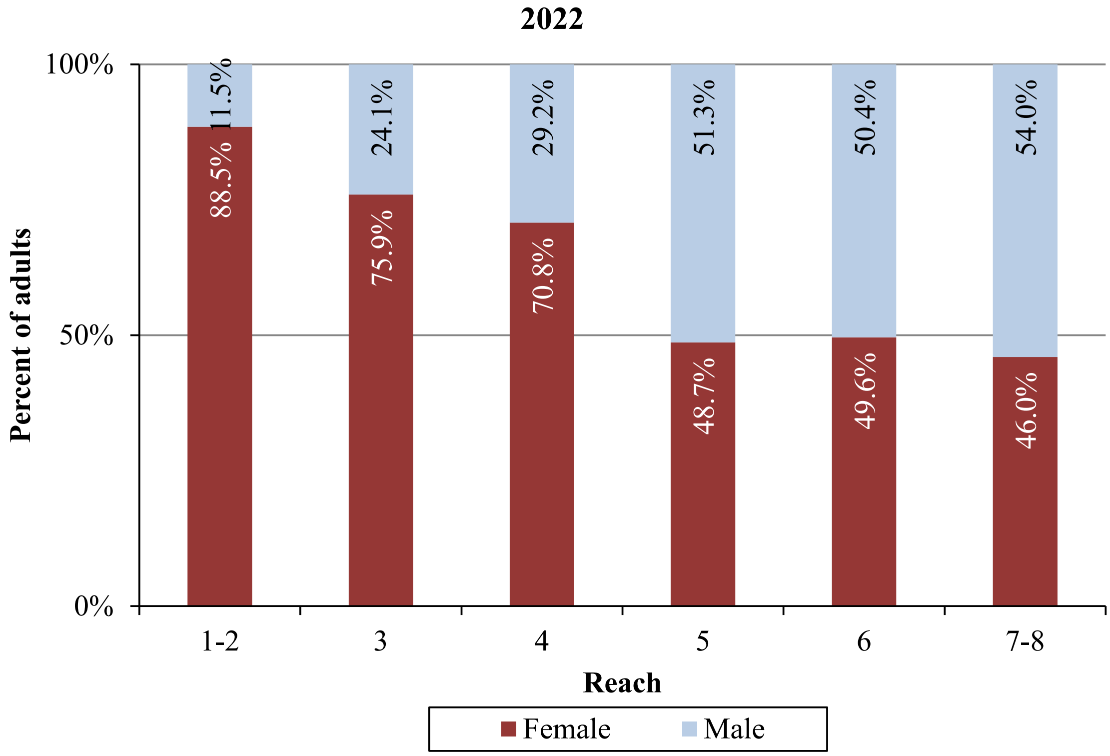


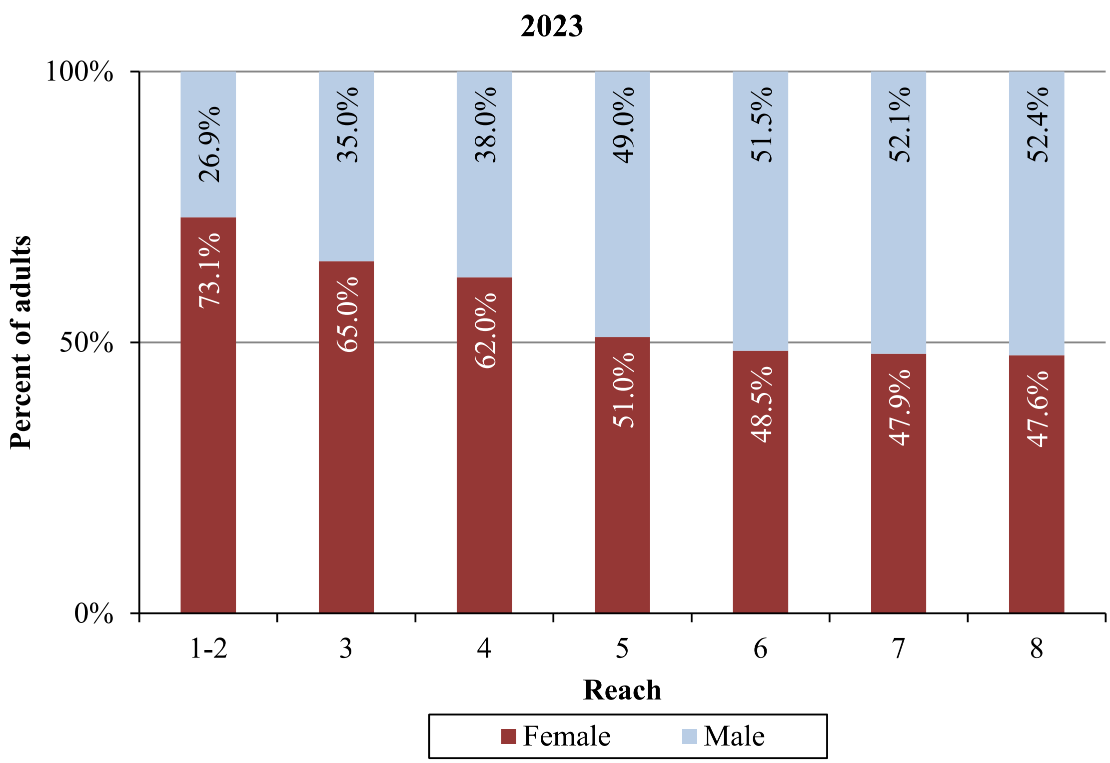
Appendix E. Proportions of adult female and male fall-run Chinook Salmon carcasses by reach, Klamath River surveys, 2020-2023.Reaches 1 and 2 as well as Reaches 7 and 8 were combined some years because at least one reach in each pair contained a small sample size.





Appendix E (continued). Proportions of adult female and male fall-run Chinook Salmon carcasses by reach, Klamath River surveys, 2020-2023.Reaches 1 and 2 as well as Reaches 7 and 8 were combined some years because at least one reach in each pair contained a small sample size.



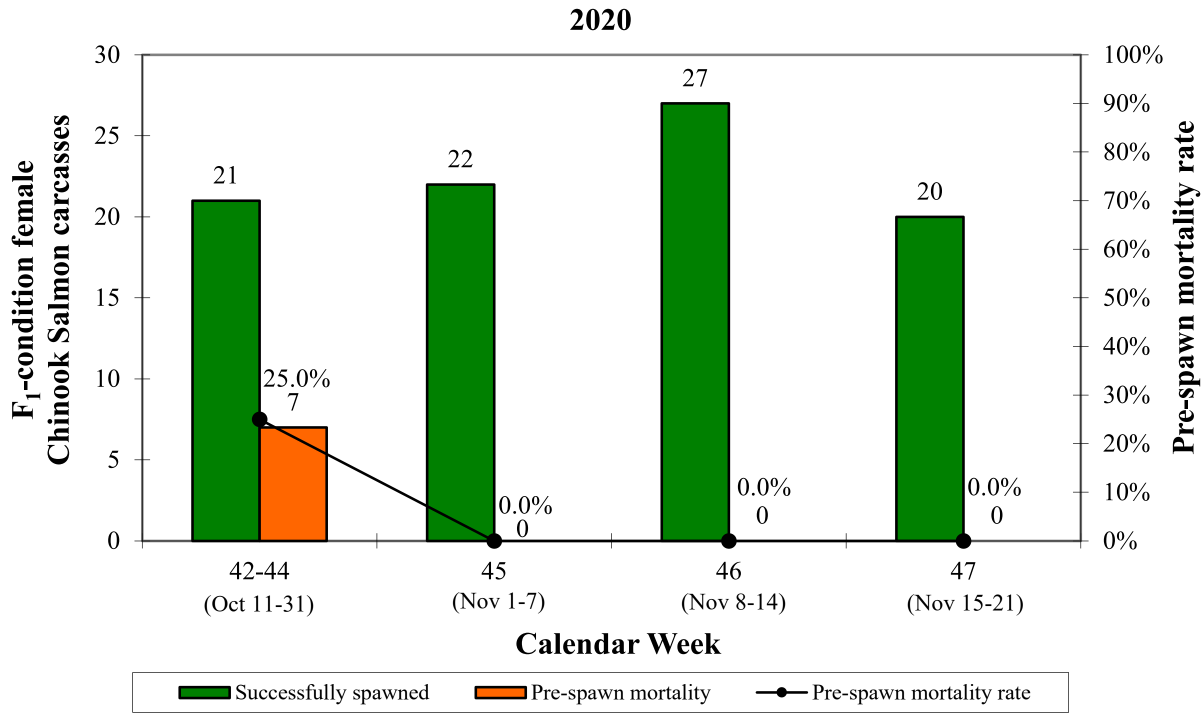


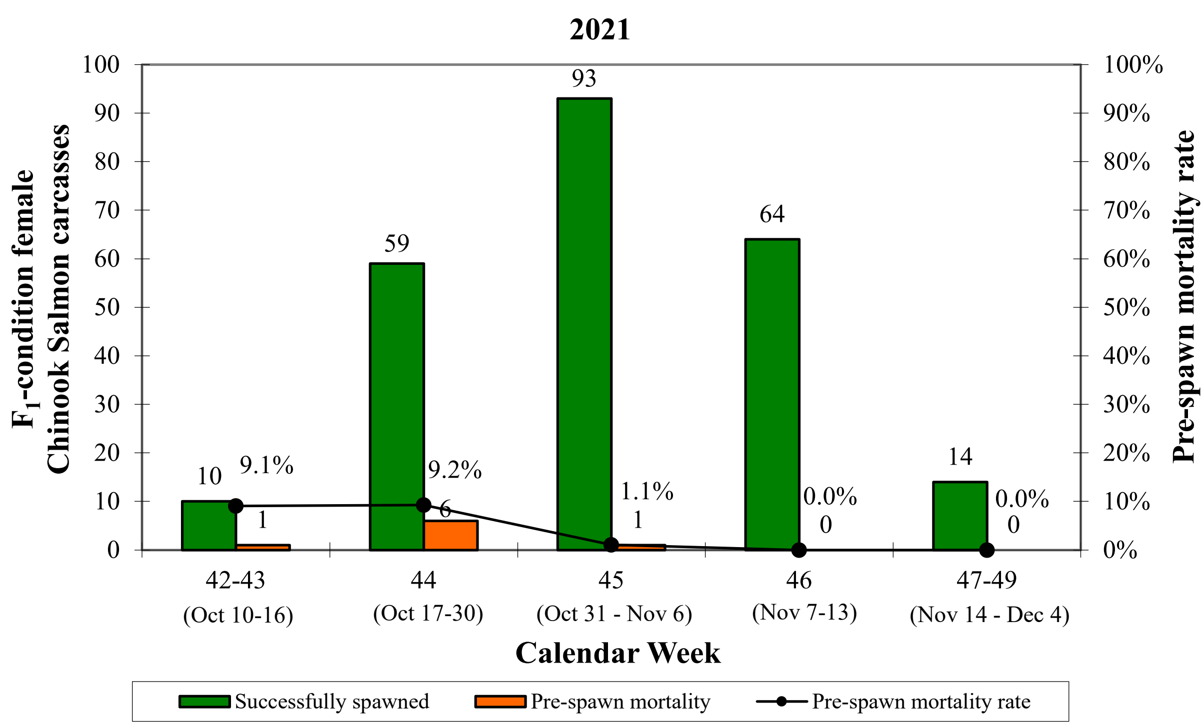
Appendix F. Proportions of female and male fall-run Chinook Salmon returning to IGH and the mainstem Klamath River, 2001–2023. IGH adult proportions were determined by first subtracting the jack percentage from the male percentage. Proportions of adult females and males were then recalculated from the remaining adult numbers. IGH data compiled from CDFG (2003), Hampton (2005), Richey (2006, 2007), Chesney (2007–2009), Chesney and Knechtle (2010–2017), Giudice and Knechtle (2018–2023), and Giudice and Kang (2024).

	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%
2016	47.9%	52.1%	5.8%	50.8%	49.2%	60.2%	39.8%
2017	41.1%	58.9%	30.0%	58.7%	41.3%	65.4%	34.6%
2018	55.6%	44.4%	3.7%	57.7%	42.3%	64.8%	35.2%
2019	56.7%	43.3%	6.1%	60.4%	39.6%	68.0%	32.0%
2020	44.0%	56.0%	9.3%	48.5%	51.5%	53.9%	46.1%
2021	45.0%	55.0%	6.6%	48.2%	51.8%	65.6%	34.4%
2022	49.8%	50.2%	2.2%	50.9%	49.1%	66.2%	33.8%
2023	49.8%	50.2%	1.9%	50.8%	49.2%	59.1%	40.9%

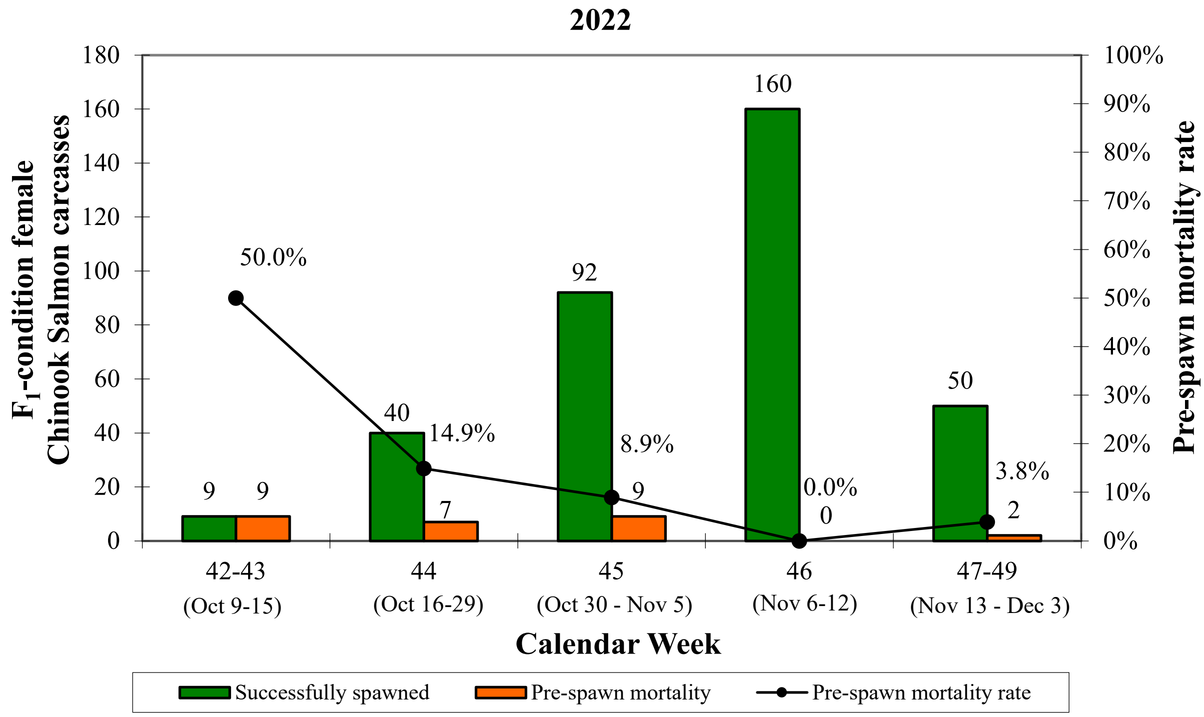
[a] Female and male proportions were calculated prior to distinguishing jacks and therefore total 100%

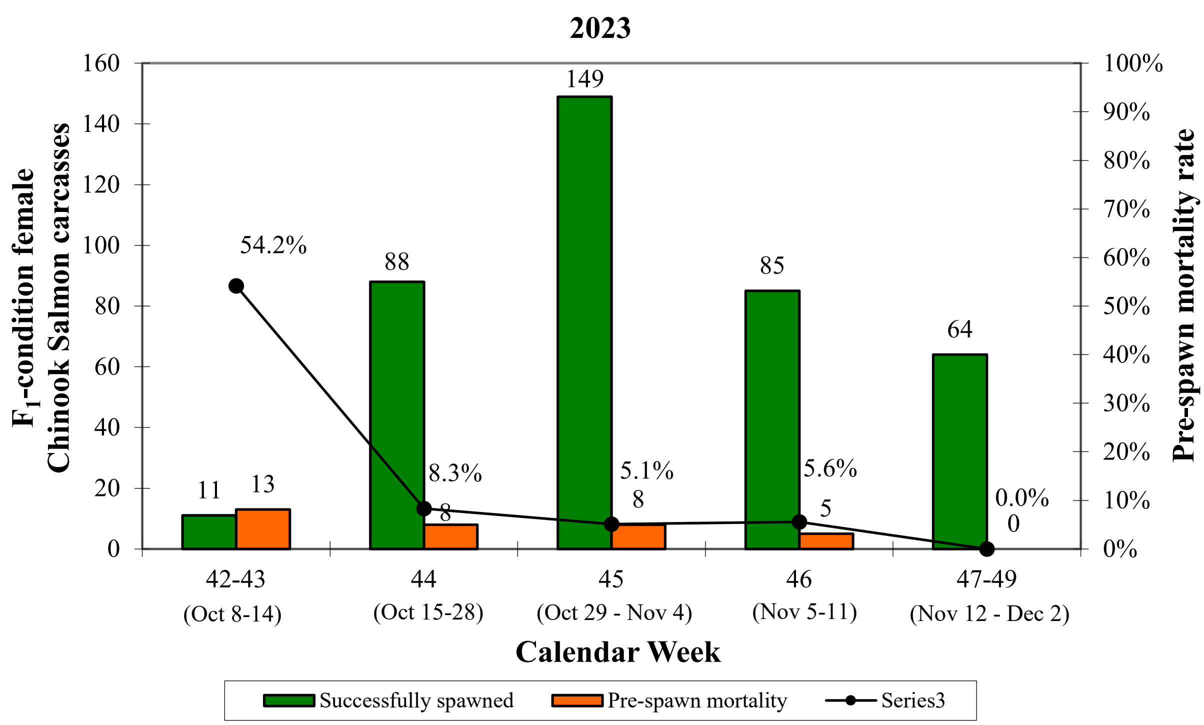
Appendix G. Weekly pre-spawn mortality from F_1-condition female fall-run Chinook Salmon carcasses, Klamath River surveys, 2020–2023. Only F_1-condition carcasses were included since we can assume only those fish expired the week they were found. The first two or three calendar weeks were combined as well as calendar weeks 47–49 since sample sizes were low.



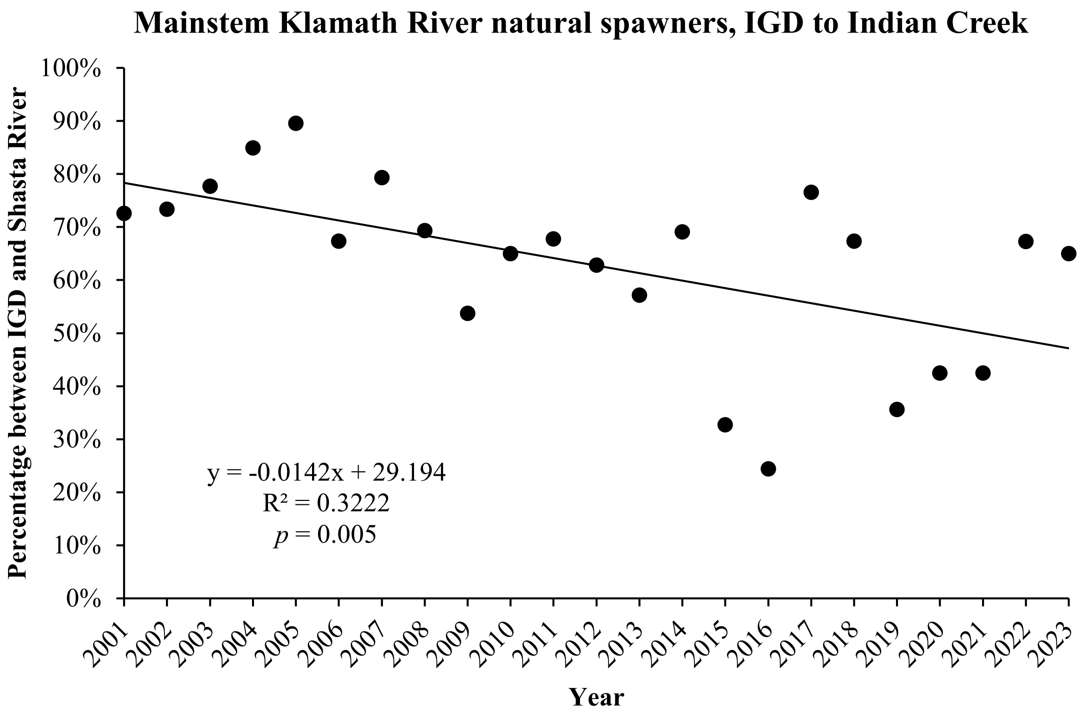


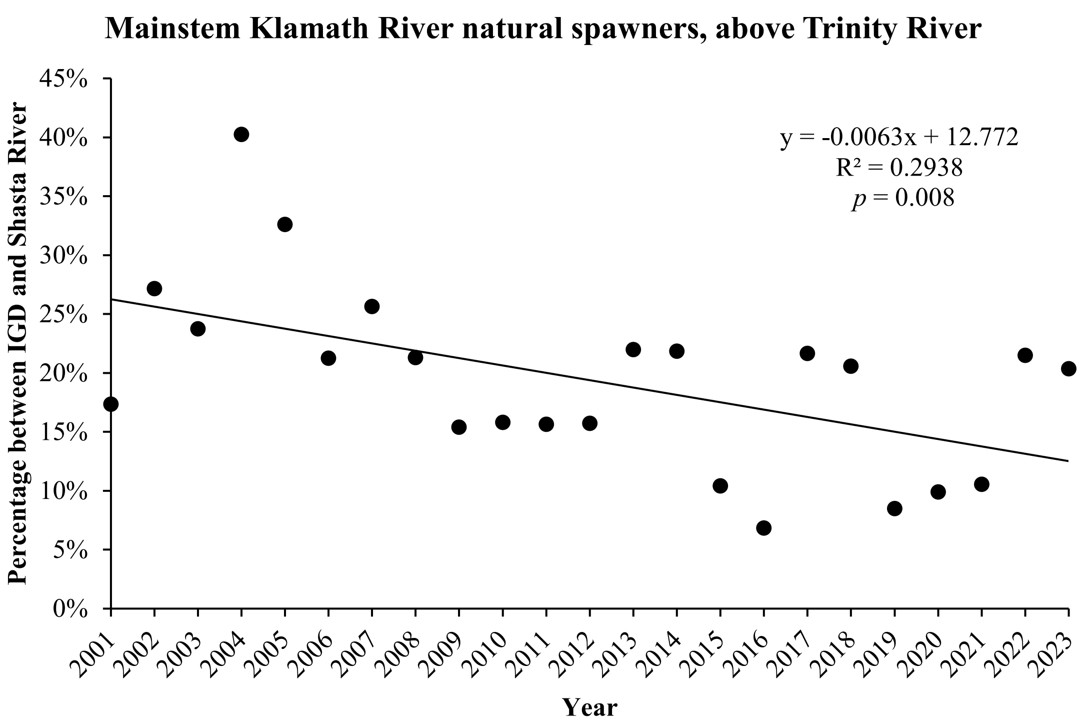
Appendix G (continued). Weekly pre-spawn mortality from F_1-condition female fall-run Chinook Salmon carcasses, Klamath River surveys, 2020–2023. Only F_1-condition carcasses were included since we can assume only those fish expired the week they were found. The first two or three calendar weeks were combined as well as calendar weeks 47–49 since sample sizes were low.



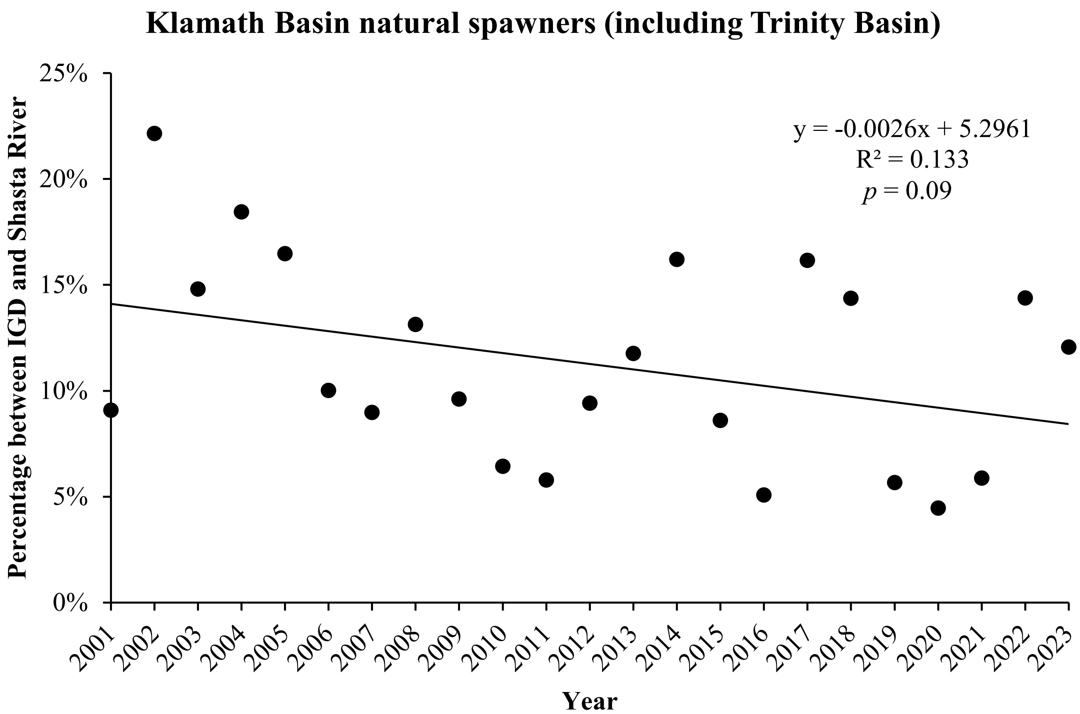


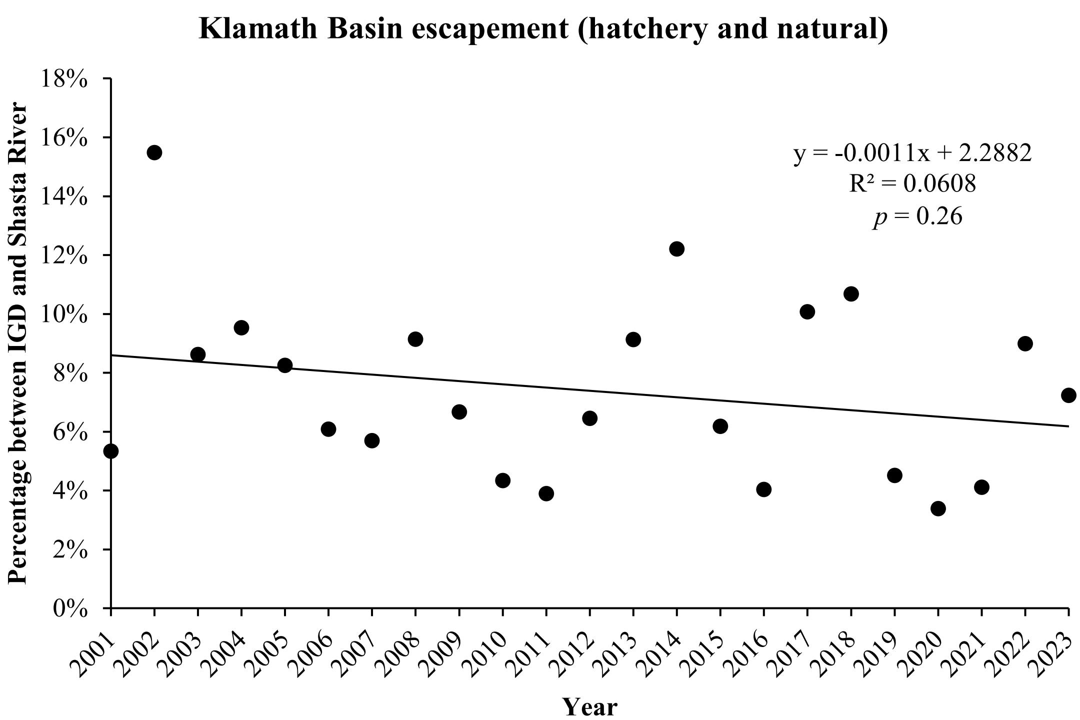
Appendix H. Proportions of fall-run Chinook Salmon adult spawners in the mainstem Klamath River from Iron Gate Dam to the Shasta River confluence within different scales of the Klamath River Basin, 2001–2023. Data compiled from KRTAT (2003a, 2003b, 2004), KRTAT (2005–2009), and KRTT (2010–2023, 2024a).



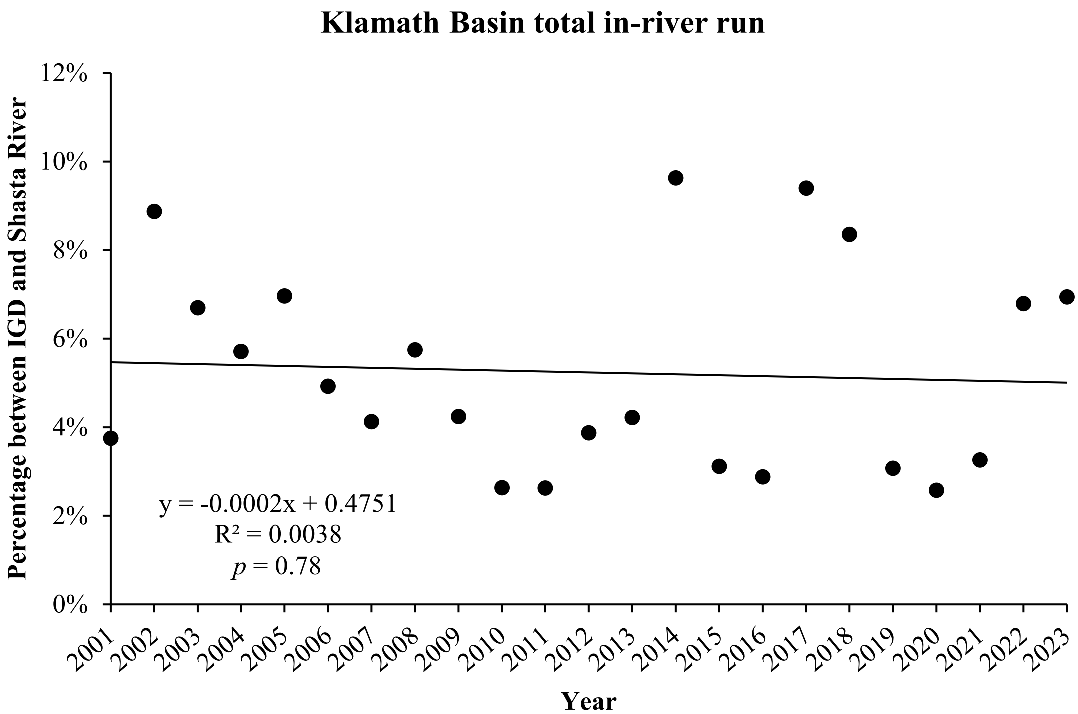


Appendix H (continued). Proportions of fall-run Chinook Salmon adult spawners in the mainstem Klamath River from Iron Gate Dam to the Shasta River confluence within different scales of the Klamath River Basin, 2001–2021. Data compiled from KRTAT (2003a, 2003b, 2004), KRTAT (2005–2009), and KRTT (2010–2023, 2024a).

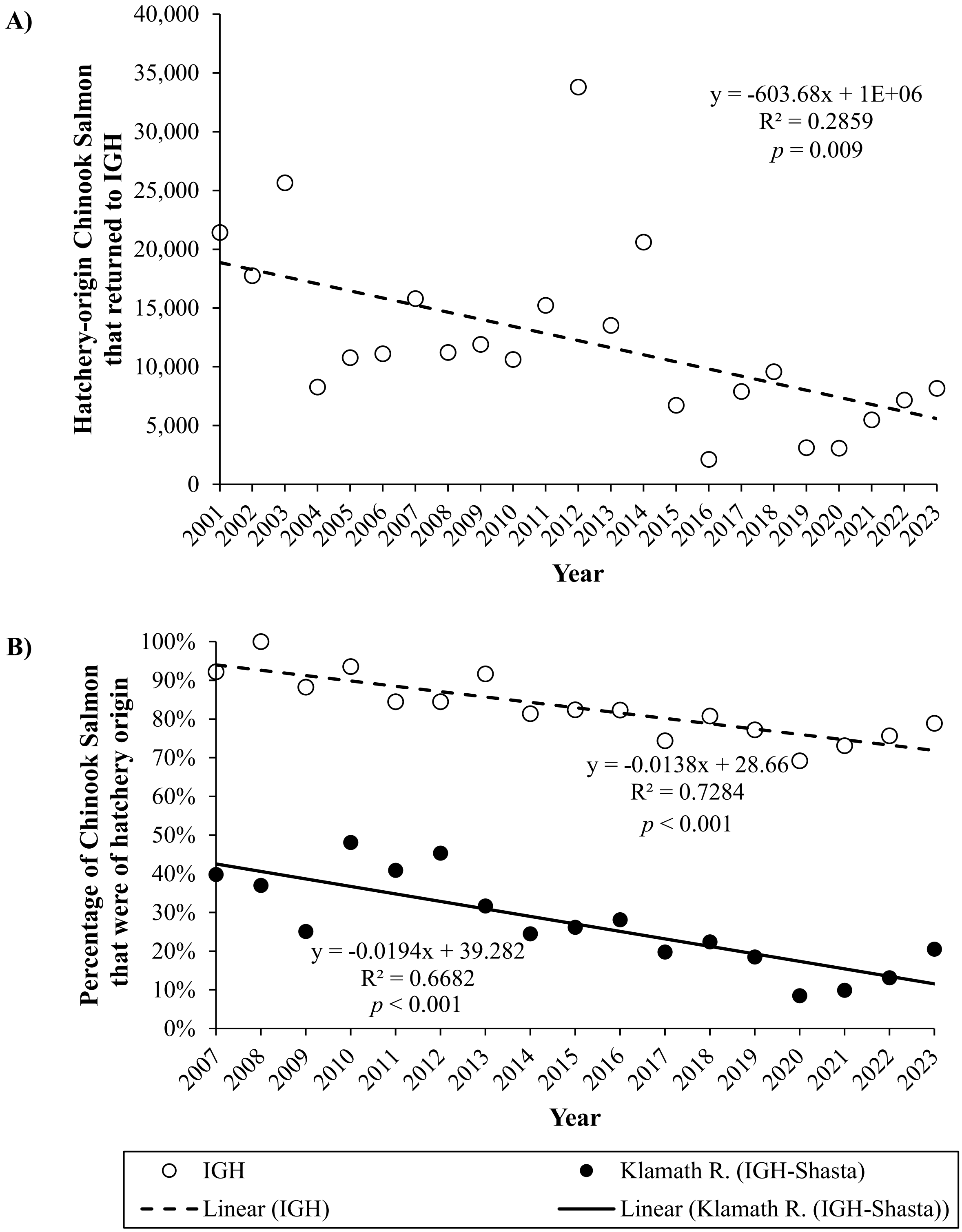




Appendix H (continued). Proportions of fall-run Chinook Salmon adult spawners in the mainstem Klamath River from Iron Gate Dam to the Shasta River confluence within different scales of the Klamath River Basin, 2001–2021. Data compiled from KRTAT (2003a, 2003b, 2004), KRTAT (2005–2009), and KRTT (2010–2023, 2024a).



Appendix I. Numbers of hatchery-origin Chinook Salmon that returned to Iron Gate Hatchery (IGH) from 2001 to 2023 (A) and the proportion of Chinook Salmon that were of hatchery origin that returned to Iron Gate Hatchery and the Iron Gate Dam–Shasta River (IGD–Shasta) study area of the Klamath River from 2007 to 2023 (B).



Appendix J. Hatchery composition of fall-run Chinook Salmon in the mainstem Klamath River from IGD to the Shasta River confluence based on carcass survey data from 2001 to 2023. 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 2011–2023 results. Also, data from 2011 to 2023 are presented in a separate table since a different methodology was used to calculate hatchery composition.

Year	Total carcass capture	Ad-clip carcass capture [a]	Percentage of hatchery-produced fish with ad-clip at IGH	Estimated capture of hatchery-origin carcasses	Estimated hatchery-origin percentage [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 fresh carcass count	Ad-clip carcass capture	Snout samples from ad-clip carcasses	CWTs recovered	CWTs decoded	Estimated count of hatchery-origin carcasses	Estimated hatchery-origin percentage	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
2016	257	18	16	16	16	72	28.1%	746	210
2017	1,262	60	60	60	56	249	19.8%	4,740	939
2018 [c]	2,576	46	45	42	42	577	22.4%	8,162	1,828
2019	346	16	16	16	16	64	18.5%	1,318	244
2020	408	13	12	8	8	35	8.5%	1,225	104
2021	662	27	27	16	15	65	9.9%	2,105	208
2022 [c]	944	51	33	29	29	123	13.1%	3,243	424
2023 [c]	1,179	165	89	82	77	242	20.5%	4,211	864

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

Appendix K. Annual fall-run Chinook Salmon redd counts by reach, Klamath River surveys, 1993–2023. Reach R1 = Iron Gate Dam to Shasta River, R2 = Shasta River to Beaver Creek (note: the 2.7-km section from the Shasta River to Ash Creek was not surveyed and was assumed to have no redds), R3 = Beaver Creek to Blue Heron river access, R4 = Blue Heron river access to Seiad Bar, R5 = Seiad Bar to China Point, R6 = China Point to Indian Creek R7 =Indian Creek to Wingate Bar; '-' = no survey.

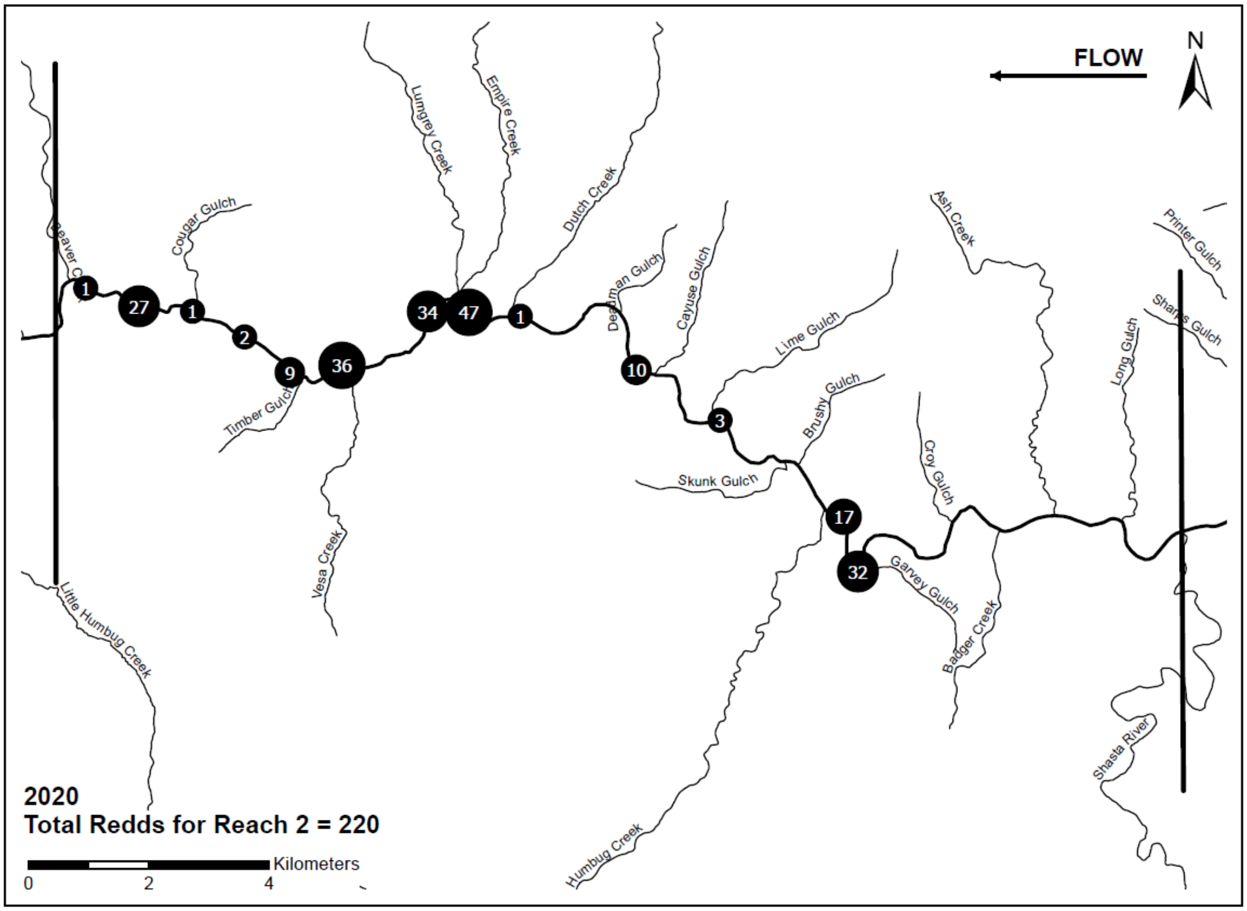
		Redd count by reach							
Year	Survey dates	R1	R2	R3	R4	R5	R6	R7	Total
1993	Oct 25 - Nov 18	87	38	56	31	31	87	-	330
1994	Oct 17 - Nov 18	831	109	178	159	119	260	-	1,656
1995	Oct 16 - Dec 1	1,779	187	410	172	215	473	-	3,236
1996	Oct 21 - Nov 15	704	64	151	40	200	213	-	1,372
1997	Oct 16 - Nov 14	1,020	76	162	162	62	257	-	1,739
1998	Oct 14 - Nov 19	1,010	82	126	42	39	116	-	1,415
1999	Oct 13 - Nov 19	723	69	62	28	38	69	-	989
2000	Oct 16 - Nov 22	789	208	196	164	42	180	-	1,579
2001	Oct 15 - Dec 14	830	269	435	220	140	278	-	2,172
2002	Oct 10 - Dec 6	2,113	566	726	441	311	495	-	4,652
2003	Oct 14 - Dec 3	1,472	343	484	292	285	426	-	3,302
2004	Oct 11 - Dec 3	513	117	134	55	48	49	-	916
2005	Oct 18 - Nov 17	-	39	40	46	28	115	-	268 [a]
2006	Oct 16 - Nov 29	453	57	117	146	71	342	-	1,186
2007	Oct 16 - Nov 29	-	89	136	138	65	284	-	712 [a]
2008	Oct 15 - Dec 4	-	147	135	170	92	354	-	898 [a]
2009	Oct 14 - Dec 4	-	201	345	342	218	734	-	1,840 [a]
2010	Oct 13 - Dec 2	-	87	57	148	61	293	-	646 [a]
2011	Oct 12 - Dec 1	-	34	105	72	92	328	-	631 [a]
2012	Oct 10 - Nov 28	-	230	555	806	490	1,309	-	3,390 [a]
2013	Oct 22 - Dec 5	-	253	582	468	406	902	-	2,611 [a]
2014	Oct 7 - Dec 4	-	314	877	652	548	1,065	-	3,456 [a]
2015	Oct 6 - Dec 3	-	298	421	734	240	799	-	2,492 [a]
2016	Oct 4 - Dec 1	-	112	173	124	241	447	-	1,097 [a]
2017	Oct 10 - Nov 30	-	68	69	57	80	194	10	478 [a, b]
2018	Oct 10 - Nov 29	-	354	398	382	205	507	23	1,869 [a, b]
2019	Oct 8 - Dec 5	-	123	293	260	75	273	14	1,038 [a, b]
2020	Oct 13 - Nov 20	-	122	151	179	112	205	23	792 [a, b, c]
2021	Oct 13 - Dec 3	-	102	353	176	180	347	34	1,192 [a, b]
2022	Oct 12 - Dec 1	-	173	136	171	98	173	21	772 [a, b]
2023	Oct 11 - Nov 17	-	130	319	95	204	301	19	1,068 [a, b]

[a] Reach R1 not surveyed

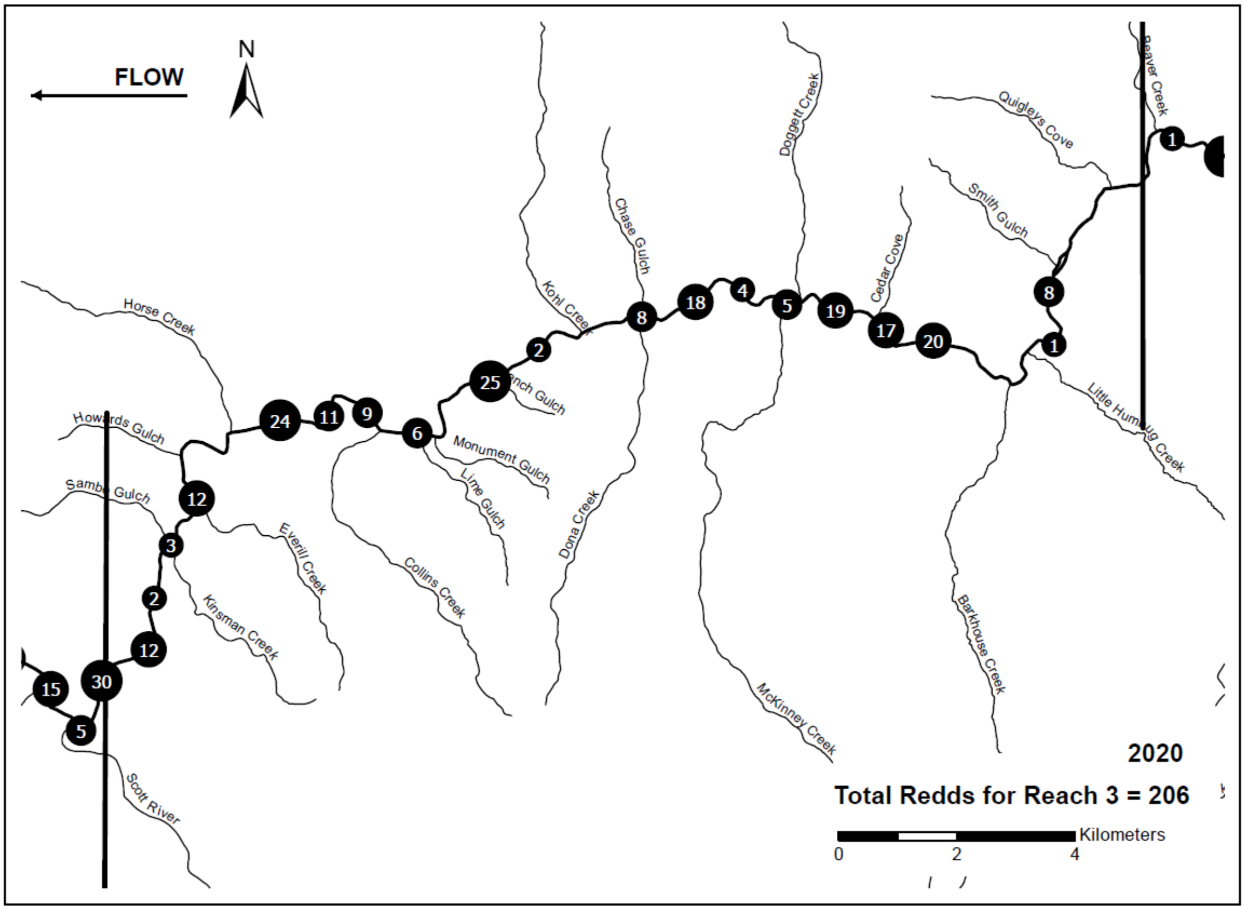
[b] Includes redds counted in Reach R7, which was added to the survey in 2017

[c] Survey season ended early due to Covid-19 concerns; redd numbers projected from mean ratio of counts of last survey week to penultimate survey week using data from 2009 to 2019

Appendix L. Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2020. Redds are binned to the nearest 0.5 rkm.



Appendix L (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2020. Redds are binned to the nearest 0.5 rkm.



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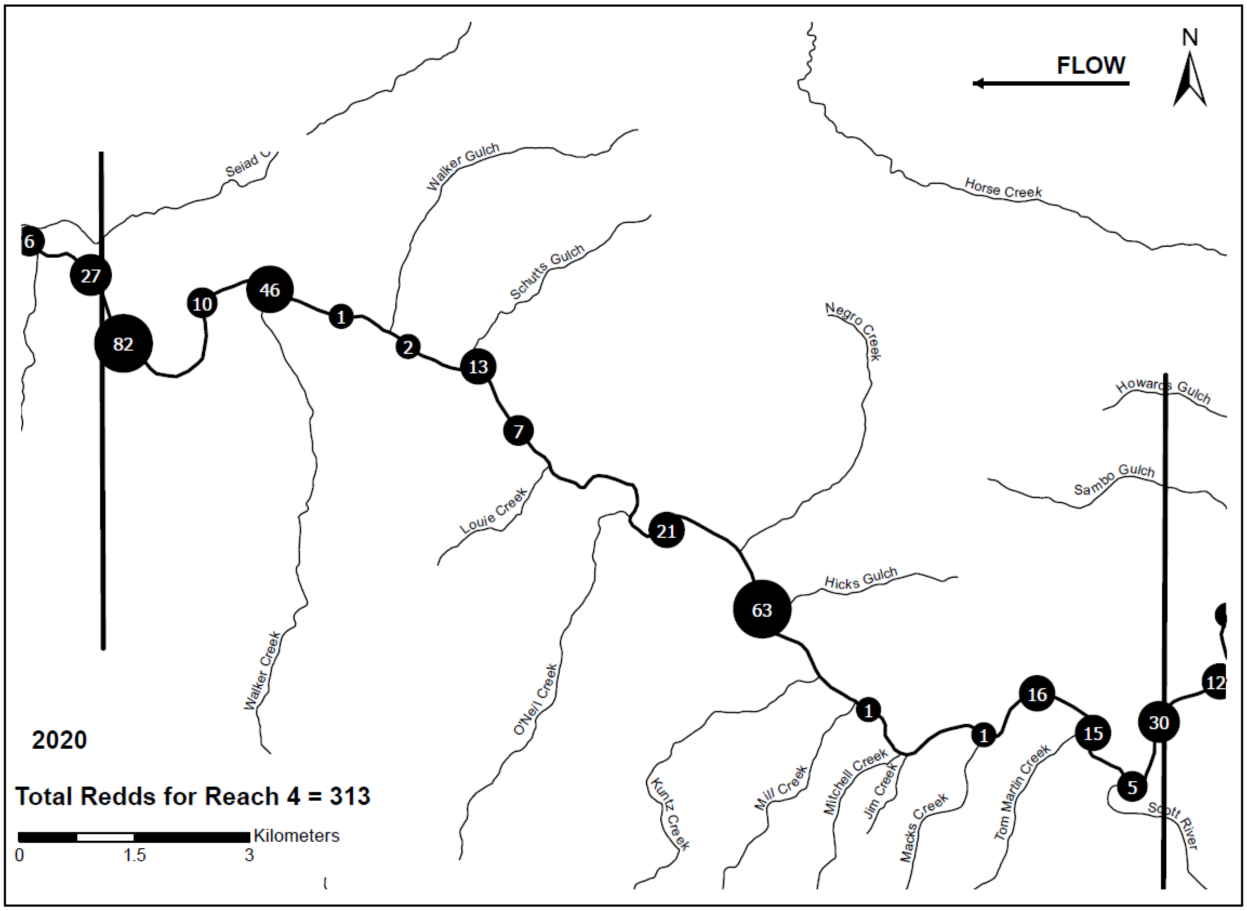
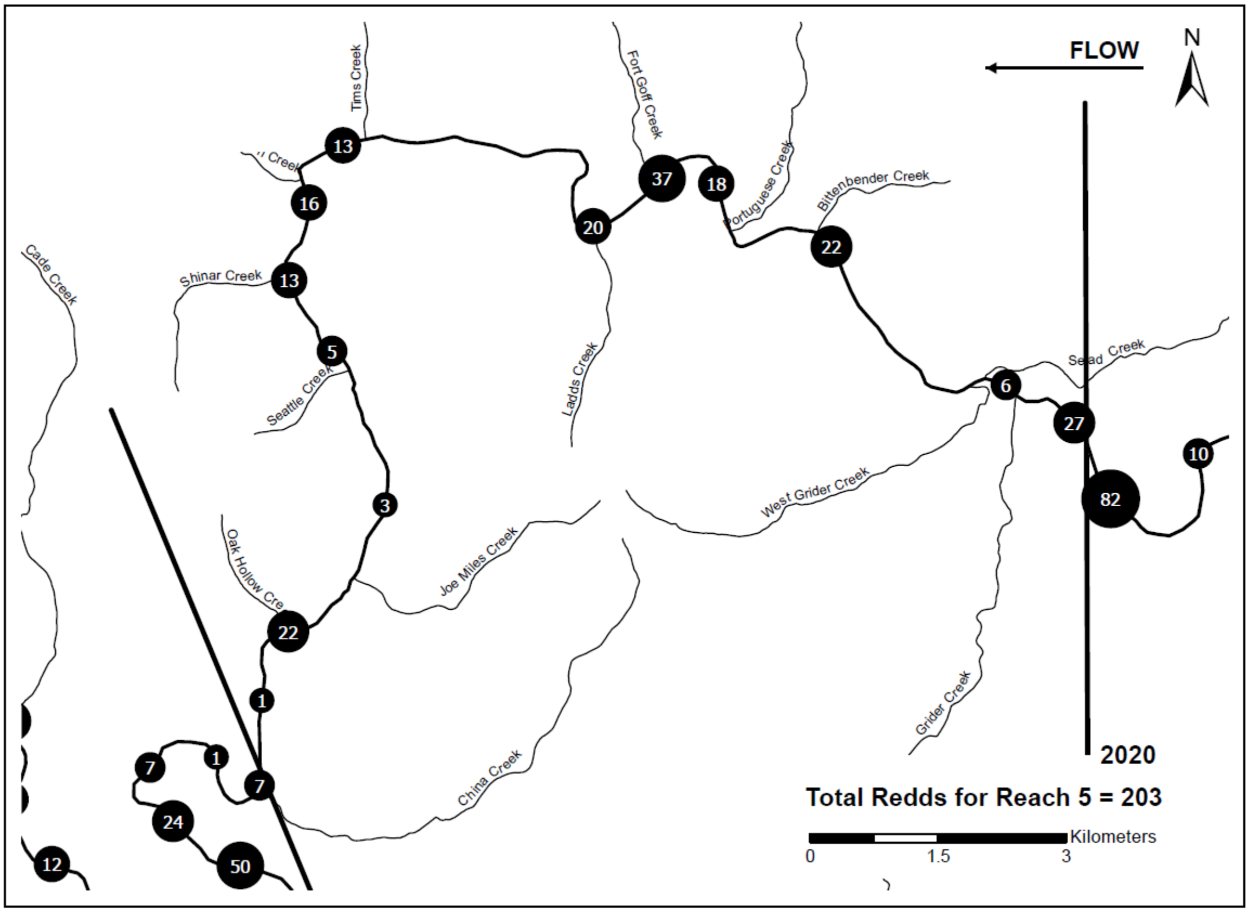
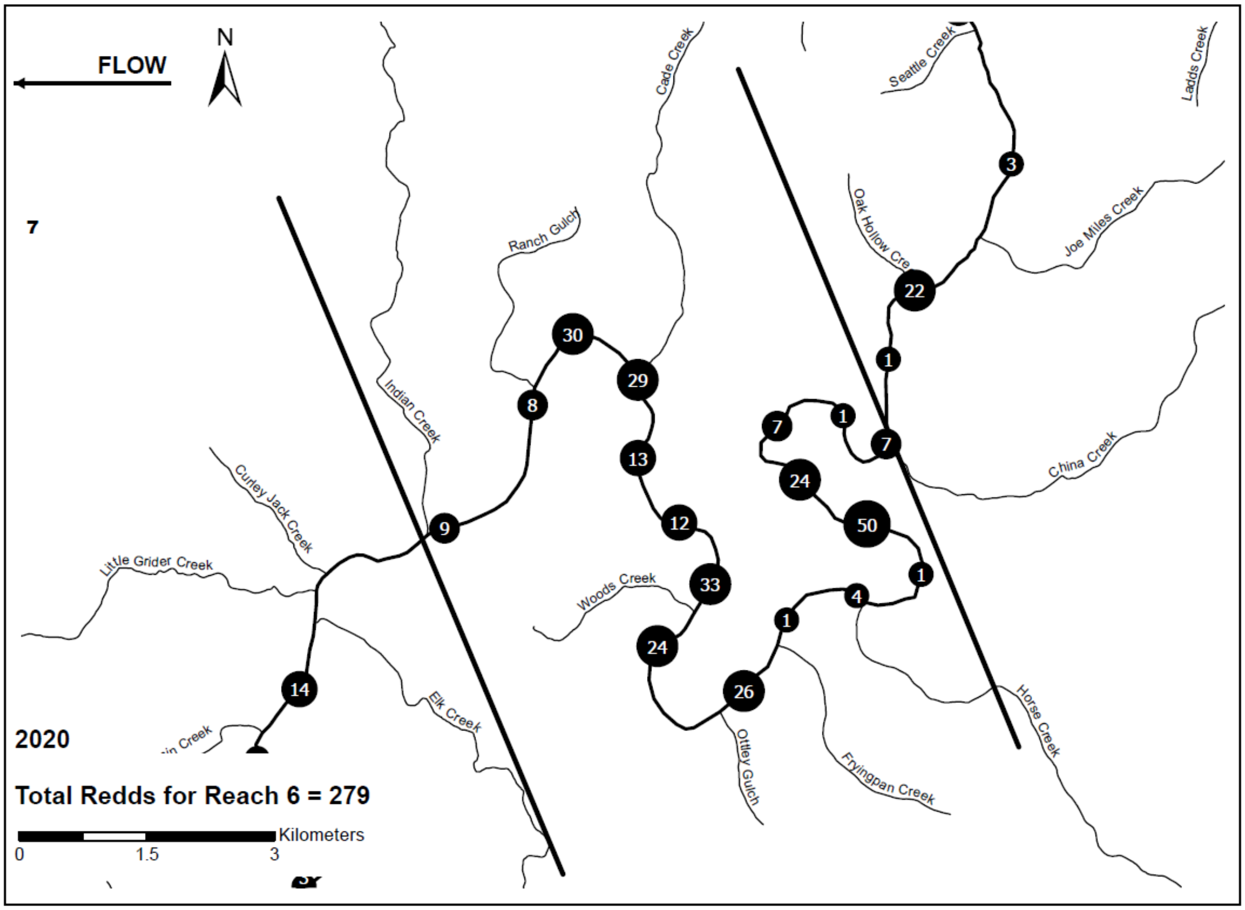


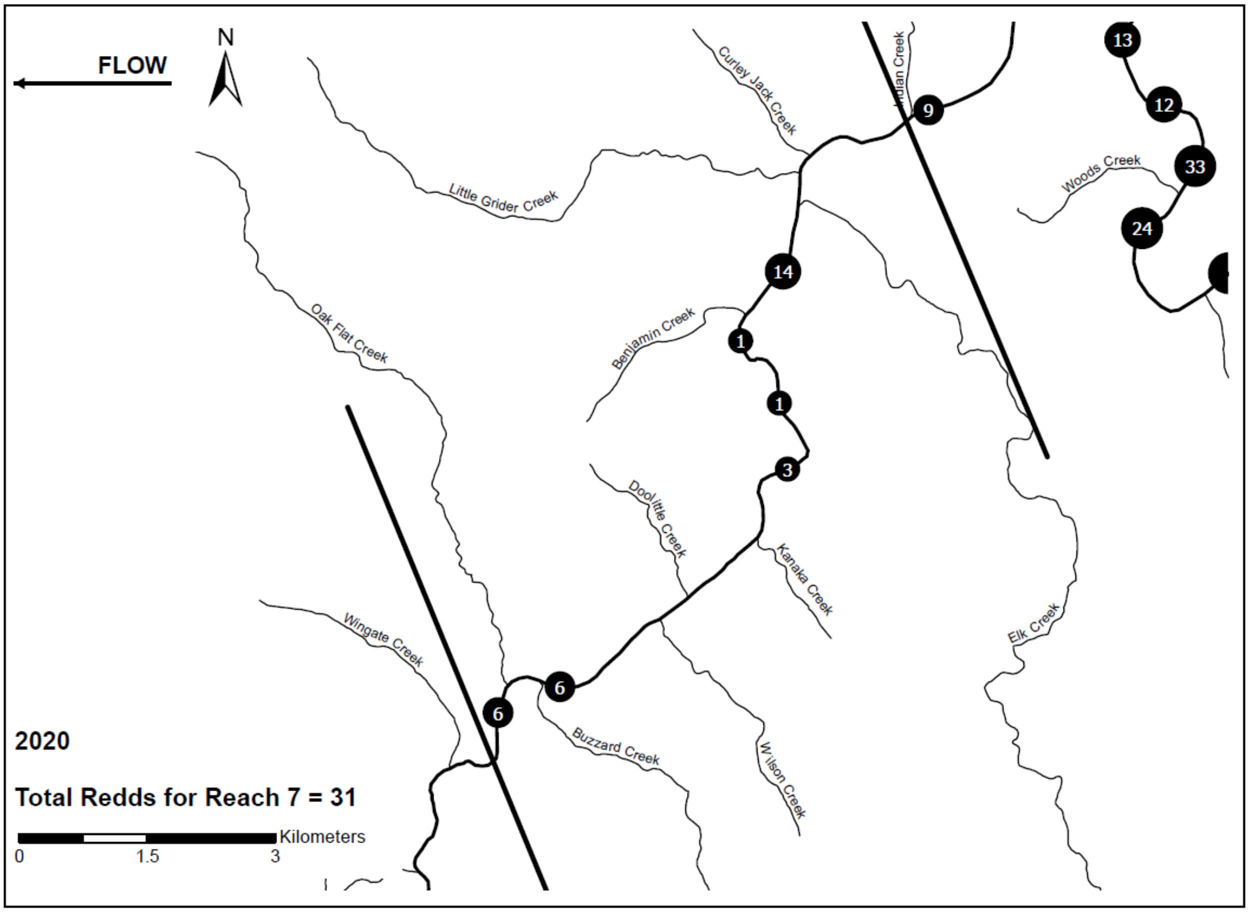
Appendix L (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2020. Redds are binned to the nearest 0.5 rkm.



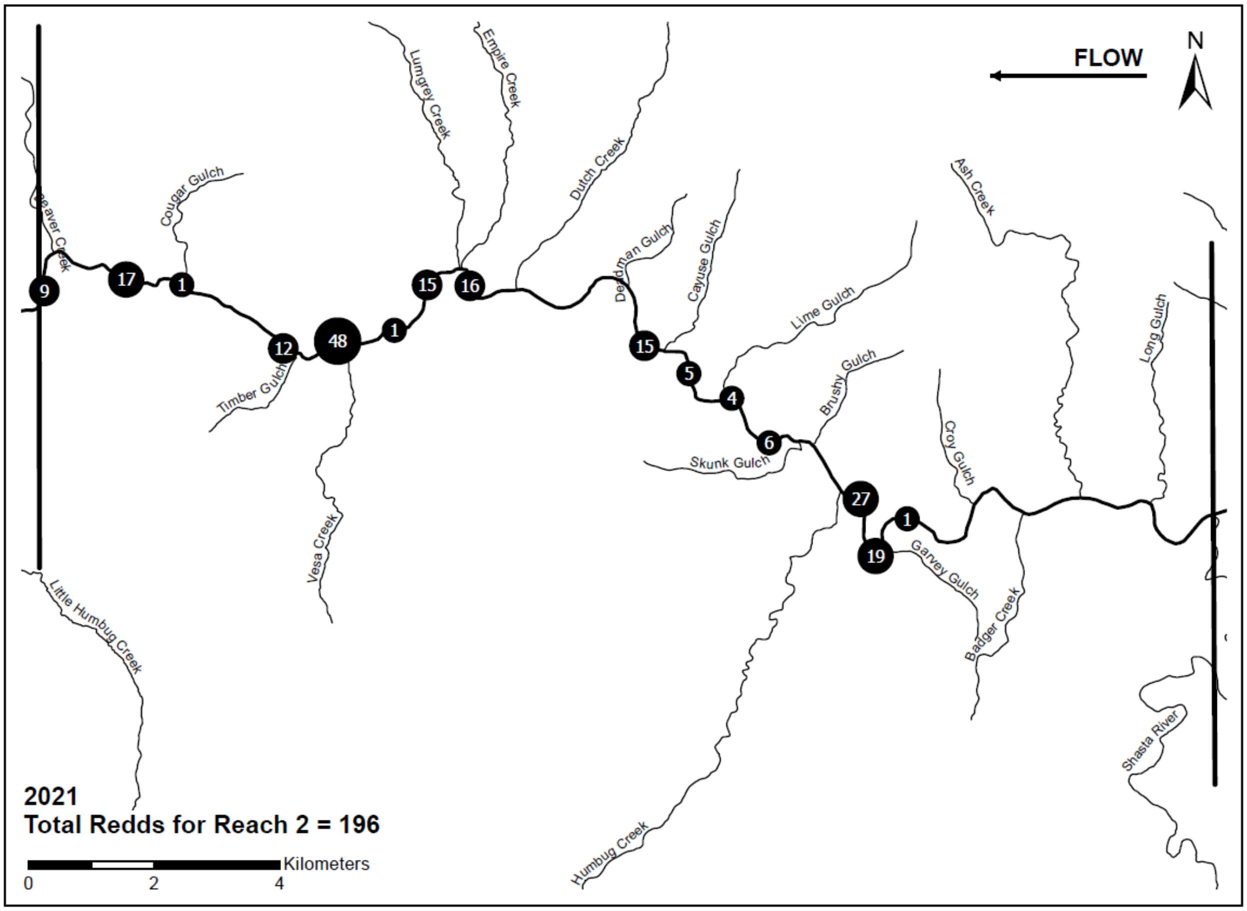
Appendix L (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2020. Redds are binned to the nearest 0.5 rkm.



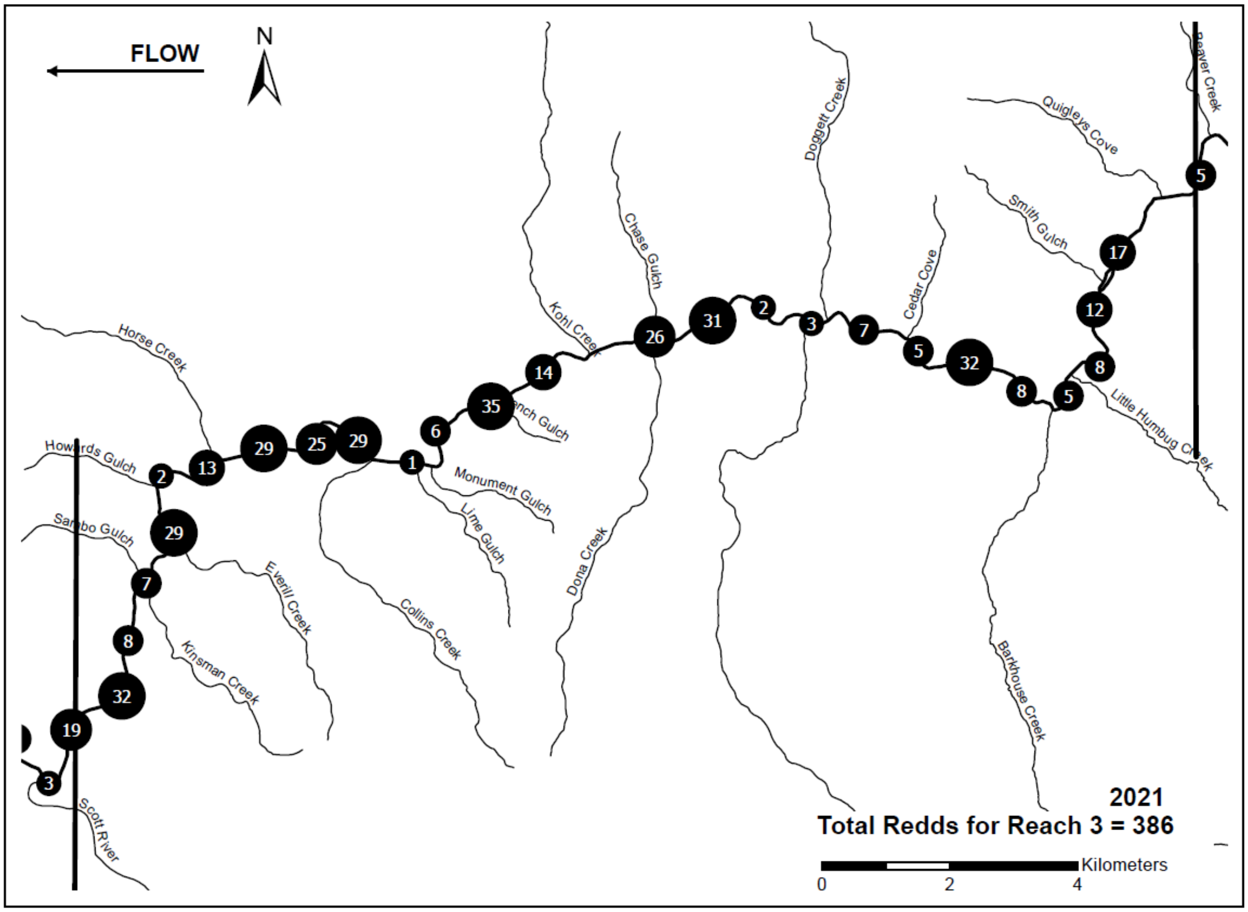
Appendix L (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2020. Redds are binned to the nearest 0.5 rkm.



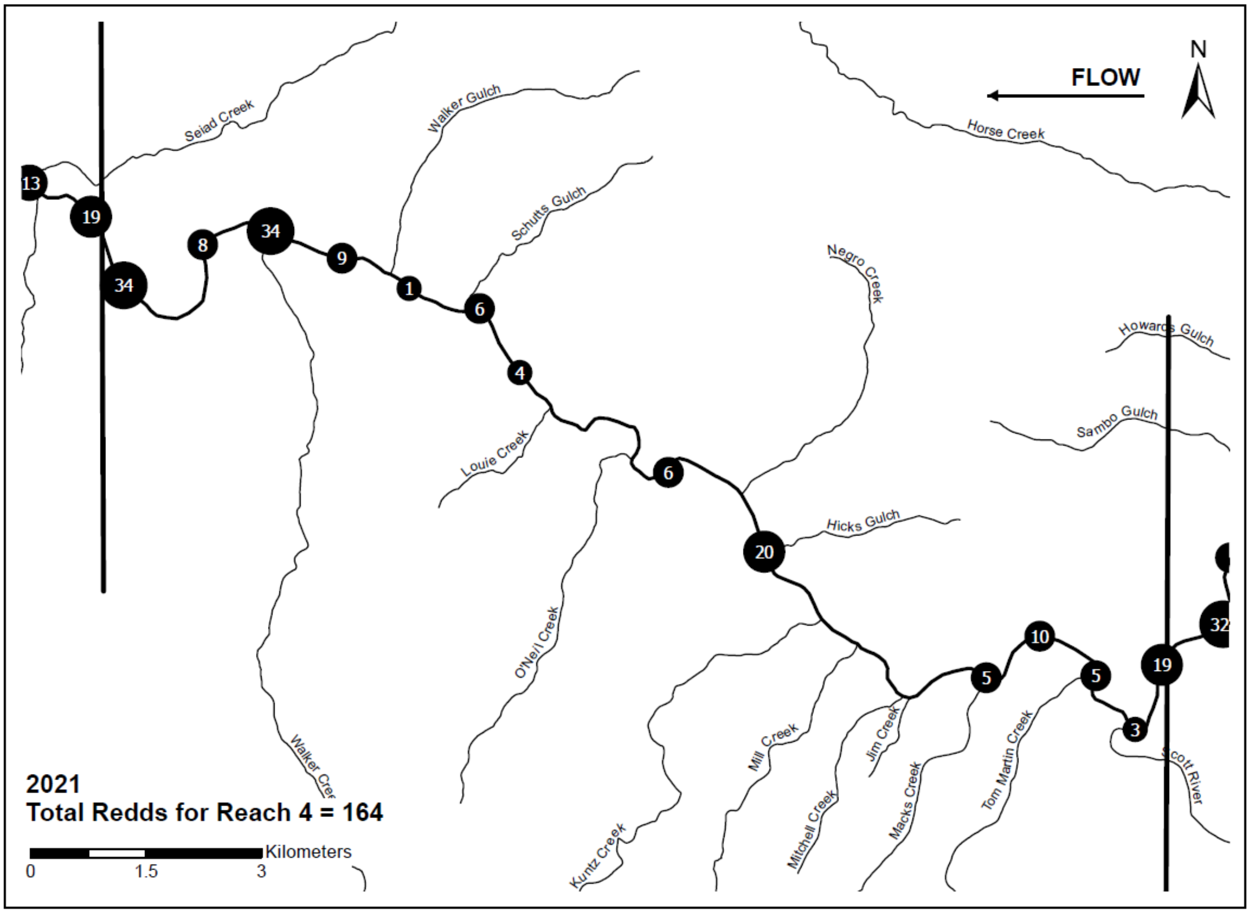
Appendix M. Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2021. Redds are binned to the nearest 0.5 rkm.



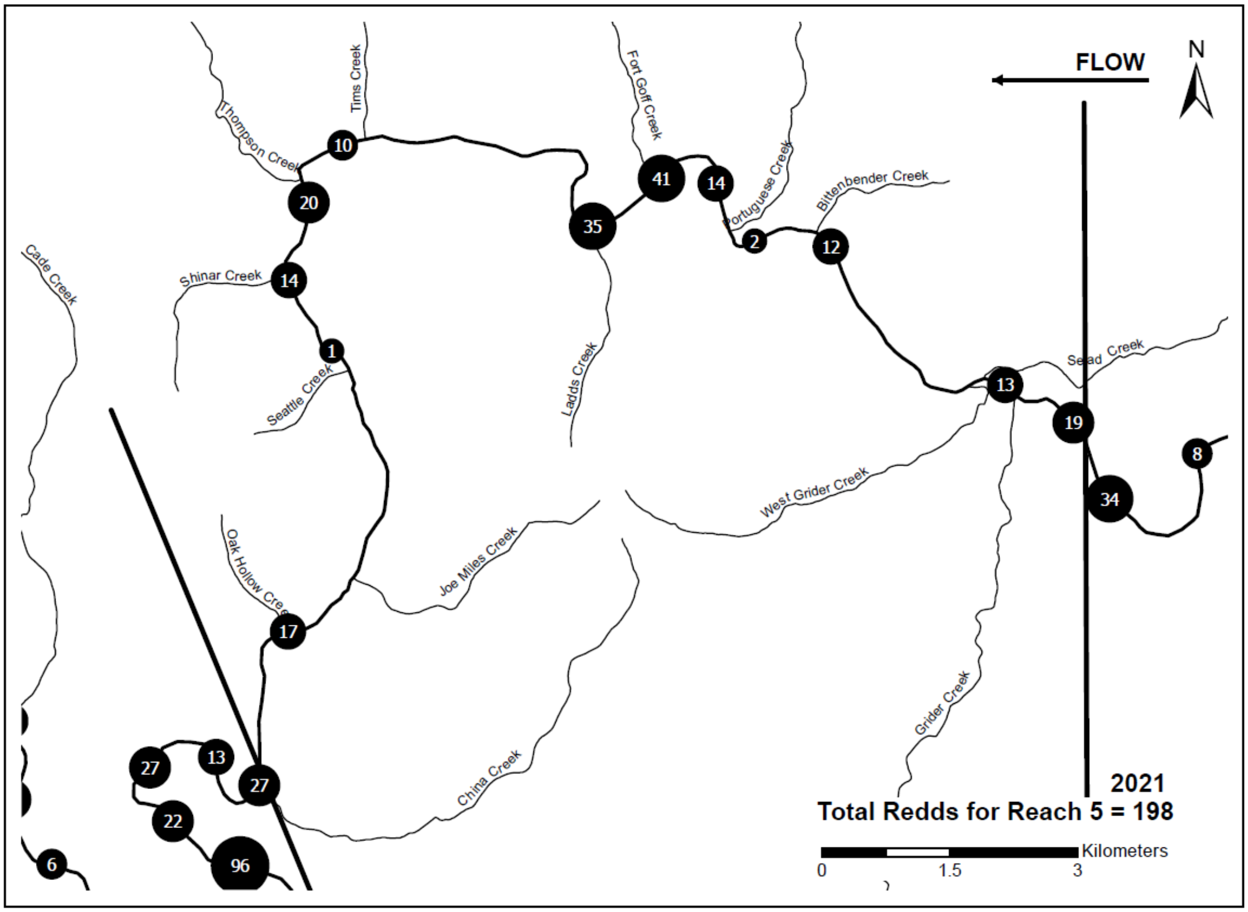
Appendix M (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2021. Redds are binned to the nearest 0.5 rkm.



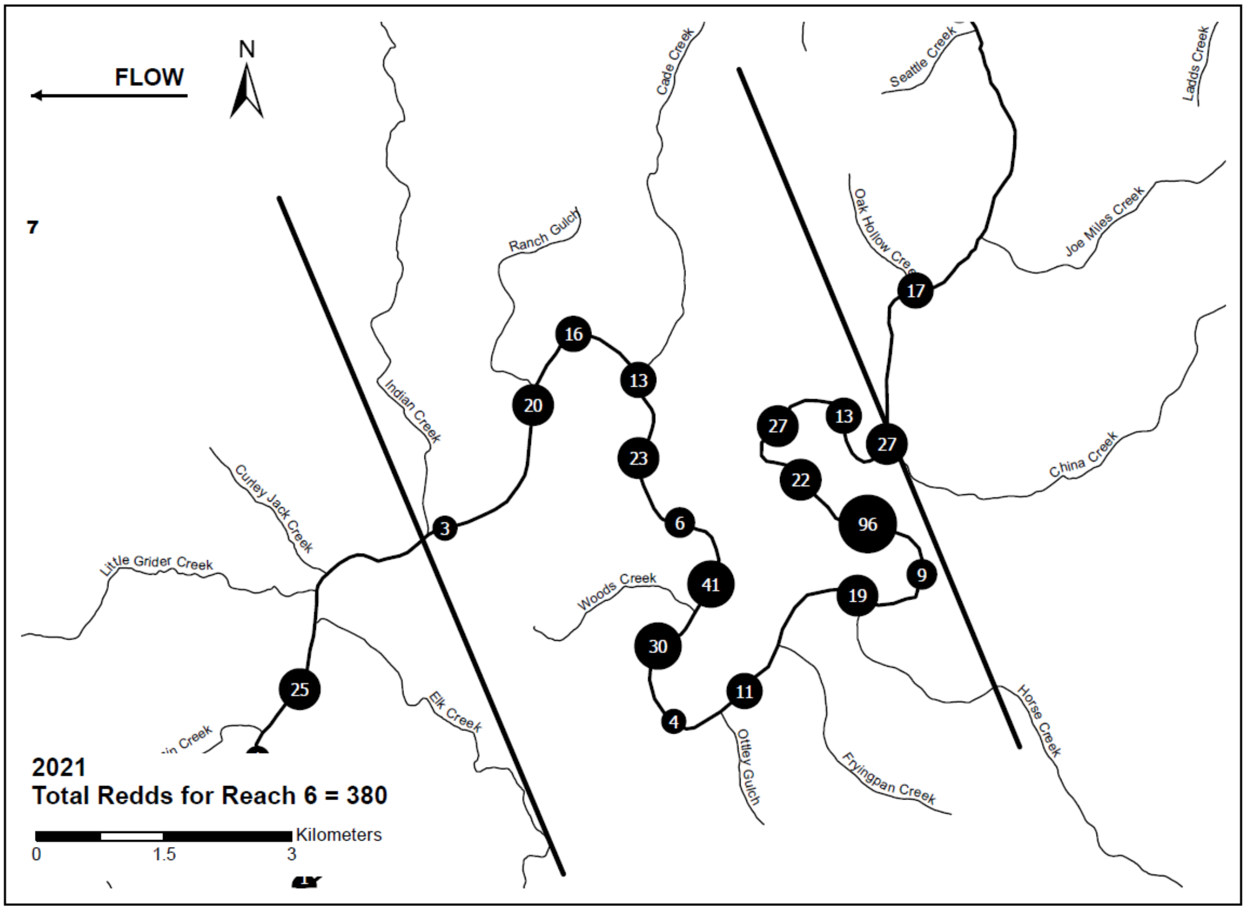
Appendix M (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2021. Redds are binned to the nearest 0.5 rkm.



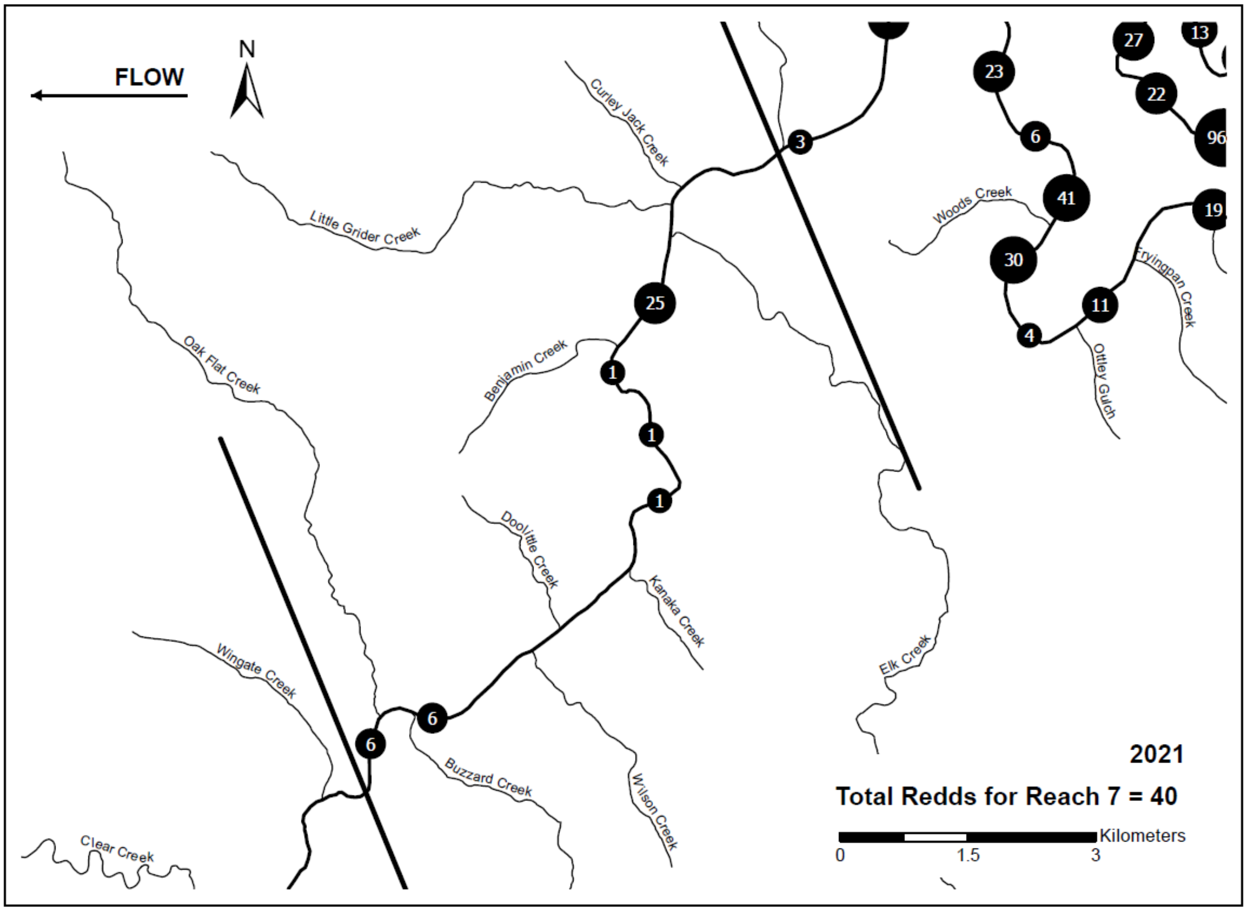
Appendix M (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2021. Redds are binned to the nearest 0.5 rkm.



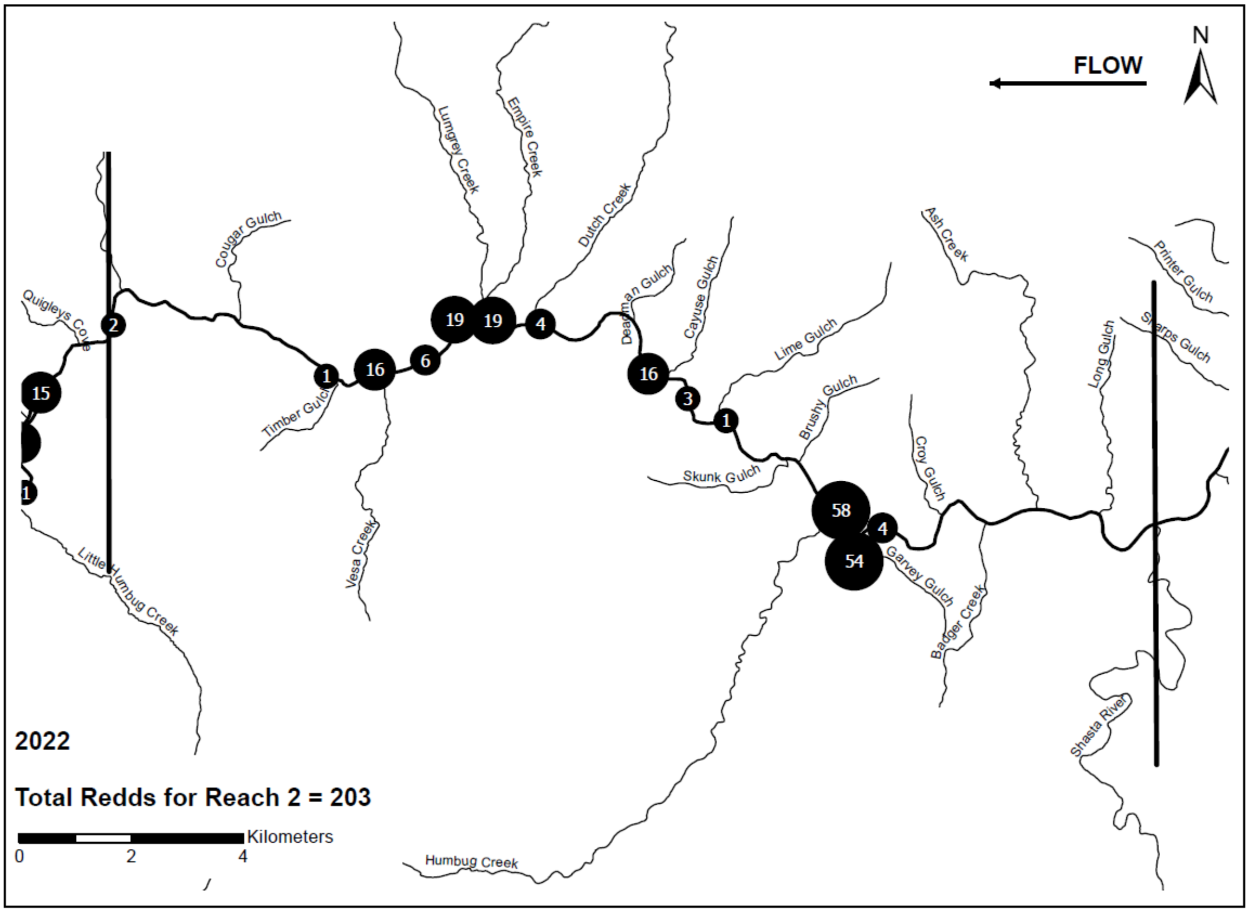
Appendix M (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2021. Redds are binned to the nearest 0.5 rkm.



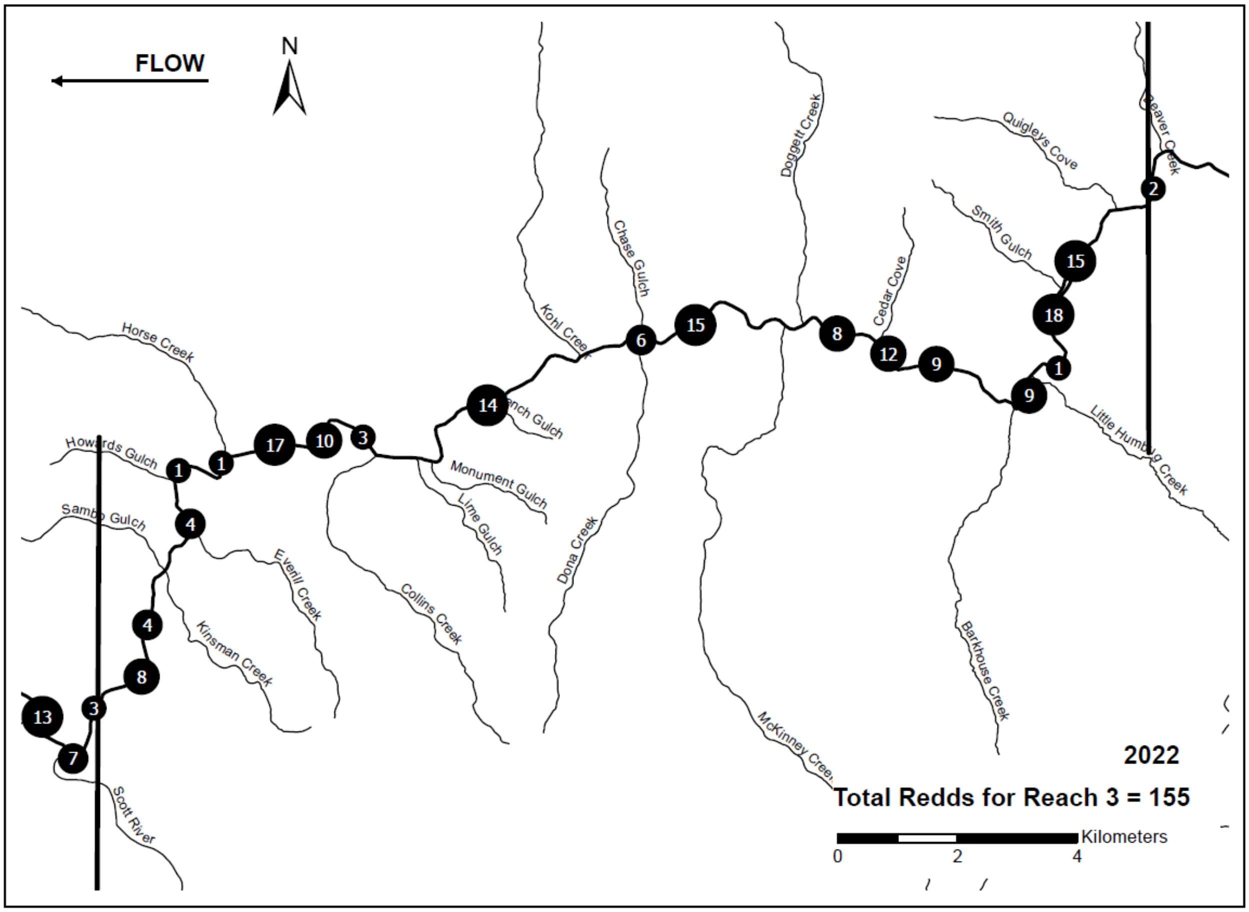
Appendix M (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2021. Redds are binned to the nearest 0.5 rkm.



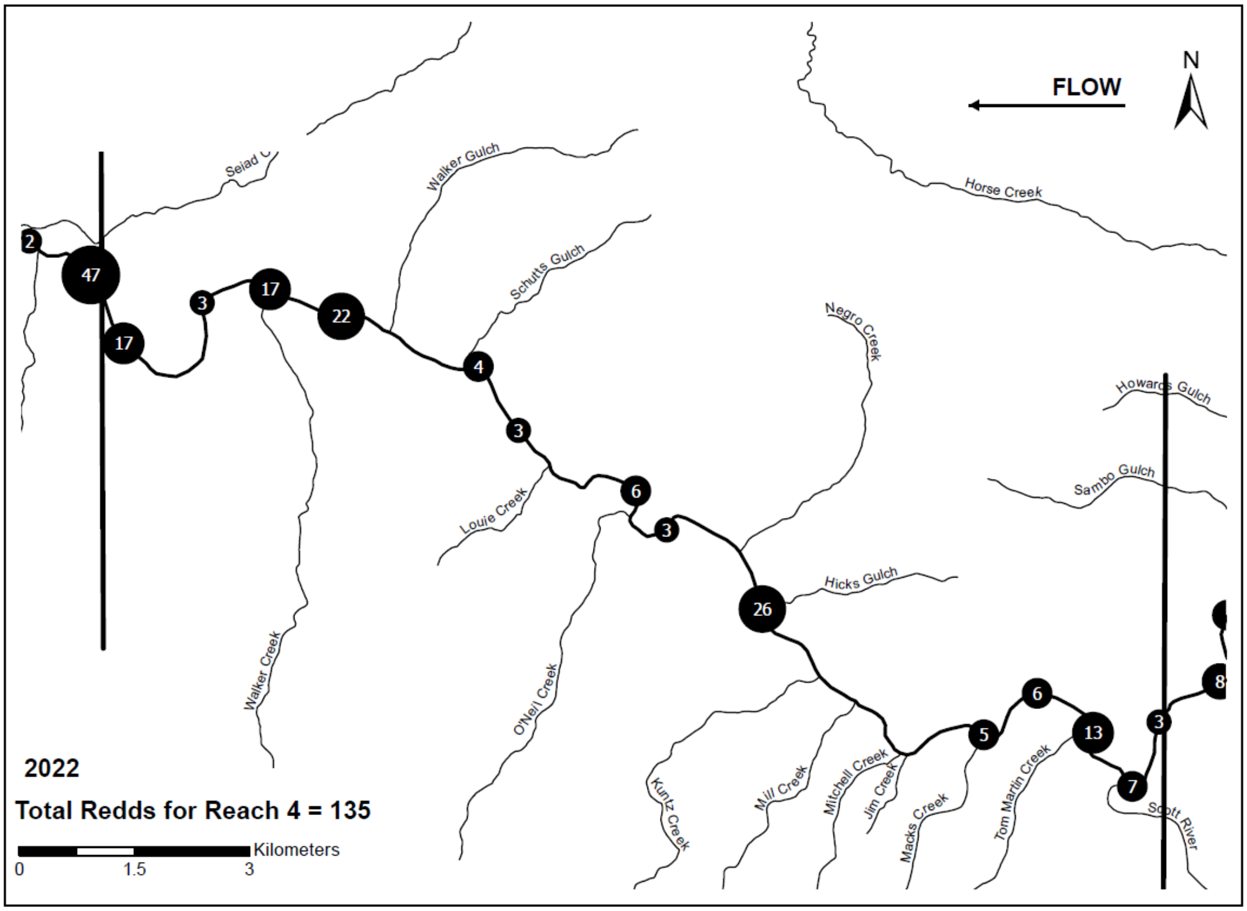
Appendix N. Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2022. Redds are binned to the nearest 0.5 rkm.



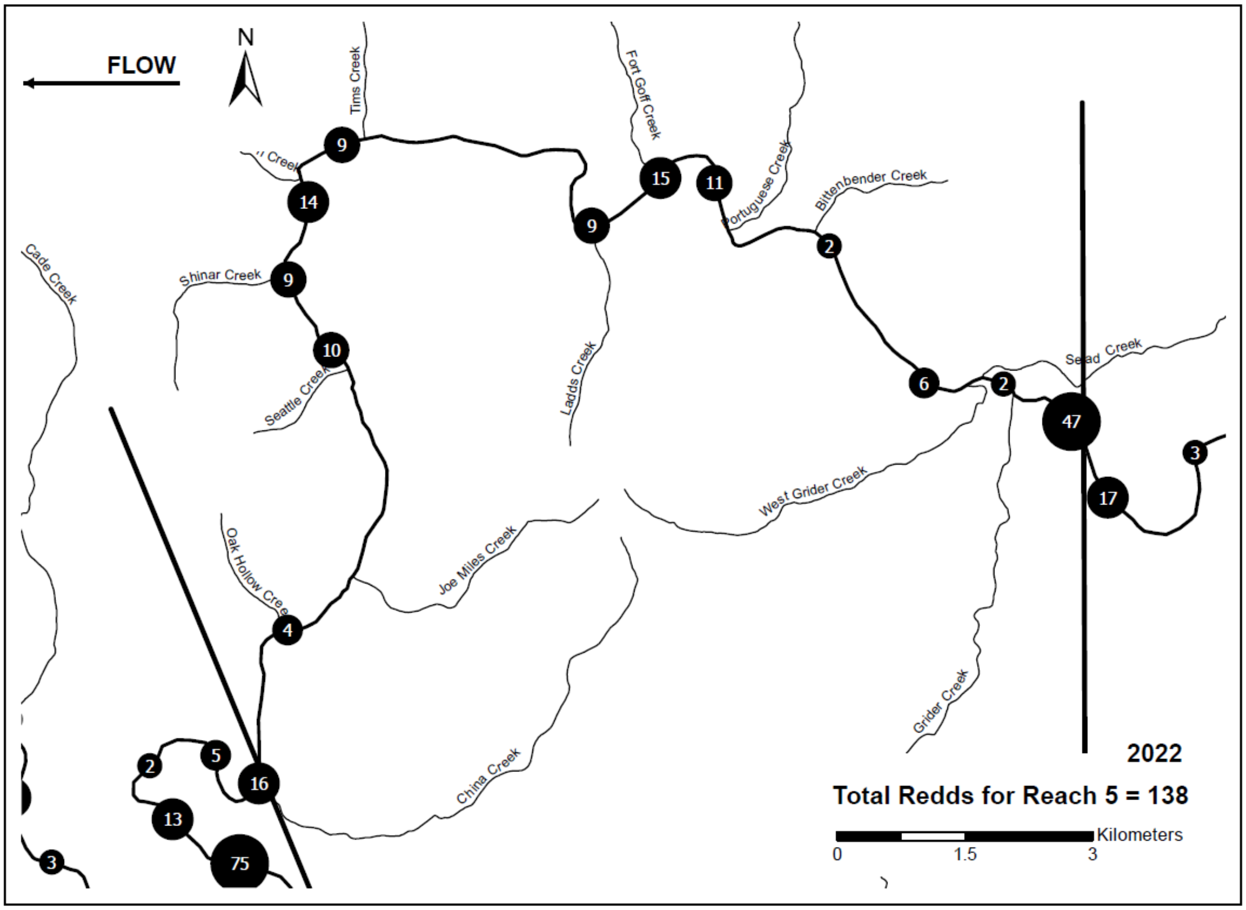
Appendix N (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2022. Redds are binned to the nearest 0.5 rkm.



Appendix N (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2022. Redds are binned to the nearest 0.5 rkm.



Appendix N (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2022. Redds are binned to the nearest 0.5 rkm.



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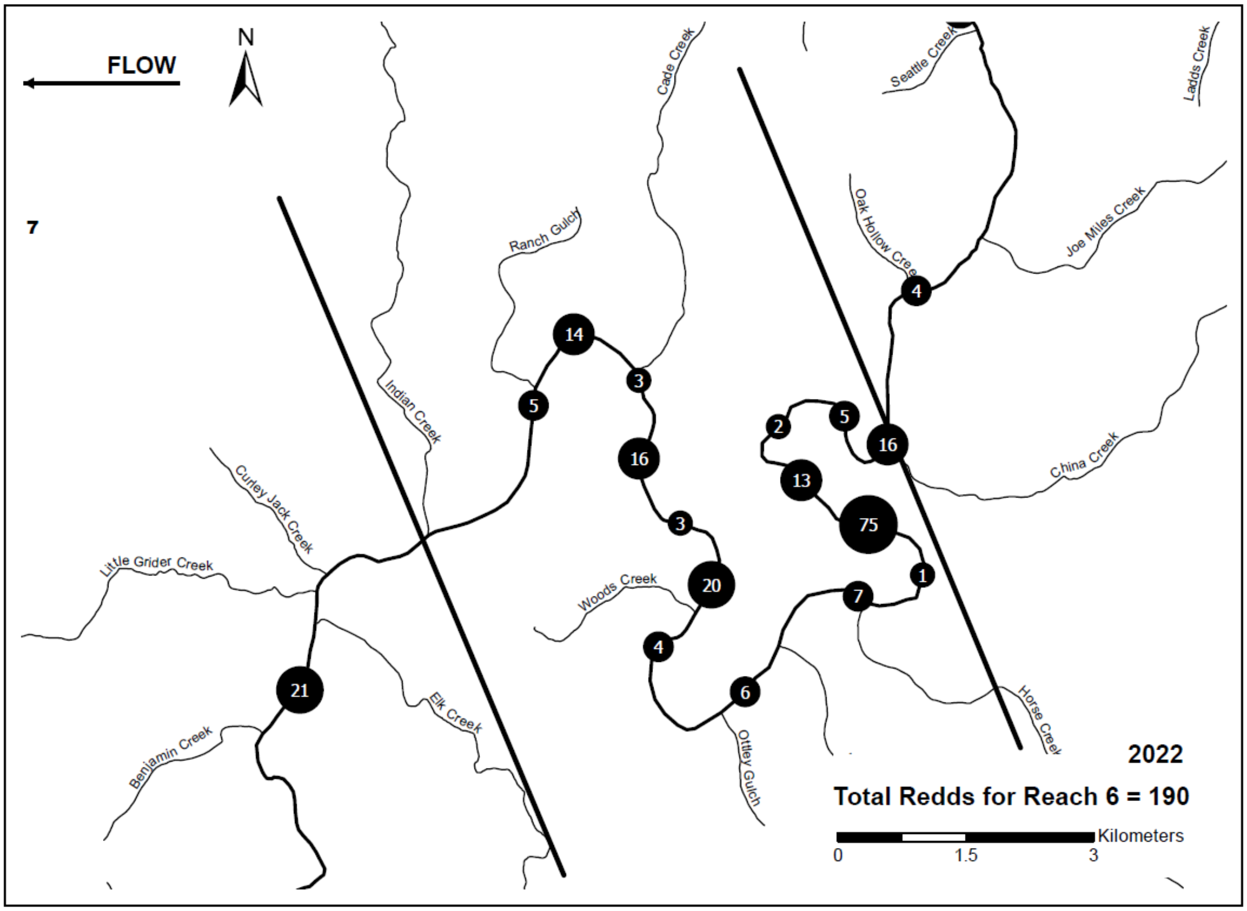
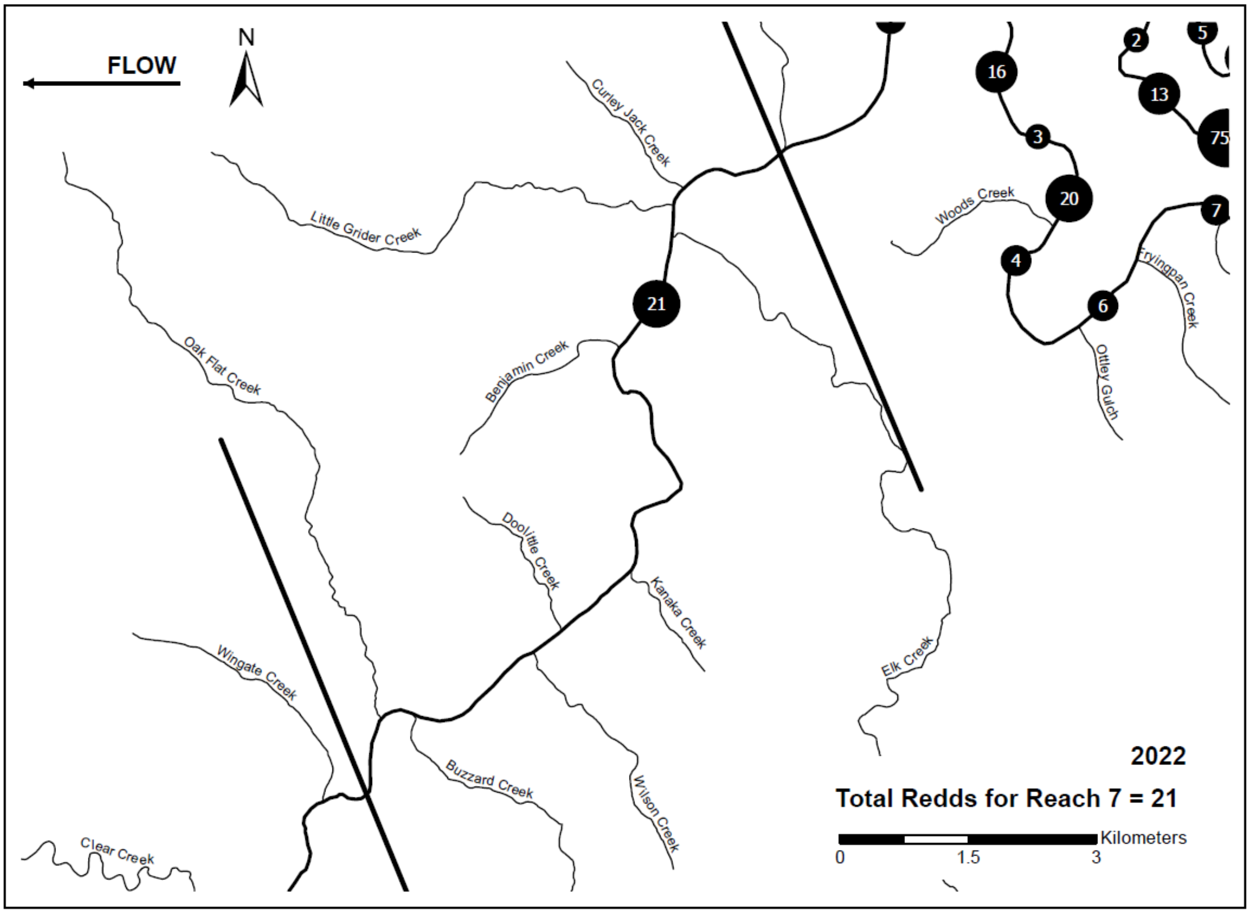
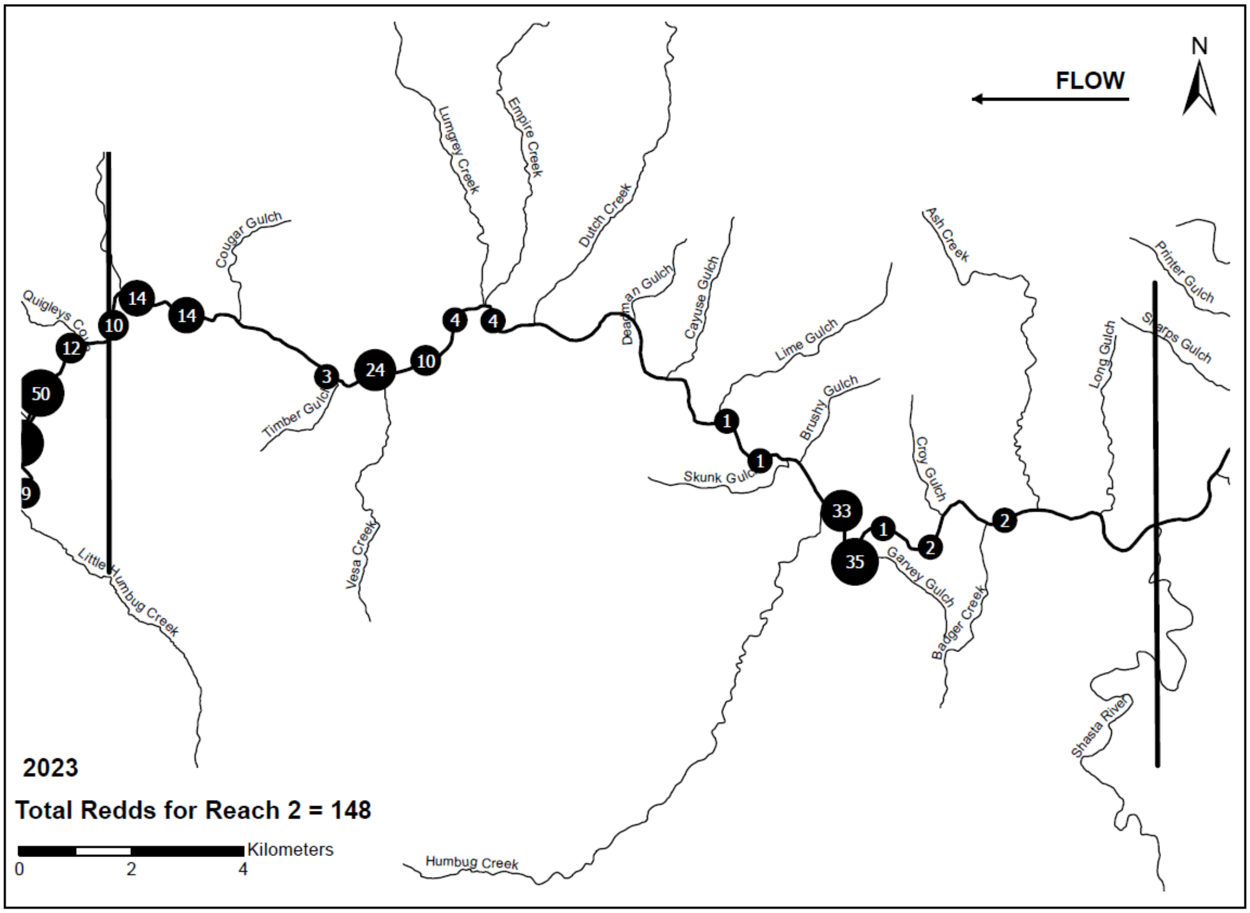


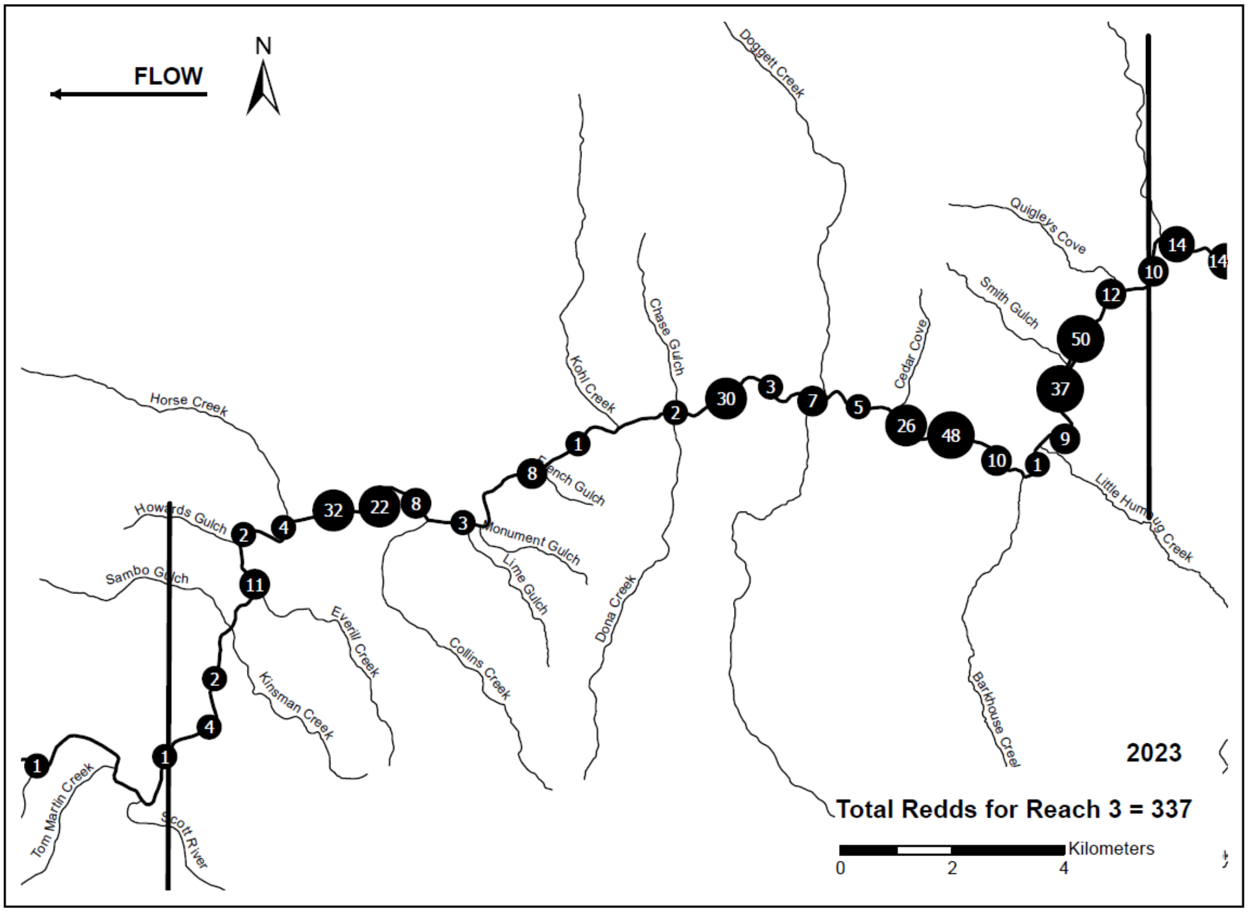
Appendix N (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2022. Redds are binned to the nearest 0.5 rkm.



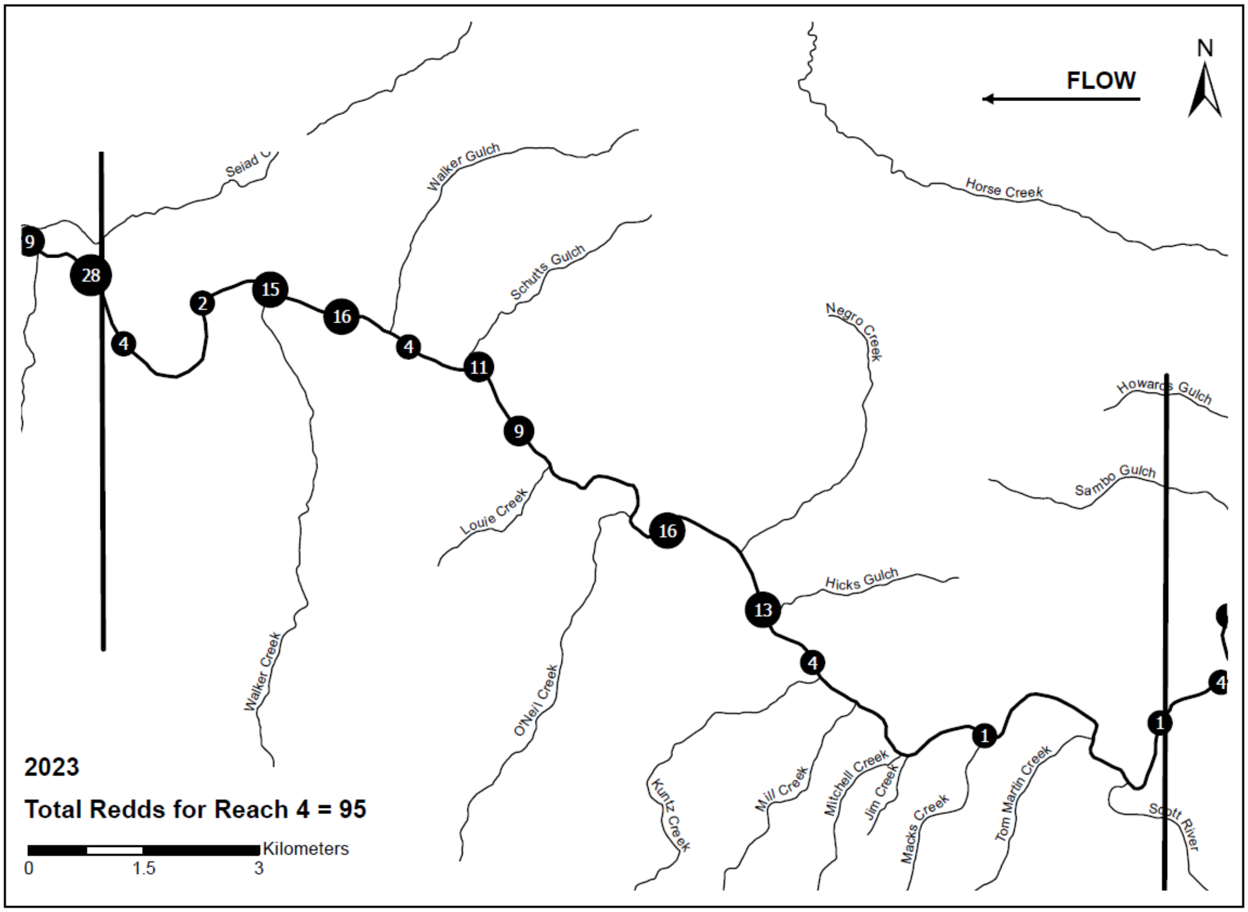
Appendix O. Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2023. Redds are binned to the nearest 0.5 rkm.



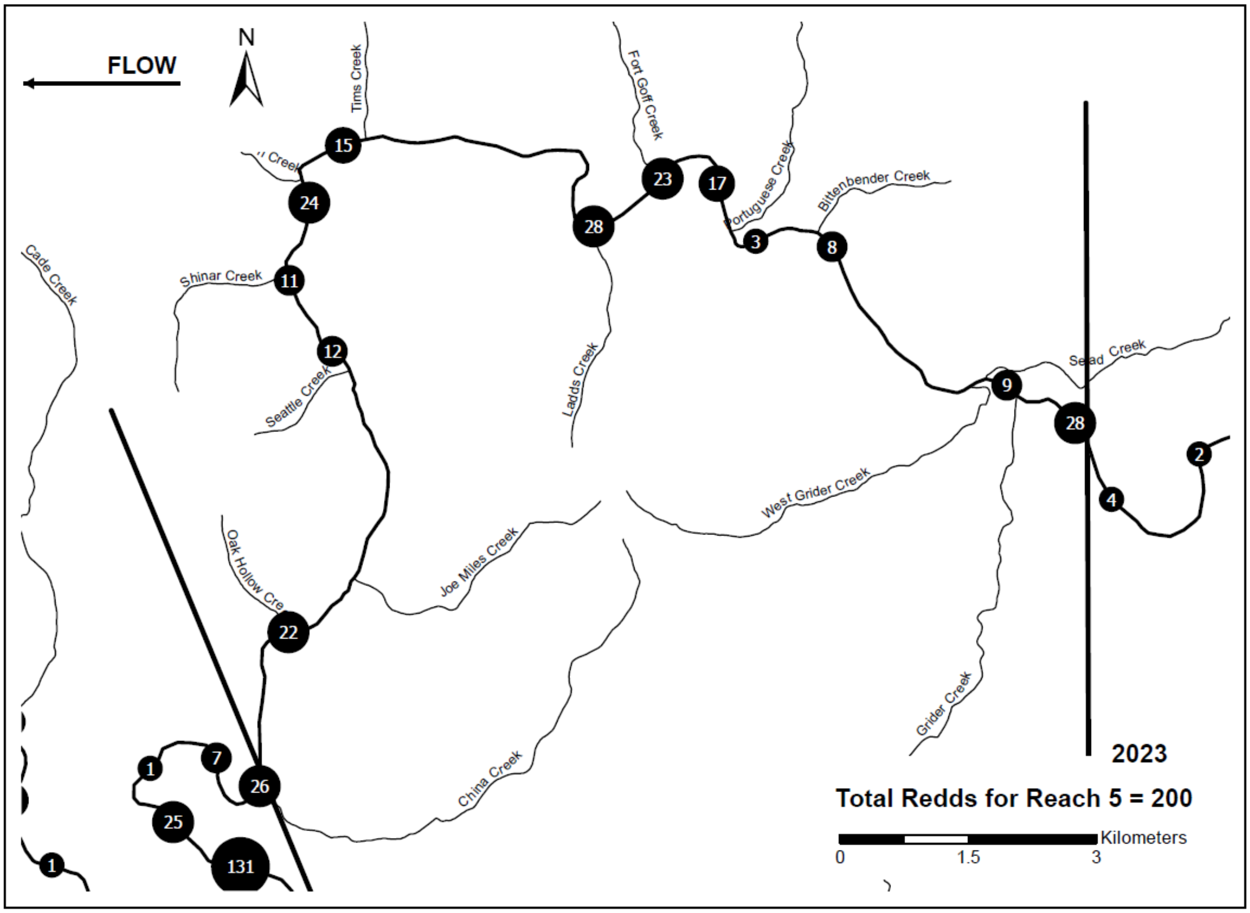
Appendix O (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2023. Redds are binned to the nearest 0.5 rkm.



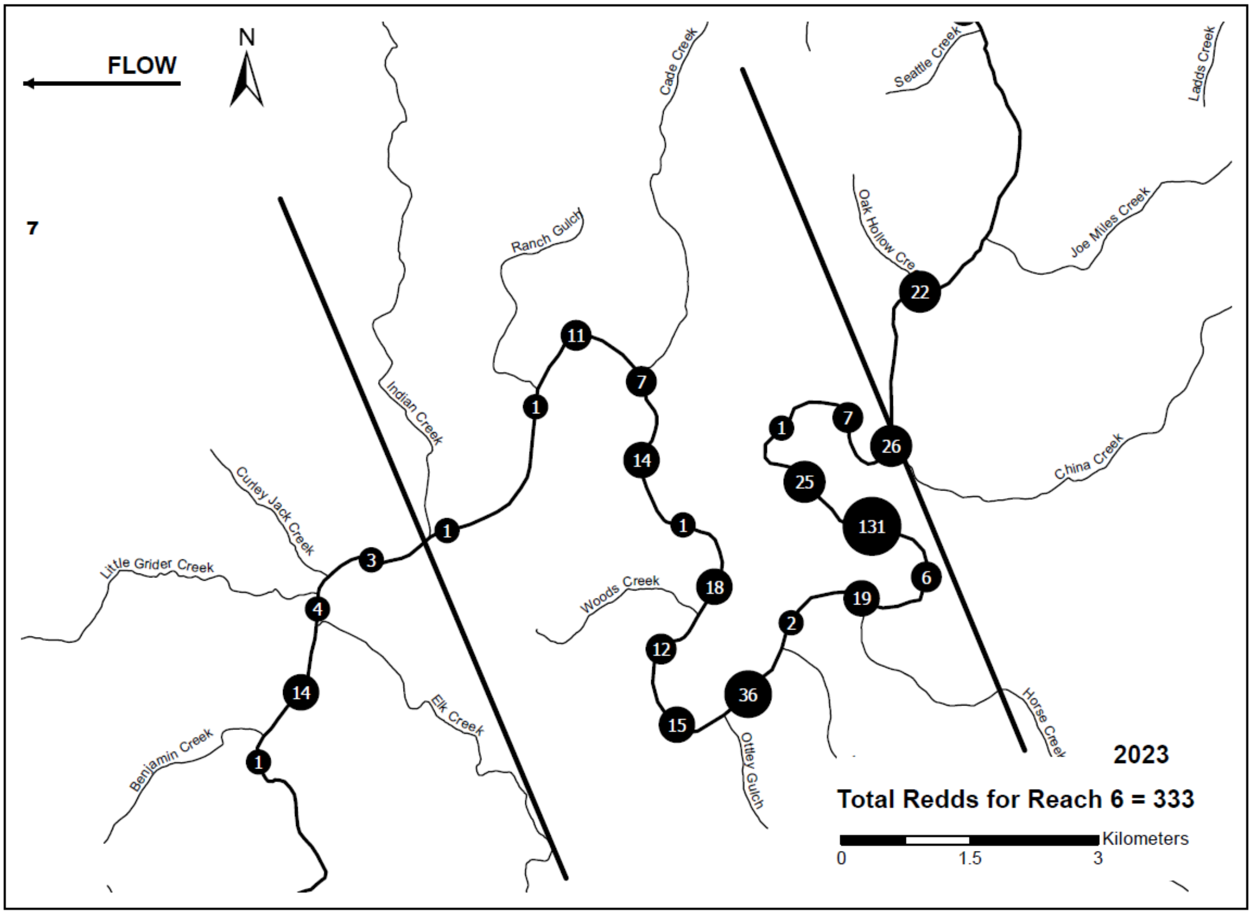
Appendix O (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2023. Redds are binned to the nearest 0.5 rkm.



Appendix O (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2023. Redds are binned to the nearest 0.5 rkm.



Appendix O (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2023. Redds are binned to the nearest 0.5 rkm.



Appendix O (continued). Distribution of redd counts in the mainstem Klamath River, California, between the Shasta River and Wingate Bar (Reaches R2–R7 shown separately), 2023. Redds are binned to the nearest 0.5 rkm.