California Department of Fish and Wildlife
North Central Region

Lower American River Fall-run Chinook Salmon Escapement Survey
October 2021 - January 2022

Presented to the United States
Bureau of Reclamation

by
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INTRODUCTION

The American River is the second-largest tributary to the Sacramento River and flows through a highly developed urban environment (Williams 2001). The lower American River (LAR) is a 23 mile stretch of the American River starting at the base of Nimbus Dam and extending downstream to the confluence with the Sacramento River at Discovery Park. The LAR supports both wild and hatchery fall-run Chinook salmon (FRCS, *Oncorhynchus tshawytscha*) spawning and rearing life stages. Historically, the LAR supported spawning of fall, spring, and late fall runs of Chinook salmon (Yoshiyama et al. 2000); spring-run Chinook was extirpated from the LAR following the construction of Folsom Dam in 1955. The fall-run represents the largest run of Chinook salmon found in California's Central Valley, although current FRCS populations are heavily supported by hatchery production (Yoshiyama et al. 2000). Adult FRCS are typically found in the LAR from September to January, and generally begin to spawn in the LAR in early October, or when water temperatures drop below 60°F, with the peak of the run occurring in late November to early December (Williams 2001).

The LAR is heavily influenced by the presence of dams that limit salmon occurrence to the lowest 23 river miles. The Nimbus Fish Hatchery, constructed in 1958 to compensate for the loss of spawning and rearing habitat due to the construction of Nimbus Dam, releases approximately 4 million Chinook salmon annually (CDFW 2022). FRCS mark-recapture escapement surveys are performed to estimate spawner abundance and distribution, and have been conducted in the LAR since 1976, although escapement estimates of Central Valley salmon have been conducted since the 1940's and 1950's (Bergman et al. 2012). Data collected during escapement surveys are also used to examine life history traits, population age structure, pre-spawn mortality, the ratio of hatchery and natural origin FRCS, and environmental effects on the population. Evaluation of stock-recruitment relationships from escapement survey data is used to aid in establishing harvest limits and fishing seasons. Because of environmental stochasticity and anthropogenic activity, salmon runs in California have exhibited a high degree of variation over time (Satterthwaite and Carlson 2015).

The objectives of the 2021-2022 escapement survey were to: 1) estimate the size of FRCS escapement in the LAR, 2) determine the ratio of adults to grilse, as well as the sex ratios of adults and grilse, 3) determine the degree of female pre-spawn mortality, and 4) collect coded-wire tags (CWT) to investigate the number and origin of hatchery-reared FRCS using spawning habitat in the LAR.

METHODS

A 13.4-mile section of the lower American River, beginning at the Nimbus Dam and ending at the Watt Avenue bridge, was surveyed from October 18, 2021 to January 5, 2022. The survey area was divided into six sections (Figure 1, Table 1), each surveyed once over a 3 to 4-day survey period. Nimbus Basin (NB) is composed of a deep pool at the base of the dam, a riffle and run in the main channel, and two side channels composed of riffles, runs, and pools. In 2021, a rock channel was constructed as an entrance to a new fish ladder for the Nimbus Fish

Hatchery. The rock channel entrance is in the upstream portion of NB but was surveyed as a distinct section during the 2021 survey. The location of the Nimbus Fish Hatchery weir structure separates NB from section 1 and is located adjacent to the Nimbus Fish Hatchery. However, the weir pickets were not installed for the 2021-2022 spawning season since completion of a new fish ladder precluded the need for the weir. Section 1 has continuously had the highest number of FRCS spawning activity and is composed primarily of riffles, glides, and a few deep pools. This section is broken up into sections 1A and 1B for sampling purposes because of the high number of carcasses typically encountered. Section 2 contains a few riffles, but is composed primarily of large, deep-water glides. Section 3 consists of riffles, deep-water glides, and several stretches of braided side-channels. The LAR downstream of Watt Avenue has little spawning habitat and is primarily a migration corridor and, therefore, it is not included in the escapement survey.

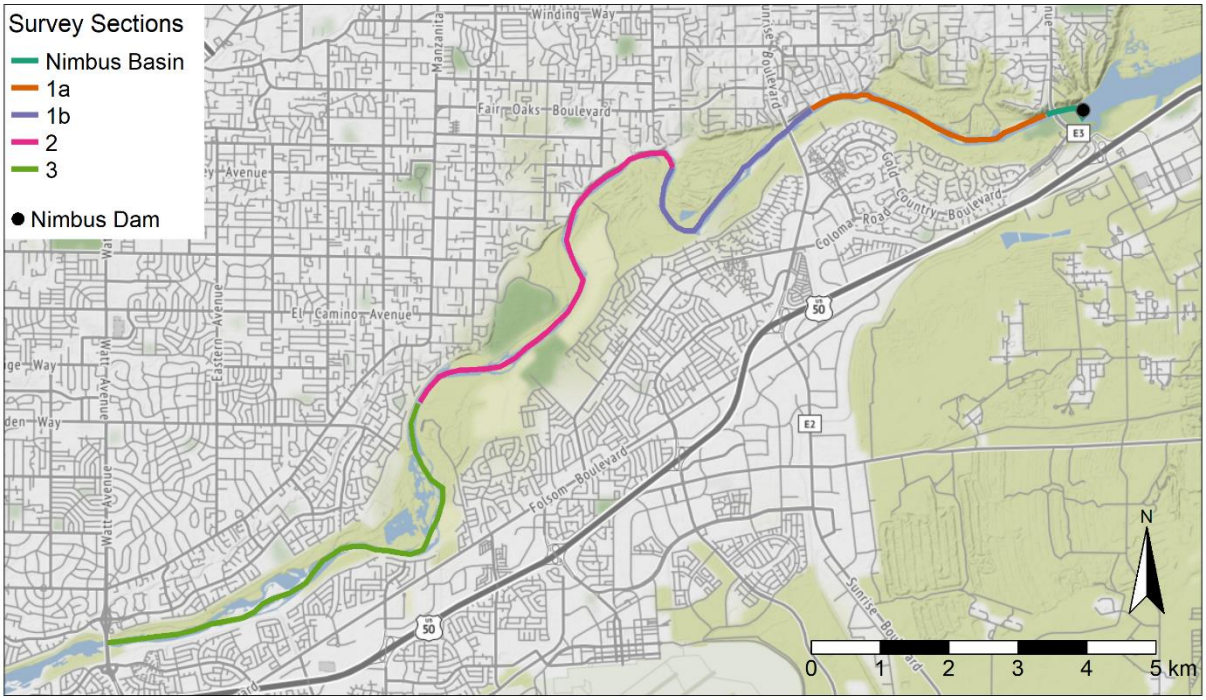

Figure 1. Map of survey sections for the lower American River Chinook salmon escapement survey.

Surveys were conducted by a crew consisting of 5-10 members searching for submerged salmon carcasses while walking the riverbanks or paddling kayaks; a jet boat was not operable on the river this season due to the low water levels. Each river section was surveyed once per survey period. NB was surveyed only on foot from the banks; section 1 was surveyed by kayak and from the banks; and due to habitat complexity, sections 2 and 3 were surveyed by kayaks and walking portions of the banks. Surveys began at the upstream boundary of each river section and progressed downstream, with crew members processing each carcass encountered. Salmon carcasses ≤50% submerged were not included in the escapement survey, as these carcasses do not represent an equal probability of detection, and once dried require a longer time to decompose, which can skew mark-recapture analysis (Bergman et al. 2012). Each

carcass was examined for the following: 1) presence of an external tag, 2) presence of an adipose fin, 3) extent of carcass degradation, and 4) extent of egg retention in females.

Table 1. Survey section distances and descriptions of the fall-run Chinook salmon escapement survey on the lower American River.

Section	Description	Miles
L	Nimbus Hatchery Fish Ladder Entrance Channel	NA
NB	Nimbus Dam to Nimbus Fish Hatchery Weir	0.3
1A	Nimbus Fish Hatchery Weir to Sunrise Blvd River Access	2.6
1B	Sunrise Blvd River Access to El Manto Dr River Access	1.7
2	El Manto Dr River Access to River Bend Park River Access	4.7
3	River Bend Park River Access to Watt Ave River Access	4.1
	Total	13.4

Carcasses were processed in one of three ways: 1) head collection for coded-wire tag (CWT) retrieval, 2) inclusion in the mark-recapture model, or 3) chopped in half and tallied. At the fish ladder entrance channel, only carcasses missing an adipose fin were processed; carcasses with an intact adipose fin were released into a thalweg in NB to simulate the natural downstream movement of carcasses. Heads were removed and retained from adipose fin clipped carcasses for CWT removal. Carcasses with an intact adipose fin were either included in the mark-recapture model or chopped and tallied. To be included in the mark-recapture model, a carcass must be in a fresh enough condition to be detected during subsequent survey periods; any carcasses not meeting these criteria were chopped in half to prevent inclusion in future surveys. The degree of carcass decomposition was determined by the examination of the eyes and gills. Carcasses were considered fresh if at least one eye was clear or the gills were red. Scale samples were also collected from fresh carcasses by removing a one-inch square scale sample from the left side of the carcass above the lateral line and posterior to the dorsal fin. Carcasses were chopped and tallied if they were in an advanced state of decomposition (i.e., not fresh).

Carcasses included in the mark-recapture model were fitted with a hog ring and numbered disk-tag on the left maxilla. Each tag was marked with colored flagging unique to the survey period and the tagged carcasses were deposited in the thalweg adjacent to the tagging location. The 2021 LAR FRCS escapement estimate was derived using a Cormack-Jolly-Seber (CJS) mark-recapture model for open populations (Cormack 1964, Bergman et al. 2012) using the escapeMR package (McDonald 2021) in R version 4.1.2 (R Core Team 2021).

Covariate data were collected from all carcasses utilized in the mark-recapture model and those destined for CWT retrieval. Covariate data included sex, fork length (FL), level of egg retention in females, and degree of decomposition. Sex was determined through a combination of

characteristics including body morphology, presence or absence of a kype, and examination of gametes. FL was measured from the tip of the snout to the fork of the caudal fin and rounded to the nearest centimeter. At the end of the survey season, FLs were pooled by sex and plotted in a frequency distribution to classify carcasses as grilse (a two-year old, sexually mature fish) or adults. The level of egg retention was determined by examining female carcasses, classifying each female as unspawned if >70% of eggs were present, partially spawned if 30-70% of eggs were retained, or spawned if <30% of eggs were retained.

Water temperature data were obtained for each survey period from the United States Geological Survey gauge for the American River at Fair Oaks (gauge id 11446500) through the USGS website (USGS 2022). The Fair Oaks gauge is located at the upper end of section 1 approximately one hundred meters downstream of the weir structure. Daily average temperature and discharge recordings were selected to best measure changes in water temperature and flow through the duration of the study.

RESULTS

Survey Periods

The 2021 LAR survey consisted of 12 survey periods from October 18, 2021 to January 5, 2022. All sections were surveyed in each survey period, except for survey period 11, when sections 2 and 3 were not surveyed due to a rapid increase in discharge that created a potentially dangerous environment for crews to survey (Table 2). No subsampling was required at any time during the study.

Table 2. Survey dates and sampling regime for the 2021 lower American River Chinook salmon escapement survey.

Survey Period	Dates	Sections Not Surveyed
1	October 18-21	None
2	October 26-28	None
3	November 1-3	None
4	November 8-10	None
5	November 15-18	None
6	November 22-24	None
7	November 29-December 2	None
8	December 6-9	None
9	December 13-16	None
10	December 20-22	None
11	December 28-29	2 and 3
12	January 3-5	None

Environmental Conditions

Daily average LAR temperatures generally decreased over the duration of the survey season. The maximum mean daily temperature recorded was 61°F on October 18-22, 2021, and the minimum mean daily temperature was 48°F on January 2-5, 2022 (Figure 2). Water temperature decreased to a level suitable for spawning on November 24, when mean daily temperature dropped below 56°F.

The USBR initiated a 50 cubic feet per second (cfs) power bypass to access the cold water pool (CWP) at Folsom Dam on October 11, 2021 and increased the power bypass incrementally to 150 cfs by October 13 in order to hold a temperature of approximately 62°F through the end of October. The power bypass was increased to 250 cfs on October 25 and 350 cfs on October 26 to target 56°F in the LAR. Suitable temperatures were not attained until late November and the power bypass continued until December 5th when resources were depleted.

Discharge consistently held at approximately 550 cfs through the survey with two exceptions: an increase in mean daily flow to 2,020 cfs on October 25, 2021 and another flow increase up to approximately 5,100 cfs on December 28 and lasting through the end of the survey. The maximum mean daily flow recorded was 5,100 cfs on December 31, 2021 and the minimum mean daily flow was 528 cfs on October 20, 2021 (Figure 2).

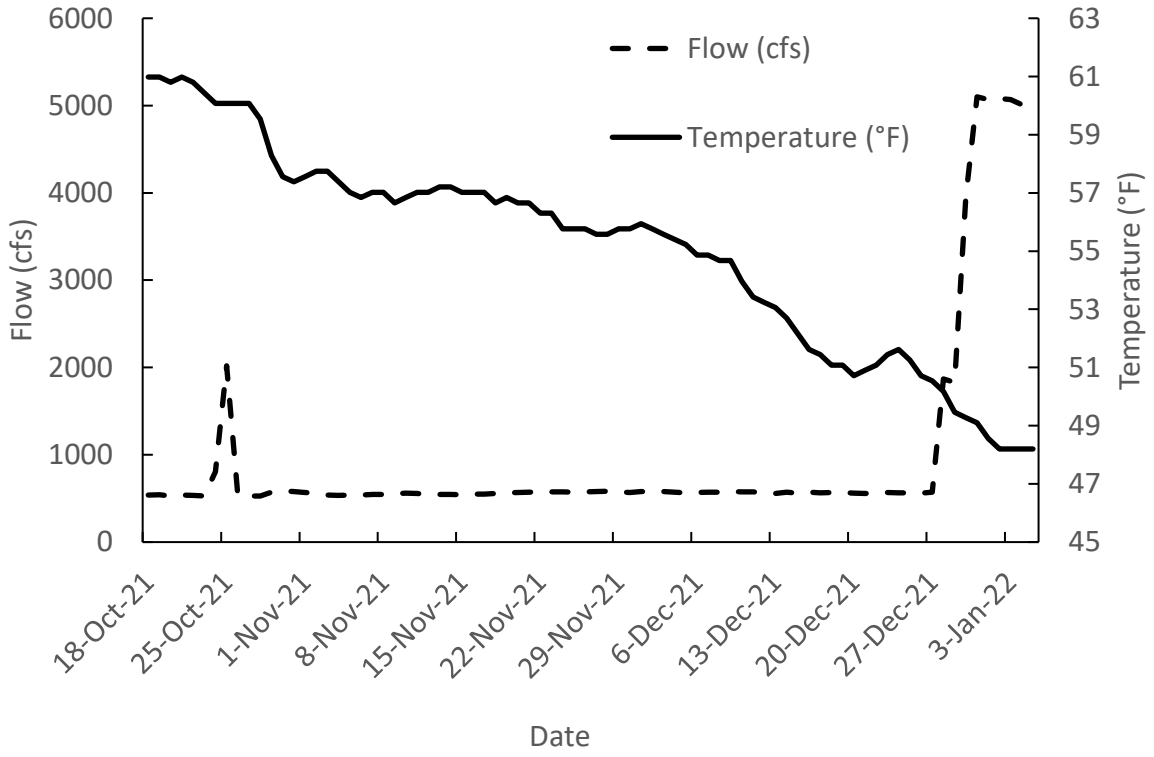

Figure 2. Daily average flow and water temperatures encountered during the 2021 lower American River Chinook salmon escapement survey. Temperature and flow were reported by USGS, American River at Fair Oaks gauge (USGS 2022).

Final Carcass Count

During the 2021 lower American River escapement survey, 5,249 carcasses were observed and processed (Figure 3). The highest number of carcasses processed in a single survey period (n = 1,886) occurred during survey period 7 (November 29 - December 2). Of the carcasses processed during the season, 664 fresh carcasses were encountered (Figure 4). Fresh carcasses were observed during each of the 12 sampling periods, reaching a high of 212 fresh carcasses processed during sampling period 7 (November 29 - December 2).

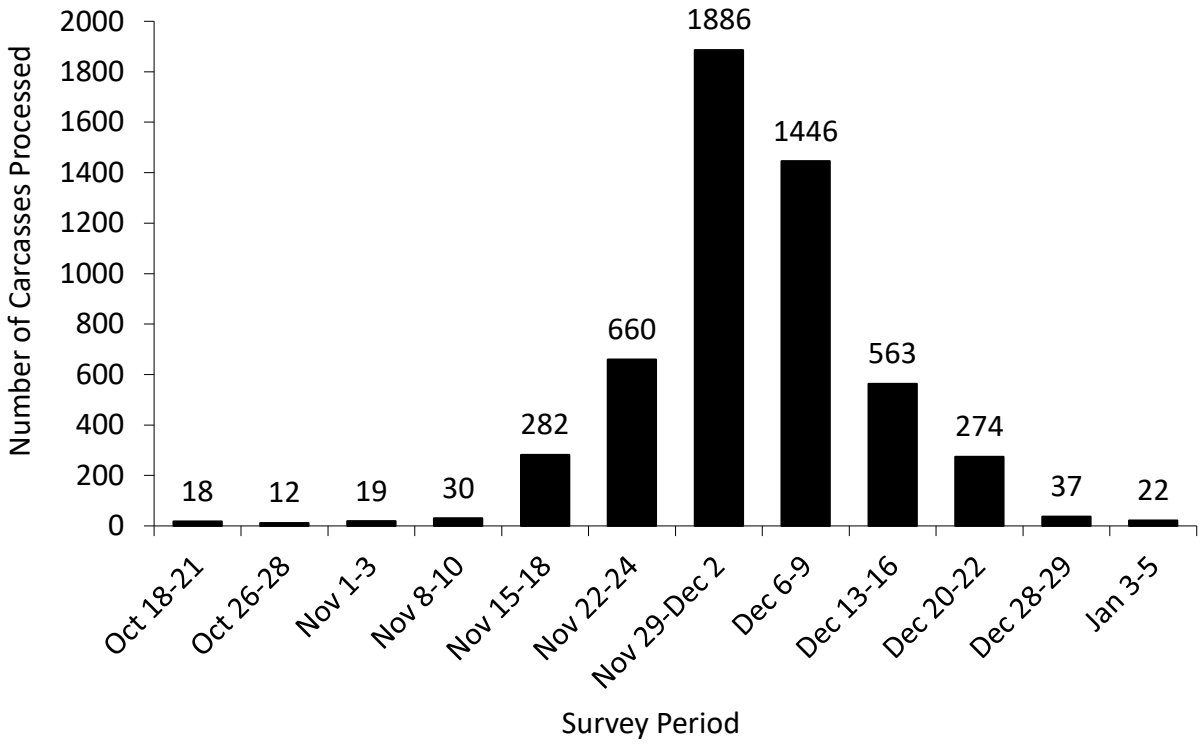

Figure 3. Numbers of carcasses observed and processed during the 2021 lower American River Chinook salmon escapement survey.

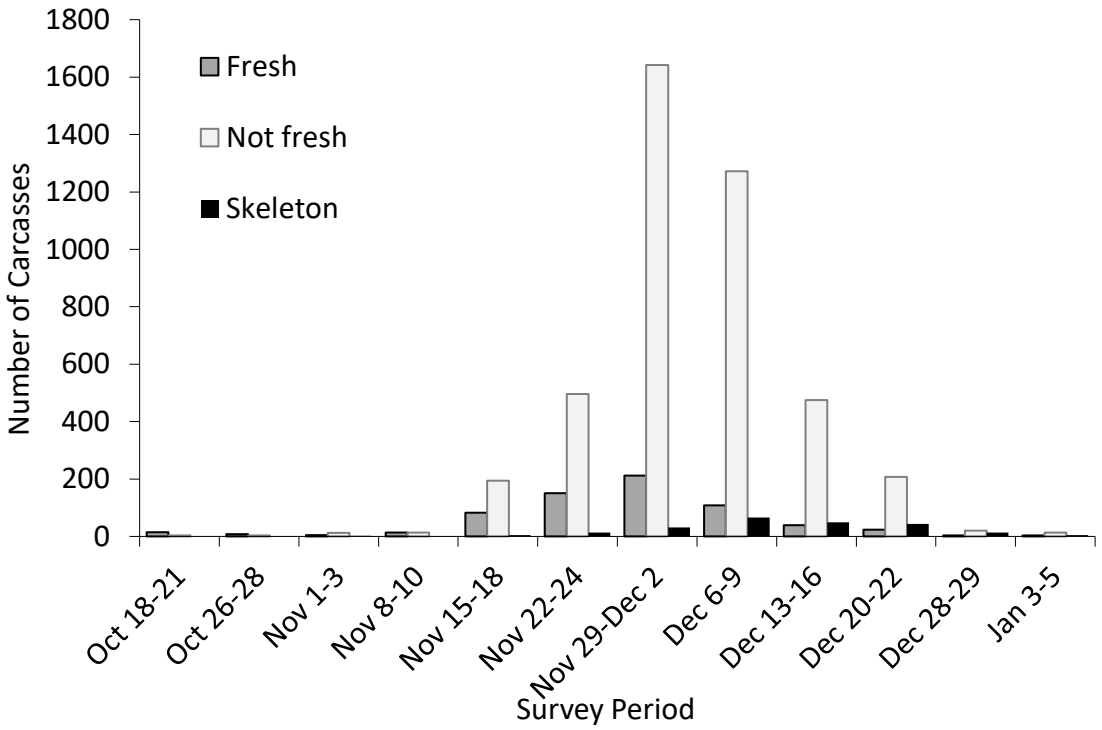

Figure 4. Number of fresh, not fresh, and skeleton carcasses processed in each survey period for the 2021 lower American River Chinook salmon escapement survey.

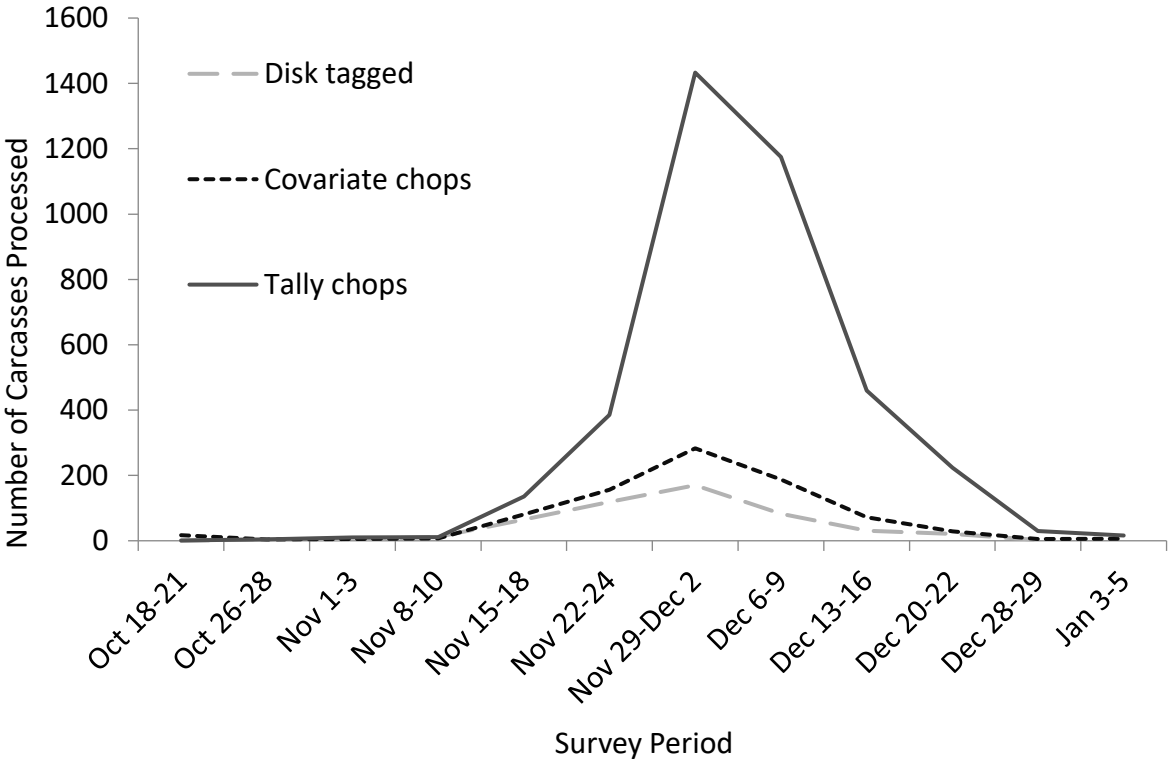

Figure 5. Frequency of processing method for carcasses collected during the 2021 lower American River Chinook salmon escapement survey.

Carcass Processing

Of the 5,249 carcasses processed, 3,885 (74%) were in an advanced stage of decomposition and were chopped and tallied. Of the remaining carcasses, 853 (16%) were processed for covariate data collection and chopped, including 753 heads retained for CWT extraction, while 511 (10%) were disk-tagged and included in the mark-recapture study (Figure 5).

Spatial Distribution

Of the total number of carcasses processed during the survey, less than 1% were detected in the fish ladder entrance channel (n = 16), 3% in NB (n = 160), 83% in section 1 (n = 4,347), 12% in section 2 (n = 642), and 2% in section 3 (n = 84) (Figure 6, Table 3).

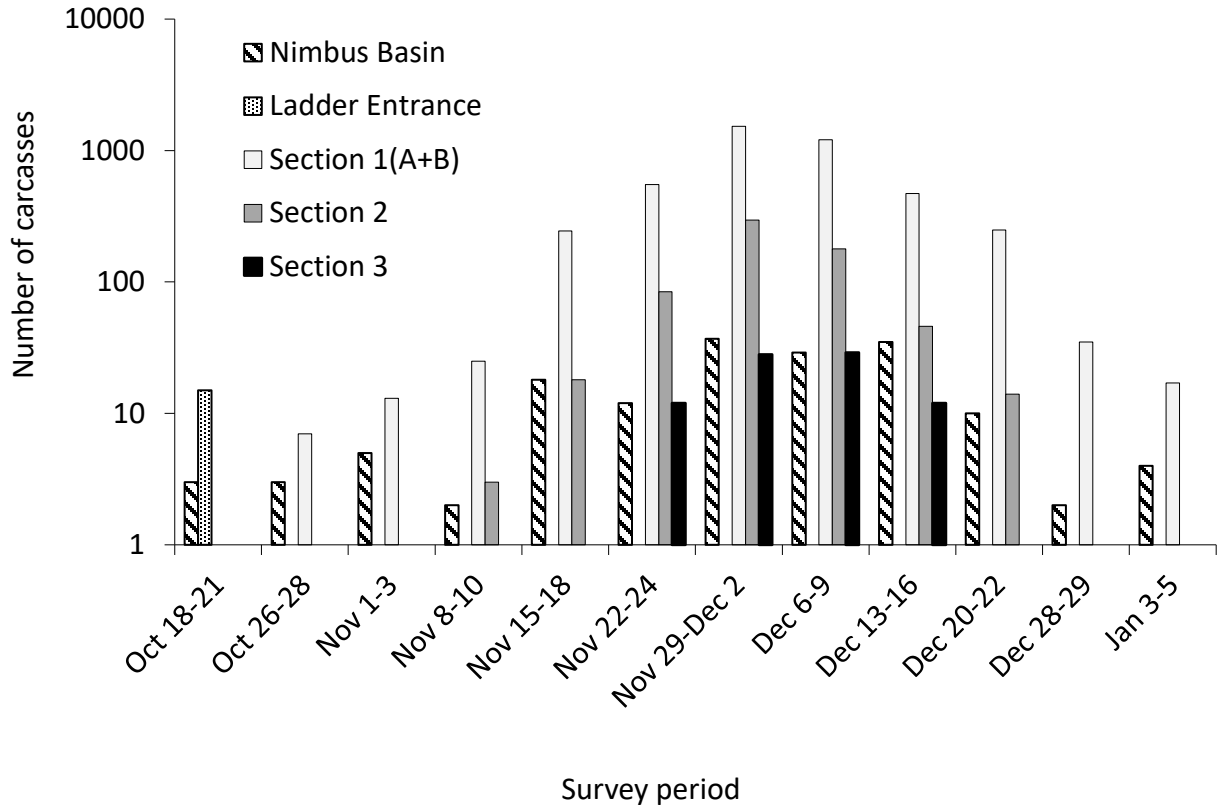

Figure 6. Spatial distribution of carcasses by survey period for the 2021 lower American River Chinook salmon escapement survey. Please note the log scale on the y axis.

Table 3. Spatial distribution of carcasses processed by survey period during the 2021 lower American River Chinook salmon escapement survey.

Survey Period	Date	Ladder Entrance	Nimbus Basin	Section 1	Section 2	Section 3	Total
1	Oct 18-21	15	3	0	0	0	18
2	Oct 26-28	0	3	7	1	1	12
3	Nov 1-3	0	5	13	1	0	19
4	Nov 8-10	0	2	25	3	0	30
5	Nov 15-18	0	18	245	18	1	282
6	Nov 22-24	0	12	552	84	12	660
7	Nov 29-Dec 2	0	37	1526	295	28	1886
8	Dec 6-9	0	29	1209	179	29	1446
9	Dec 13-16	0	35	470	46	12	563
10	Dec 20-22	1	10	248	14	1	274
11	Dec 28-29	0	2	35	NA	NA	37
12	Jan 3-5	0	4	17	1	0	22
Total		16	160	4347	642	84	5249
Total (%)		<1	3	83	12	2	

Sex Ratios

Sex data were recorded for 1,362 carcasses. Females represented 41% (n = 554) of the carcasses and males represented 59% (n = 808). Sex could not be determined for the remaining 3,887 carcasses because gonads were too deteriorated. Males were consistently found more frequently through the 12 week survey (Figure 7).

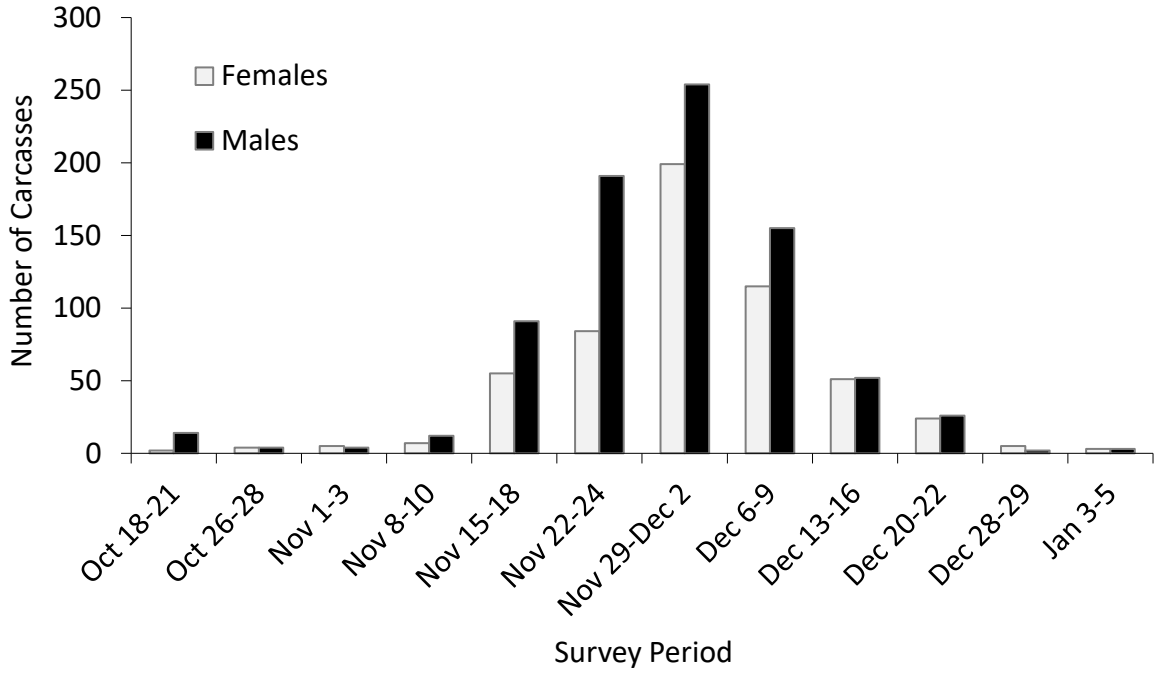

Figure 7. Distribution of male and female carcasses by survey period processed during the 2021 lower American River Chinook salmon escapement survey.

Length Distributions

Fork length was recorded for 1,363 carcasses of known sex (Figure 8). The average length for females (n = 553) was 76 cm with a range of 50 cm to 100 cm. The average length for males (n = 808) was 76 cm with a range of 50 cm to 111 cm. There were 2 unknown sex carcasses measuring 61 cm and 78 cm.

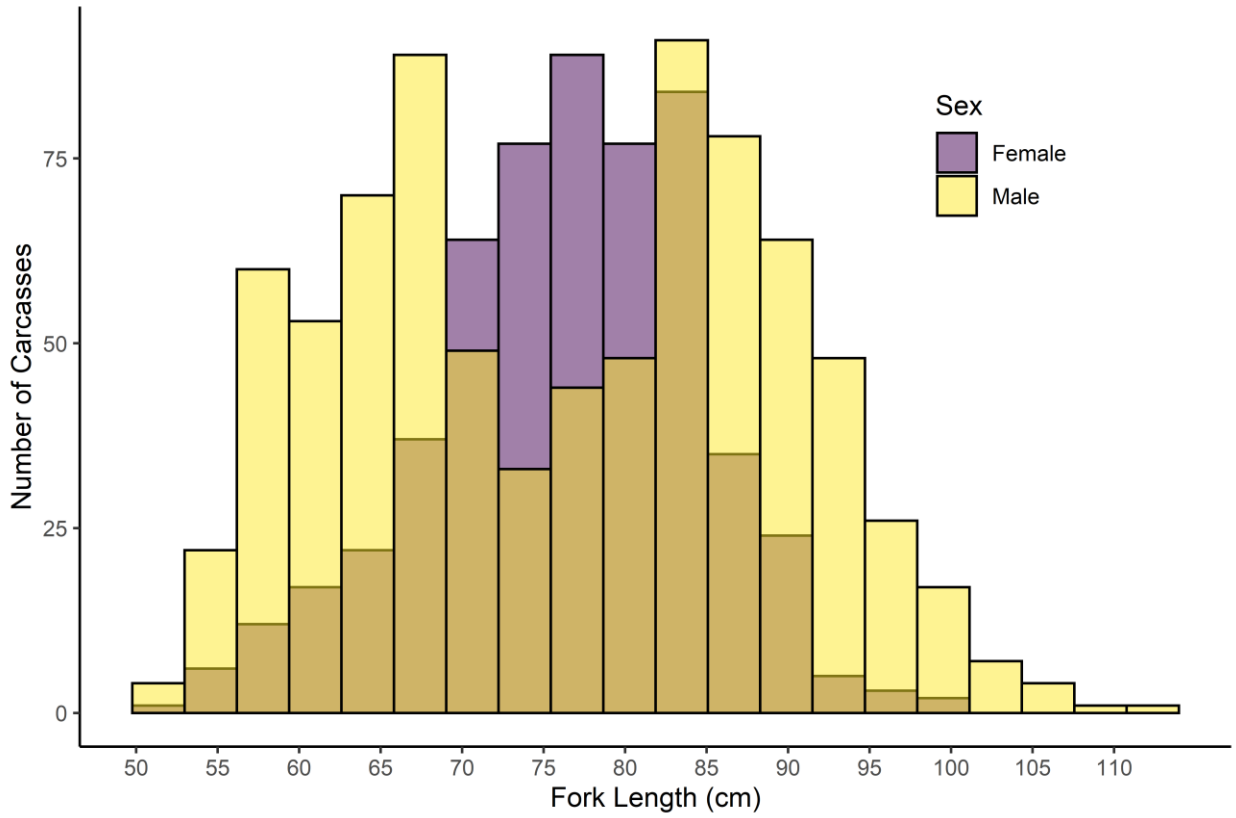

Figure 8. Fork length frequency histogram by sex for carcasses processed during the 2021 lower American River Chinook salmon escapement survey.

Age Classification

Length-frequency distributions of known-age CWT carcasses were used to determine the size boundaries for adult and grilse carcasses for each sex (Figure 9). Fish were classified as adults (≥3 years-old) if females had a FL ≥65 cm and males had a FL ≥74 cm. Fish were classified as grilse (≤2 years-old) if females had a FL of ≤64 cm and males had a FL of ≤73 cm. These cut-off lengths were determined to reduce age class misclassifications at a rate of 6.8% for males and 5% for females for known-age CWT carcasses.

A total of 945 (69%) carcasses were classified as adult and 418 (31%) carcasses were classified as grilse. The adult age class consisted of 497 (53%) females, 447 (47%) males, and 1 adult of unknown sex (<1%). The grilse age class consisted of 361 (86%) males, 56 (13%) females, and 1 grilse of unknown sex (<1%) (Figure 10). Adults and grilse were observed during every survey period. Grilse and adult numbers both peaked during survey period 7 (Table 4).

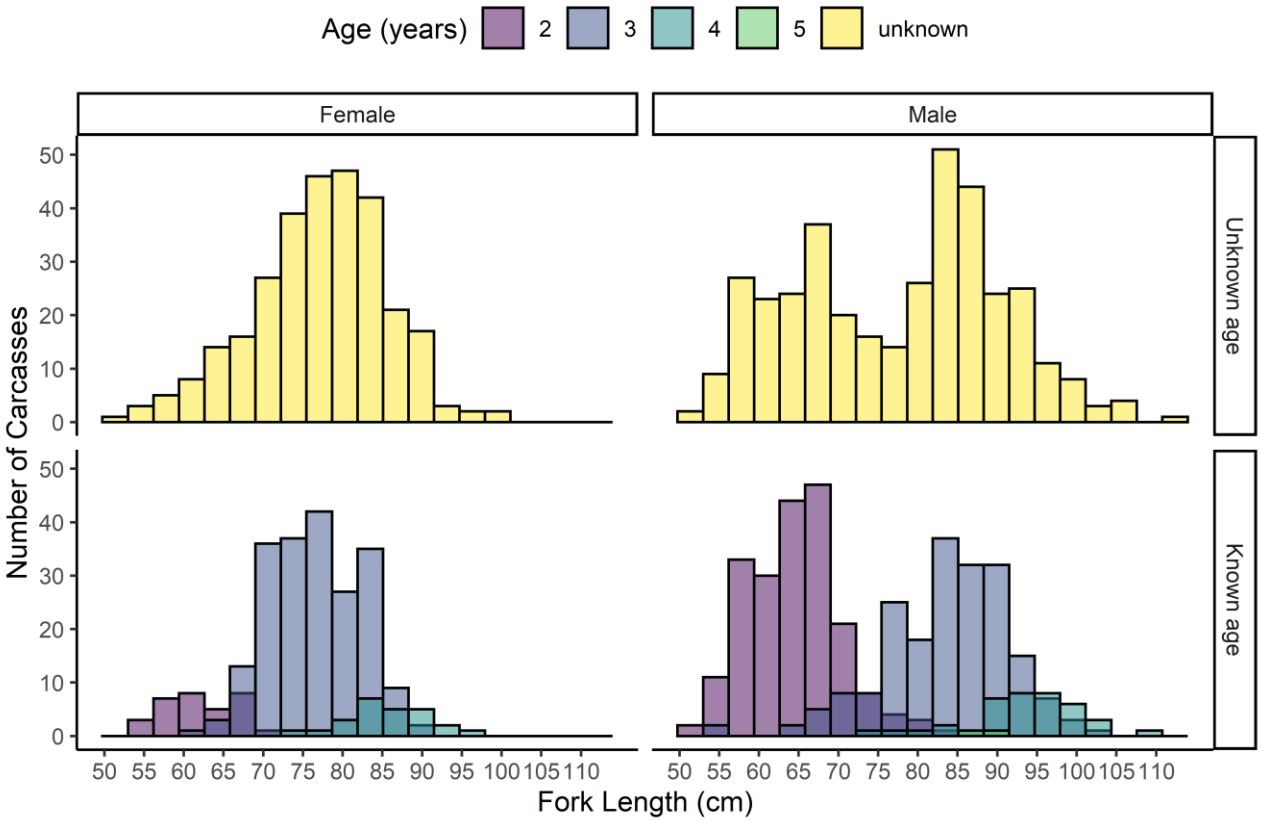

Figure 9. Fork length-frequency distribution of known-age coded wire tagged carcasses and unknown age carcasses processed during the 2021 lower American River Chinook salmon escapement survey.

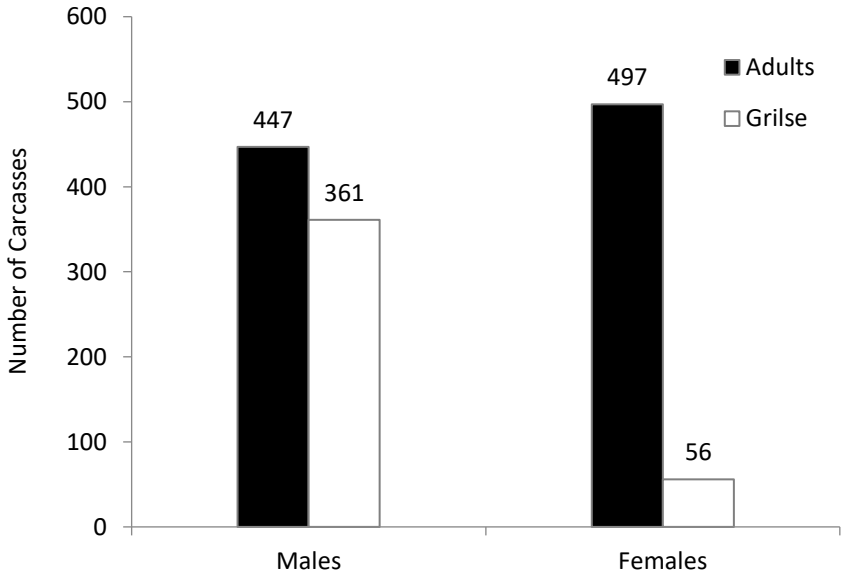

Figure 10. Number of male and female carcasses assigned to adult or grilse age classes during the 2021 lower American River Chinook salmon escapement survey.

Table 4. Summary of processed salmon carcasses by age class during the 2021 lower American River Chinook salmon escapement survey.

Survey Period	Date	Grilse		Adult	
		n	%	n	%
1	Oct 18-21	13	76	4	24
2	Oct 26-28	2	25	6	75
3	Nov 1-3	2	22	7	78
4	Nov 8-10	5	26	14	74
5	Nov 15-18	42	29	104	71
6	Nov 22-24	107	39	168	61
7	Nov 29-Dec 2	139	31	314	69
8	Dec 6-9	75	28	196	72
9	Dec 13-16	20	20	82	80
10	Dec 20-22	10	20	40	80
11	Dec 28-29	1	14	6	86
12	Jan 3-5	2	33	4	67
	Total	418		945	
	Total (%)	31		69	

Pre-spawn Mortality

Degree of egg retention was determined for 480 female carcasses (Table 5). Spawned females accounted for 74% (n = 355), partially spawned accounted for 11% (n = 51), and unspawned accounted for 15% (n = 74) of examined female carcasses. Only unspawned female carcasses were recovered during the first three weeks of the survey (n = 6). The proportion of spawned females varied from week 4 through the remainder of the survey. During weeks 4 (n = 5) and 10 (n = 16), all recovered females were spawned (Figure 11).

Table 5. Egg retention status of female carcasses and mean water temperature by survey period during the 2021 lower American River Chinook salmon escapement survey. Unspawned females retained >70% of eggs, partially spawned females retained 30-70% of eggs and spawned females retained <30% of eggs. Water temperature data were reported by USGS, American River at Fair Oaks gauge (USGS 2022).

Survey Period	Date	Mean Water Temperature	Unspawned	Partial	Spawned	Total
1	Oct 18-21	60.9°F	2	0	0	2
2	Oct 26-28	59.9°F	3	0	0	3
3	Nov 1-3	57.7 °F	1	0	0	1
4	Nov 8-10	56.8 °F	0	0	5	5
5	Nov 15-18	56.9 °F	1	9	38	48
6	Nov 22-24	56.2 °F	14	7	57	78
7	Nov 29-Dec 2	55.8 °F	25	25	130	180
8	Dec 6-9	54.8 °F	16	7	76	99
9	Dec 13-16	52.4 °F	10	3	30	43
10	Dec 20-22	50.9 °F	0	0	16	16
11	Dec 28-29	49.8 °F	1	0	2	3
12	Jan 3-5	48.2 °F	1	0	1	2
	Total		74	51	355	480
	Total (%)		15	11	74	

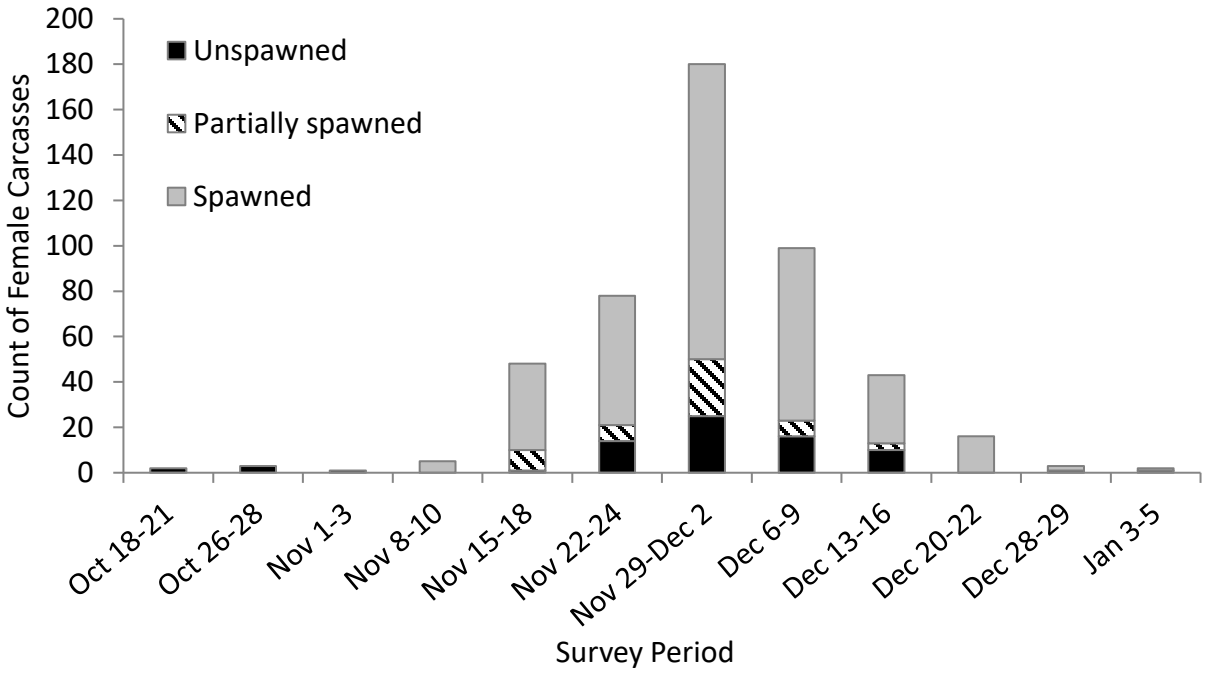

Figure 11. Egg retention status of female carcasses per survey period for the 2021 lower American River Chinook salmon escapement survey.

CWT Carcasses

All Chinook salmon carcasses were inspected for the presence or absence of an adipose fin. Adipose fin clipped carcasses were recovered during all weeks of the survey (Table 6, Figure 12). A total of 856 (16%) carcasses had an adipose fin clip, of those, heads were collected from 753 for CWT recovery. Adipose fins were intact for 4,015 (77%) of carcasses and presence or absence could not be determined for 378 (7%) of carcasses. Of the carcasses that could be assessed, 18% had a clipped adipose fin, which is a similar rate to what was observed from fish that entered the Nimbus Fish Hatchery (20%).

Preliminary data from CWTs recovered by the CDFW Central Valley Salmonid Archive staff indicates a high proportion of FRCS produced at hatcheries other than Nimbus Fish Hatchery strayed into the LAR. Hatcheries in the Central Valley generally mark and tag approximately 25% of hatchery-reared FRCS with CWTs. Of the 753 carcass heads collected for CWT extraction, 57% (431) originated from Nimbus Fish Hatchery, 32% (240) from Mokelumne River Hatchery, 2% (17) from Merced River Fish Facility, 2% (14) from Feather River Hatchery, and <1% (2) were spring-run Chinook salmon. The remaining 7% (49) Chinook salmon heads collected either had no CWT or the CWT was lost during extraction. Of the CWT returns for FRCS, approximately 39% (271 of 702) originated from hatcheries outside of the American River watershed.

Table 6. Adipose condition of carcasses by survey period for the 2021 lower American River escapement survey.

Survey Period	Date	Adipose Intact	Adipose Clipped	Skeleton/Unknown	Total
1	Oct 18-21	1	17	0	18
2	Oct 26-28	6	4	2	12
3	Nov 1-3	13	4	2	19
4	Nov 8-10	21	6	3	30
5	Nov 15-18	219	56	7	282
6	Nov 22-24	515	129	16	660
7	Nov 29-Dec 2	1498	321	67	1886
8	Dec 6-9	1134	206	106	1446
9	Dec 13-16	400	75	88	563
10	Dec 20-22	177	32	65	274
11	Dec 28-29	16	5	16	37
12	Jan 3-5	15	1	6	22
	Total	4015	856	378	5249
	Total (%)	77	16	7	

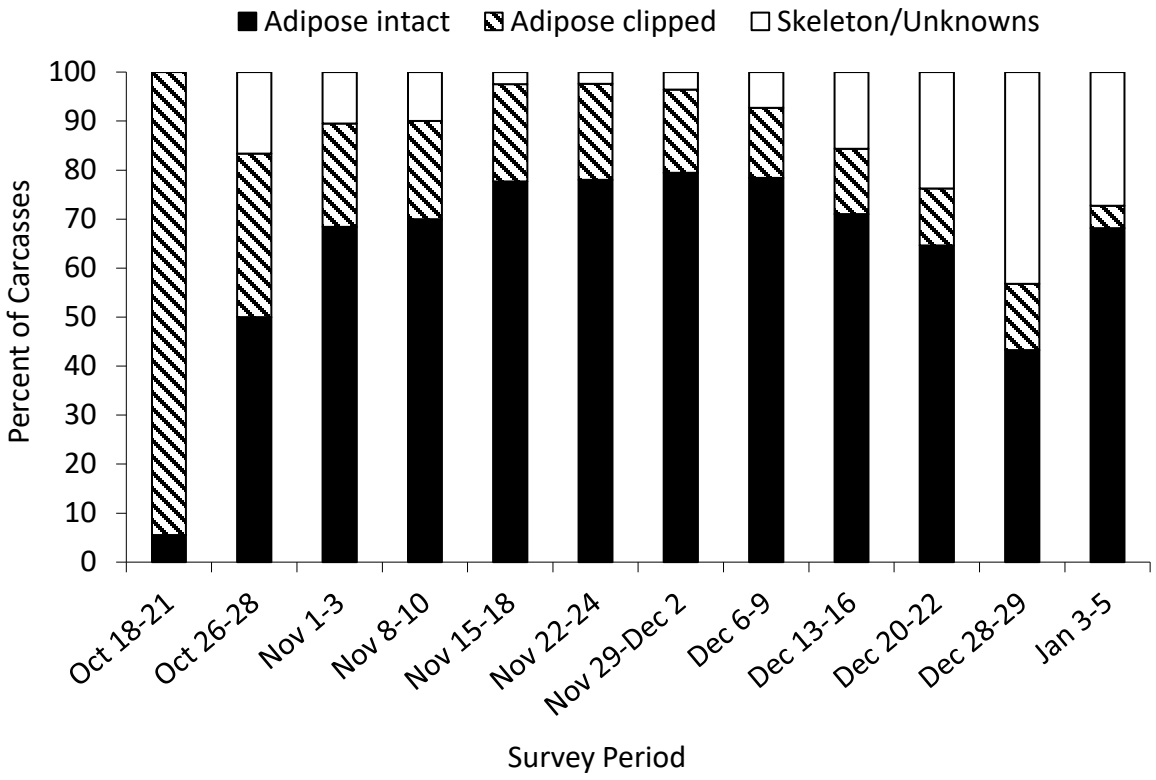

Figure 12. Temporal distribution of adipose fin condition for carcasses processed during the 2021 lower American River escapement survey.

Escapement Estimate

To calculate an escapement estimate, 511 fresh carcasses were marked with uniquely numbered disk tags for inclusion in the CJS population model. Of the tagged carcasses, 180 carcasses (35%) were recaptured at least once, with 199 recapture events in total. The LAR escapement estimate for 2021 was 11,232 fall-run Chinook salmon (90% CI = 10,376 to 11,983). The bootstrap (n = 1,000) estimate of standard error was 500 FRCS. The total escapement estimate was multiplied by the fraction of adults and grilse (approximately 69% and 31%, respectively) to obtain an escapement estimate of 7,787 and 3,445 for adults and grilse, respectively. In addition to the in-river escapement, 11,075 Chinook (7,332 adults and 3,743 grilse) entered Nimbus Fish Hatchery via a fish ladder. The hatchery uses a length boundary of 68 cm to assign an age class for both sexes.

DISCUSSION

Various factors influence the annual LAR escapement estimates, including escapement and spawning success of previous brood years, juvenile survival during emigration, ocean conditions, predation and harvest of adults, and river conditions (e.g., flow and water temperature). The 2021 LAR escapement estimate (11,232 FRCS) is a 50% decrease compared

to the previous year (22,456 FRCS) and the lowest since 2017 (7,457 FRCS) (Figure 13). The majority of salmon that returned to the LAR in 2021 were expected to be from brood year 2018. The reported 2018 escapement estimate (21,092 FRCS) was the first year to include the Nimbus Basin and weir for the in-river escapement estimate and was three times larger than an estimate derived for only sections 1-3 (6,819 FRCS). Additionally, the low flow on the LAR and prolonged periods of water temperatures exceeding 56°F during spawning periods likely created stressful river conditions for returning adult FRCS (Carter 2005).

Further exacerbating the stressful river conditions, returning adult Chinook salmon that fed off the coast of central California during 2018 and 2019 may have been susceptible to a deficiency of thiamine (vitamin B1). During those years, there was a high abundance on anchovy off the coast of central California (Mantua et al. 2021). Anchovies produce an enzyme called thiaminase which breaks down thiamine, an essential vitamin that supports metabolic function. Thiamine deficiency in returning adult female salmon can impact juvenile survival and is currently being investigated by researchers (Mantua et al. 2021). Central Valley hatcheries have been successful in treating hatchery produced salmon for thiamine deficiency but the sub-lethal effects and impact this may have on in-river juvenile production is still being investigated.

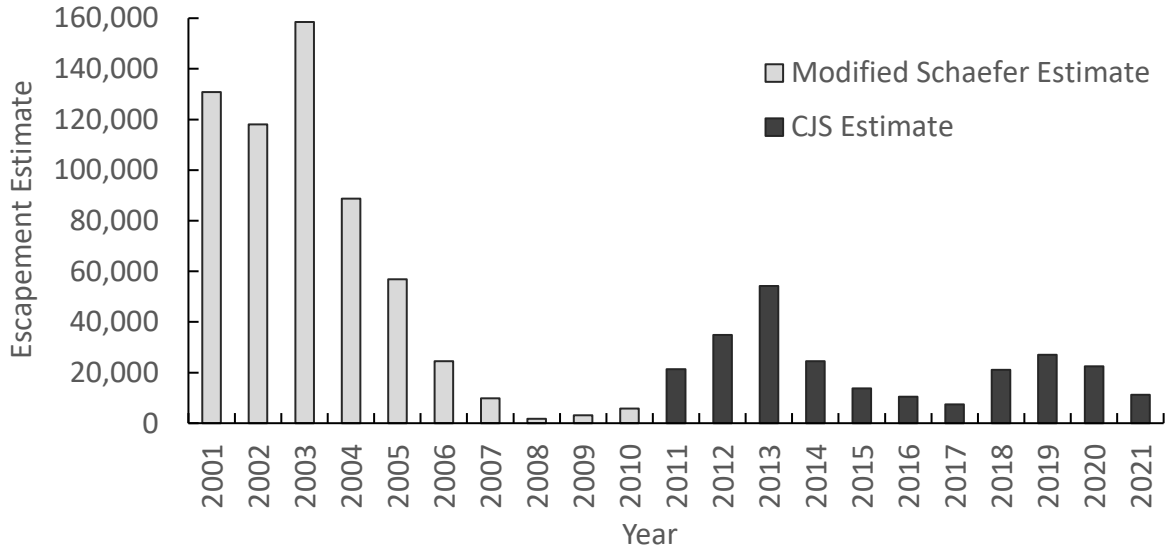

Figure 13. Historical in-river escapement estimates for the lower American River escapement survey from 2001-2021.

Discharge from Nimbus Dam was approximately 550 cfs at the beginning of the survey on October 18 and remained consistent throughout most of the survey. Dry riverbed side channels were observed during the survey and limited the available spawning habitat which likely limited successful spawning activity. In addition to potentially compromising river connectivity, the low overall discharge levels may have threatened the successful incubation of redds. Low levels of intra-gravel dissolved oxygen can have lethal and sublethal effects on salmon embryos, including changes to the time to hatching and size of emerging fry (Bjornn and Reiser 1991,

Carter 2005, Geist et al. 2006). Additionally, higher temperatures increase oxygen demand, exacerbating the challenge of egg survival in a highly altered system undergoing climate change (Martin et al. 2020).

Climate driven variations in temperature are of increasing relevance for the Central Valley population of FRCS, which spawn at the southern extent of the species' range, therefore making it more susceptible to climate change (Williams 2006). The 2021 LAR FRCS spawning season began slowly with only 361 carcasses processed over the first 5 survey periods. Water conditions reached a maximum suitable spawning temperature of 56°F at the end of survey period 6. Pre-spawn mortality of females (15%) was the lowest rate since 2015 (6%). However, both 2015 and 2021 had low escapement estimates and poor river conditions so it is unlikely either of these years would result in a significant increase to juvenile recruitment. The average pre-spawn mortality rate from 2000-2021 is 21%. Releases of cool water from reservoirs has been identified as an important management practice for providing suitable spawning and rearing habitat for Chinook salmon in the Sacramento basin (Yates et al. 2008). The maintenance of the CWP behind Folsom Dam and cold-water releases continues to be increasingly relevant for survival of FRCS stocks in the LAR.

Unique to the survey this year was the operation of new Nimbus Hatchery fish ladder, precluding the use of the weir. In prior years, the weir was used to direct Chinook salmon to the Nimbus Fish Hatchery fish ladder and prevent migration past the ladder into NB, but the deterioration of the weir over several decades and damage from high flows no longer prevented salmon from entering NB. While the weir was in place, fish were unable to freely move out of the Nimbus Basin area and this often resulted in redd superimposition (Thorpe and Cardenas 2015) and potentially increased prespawn mortality due to overcrowding. The weir also prevented carcasses within NB from drifting downstream of the weir. The entrance to the new Nimbus Hatchery fish ladder at the upstream end of NB allows fish movement in and out of NB and eliminated the barrier preventing natural downstream drift of carcasses. Since NB is typically the most temperature suitable habitat of the LAR, it is a positive change that fish can utilize the area but freely move downstream if suitable habitat for redd building is unavailable.

The absence of the weir resulted in substantial changes in the spatial distribution of carcasses this year, most notable was a decrease in the percent of carcasses processed in NB (3%) compared to 2020 (35%). The majority of carcasses processed were recovered in section 1, which is consistent with previous surveys (Kelly and Phillips 2020; Snider and Reavis 1996). The proportion of carcasses processed in section 1 this year was higher than in 2020 (83% and 53%, respectively). This more closely resembled spatial distribution patterns prior to the 2018 survey, when the weir and Nimbus Basin were not included in this survey (Figure 14).

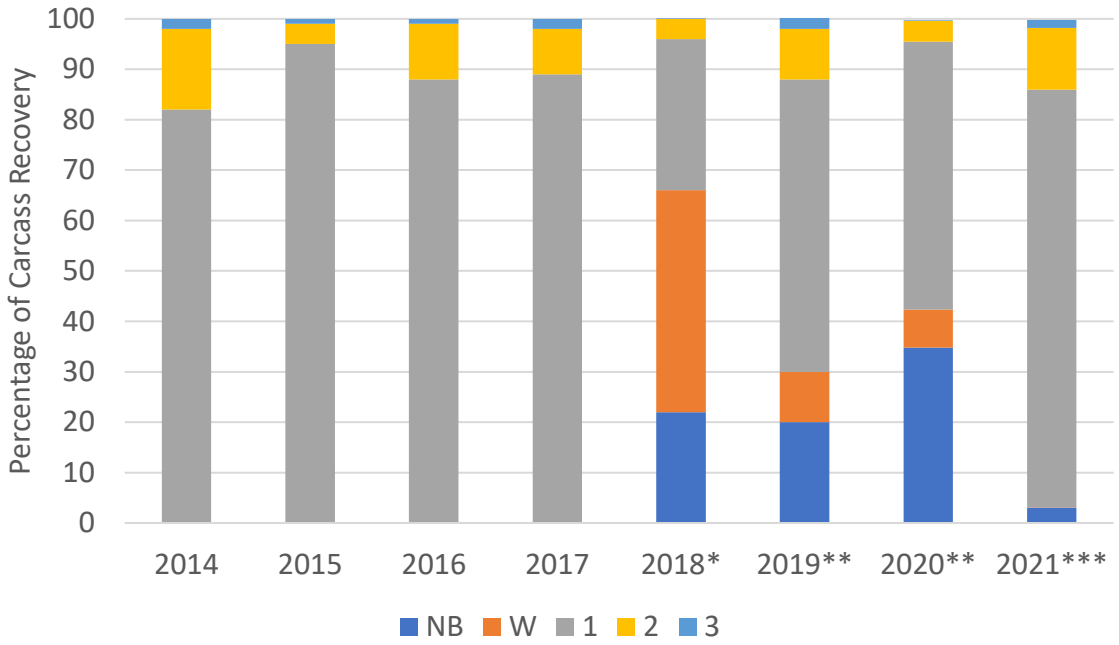

Figure 14. Comparison of spatial distribution for lower American River escapement surveys from 2014-2021.
*Nimbus Basin and the weir were added to the survey in 2018. All carcasses on the weir were processed.
**Only adipose clipped carcasses recovered from the weir were processed in 2019 and 2020. All other carcasses were passed downstream of the weir to mimic natural downstream movement.
***The weir was not in use during 2021.

The Central Valley Project Improvement Act (U.S. Fish and Wildlife Service 2015) established the goal to double the number of naturally spawning anadromous fish in the Central Valley based on a baseline period of 1967-1991. Mark-recapture efforts during the 2021 lower American River escapement survey produced an escapement estimate of 11,232 fall-run Chinook salmon and is still far below the doubling goal of 160,000 fall-run Chinook salmon on the American River (U.S. Fish and Wildlife Service 2015). Peak carcass recovery occurred during survey period 7 (November 29 - December 2), which is consistent with the historical average for LAR FRCS and corresponds with the peak spawn timing from 2018 (December 3-7), the brood year for most of the 2021 spawners. Although the reported escapement estimate for 2018 was nearly twice as much as this year, the inclusion of fish recovered from the Nimbus Basin and the weir in the 2018 estimate were not likely to contribute to juvenile recruitment and adult returns during the 2021 survey.

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