California Department of Fish and Wildlife
North Central Region

Lower American River Fall-run Chinook Salmon Escapement Survey, October 2018- January 2019

Presented to the United States Bureau of Reclamation

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INTRODUCTION

The lower American River (LAR) is a 23-mile stretch of the American River extending from the base of Nimbus Dam downstream to the confluence of the Sacramento River at Discovery Park. The LAR supports both wild and hatchery fall-run Chinook salmon (FRCS, *Oncorhynchus tshawytscha*) spawning and rearing. Adult escapement to the LAR has historically represented an average of 19% of all returning FRCS runs to the Central Valley (Azat 2018). Historically, the LAR has supported three seasonal runs of Chinook salmon: fall-, late fall- and spring-runs; the spring-run is believed to have been extirpated (Yoshiyama, et al. 1996; Zeug, et al. 2010). Federally endangered Sacramento River winter-run Chinook salmon also use the LAR as a critical rearing habitat during their outward migration to the Pacific Ocean (Phillis et al. 2018), and it is assumed that successful reproduction of this Environmentally Significant Unit (ESU) has occurred within the LAR (Silva and Bouton 2015). FRCS traditionally enter the LAR in mid-September and continue their spawning run through January with the heaviest migration occurring November through mid-December. FRCS spawning typically starts in early November, or when water temperatures drop below 60° (Williams 2001).

The 13.4-mile stretch of river from the Nimbus Basin (Basin) downstream to Watt Avenue was broken up into six sections and surveyed once for salmon carcasses over a three- to four-day period (Figure 1, Table 1). The Basin is comprised of a deep pool at the base of the dam, a riffle and run in the main channel and a braided side channel. Sections 1A and 1B are composed primarily of riffles and glides with a few pools. Historically, Sections 1A and 1B support the most FRCS spawners (Snider and Vyverberg 1996). Section 2 contains a few high-gradient riffles, but consists mainly of large, deep-water glides. Section 3 contains riffles, deep glides and several braided side-channels and requires crews to survey from the shore, jet boat, and kayaks. The section of river between the mouth and Watt Avenue has very little spawning habitat and is primarily a migration corridor.

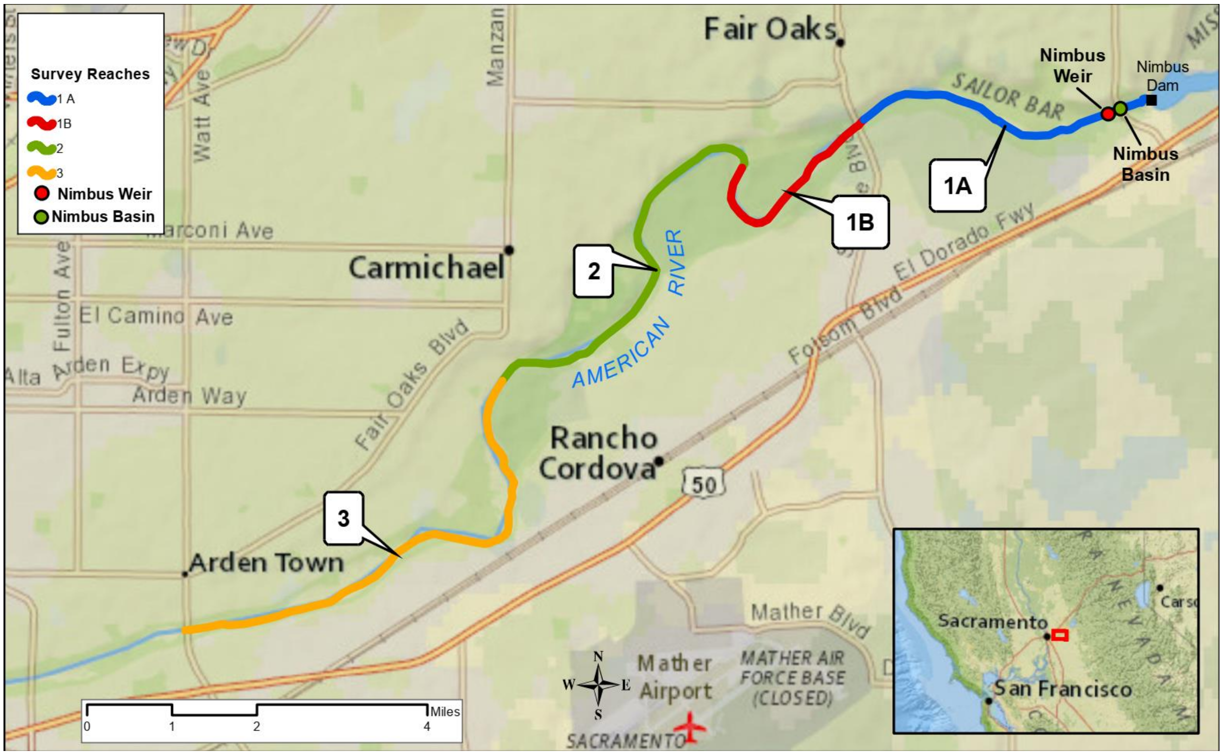

Figure 1. Map of survey sections of the lower American River salmon escapement survey.

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

Section	Location	Miles
NB	Nimbus Dam Basin to Nimbus Hatchery Weir	0.3
W	Nimbus Hatchery Weir	n/a
1A	Nimbus Hatchery Weir to Sunrise Blvd access	2.6
1B	Sunrise Blvd Access to Elmanto Dr access	1.7
2	Elmanto Dr access to River Bend Park	4.7
3	River Bend Park to Watt Ave access	4.1
	Total	13.4

Natural FRCS juvenile production on the LAR is supplemented with hatchery production from Nimbus Fish Hatchery (NFH). NFH was constructed in 1958 by the United States Bureau of Reclamation (USBR), to mitigate for the loss of spawning habitat upstream of Nimbus Dam (USFWS and CDFG 1953; CDFW 2017). Currently, the California Department of Fish and Wildlife (CDFW) oversees hatchery operations with funding from USBR (CDFW 2017).

Adult salmon escapement surveys have been conducted on the LAR since 1944 (Gerstung 1971). Escapement survey data are used in preparing commercial and sport fishing regulations, seasons and harvest limits. Other uses include the planning and implementation of habitat restoration activities to evaluate proposed water project operations, to monitor hatchery success, and as a factor to consider in seasonal water operations.

The objectives of the LAR escapement survey were to, (1) estimate FRCS escapement in the LAR; (2) determine the ratio of adults to grilse and sex ratios of adults and grilse; (3) determine the degree of female pre-spawn mortality; and (4) collect coded-wire tags (CWT) from hatchery-reared salmon to provide data for the investigation of the contribution of hatchery-reared salmon in ocean and fresh water harvests and escapement.

METHODS

Survey crews consisting of 4-9 members searched for submerged salmon carcasses within each section while walking along the riverbanks, riding in a jet boat, or paddling a kayak. Crews started at the upstream border of each section and moved downstream processing all carcasses encountered. Salmon carcasses found to be ≤50% submerged were not included in the escapement survey because they do not present an equal probability of detection, and once dried they require a longer time to decompose which can skew mark-recapture analyses. Each carcass encountered was examined for the following: (1) presence of an external tag, (2) presence or absence of an adipose fin, (3) extent of carcass deterioration, and (4) extent of egg retention in females. Flow and water temperature data were obtained for each survey period from the United States Geological Survey gauge, 11446500 American R at Fair Oaks, by accessing the USGS website (USGS 2019). Carcasses were processed for (1) the mark-recapture model, (2) head collection for CWT retrieval, or (3) simply chopped and tallied.

Salmon carcasses possessing an intact adipose fin were either utilized in the mark-recapture model if they were fresh enough for the carcass to remain intact for at least one more survey period or chopped and tallied if in a state of advanced decomposition. Salmon carcasses utilized in the mark-recapture study were fitted with a hog ring on the left maxilla containing a uniquely numbered aluminum disk-tag and colored flagging specific to each survey period. Disk-tagged carcasses were deposited into the thalweg nearest to the area they were encountered. Upon the recovery of a disk-tagged carcass in a subsequent survey period, field staff recorded the disk-tag number and either chopped or released the carcass based on the level of decomposition. The 2018 LAR FRCS in-river escapement estimate was derived using the Cormack-Jolly-Seber (CJS) mark-recapture model for open populations (Cormack 1964;

Bergman et al. 2012) using R statistical software, version 3.3.2 (www.r-project.org). Two escapement estimates were generated because of the addition of the Basin and Nimbus Fish Hatchery weir (weir) sections to the 2018 lower American River escapement survey.

Covariate data were collected on all carcasses used in the mark-recapture study and adipose-clipped carcasses destined for CWT removal. Data collected included: sex, fork length, level of egg retention in females, and state of decomposition. Sex was determined by a combination of distinguishing characteristics including presence or absence of a kype, body morphology, and the presence of eggs or milt. Fork length (FL) was measured from the tip of the snout to the fork of the caudal fin and rounded to the nearest centimeter.

At the conclusion of the survey, fork lengths were pooled separately by sex and plotted in a frequency distribution to determine the FL range used to classify carcasses as adult or grilse (two-year-old sexually mature fish). Fork lengths from known-age CWT carcasses were used to corroborate the range of adult and grilse lengths of adipose-intact carcasses. The state of carcass decomposition was determined by examining the condition of the eyes and gills. Salmon carcass condition was considered fresh if one clear eye or bright red gills were present and not fresh if one or both eyes were cloudy, or gills were pink or brown. The level of egg retention was determined by inspecting female carcasses and was recorded as unspawned if >70% of eggs were present, partially spawned if there was 30-70% egg retention, or spawned if there was <30% egg retention.

RESULTS

Survey Periods

The survey was conducted over 13 weeks from October 15, 2018, to January 9, 2019. Subsampling carcasses was not necessary during this survey. During survey period 5 section 3 was not surveyed due to poor air quality from a local forest fire, and during survey period 6 sections 2 and 3 were not surveyed because of a corresponding holiday (Table 2).

Table 2. Survey periods and sampling regime for the 2018 lower American River salmon escapement survey.

Survey period	Date range	Sections Not Surveyed
1	Oct 15-19, 2018	None
2	Oct 22-26, 2018	None
3	Oct 29-Nov 2, 2018	None
4	Nov 5-9, 2018	None
5	Nov 13-15, 2018	3
6	Nov 20-21, 2018	2, 3
7	Nov 26-30, 2018	None
8	Dec 3-7, 2018	None
9	Dec 10-13, 2018	None
10	Dec 17-20, 2018	None
11	Dec 26-28, 2018	None
12	Dec 31, 2018-Jan 3, 2019	None
13	Jan 7-9, 2019	None

Environmental Conditions

LAR water temperature decreased throughout the survey season. The maximum and minimum recorded water temperatures were 63°F on October 15, 20, 21, and 22, 2018, and 49°F from January 1-9, 2019, with an average daily temperature of 56°F (Figure 2) (USGS 2019). LAR flows ranged from a minimum of 1,530 cubic feet per second (cfs) on October 15, 2018, to 1,910 cfs on November 15, 17, 18 and 19, 2018.

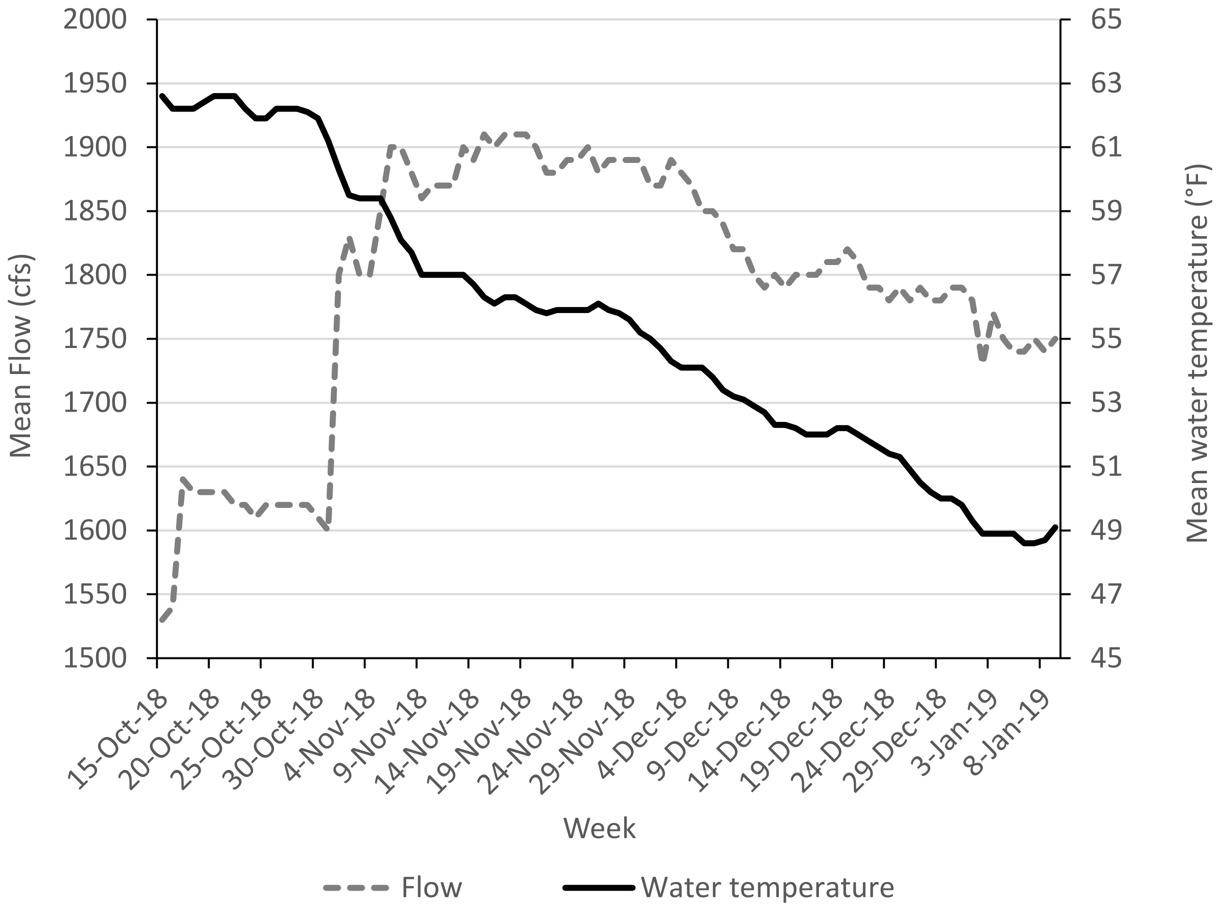

Figure 2. Mean daily river flows and mean daily water temperature observed during the 2018 lower American River salmon escapement survey.

Final Carcass Count

A total of 12,238 salmon carcasses were observed and processed during the survey. The maximum number of carcasses processed in a single survey period was 2,208 during the week of December 3-7, 2018 (survey period 8) (Figure 3).

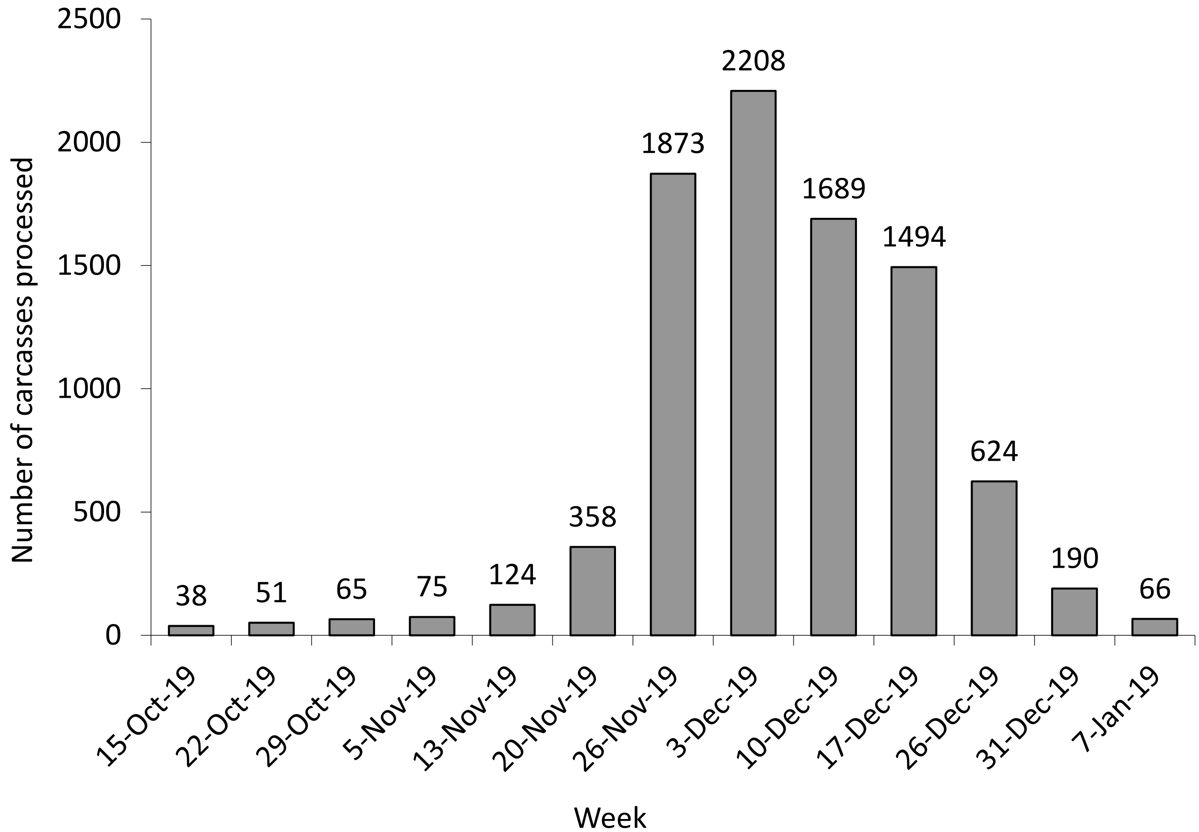

Figure 3. Temporal distribution of carcasses processed during the 2018 lower American River escapement survey.

Fresh salmon carcasses were processed each survey period except during the last week of the survey (Table 3). The majority of fresh salmon carcasses were observed during survey period 8 (Table 3).

Table 3. Summary of carcass decomposition during the 2018 lower American River salmon escapement survey.

Week	Survey period	Fresh	Decayed	Week total	Unknown
15-Oct-19	1	13	14	57	0
22-Oct-19	2	29	31	75	0
29-Oct-19	3	25	28	83	0
5-Nov-19	4	50	54	109	0
13-Nov-19	5	21	26	178	1
20-Nov-19	6	164	170	591	0
26-Nov-19	7	259	266	2520	50
3-Dec-19	8	472	480	3076	34
10-Dec-19	9	142	151	2321	4
17-Dec-19	10	85	95	2032	8
26-Dec-19	11	16	27	778	8
31-Dec-19	12	11	23	230	0
7-Jan-19	13	0	13	83	0
Totals		1287	1287	12133	105

Processing Type

Of the 12,238 carcasses processed, 41% (*n*=5,072) were chopped and tallied. Covariate data were collected from the remaining 59% of carcasses and were processed for CWT extraction (*n*=3,383), disk-tagged for the mark-recapture study and released (*n*=565), or chopped (*n*=3,218) (Table 4).

Table 4. Processing types for salmon carcasses encountered on the 2018 lower American River salmon escapement survey.

Week	Survey period	Tally chops	Disk tagged	Misc chops	CWT	Week Total
15-Oct-18	1	7	1	30	19	38
22-Oct-18	2	8	3	40	24	51
29-Oct-18	3	14	3	48	18	65
5-Nov-18	4	15	6	54	34	75
13-Nov-18	5	11	5	108	55	124
20-Nov-18	6	85	75	198	233	358
26-Nov-18	7	135	82	1656	697	1873
3-Dec-18	8	960	168	1080	902	2208
10-Dec-18	9	1565	122	2	636	1689
17-Dec-18	10	1419	73	2	546	1494
26-Dec-18	11	607	17	0	162	624
31-Dec-18	12	180	10	0	40	190
7-Jan-19	13	66	0	0	17	66
Totals		5072	565	3218	3383	12238
		41%	5%	26%	28%	

Spatial Distribution

Most salmon carcasses were encountered at the weir (44%, *n*=5,393). Thirty percent (*n*=3,640) of carcasses were detected in Section 1A/1B, and 22% (*n*=2,674) in the Basin. The fewest carcasses were observed in Sections 2 and 3, where 4% (*n*=449) and 1% (*n*=82) of all carcasses were observed, respectively.

Sex Ratios

Sex was recorded for 7,158 carcasses. Females comprised 45% (*n*=3,196) of the total, and males comprised the remaining 55% (*n*=3962) (Table 5).

Table 5. Temporal distribution of carcass sex ratios processed during the 2018 lower American River salmon escapement survey.

Week	Survey period	Females	Males
15-Oct-18	1	27	23
22-Oct-18	2	30	37
29-Oct-18	3	20	49
5-Nov-18	4	41	53
13-Nov-18	5	75	93
20-Nov-18	6	226	275
26-Nov-18	7	1091	1342
3-Dec-18	8	1037	1112
10-Dec-18	9	339	421
17-Dec-18	10	226	395
26-Dec-18	11	58	121
31-Dec-18	12	16	34
7-Jan-19	13	10	7
Total		3196	3962
		45%	55%

Length Composition

FL was recorded for 7,151 carcasses (Figure 4). The minimum and maximum FLs recorded for male carcasses were 38 cm and 104 cm, respectively, with a mean of 71 cm and a mode of 64 cm. Minimum and maximum FLs recorded for female carcasses were 45 cm and 95 cm, respectively, with a mean of 76 cm and a mode of 79 cm.

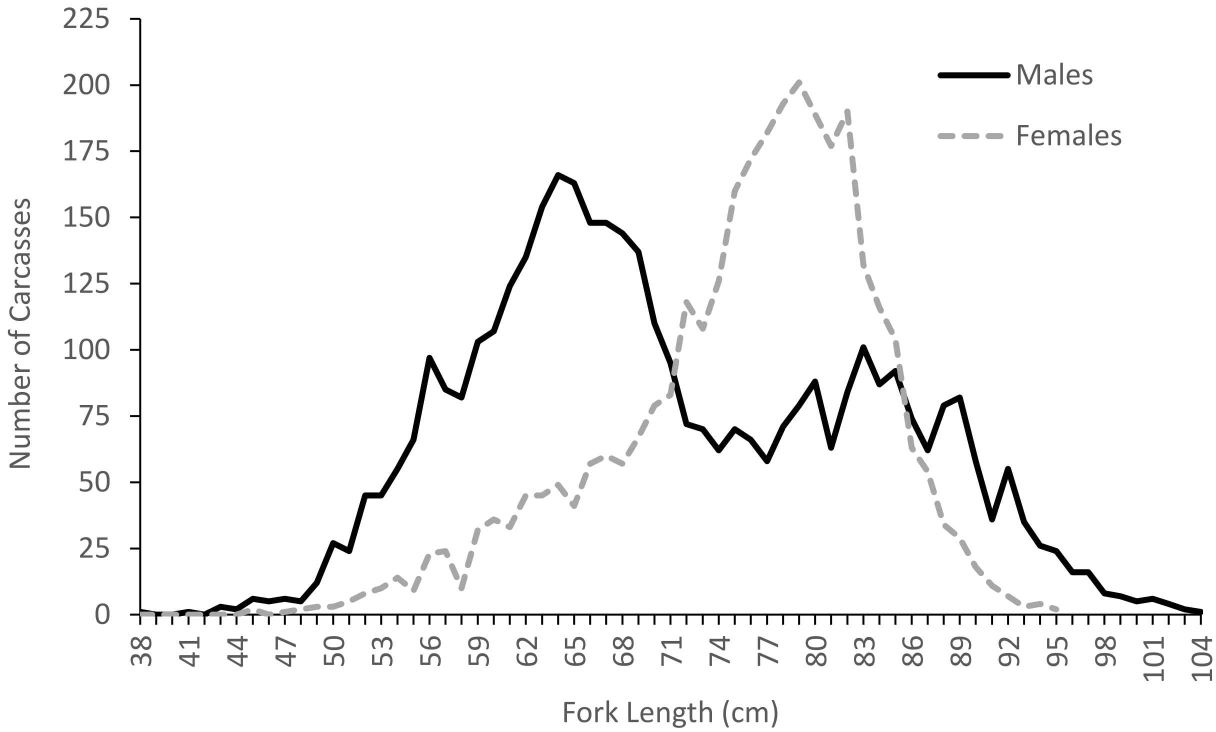

Figure 4. Fork length frequency by sex of carcasses processed during the 2018 lower American River salmon escapement survey.

Age Classification

A total of 7,151 salmon carcasses were assigned to one of two distinct age classes based on a length frequency distribution calculated from all FLs recorded during the survey (Figure 5 and Figure 6). Carcasses were classified as adults (≥ 3 years old) if females had a FL ≥ 69 cm and males had a FL ≥ 75 cm. Carcasses were classified as grilse (≤ 2 years old) if female FLs were ≤ 68 cm and male FLs were ≤ 74 cm. Fifty-seven percent (*n*= 4,077) were classified as adults while 43% (*n*=3,074) were classified as grilse. Both age classes were observed during each survey period. The adult and grilse contributions to the lower American River escapement survey both peaked during survey period 7 (November 26-30) (Table 6).

Table 6. Weekly distribution of age-class assignments for carcasses processed during the 2018 lower American River salmon escapement survey.

Week	Survey period	Grilse	Adults
15-Oct-18	1	12	37
22-Oct-18	2	23	44
29-Oct-18	3	30	39
5-Nov-18	4	33	61
13-Nov-18	5	72	96
20-Nov-18	6	196	305
26-Nov-18	7	1066	1364
3-Dec-18	8	866	1280
10-Dec-18	9	307	453
17-Dec-18	10	322	299
26-Dec-18	11	105	74
31-Dec-18	12	30	20
7-Jan-19	13	12	5
Total		3074	4077
		43%	57%

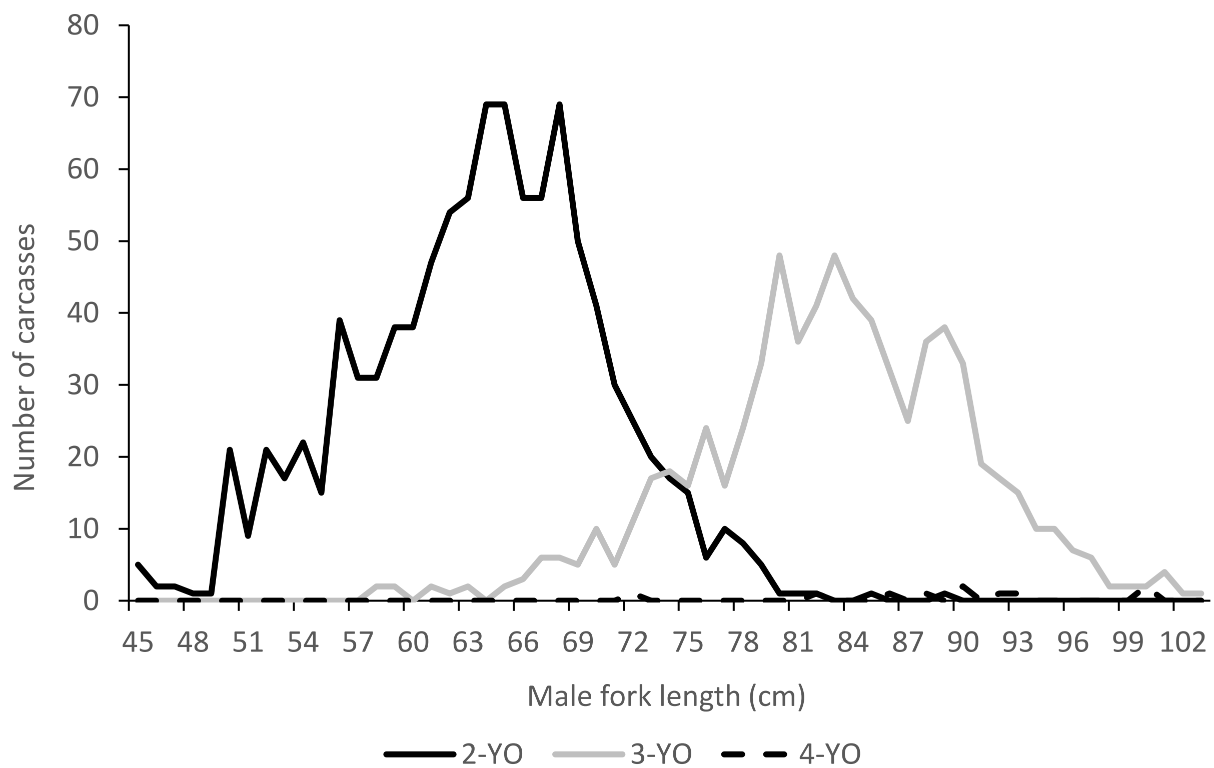

Figure 5. Length frequency histogram for known-age coded wire tagged male carcasses processed during the 2018 lower American River salmon escapement survey.

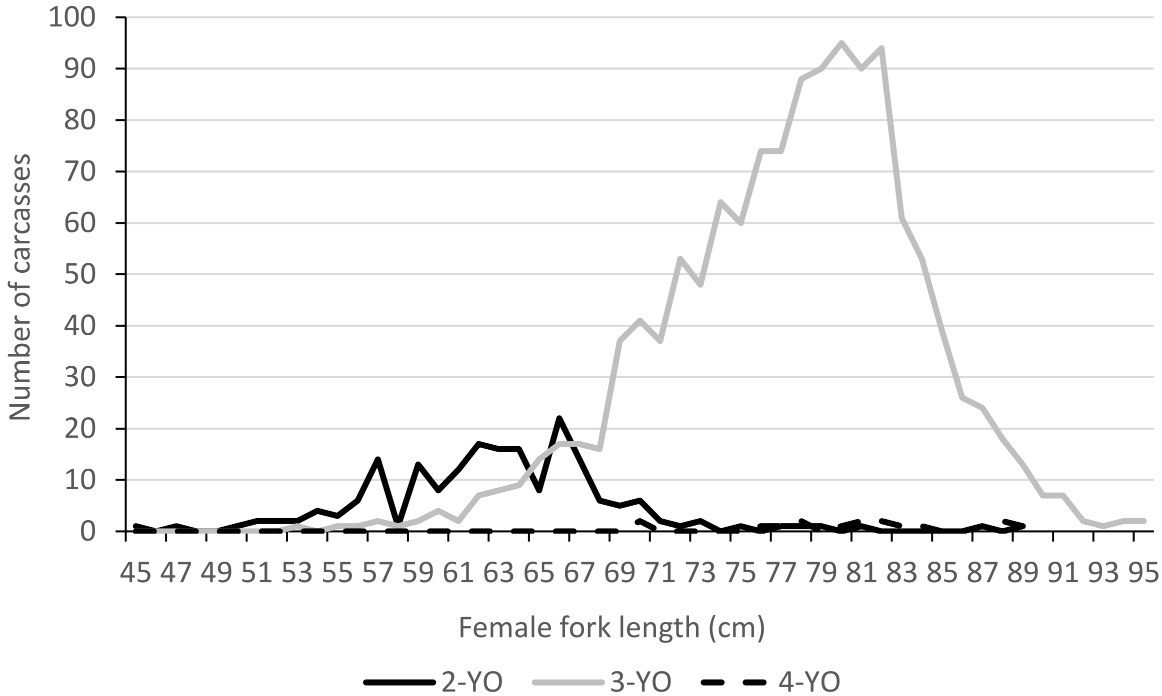

Figure 6. Length frequency histogram for known-age coded wire tagged female carcasses processed during the 2018 lower American River salmon escapement survey.

The ratio specific to males and females were also determined within each age class (Figure 7). Of the 3,074 grilse carcasses, 81% (*n*=2,505) were male and 19% (*n*=569) were female. Of the 4,077 adult carcasses 64% (*n*=2,622) were male and 36% (*n*=1,455) were female.

Figure 7. Age classifications by sex of carcasses processed during the 2018 lower American River salmon escapement survey.

Pre-spawn Mortality

A total of 2,876 female carcasses were assessed for egg retention (Table 7, Figure 8). Sixty-four percent (*n*=1,829) of female salmon were spawned, 17% (*n*=476) were partially spawned, and 20% (*n*=571) were unspawned. The proportion of spawned females were highest (> 50%) during survey periods 6 through 13 (Figure 7).

Table 7. Temporal distribution of egg retention status during the 2018 lower American River salmon escapement survey.

Week	Survey period	Unspawned	Partially spawned	Spawned
15-Oct-18	1	24	0	1
22-Oct-18	2	21	4	1
29-Oct-18	3	12	2	2
5-Nov-18	4	32	5	4
13-Nov-18	5	26	13	31
20-Nov-18	6	16	46	150
26-Nov-18	7	137	163	714
3-Dec-18	8	221	182	542
10-Dec-18	9	58	40	191
17-Dec-18	10	21	19	139
26-Dec-18	11	2	2	34
31-Dec-18	12	1	0	12
7-Jan-19	13	0	0	8
Totals		571	476	1829
		20%	17%	64%

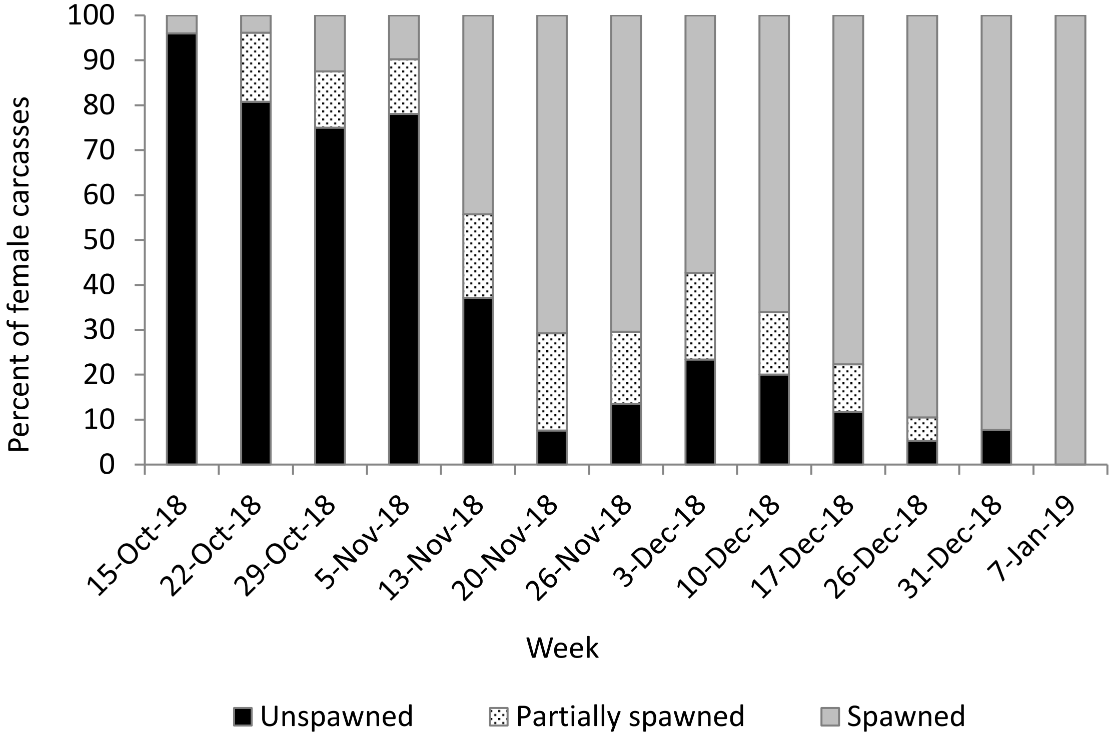

Figure 8. Temporal distribution of egg retention status for female carcasses processed during the 2018 lower American River salmon escapement survey.

CWT Carcasses

All salmon carcasses encountered were examined for the presence of an adipose fin. Twenty-eight percent (*n*=3,468) of processed carcasses were found to be missing an adipose fin. Of those salmon missing an adipose fin, 3,383 heads were collected for CWT retrieval. Adipose-clipped salmon were observed each week of the survey (Table 8, Figure 9). The largest proportion of adipose-clipped carcasses were observed during survey periods 7-10 (Table 8).

Table 8. Adipose condition of carcasses during each survey period of the 2018 lower American River salmon escapement survey.

Week	Survey Period	Adipose Intact	Adipose Clipped	Skeletons/ Unknown
15-Oct-18	1	34	21	2
22-Oct-18	2	44	29	2
29-Oct-18	3	64	18	1
5-Nov-18	4	71	36	2
13-Nov-18	5	118	50	5
20-Nov-18	6	343	235	13
26-Nov-18	7	1806	725	39
3-Dec-18	8	2134	926	50
10-Dec-18	9	1651	651	23
17-Dec-18	10	1446	549	45
26-Dec-18	11	570	165	51
31-Dec-18	12	141	40	49
7-Jan-19	13	42	17	24
Total		8464	3468	306
(%)		69	28	3

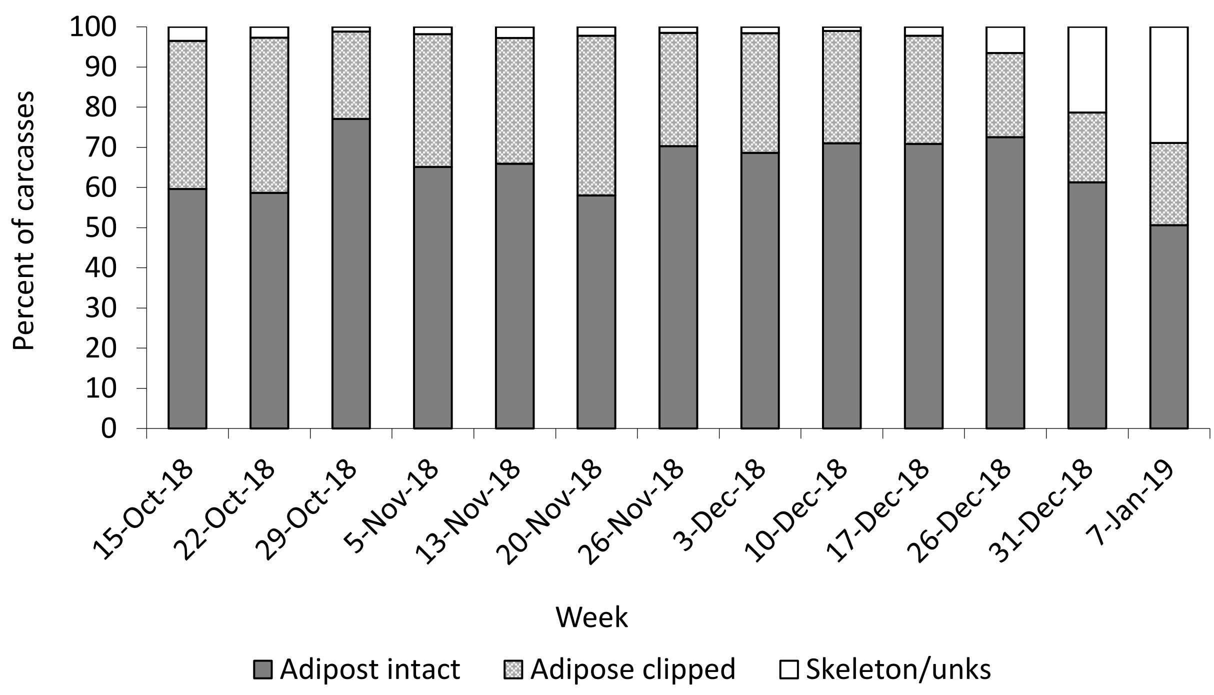

Figure 9. Temporal distribution of adipose status of carcasses processed during the 2018 lower American River salmon escapement survey.

Escapement Estimate

Two escapement estimates were generated using the CJS population model (Cormack 1964; Bergman et al. 2012) because of the addition of the Basin and weir sections to the 2018 lower American River escapement survey. A total of 565 salmon carcasses were disk-tagged for the mark-recapture study, and the total number of disk-tagged carcasses recaptured was 258. The in-river FRCS escapement estimate for the LAR from the Basin to the terminus of the survey area at Watt Avenue was 21,092. The standard error of the bootstrap estimate (n=1,000) was 783. The 90% confidence interval was 19,792 to 22,303. The in-river FRCS escapement estimate for the LAR from below the weir to the terminus of the survey area at Watt Avenue was 6,819. The standard error of the bootstrap estimate was 325 (n=1,000). The 90 percentile confidence interval was 6,343 to 7,402.

DISCUSSION

Unique to the 2018 survey was the permanent addition of two new sections, Nimbus Basin (Basin) and Nimbus Fish Hatchery weir (weir). A permanent fishing closure in the Basin was enacted in 2018 in anticipation of the construction of a new fish ladder for Nimbus Hatchery. In previous years, roving angler surveys were used to develop salmon sport harvest estimates in the Basin, but the Basin was not included in in-river escapement surveys nor were the carcasses that were recovered from the weir.

The purpose of the weir is to direct salmon to the Nimbus Hatchery fish ladder and to prevent migration past the ladder into the Basin. However, the deterioration of the weir over several decades and damage from high flows no longer keeps salmon from migrating into the Basin. Over the past several years, angler harvest estimates for the Basin have numbered in the tens of thousands of salmon (R. Titus, CDFW, pers. comm.). In the absence of angler harvest this season, thousands of salmon were trapped above the weir and contributed to the in-river harvest estimate, but it is unlikely there will be a significant contribution to juvenile recruitment in 2019 because spawning habitat in the Basin is limited.

To investigate the increase in the size of the in-river escapement with the new survey area at and above the weir, two escapement estimates were calculated: an estimate for sections 1-3 commonly surveyed from below the weir to Watt Avenue, and a new estimate for sections 1-3 including the Basin and the weir. The in-river escapement estimate (21,092) including the new sections is three times larger than the estimate (6,819) derived for sections 1-3 alone. Although the estimate of 21,092 is reported for in-river escapement, the estimate of 6,819 for sections 1-3 is more representative of spawning with successful juvenile recruitment based on available habitat. Only 34 percent of the carcasses processed during the survey were encountered in sections 1-3. Preliminary catch data collected from rotary screw traps placed below spawning areas in the river to monitor juvenile salmonid out-migration provide further evidence of a low recruitment rate from the 2018 escapement (K. Hickey, PSMFC, pers. comm.) which is consistent with the in-river escapement estimate excluding the Basin and weir. The escapement estimate in 2015 (13,739) was the eighth lowest during the previous 18 years (Figure 10).

Preliminary CWT data recovered by CDFW Central Valley Salmonid Archive staff from carcasses processed during the survey revealed that approximately 69% (*n*=2,205) of adipose-clipped carcasses were strays from other Central Valley hatcheries, specifically Mokelumne River Hatchery (59%), Feather River Hatchery (5%), Merced River Fish Facility (2%), Coleman National Fish Hatchery (<1%), and the San Joaquin River (<1%). The majority of salmon that returned to the LAR in 2018 were expected to be 3 years old, i.e., from brood year 2015. The poor escapement was likely because of prolonged drought from 2012-2016 which resulted in higher water temperatures and low flows during critical migration, spawning, and rearing periods.

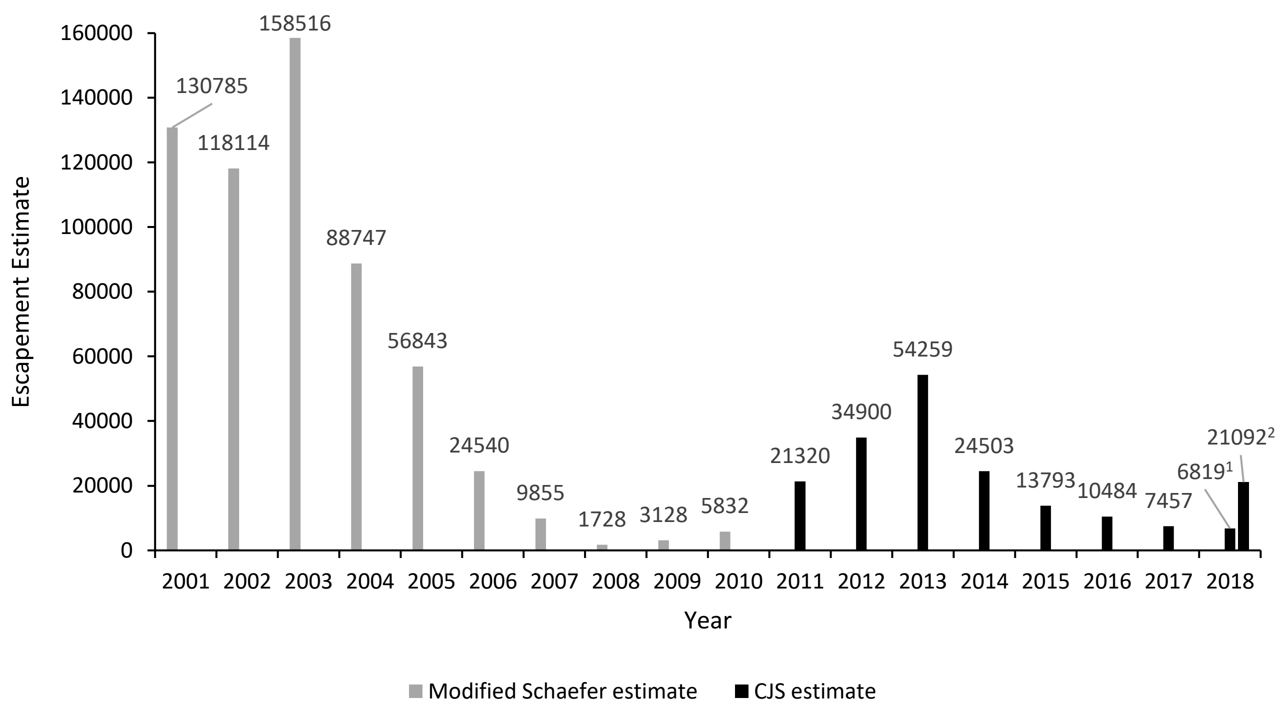

Figure 10. Comparison of lower American River fall-run Chinook salmon escapement estimates from 2001 to 2018 calculated using the modified Schaefer or Cormack-Jolly-Seber (CJS) models. In 2011 the modified Schaefer model was replaced by the CJS to achieve a more accurate estimate due to concerns the modified Schaefer is believed to over-estimate escapement.

[1] Escapement estimate for 2018 from below the Nimbus Fish Hatchery weir downstream to the terminus of survey Section 3.

[2] Escapement estimate for 2018 from the Nimbus Dam Basin, Nimbus Fish Hatchery weir, and downstream to the terminus of survey Section 3.

Water temperature decreased to a favorable spawning temperature of <59°F on November 7, 2018. Redd building was not observed until the second week of November. Although the arrival of fish was delayed in comparison to previous years, the peak of the run and spawning activity still occurred during the usual time frame.

Pre-spawn mortality this season (20%) was the highest since 2012 when it was 29%. Water temperatures higher than 61.7°F decrease survival of Chinook salmon eggs (Geist et al. 2006) and water temperatures above 62°F can result in 100% mortality prior to the eyed-egg stage of FRCS eggs in the American River (Hinze 1959). In addition to in-river pre-spawn mortality, FRCS spawned at Nimbus Hatchery regularly contain dead eggs at the beginning of spawning season (P. Hoover, Nimbus Hatchery Manager, pers. comm.), presumably as a result of adults staging in the LAR in elevated water temperatures. This temporal selection for later migrants has resulted in a shift in run timing (P. Hoover, Nimbus Fish Hatchery, 2018; Quinn et al. 2007), and may lower phenotypic variability and reduce recruitment.

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