California Department of Fish and Wildlife
North Central Region

Lower American River Fall-Run Chinook Salmon Escapement Survey October 2016 - January 2017

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 LAR has historically represented an average of 14% of all returning FRCS stocks to the Central Valley (Vincik and Mamola 2010). FRCS spawning typically starts in early November, or when water temperatures drop to 60°F or lower (Williams 2001).

Annual FRCS juvenile production on the LAR is supplemented by the yearly release of salmon cohorts raised at the Nimbus Fish Hatchery. The hatchery was constructed in 1958 by the United States Bureau of Reclamation (USBR), to mitigate for the loss of historic spawning habitat upstream of Nimbus Dam (USFWS and CDFG 1953, CDFW 2017). Currently, the California Department of Fish and Wildlife (CDFW) oversees hatchery operations while funding for Nimbus Hatchery operations are provided by the USBR (CDFW 2017).

Escapement surveys and the escapement estimate are important components of research which may be utilized to examine the life history, trends in population size, age structure, stock-recruitment relationships, patterns in spawning distribution, and environmental effects on salmon. Salmon escapement surveys have been conducted on the LAR since 1944 (Gerstung 1971). Annual escapement survey data are used extensively as an aid in preparing fishing regulations and harvest limits, as an index to the status of the resource, to evaluate proposed water project developments, a factor to consider in seasonal water operations, and the basis for the planning and implementation of habitat restoration activities.

The objectives of this survey are to estimate, (1) the size of FRCS escapement; (2) the age class (adult or grilse) and sexual composition; (3) the rate of female egg retention; and (4) the number of hatchery-reared, coded-wire tagged (CWT) FRCS utilizing spawning habitat in the LAR.

METHODS

The 2016 LAR escapement survey began in mid-October. Ideally, the survey begins just prior to salmon dying in order to achieve a more accurate escapement estimate. Each survey period, i.e., one week, the 13.1-mile stretch of river from the Nimbus Weir downstream to Watt Avenue are broken up into four sections and surveyed once for salmon carcasses over a 3-4 day period (Figure 1, Table 1). Section 1A and 1B are composed mainly of moderate riffles, glides and backwater pools. The majority of spawning in the LAR takes place in these sections. Section 2 contains a few rapids, but consists mainly of large, deepwater glides. Section 3 contains moderate riffles, large deepwater glides and several braided side-channels and requires crews to survey from the shore, jet boat, and kayaks. This upper-most stretch of the lower American River has been found to contain the greatest concentrations of salmon (Snider and Vyverberg 1996), whereas the section of river between the mouth and Watt Avenue is primarily a migration coridor.

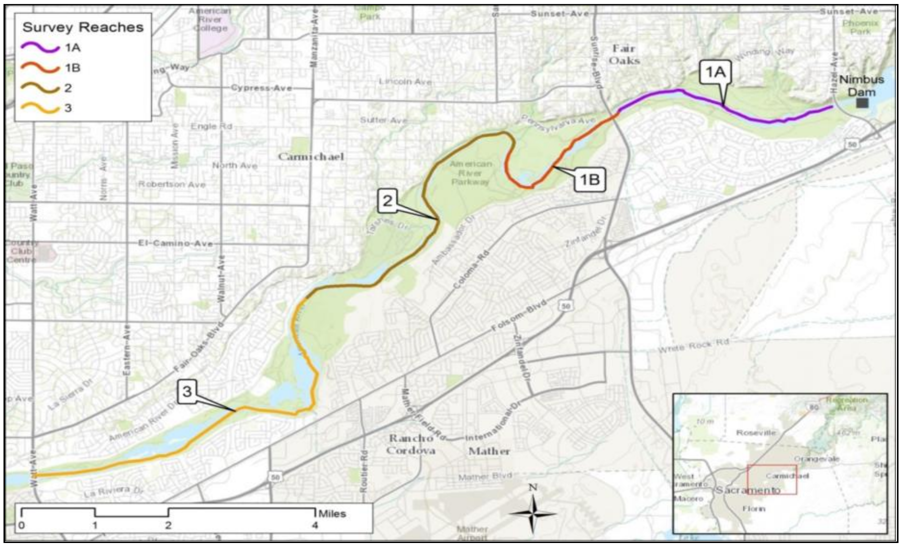

Figure 1. Survey sections of the lower American River salmon escapement survey.

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

Section	Location	Miles
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	**13.1**

Survey crews comprised of 4-9 members searched for submerged salmon carcasses within each section while walking on the banks, riding in a boat or paddling a kayak. Crews moved downstream and processed all carcasses encountered. Salmon carcasses found to be $\leq$ 50% submerged were not included in the escapement survey, because they do not present an equal probability of detection, and once dried and re-submerged in water, they require a longer time to decompose which can skew survival rates for mark-recapture carcasses.

Each carcass was examined for the following: (1) presence of an external tag, (2) presence or absence of an adipose fin, and (3) extent of carcass deterioration; and processed for (1) the multiple mark/recapture study, (2) head collection for coded-wire tag (CWT) retrieval, or (3) tally chop.

Salmon carcasses possessing an intact adipose fin were either, (1) utilized in a multiple mark/recapture study if they were fresh enough for the carcass to remain intact for at least one more survey period, or (2) 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.

Covariate data were collected on all carcasses used in the mark/recapture study and adipose-clipped carcasses destined for CWT removal. Covariate data collected included sex, fork length, egg retention in females, and degree of decomposition. Sex was determined by a combination of distinguishing characteristics including presence or absence of a kype, laterally compressed body, 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, FL's for each sex were pooled separately and plotted in a frequency distribution in order to determine the size boundaries for adult and grilse carcasses. The degree 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% egg retention, partially spawned if 30-70% egg retention, or spawned if <30% egg retention.

Flow and water temperature data were obtained for each survey period from the United States Geological Survey gauge, 11446500 American R A Fair Oaks, by accessing the USGS (USGS 2017) website. The Fair Oaks gauge is located a few hundred yards downstream of the Nimbus weir. Water clarity was measured with a secchi disk 3 or 4 days per survey period.

The 2016 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).

RESULTS

<u>Survey Periods</u>

The survey was conducted over 10 survey periods from October 17, 2016 to January 5, 2017. During December and January, periods of heavy rains resulted in increased reservoir releases to the LAR that created environments too dangerous for crews to survey. The survey was suspended for two weeks from December 19-30 during what would have historically been survey periods 10 and 11, and ended approximately two weeks early on January 5 during survey 12. Survey periods 13 and 14 were cancelled due to high flows. Since no data were collected during survey periods 10, 11, 13 and 14, they have been eliminated from subsequent figures and tables in this report. No subsampling was necessary during any of the survey periods. (Table 2)

Table 2. Survey periods and sampling regime for the 2016 lower American River salmon escapement survey.

Survey period	Date range	Sampling regime
1	Oct 17-20	all
2	Oct 24-27	all
3	Oct 31-Nov 3	all
4	Nov 7-10	all
5	Nov 14-17	all
6	Nov 21-23	all
7	Nov 28-Dec 1	all
8	Dec 5-8	all
9	Dec 12-14	all
10	Dec 19-22	no survey
11	Dec 27-30	no survey
12	Jan 3 to 5	all
13	Jan 9-12	no survey
14	Jan 17-20	no survey

Final Carcass Count

A total of 4,018 salmon carcasses were observed and processed during the survey (Table 3). The maximum number of carcasses observed and processed in a single survey period was 1,088 during survey period 7 (Nov. 28 – Dec. 1) (Table 3, Figure 2).

Table 3. Total carcasses processed by survey period during the 2016 lower American salmon escapement survey.

Survey Period	Date	Salmon Carcasses Observed/Processed
1	Oct 17 to 20	22
2	Oct 24 to 27	64
3	Oct 31 to Nov 3	109
4	Nov 7 to 10	162
5	Nov 14 to 17	571
6	Nov 21 to 23	774
7	Nov 28 to Dec 1	1088
8	Dec 5 to 8	746
9	Dec 12 to 14	397
12	Jan 3 to 5	85
	Total	**4018**

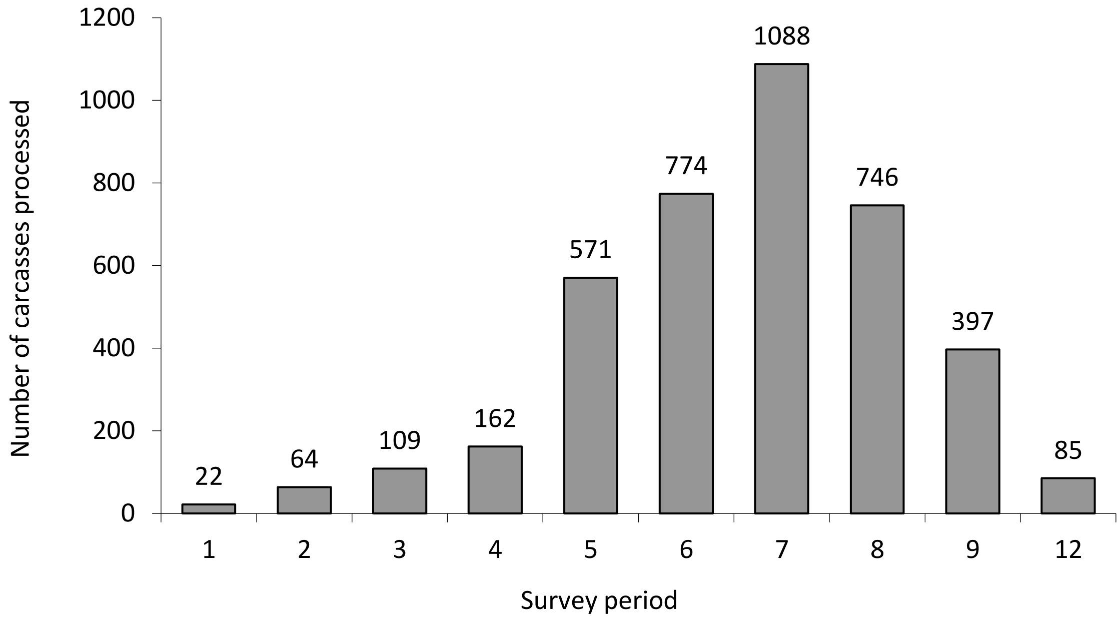

Figure 2. Temporal distribution of carcasses processed during the 2016 lower American River salmon escapement survey.

Fresh salmon carcasses were processed each survey period (Table 4, Figure 3). The greatest number of fresh salmon carcasses were observed during survey period 5 when 163 were processed, while the fewest number of fresh salmon carcasses were observed during survey period 1. Condition was not recorded for 4 salmon carcasses during survey periods 5, 6, and 7 and are noted in Table 4 in the "Unknown" column.

Table 4. Summary of carcass freshness during the 2016 lower American River salmon escapement survey.

Survey Period	Dates	Fresh Carcasses	Not Fresh	Unknown
1	Oct 17 to 20	8	14	0
2	Oct 24 to 27	10	54	0
3	Oct 31 to Nov 3	31	78	0
4	Nov 7 to 10	42	120	0
5	Nov 14 to 17	163	407	1
6	Nov 21 to 23	129	643	2
7	Nov 28 to Dec 1	136	951	1
8	Dec 5 to 8	106	640	0
9	Dec 12 to 14	30	367	0
12	Jan 3 to 5	28	57	0
	Total	**683**	**3331**	**4**

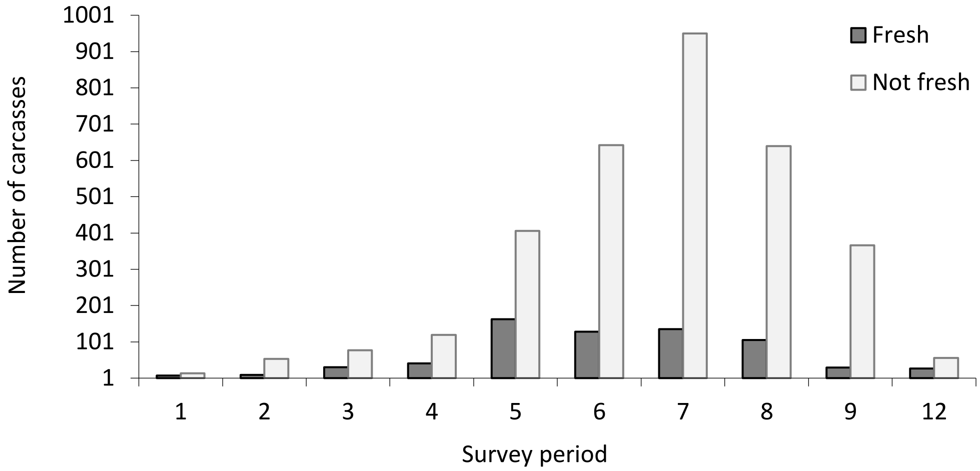

Figure 3. Temporal distribution of carcass freshness during 2016 the lower American River salmon escapement survey.

<u>Processing Type</u>

Of the 4,018 carcasses processed 2,271 (57%) were chopped and tallied, and 1,010 (25%) were disk tagged and used in the mark/recapture study. Covariate data were also collected from 737 (18%) carcasses missing adipose fins or carcasses that were not used in the mark/recapture study (Table 5 and Figure 4). From this group of carcasses, 707 heads were collected for CWT retrieval.

Table 5. Processing types for salmon carcasses encountered on the 2016 lower American River salmon escapement survey.

Survey Period	Dates	Tally chops	Mark/ Recapture	Covariate Data	Period total	%
1	Oct 17 to 20	8	13	1	**22**	0.5
2	Oct 24 to 27	41	13	10	**64**	1.6
3	Oct 31 to Nov 3	43	43	23	**109**	2.7
4	Nov 7 to 10	71	58	33	**162**	4.0
5	Nov 14 to 17	206	266	99	**571**	14.2
6	Nov 21 to 23	420	173	181	**774**	19.3
7	Nov 28 to Dec 1	684	208	196	**1088**	27.1
8	Dec 5 to 8	443	165	138	**746**	18.6
9	Dec 12 to 14	309	46	42	**397**	9.9
12	Jan 3 to 5	46	25	14	**85**	2.1
	Total	**2271**	**1010**	**737**	**4018**	**100**
	(%)	(57)	(25)	(18)		

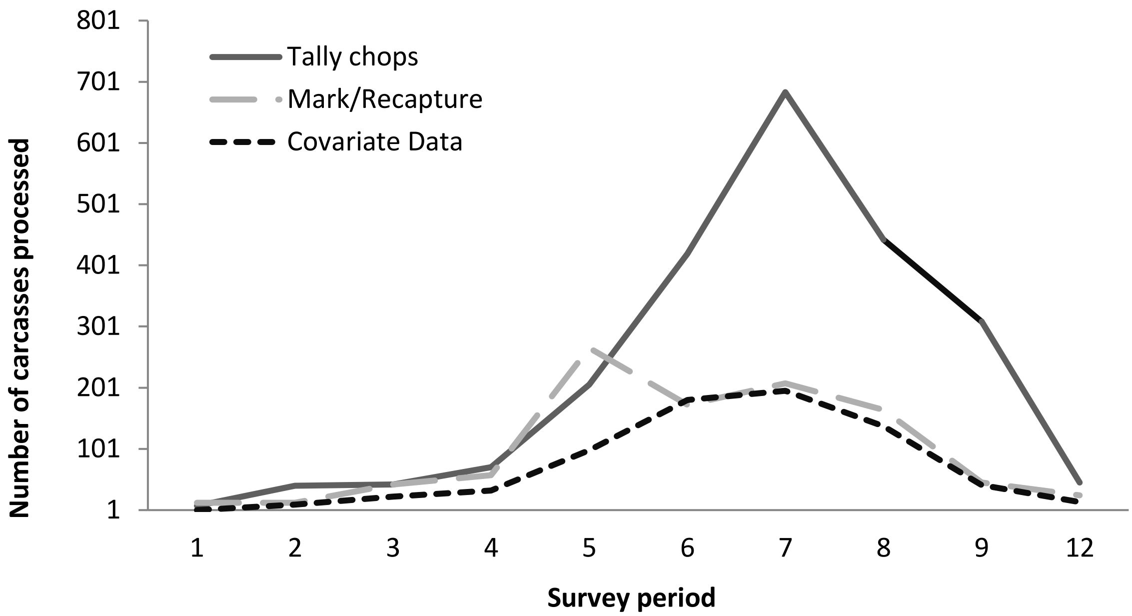

Figure 4. Temporal distribution of salmon carcass processing type during the 2016 lower American River escapement survey.

Spatial Distribution

The majority of salmon carcasses were observed in sections 1A/1B (88%, *n*= 3,547) with fewer encounters in sections 2 and 3. Eleven percent (*n*= 426) of the detected carcasses occurred in Section 2 and 1% (*n*= 45) in Section 3 (Table 6, Figure 5).

Table 6. Number of salmon carcasses processed by river section during the 2016 lower American River escapement survey. (Percentage calculations may not equal 100 due to rounding off.)

Survey Period	Dates	Section		
		1A/1B (%)	**2 (%)**	**3 (%)**
1	Oct 17 to 20	21 (95)	1 (5)	0 (0)
2	Oct 24 to 27	59 (91)	4 (6)	1 (2)
3	Oct 31 to Nov 3	95 (87)	9 (8)	5 (5)
4	Nov 7 to 10	141 (87)	16 (10)	5 (3)
5	Nov 14 to 17	492 (86)	73 (13)	6 (1)
6	Nov 21 to 23	673 (87)	101 (13)	0 (0)
7	Nov 28 to Dec 1	966 (89)	112 (10)	10 (1)
8	Dec 5 to 8	636 (85)	92 (12)	18 (2)
9	Dec 12 to 14	383 (96)	14 (4)	0 (0)
12	Jan 3 to 5	81 (95)	4 (5)	0 (0)
	Total	**3547**	**426**	**45**
	(%)	(88)	(11)	(1)

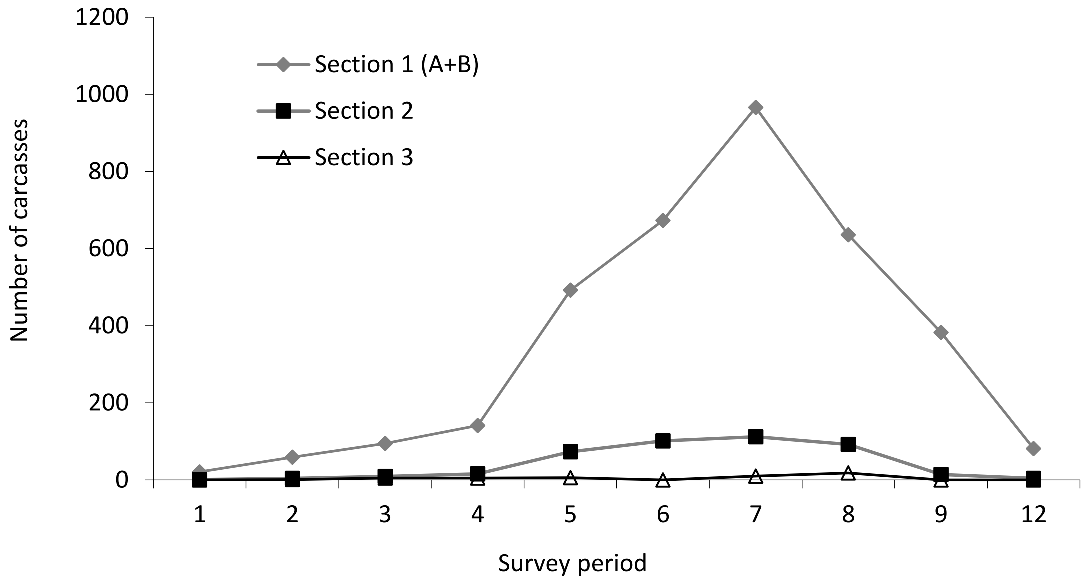

Figure 5. Number and temporal distribution of salmon carcasses processed by river section during the 2016 lower American River escapement survey.

Sex Ratios

Sex was recorded for 1,738 carcasses. Females comprised 41% (*n*=721) of the total and males comprised 59% (*n*=1,017) (Table 7). Female and male carcasses were encountered in approximately equal numbers during survey periods 1, 3 and 4, then male carcasses were the majority of carcasses found in survey periods 5 through 9 (Figure 6).

Table 7. Sex ratio of carcasses processed during the 2016 lower American River salmon escapement survey.

Survey Period	Dates	Females	Males
1	Oct 17 to 20	7	7
2	Oct 24 to 27	17	6
3	Oct 31 to Nov 3	34	32
4	Nov 7 to 10	45	45
5	Nov 14 to 17	147	218
6	Nov 21 to 23	141	208
7	Nov 28 to Dec 1	164	237
8	Dec 5 to 8	121	182
9	Dec 12 to 14	24	64
12	Jan 3 to 5	21	18
	Total	**721**	**1017**
	(%)	(41)	(59)

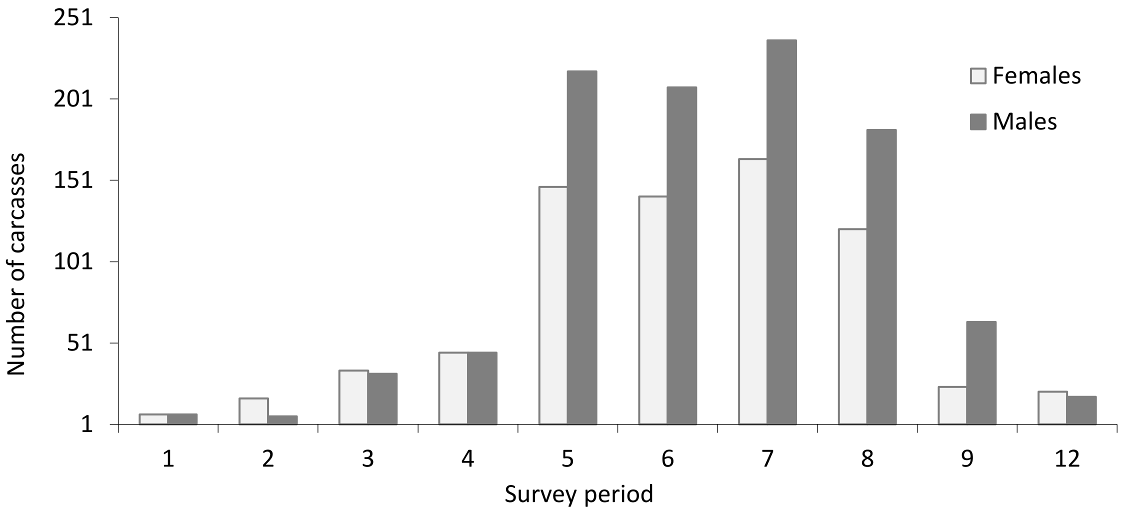

Figure 6. Temporal distribution of female and male carcasses processed during the 2016 lower American River salmon escapement survey.

Length Composition

Fork length was recorded for 1,745 carcasses. The minimum and maximum FL's for male carcasses were 43 cm and 107 cm, respectively, with a mean of 77 cm and a mode of 89 cm. Minimum and maximum recorded FL's for female carcasses were 44 cm and 96 cm, respectively, with a mean of 75 cm and a mode of 74 cm. (Figure 7)

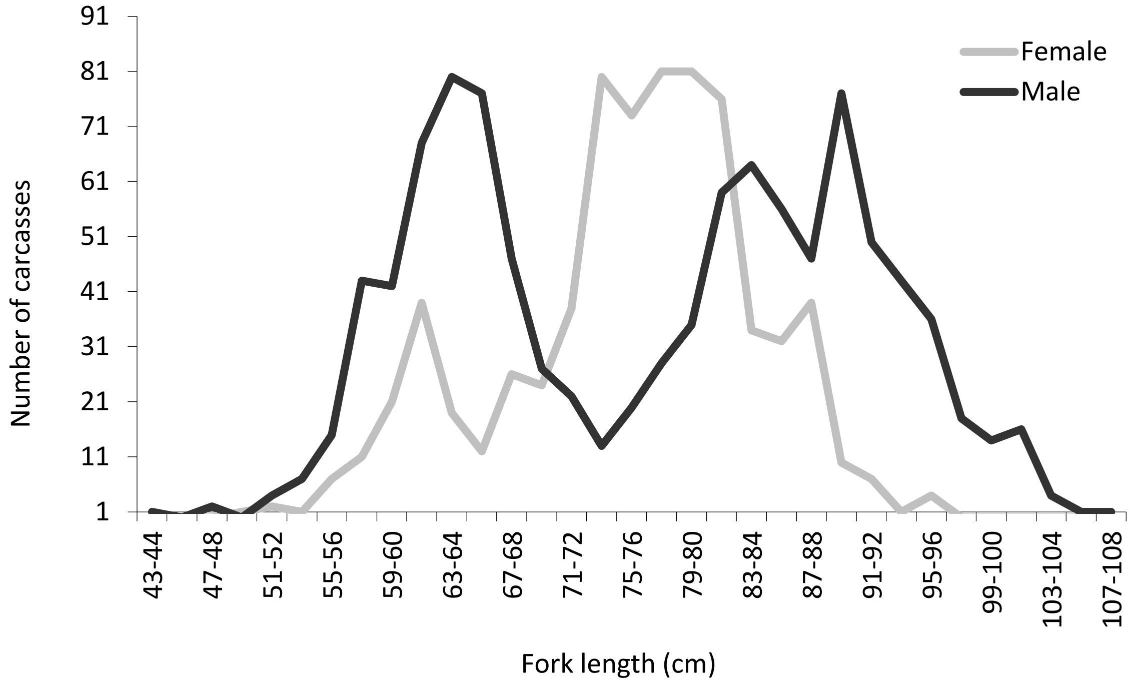

Figure 7. Fork length frequency by sex of carcasses processed during the 2016 lower American River salmon escapement survey.

<u>Age Classification</u>

A total of 1,745 salmon carcasses were assigned to one of two distinct age classes based on a length frequency distribution calculated from all FL's recorded during the survey (Figure 7). Carcasses were classified as adults (≥ 3 years old) if females had a FL ≥ 66 cm, and males had a FL ≥ 74 cm. Carcasses were classified as grilse (≤ 2 years old) if female FL's were ≤ 65 cm and male FL's were ≤ 73 cm. Sixty-eight percent (*n*= 1,188) were classified as adults while 32% (*n*= 557) were classified as grilse. Both age classes were observed during each survey period. Both adult and grilse contributions to the LAR escapement survey peaked during survey period 7 (Nov 28 to Dec 1) (Table 8, Figure 8).

Table 8. Age-class assignments for carcasses processed during the 2016 lower American River salmon escapement survey and percent of total for the carcasses recovered during that survey period.

Survey Period	Dates	Grilse *n*	Grilse %	Adult *n*	Adult %
1	Oct 17 to 20	5	36	9	64
2	Oct 24 to 27	2	9	20	91
3	Oct 31 to Nov 3	9	14	57	86
4	Nov 7 to 10	23	26	67	74
5	Nov 14 to 17	114	31	251	69
6	Nov 21 to 23	120	34	234	66
7	Nov 28 to Dec 1	133	33	271	67
8	Dec 5 to 8	109	36	194	64
9	Dec 12 to 14	38	43	50	57
12	Jan 3 to 5	4	10	35	90
	Total	**557**		**1188**	
	(%)	(32)		(68)	

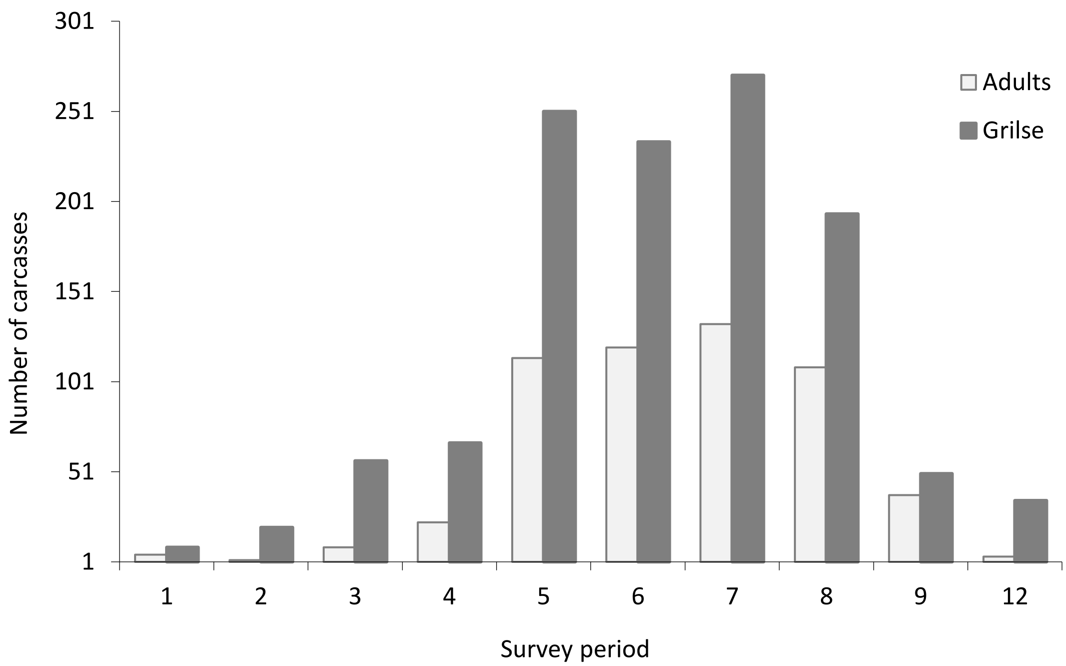

Figure 8. Temporal distribution of age classes assigned to carcasses processed during the 2016 lower American River salmon escapement survey.

The proportions of each sex were also determined within each age class. Of the 557 grilse carcasses, 79% (*n*=441) were male, 19% (*n*=108) were female, and 1% (*n*=8; not shown in figure) were of unknown sex (Figure 9).

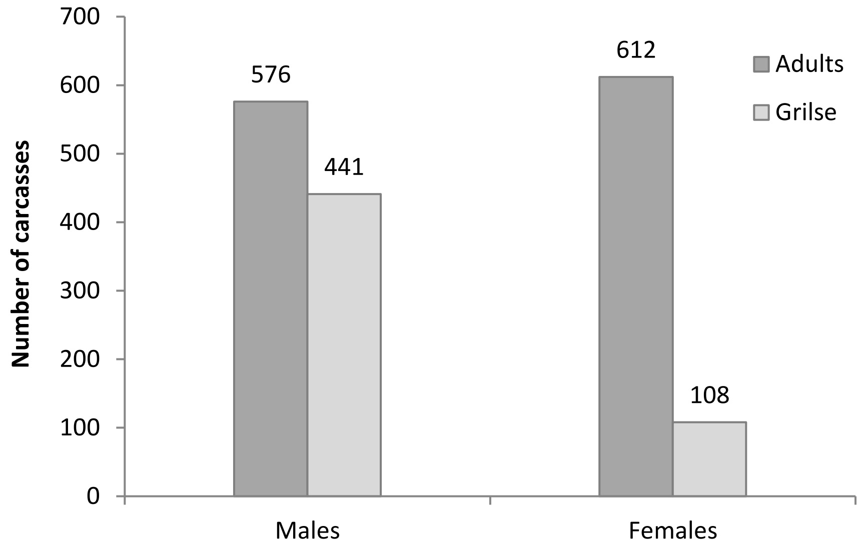

Figure 9. Classification of age by sex of carcasses processed during the 2016 lower American River salmon escapement survey.

<u>Egg Retention</u>

A total of 689 adult or grilse and fresh or unfresh female carcasses were assessed for egg retention (Table 9, Figure 10). Seventy-five percent (*n*=519) of female salmon processed were spawned, 7% (*n*=49) partially spawned, and 18% (*n*=121) were unspawned. The proportion of spawned females were highest (>50%) during survey periods 4 through 12 (Figure 10).

Table 9. Egg retention status by survey period of female carcasses processed during the 2016 lower American River salmon escapement survey.

Survey period	Date	Unspawned	Partial	Spawned	Period total
1	Oct 17 to 20	2	2	3	**7**
2	Oct 24 to 27	12	2	1	**15**
3	Oct 31 to Nov 3	20	3	8	**31**
4	Nov 7 to 10	14	3	25	**42**
5	Nov 14 to 17	24	10	107	**141**
6	Nov 21 to 23	18	9	108	**135**
7	Nov 28 to Dec 1	13	9	131	**153**
8	Dec 5 to 8	12	9	99	**120**
9	Dec 12 to 14	4	1	19	**24**
12	Jan 3 to 5	2	1	18	**21**
	Total	**121**	**49**	**519**	**689**
	(%)	(18)	(7)	(75)	

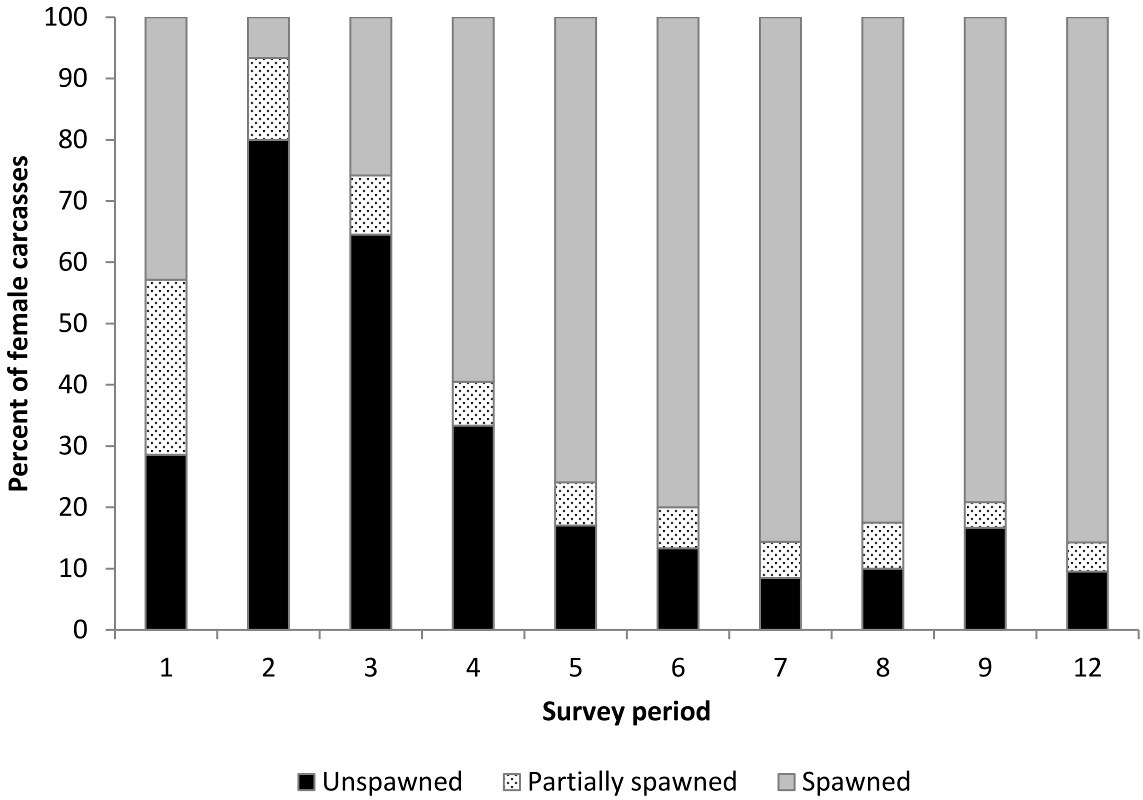

Figure 10. Temporal distribution of egg status classifications for female carcasses processed during the 2016 lower American River salmon escapement survey.

<u>CWT Carcasses</u>

All salmon carcasses encountered were examined for the presence of an adipose fin. Twenty percent (*n*=748) of processed carcasses were found to be missing an adipose fin. Of those salmon missing an adipose fin, 707 heads were collected for CWT retrieval. Adipose-clipped salmon were observed each week of the survey except survey period 1 (Table 10, Figure 11) and ranged from 15% to 25% of the total carcasses examined for each period. The largest proportion of adipose-clipped carcasses were observed during survey period 6 (25%).

Table 10. Adipose condition of carcasses during each survey period of the 2016 lower American River salmon escapement survey.

Survey Period	Dates	Adipose Intact	Adipose Clipped	Skeletons
1	Oct 17 to 20	17	0	5
2	Oct 24 to 27	42	8	14
3	Oct 31 to Nov 3	83	20	6
4	Nov 7 to 10	127	32	3
5	Nov 14 to 17	452	99	20
6	Nov 21 to 23	562	188	24
7	Nov 28 to Dec 1	839	199	50
8	Dec 5 to 8	547	141	58
9	Dec 12 to 14	272	47	78
12	Jan 3 to 5	67	14	4
	Total	**3008**	**748**	**262**
	(%)	(80)	(20)	

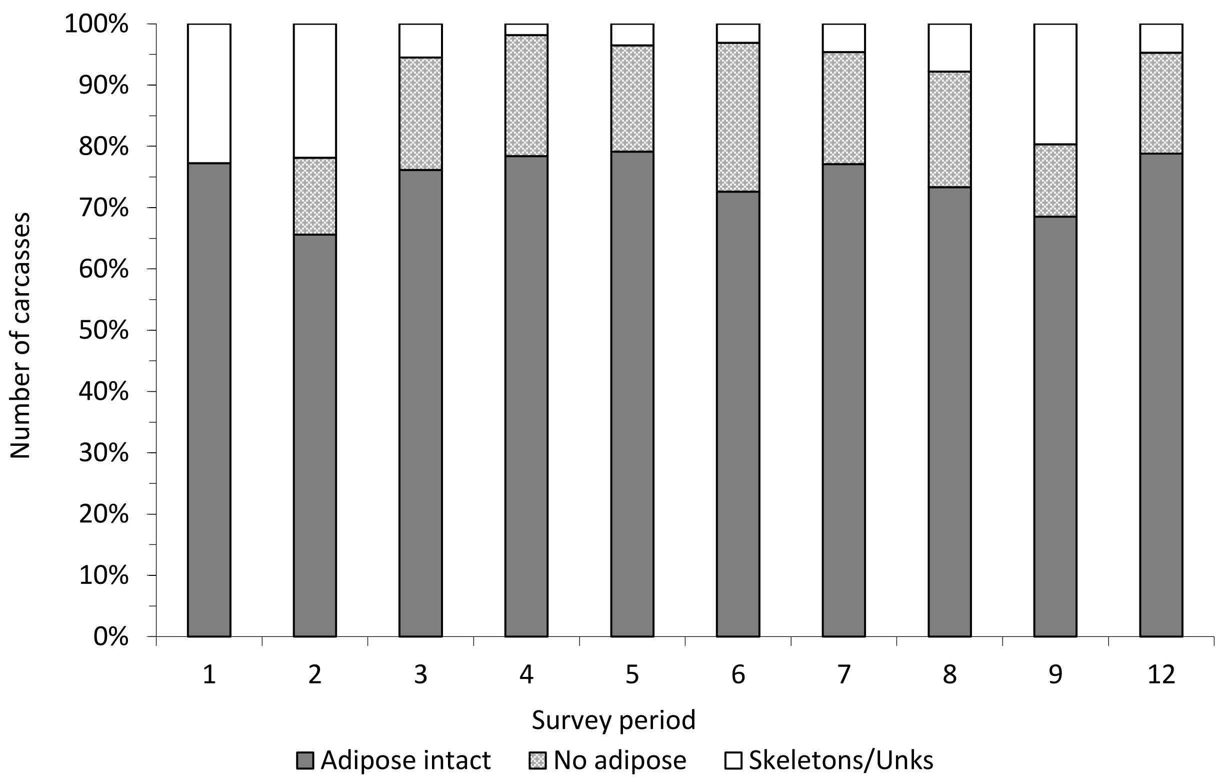

Figure 11. Temporal distribution of adipose status of carcasses processed during the 2016 lower Amerian River salmon escapement survey.

Population Estimate

The CJS population model was used to estimate the 2016 in-river FRCS escapement (Cormack 1964; Bergman, et al. 2012). A total of 1,010 salmon carcasses were disk-tagged for the mark-recapture study from. The total number of disk-tagged carcasses recaptured was 237. This model estimated in-river FRCS escapement to LAR to be 10,484. The bootstrap estimate of the standard error of estimated total escapement is 551 (n=5,000 bootstraps). The 90% bootstrap percentile confidence interval is 9,510 to 11,295. In addition to the in-river estimates, 9,420 carcasses (7,498 adult and 1,922 grilse) were collected at the Nimbus Hatchery, and 3,989 (2,408 adult and 1,581 grilse) were collected above the weir by Nimbus Hatchery staff. The combined 2016 LAR fall-run salmon escapement estimate from the in-river survey, Nimbus Hatchery and weir collections is 23,893.

Environmental Conditions

LAR water temperature decreased throughout the entirety of the escapement survey. The maximum and minimum recorded water temperatures were 65°F (10/1/2016) and 47°F (1/6/2017), respectively, with an average temperature of 57°F (Figure 11) (USGS 2017). The LAR maximum and minimum flows were 33,082 cubic feet per second (cfs) on 12/16/2016, and 972 cfs on 10/25/2016, respectively. Flows began increasing on 12/11/2016, and remained above 3,000 cfs for the remainder of the 2016 escapement survey (Figure 12). Water clarity was severely diminished as a result of increases in flows, resulting in a reduction in visibility from a mean of 294 cm during survey period 4, to a mean of 99 cm during survey period 9. The mean depth of visibility over the course of the survey way 219 cm (Figure 13).

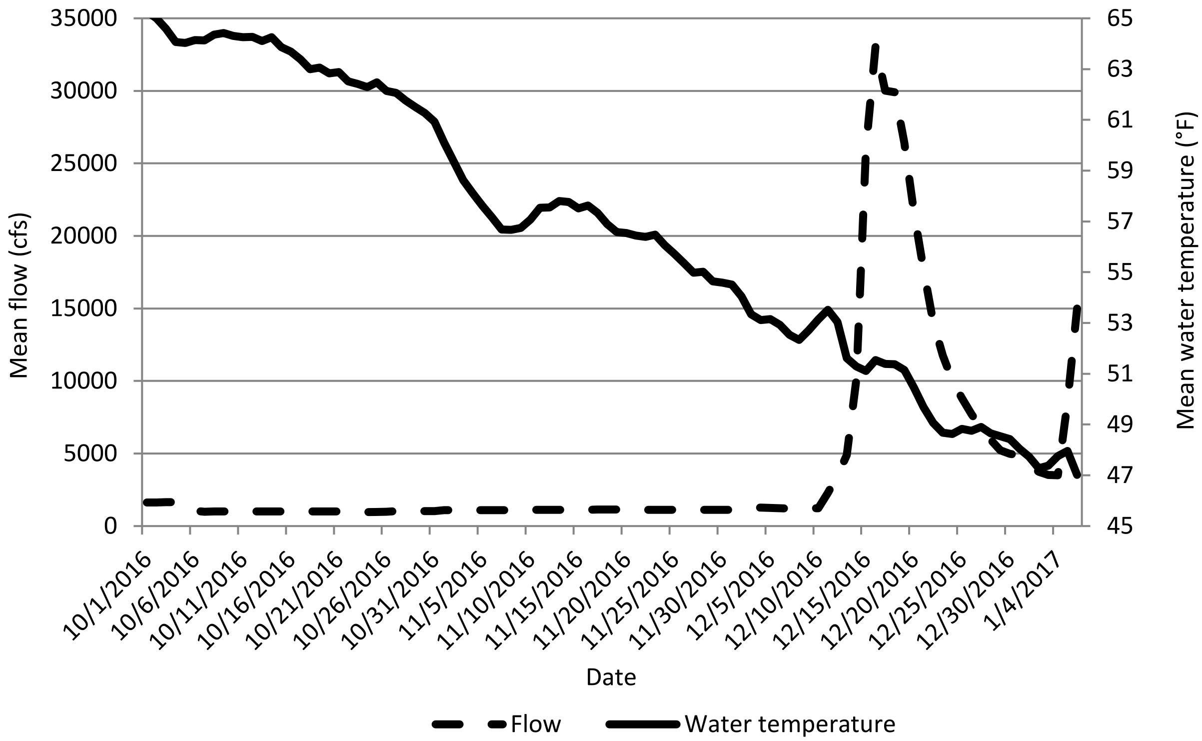

Figure 12. Mean daily river flows and mean daily water temperatures observed during the 2016 lower American River salmon escapement survey.

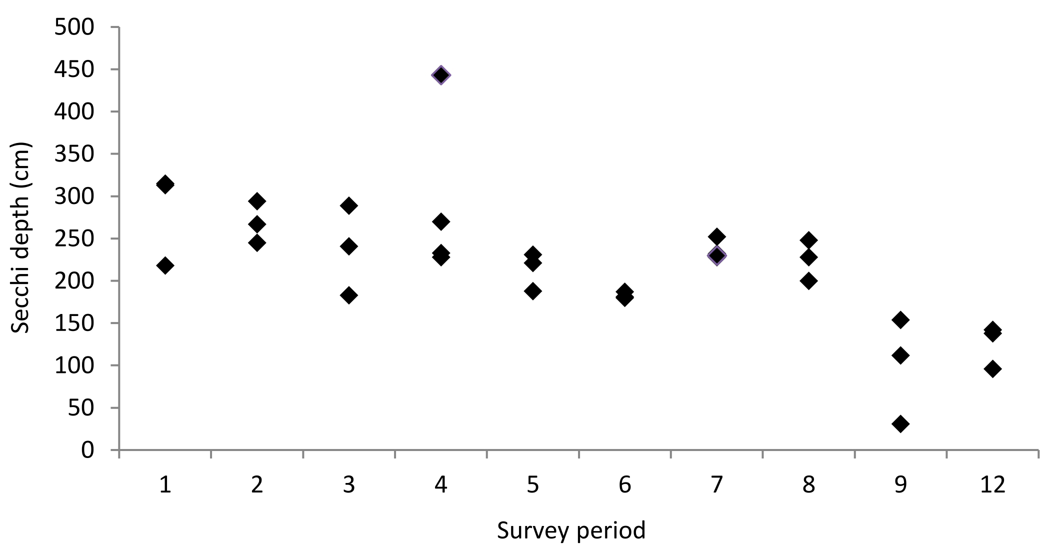

Figure 13. Temporal distribution of secchi depth measurements of water clarity collected during the 2016 lower American River salmon escapement survey.

CONCLUSION

Adverse environmental conditions occurring in December resulted in an artificial reduction of salmon carcasses encountered by escapement survey staff, and a reduced sampling season (survey cancelled for two separate 2-week periods in December and January). High, turbid flows encountered during survey periods following week 8 limited the effectiveness of field staff in identifying and re-capturing salmon carcasses involved in the mark-recapture portion of this study, and therefore may have resulted in a slightly lower in-river escapement estimate.

Water conditions reached a favorable spawning temperature of 59°F on November 2. Although salmon began arriving and holding in large numbers in the LAR in October when water temperatures were between 61-65°F, field crews did not observe redd building activities until water temperatures dropped in early November. Water temperatures higher than 61.7°F have been shown to rapidly decrease survival in Chinook salmon eggs (Geist et al. 2006), and Hinze (1959) found American River Chinook salmon eggs incubated in water above 62°F experienced 100% mortality prior to the eyed-egg stage. Eggs collected from salmon trapped at Nimbus Hatchery during the first week or two of November often contain dead eggs (P. Hoover, Nimbus Hatchery Manger, pers. comm), presumably as a result of adults staging in the LAR in elevated water temperatures. This directional selection for later migrants may result in a shift in run timing (Quinn et al. 2007), lower phenotypic variability, and reduced recruitment.

In-stream flow remained at stable levels until December 15 when flows increased from 10,109 cfs to 26,015 cfs overnight. This increase in flow was gradually reduced to 3,510 cfs on January 4 before increasing to 14,997 cfs on January 6. This series of pulses of water through the LAR's optimum salmon spawning habitat during the critical spawning season may have resulted in gravel movement and redd destruction, but to what extent is unknown.

The 2016 LAR in-river salmon escapement estimate is the lowest on record since 2010 when the in-river estimate was 5,832 (Figure 14). Since that time, LAR escapement estimates had been steadily increasing until a peak occurred in 2013 (est. 54,259), then declined each year thereafter. The majority of salmon that returned to the LAR in 2016 are expected to be from the 2013 brood year (i.e., 3 years old), based on CWT data from past escapements. Although 2013 experienced a relatively large return of salmon to the LAR, the offspring from this brood year did not return in large numbers, most likely due to the prolonged drought which has resulted in higher water temperatures and low flows during critical migration, spawning and rearing periods.

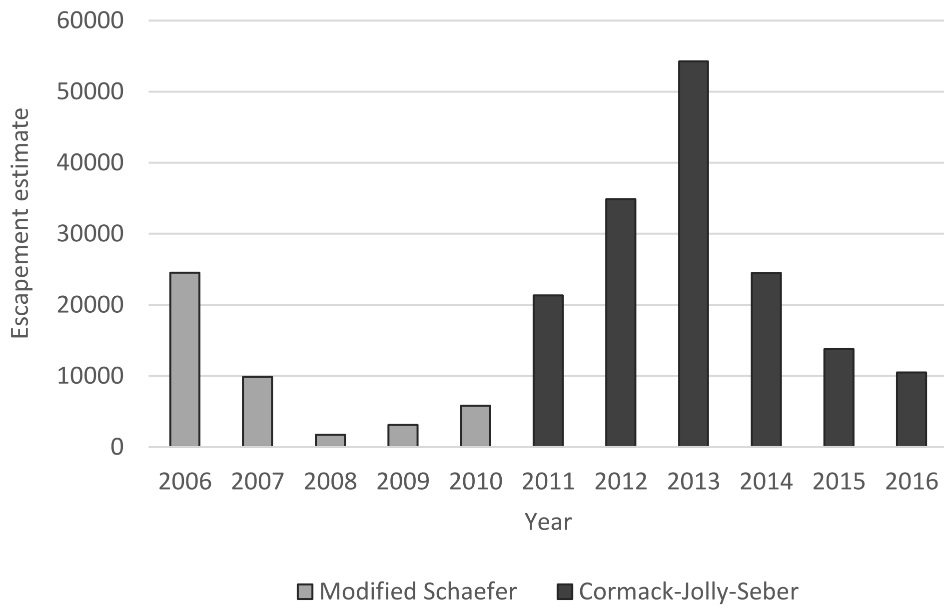

Figure 14. Comparison of lower American River fall-run Chinook salmon escapement estimates from 2006 to 2016 calculated using the modified Schaefer or Cormack-Jolly-Seber (CJS) models. In 2011, the modified Schaefer model was replaced by the CJS in order achieve a more accurate estimate. The modified Schaefer is believed to over-estimate escapement.

ACKNOWLEDGMENTS

The successful completion of the LAR escapement survey is a direct result of the dedication of the 2016 field lead, survey crew, and volunteers: Jeanine Phillips, Michael Mamola, Nicole Dunkley, Lillian McDougall, Margaux McClure, Ryan McKim, Kenny Tran, Timothy Ryan, Josef Lehr, and Albert Liwanag. The authors also want to extend our appreciation to the United States Bureau of Reclamation for funding the survey. The voluntary assistance of the Cramer Fish Sciences staff proved valuable in daily on-water data collection. Stan Allen and Amy Roberts with the Pacific States Marine Fisheries Commission were instrumental in the completion of supervisory and administrative duties.

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