California Department of Fish and Wildlife
North Central Region

Lower American River Fall-run Chinook Salmon Escapement Survey October 2015 – January 2016

Presented to the United States
Bureau of Reclamation
by

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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 (Figure 1). The LAR supports both wild and hatchery fall-run Chinook salmon (FRCS, *Oncorhynchus tshawytscha*) spawning; adult escapement to the LAR has historically represented an average of 16% of all returning FRCS stocks to the Central Valley (Azat 2015). Historically, the LAR has supported three seasonal runs of Chinook salmon: fall, late fall, and spring; of which the spring-run is believed to have been extirpated (Yoshiyama, et al. 1996; Zeug, et al. 2010). FRCS spawning typically starts in mid-October or when water temperatures drop below 60°F (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). Currently, the California Department of Fish and Wildlife (CDFW) oversees hatchery operations while funding for Nimbus Hatchery operations are provided by the USBR (CDFW 2014).

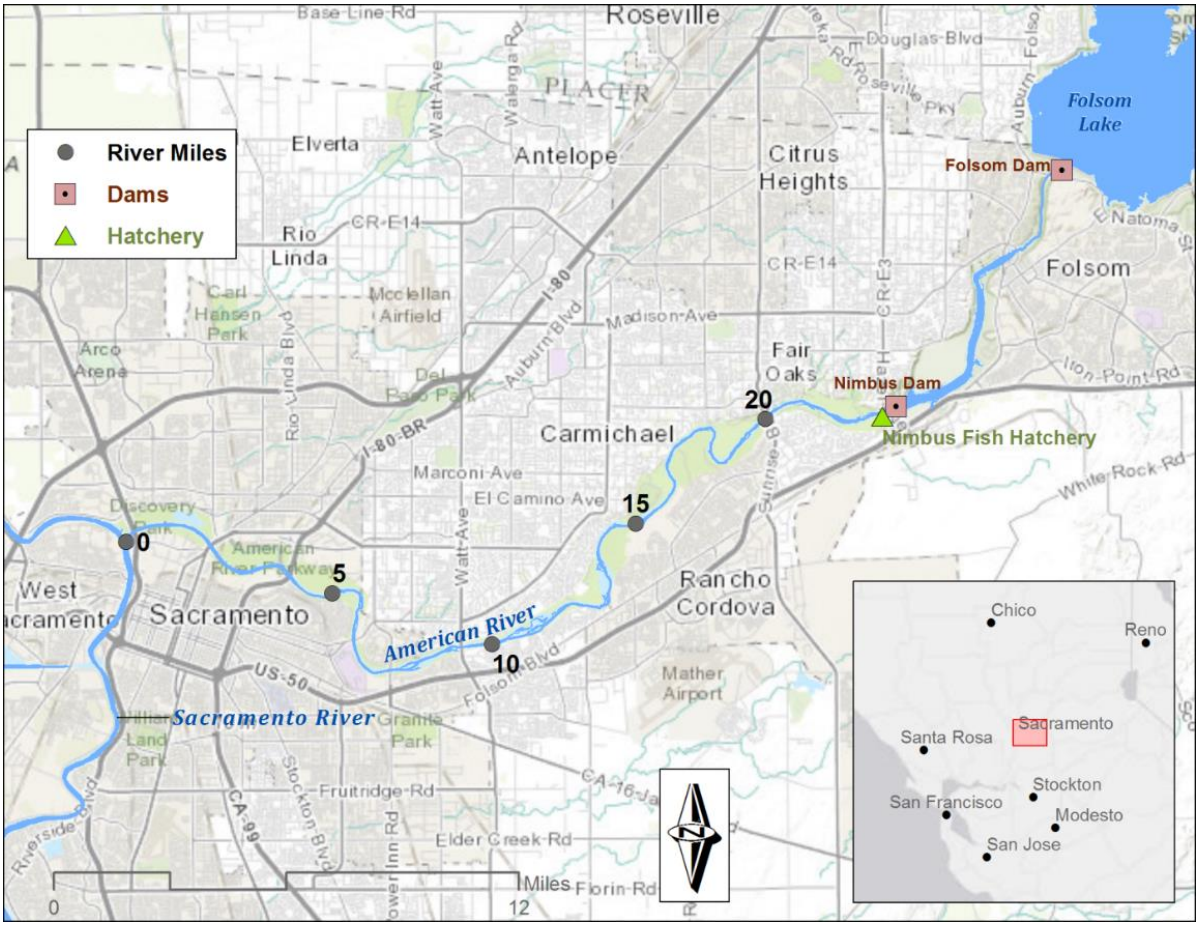

Figure 1. Map of the lower American River.

Chinook salmon escapement surveys have been conducted on the LAR since 1944 (Gerstung 1971). The objectives of this survey are to 1) estimate in-river escapement of fall-run Chinook salmon returning to the LAR by surveying a 13.1-mile section of the river from the Nimbus Hatchery weir downstream to Watt Avenue (Table 1), 2) determine the general age and sex of returning Chinook salmon, 3) determine the level of female egg retention, and 4) determine the proportion of returning hatchery-reared, coded-wire tagged (CWT) Chinook salmon spawning in the LAR.

METHODS

The 2015 LAR escapement survey was conducted over a 14-week period between October 19, 2015, and January 22, 2016. The survey area consisted of 13.1 river miles (RM) from the Nimbus Hatchery weir downstream to the Watt Avenue bridge (Figure 2). During past surveys, this stretch of the LAR was found to contain the greatest concentration of fall-run Chinook spawning activity (Snider and Vyverburg 1996). The survey area is typically divided into four sections to allow each section to be surveyed in a single day, or once per weekly interval. Due to the initial high density of carcasses encountered, Section 1 was split into two sub-sections (Table 1); however, the data for subsections 1A and 1B were combined for analysis.

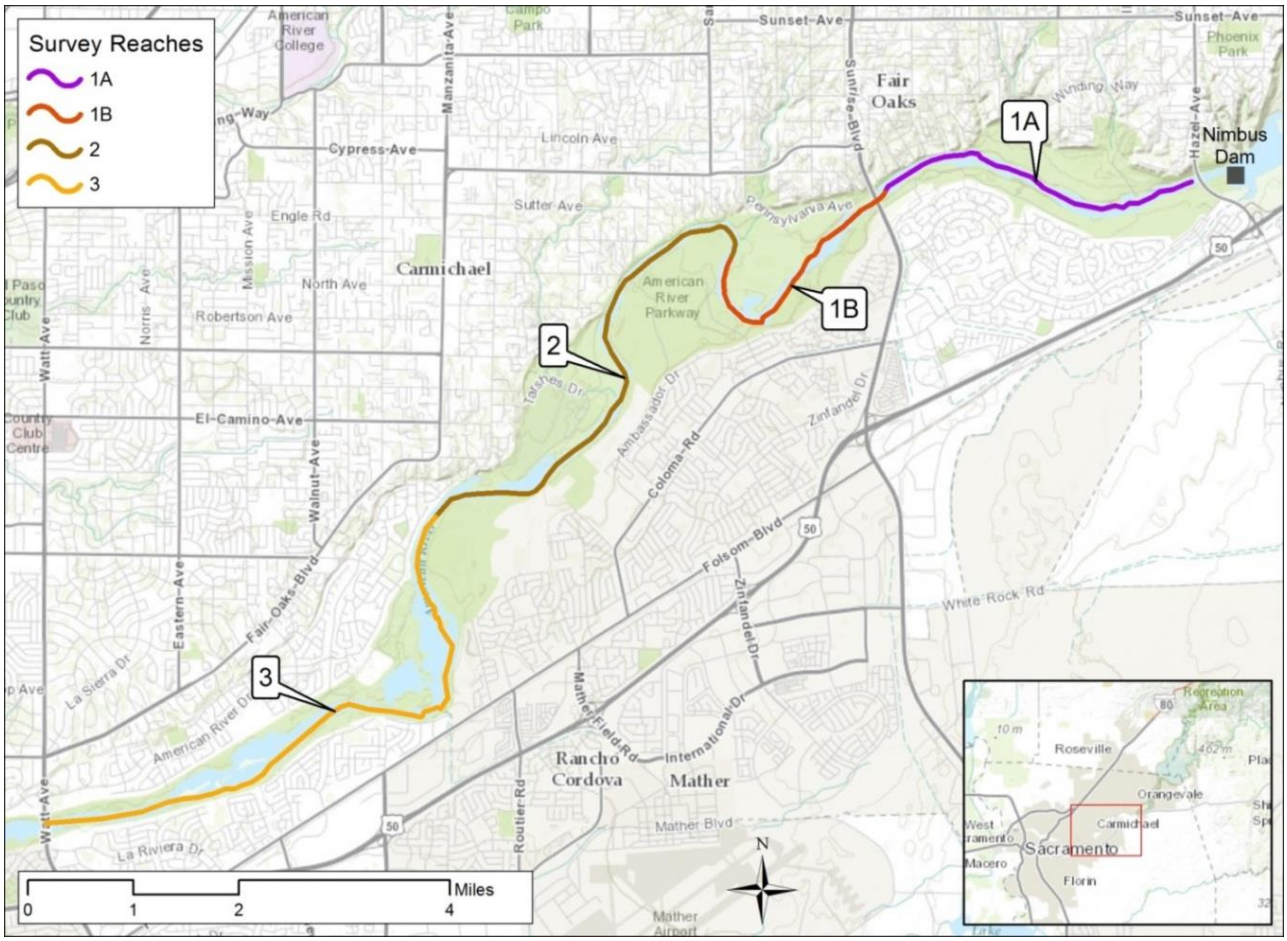

Figure 2. Lower American River Chinook escapement survey sections map.

Table 1. Lower American River escapement survey sections and distances.

Section	Location	Kilometers	Miles
1A	Nimbus Hatchery weir to Sunrise	3.7	2.3
1B	Sunrise Boat Launch to Elmanto Dr	3.2	2.0
2	Elmanto Dr Access to River Bend	7.6	4.7
3	River Bend Park to Watt Ave	6.6	4.1
	Total	**21.1**	**13.1**

The survey was conducted by four to six staff members searching for submerged salmon carcasses while walking the banks of the river and kayaking in unwadeable areas of the river. The bank crews moved downstream and processed all carcasses encountered.

Each carcass encountered 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. Carcasses were then processed for (a) the multiple mark-recapture study, (b) head collection for coded-wire tag (CWT) retrieval, or (c) tally chop.

Covariate data were collected on all carcasses used in the mark-recapture study and adipose-clipped carcasses destined for CWT removal. Covariate data consisted of adipose fin status, sex, fork length, freshness, and degree of egg retention for females. Sex was determined by a combination of distinguishing characteristics which included presence/absence of a kype, laterally compressed body, and presence of eggs or milt. Fork length (FL) was measured to the nearest centimeter from the tip of the snout to the caudal fin fork. The degree of carcass decomposition was determined by examining the condition of the eyes and gills. Salmon carcasses were considered fresh if one clear eye or bright red gills were observed, and not fresh if one or both eyes were cloudy, or gills were pink or brown. Egg retention was determined by externally probing the abdomen or by dissection. Spawning condition was recorded as unspawned if approximately more than 70 percent of eggs were retained, partially spawned if approximately 30-70 percent of eggs were retained, or spawned if approximately less than 30 percent of eggs were retained. Adipose fin status was the only covariate data collected for tally chops.

In general, fresh carcasses with an intact adipose fin were utilized for a mark-recapture study. Carcasses used in the mark-recapture study were affixed with a hog ring on the left maxilla. Each ring contained a uniquely numbered disk tag and colored flagging unique to the survey period. Disk-tagged carcasses were released nearest to the thalweg and to their initial point of detection. All disk-tagged recaptures were first examined for flag color, and only those colors indicating the carcass was marked during a previous survey period were processed. Disk tag numbers were recorded on all recaptures prior to re-releasing or chopping the carcass, depending on perceived probability of additional recaptures in subsequent survey periods. Carcasses with an intact adipose fin that were deemed unsuitable for mark-recapture tagging due to excessive deterioration were chopped and tallied.

Carcasses with missing adipose fins were assumed to contain a CWT in their snouts. Heads were either 1) removed and retained for CWT retrieval at a later date, or 2) chopped and

tallied if the carcass was in an advanced state of decomposition and unlikely to contain a CWT.

The 2015 LAR fall-run Chinook salmon escapement estimate was derived using the superpopulation Cormack-Jolly-Seber (CJS) escapement estimation model for open populations (Cormack 1964, Bergman, et al. 2012). The model was run on R statistical computing software, version 3.3.2 (R Core Team 2016).

Water flow and temperature data were collected each survey day. Flow and water temperature data were obtained via the internet from the United States Geological Survey (USGS) station (11446500 American River at Fair Oaks) on the LAR near the Nimbus weir (USGS 2016). Water clarity was measured at least once per week with a secchi disk at a specific location in each section and recorded to the nearest centimeter (cm).

RESULTS

Final Carcass Count

During the 14-week survey, 7,516 Chinook salmon carcassses were processed by field crews (Table 2). The most carcasses processed in a weekly survey period was 1,853 and occurred during survey period 9 (Dec 14 – Dec 18) (Table 2, Figure 3).

Table 2. Total salmon carcasses processed during the 2015 lower American River escapement survey.

Survey period	Dates	# of carcasses processed
1	Oct 19-22	5
2	Oct 26-29	4
3	Nov 2-5	3
4	Nov 9-13	11
5	Nov 16-19	43
6	Nov 23-25	205
7	Nov 30-Dec 3	653
8	Dec 7-11	1544
9	Dec 14-18	1853
10	Dec 21-23	1524
11	Dec 28-31	894
12	Jan 4-7	453
13	Jan 11-14	240
14	Jan 19-22	84
	Total	**7516**

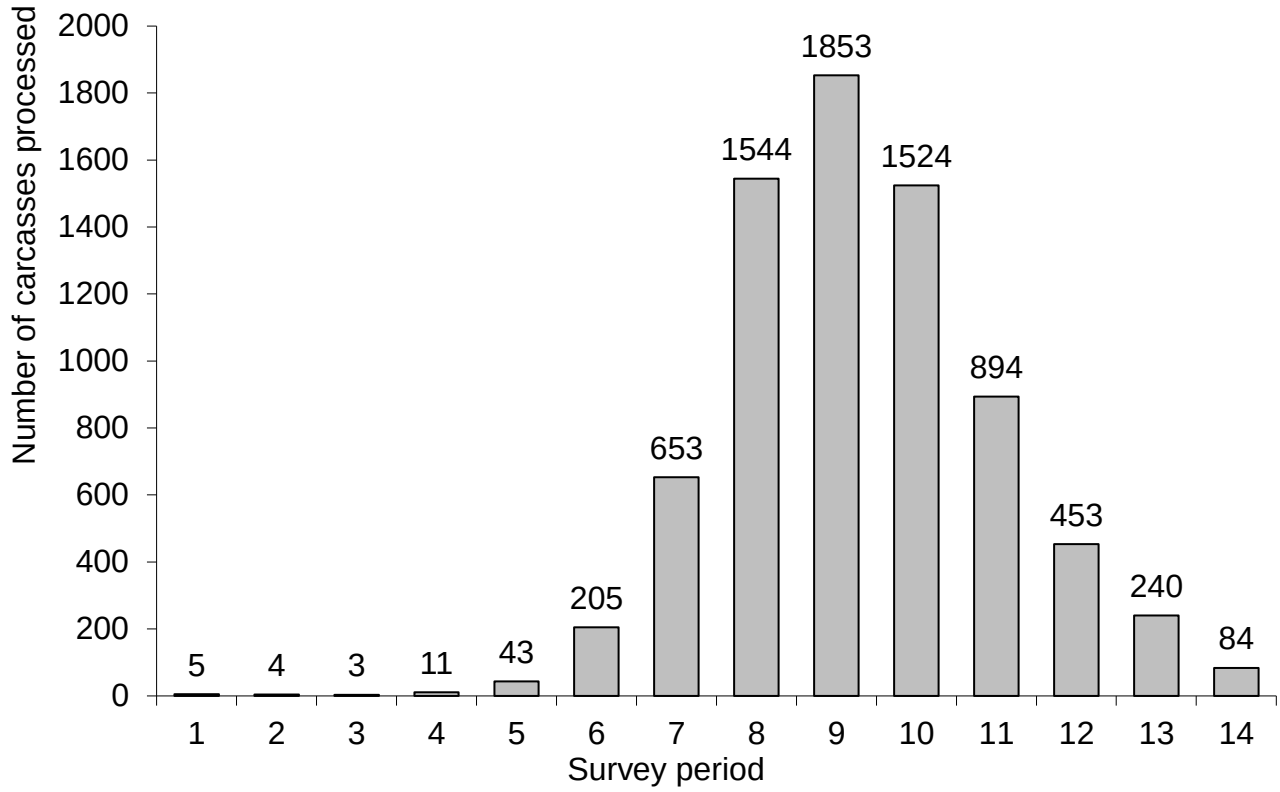

Figure 3. Temporal distribution of total salmon carcasses processed (disk-tagged, covariate chop, or tally chop) by survey period during the 2015 lower American River escapement survey.

Degree of Carcass Decomposition

Fresh carcasses were encountered and processed during each survey period. The most fresh carcasses processed occurred during survey period 8 when 164 were processed (Table 3, Figure 4). The majority of carcasses used for the mark-recapture survey were not fresh (59 percent, *n*=610). In addition, the majority of covariate chop carcasses were not fresh (82 percent, *n*=1,341).

Table 3. Summary of salmon carcass freshness during the 2015 lower American River escapement survey.

Survey period	Dates	Fresh	Not fresh	Status unknown	Total
1	Oct 19-22	0	5	0	**5**
2	Oct 26-29	1	3	0	**4**
3	Nov 2-5	2	1	0	**3**
4	Nov 9-13	5	6	0	**11**
5	Nov 16-19	19	23	1	**43**
6	Nov 23-25	64	141	0	**205**
7	Nov 30-Dec 3	111	541	1	**653**
8	Dec 7-11	164	1379	1	**1544**
9	Dec 14-18	140	1713	0	**1853**
10	Dec 21-23	97	1426	1	**1524**
11	Dec 28-31	46	848	0	**894**
12	Jan 4-7	37	416	0	**453**
13	Jan 11-14	20	220	0	**240**
14	Jan 19-22	8	76	0	**84**
	Total	**714**	**6798**	**4**	**16,617**
	(%)	(10)	(90)		

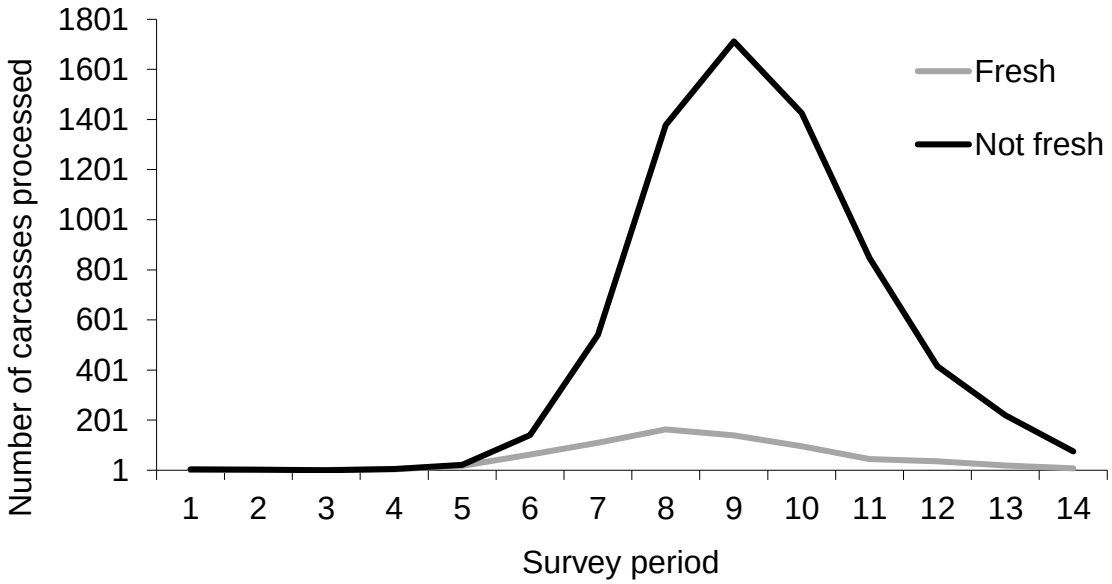

Figure 4. Temporal distribution of carcass freshness by survey period during the 2015 lower American River escapement survey.

Processing Type

Of the 7,516 salmon carcasses processed, 1,031 (14 percent) were disk-tagged for mark-recapture, 1,242 carcasses were used for covariate data collection (17 percent) and CWT retrieval, and 4,847 (64 percent) were chopped and tallied (Table 4, Figure 5). In addition,

covariate data were collected from 396 carcasses (5 percent) that were not included in the mark-recapture survey or CWT retrieval.

Table 4. Total salmon carcasses by processing type during the 2015 lower American River escapement survey.

Survey period	Dates	Tally chops	Disk-tagged	Covariate chops	Weekly total
1	Oct 19-22	5	0	0	**5**
2	Oct 26-29	2	2	0	**4**
3	Nov 2-5	1	2	0	**3**
4	Nov 9-13	5	5	1	**11**
5	Nov 16-19	12	25	6	**43**
6	Nov 23-25	83	99	23	**205**
7	Nov 30-Dec 3	341	119	193	**653**
8	Dec 7-11	949	60	535	**1544**
9	Dec 14-18	1215	301	337	**1853**
10	Dec 21-23	1036	230	258	**1524**
11	Dec 28-31	627	95	172	**894**
12	Jan 4-7	332	66	55	**453**
13	Jan 11-14	182	27	31	**240**
14	Jan 19-22	57	0	27	**84**
	Total	**4847**	**1031**	**1638**	**7516**
	%	64	14	22	

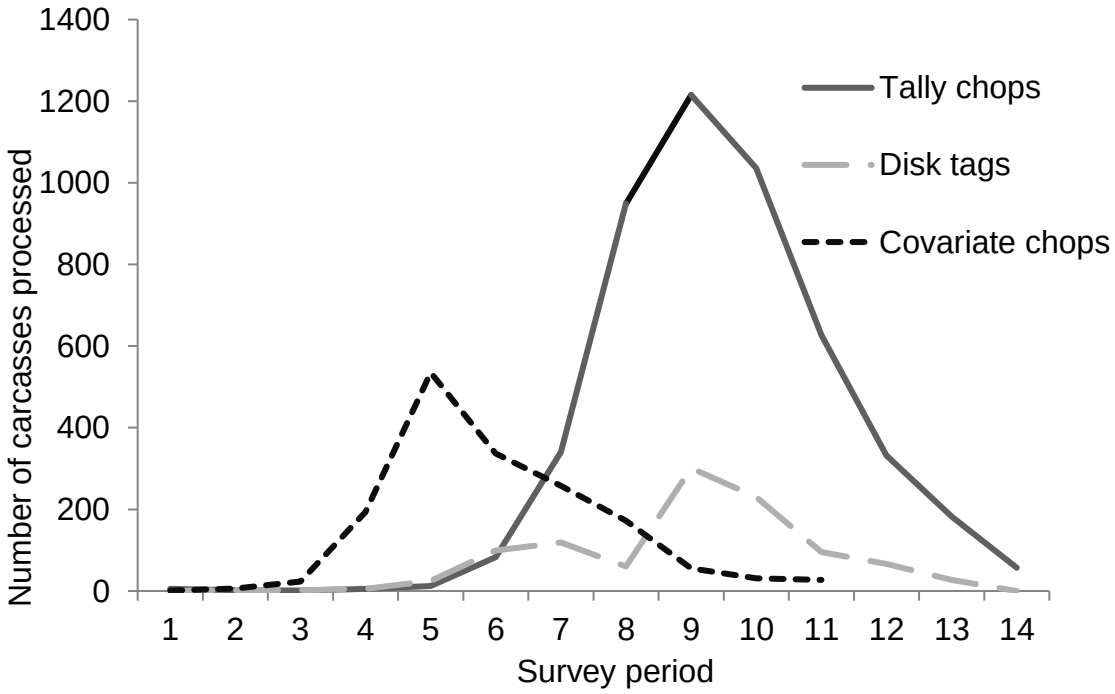

Figure 5. Temporal distribution of salmon carcass processing type during the 2015 lower American River escapement survey.

Spatial Distribution

Most carcasses were observed in sections 1A and 1B (95 percent, *n*=7,147) with a decreasing number of carcasses observed as the survey progressed downstream. Four percent (*n*=291) of carcasses were encountered in Section 2, and 1 percent (*n*=78) were encountered in Section 3. Most carcasses processed during the survey were encountered by the end of survey period 9 (December 14 – 18) (Figure 6). Section 3 was not surveyed during survey periods 6 and 10 because of state holidays and inclement weather (Table 5, Figure 6).

Table 5. Total salmon carcasses processed by survey section during the 2015 lower American River escapement survey. Section 3 was not surveyed during survey periods 6 and 10 due to state holidays and inclement weather.

Survey period	Dates	Sections			Weekly total
		1(A+B)	2	3	
1	Oct 19-22	4	1	0	**5**
2	Oct 26-29	3	1	0	**4**
3	Nov 2-5	1	2	0	**3**
4	Nov 9-13	8	0	3	**11**
5	Nov 16-19	39	3	1	**43**
6	Nov 23-25	201	4	--	**205**
7	Nov 30-Dec 3	609	33	11	**653**
8	Dec 7-11	1442	88	14	**1544**
9	Dec 14-18	1734	81	38	**1853**
10	Dec 21-23	1524	0	--	**1524**
11	Dec 28-31	820	64	10	**894**
12	Jan 4-7	440	12	1	**453**
13	Jan 11-14	238	2	0	**240**
14	Jan 19-22	84	0	0	**84**
	Total	**7147**	**291**	**78**	**7516**
	%	95	4	1	

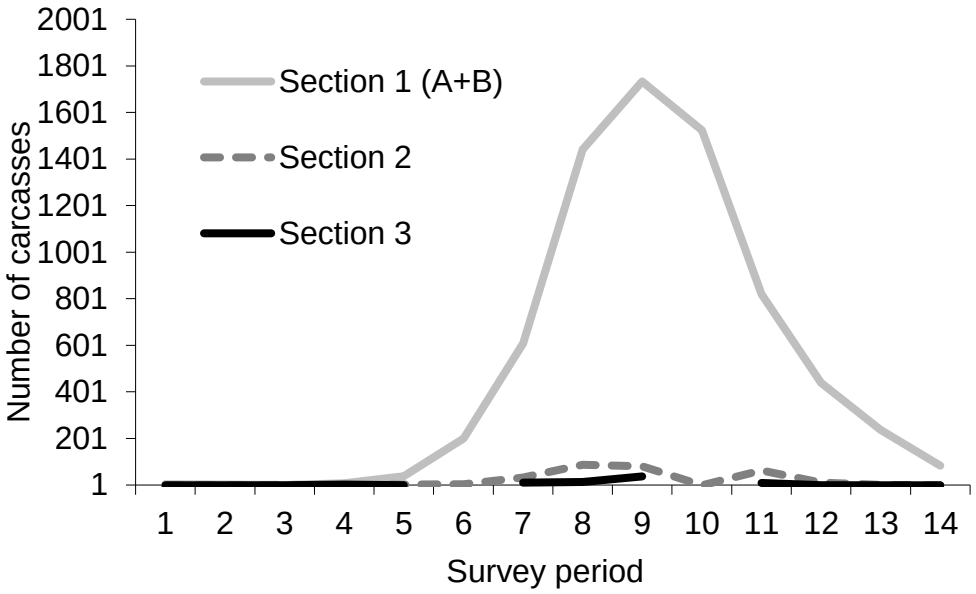

Figure 6. Temporal distribution of salmon carcasses processed by survey section and survey period during the 2015 lower American River escapement survey.

Length Composition

Fork length (FL) data were recorded for 2,665 carcasses (Figure 7). The minimum and maximum FL for male carcasses were 46 cm and 106 cm, respectively, with a mean of 78 cm and a mode of 83 cm. Minimum and maximum recorded FL for female carcasses were 50 cm and 97 cm, respectively, with a mean of 77 cm and a mode of 75 cm. Length data were recorded for four carcasses of unknown sex.

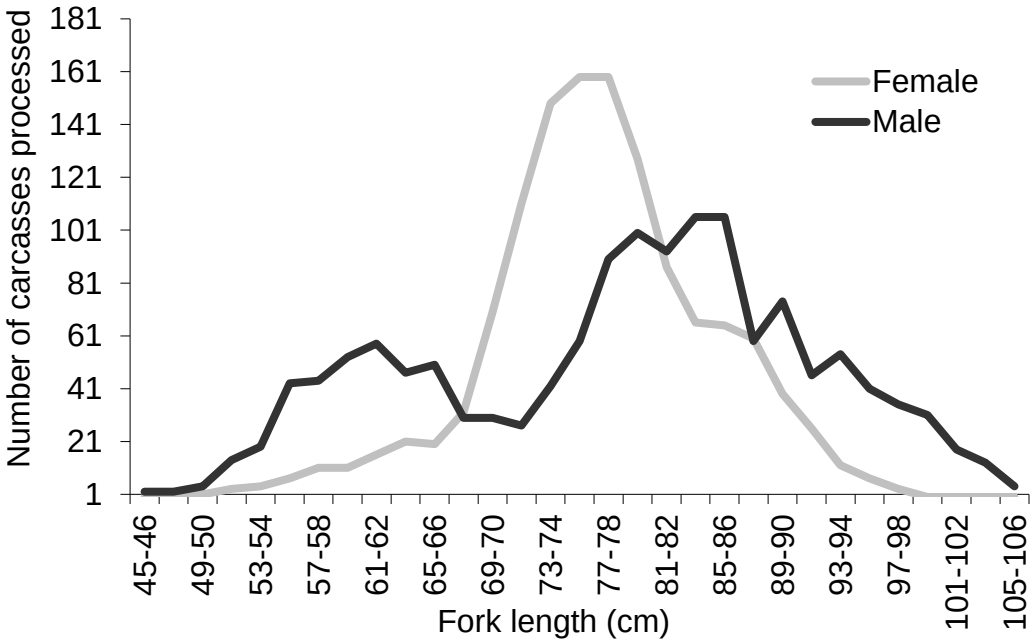

Figure 7. Salmon carcass fork length frequency distribution by sex recorded during the 2015 lower American River escapement survey.

Sex and Age Composition

Sex data were recorded for 2,665 carcasses. Females comprised 48 percent (*n*=1,268) and males comprised 52 percent (*n*=1,397) of processed carcassses (Table 6). Fork length data was not recorded for three male carcasses, and one female carcass.

Age class assignment was determined using length frequency distributions of 2,665 carcasses (Figure 7). Males were classified as adults if FL was $\geq$ 70 cm, or grilse if FL was $\leq$ 69 cm. Females were classified as adults if FL was $\geq$ 63 cm, or grilse if FL was $\leq$ 62 cm.

Eighty-four percent (*n* = 2,226) of carcasses were categorized as adults and 16 percent (*n*=439) were classified as grilse (Table 7, Figure 8). Adult carcass proportions were 45 percent male (*n*=1011), 55 percent female (*n*=1214), and less than one percent unknown sex (*n*=1) (Table 6). Grilse carcass proportions were 87 percent male (*n*=383), 12 percent female (*n*=53), and one percent unknown sex (*n*=3) (Table 6).

Table 6. Number of processed salmon carcasses by age class and sex during the 2015 lower American River escapement survey.

Survey period	Dates	Grilse		Adults		Weekly total	
		Females	Males	Females	Males	Females	Males
1	Oct 19-22	0	0	0	0	**0**	**0**
2	Oct 26-29	0	0	2	0	**2**	**0**
3	Nov 2-5	0	0	2	0	**2**	**0**
4	Nov 9-13	0	2	3	1	**3**	**3**
5	Nov 16-19	0	5	12	14	**12**	**19**
6	Nov 23-25	3	15	46	58	**49**	**73**
7	Nov 30-Dec 3	3	35	141	132	**144**	**167**
8	Dec 7-11	10	85	241	255	**251**	**343**
9	Dec 14-18	11	76	311	239	**322**	**315**
10	Dec 21-23	12	96	235	144	**248**	**240**
11	Dec 28-31	7	47	106	107	**113**	**154**
12	Jan 4-7	3	14	61	43	**64**	**57**
13	Jan 11-14	3	4	38	13	**41**	**17**
14	Jan 19-22	1	4	16	5	**17**	**9**
	Total	**53**	**383**	**1214**	**1011**	**1268**	**1397**
	%	12	87	55	45	48	52

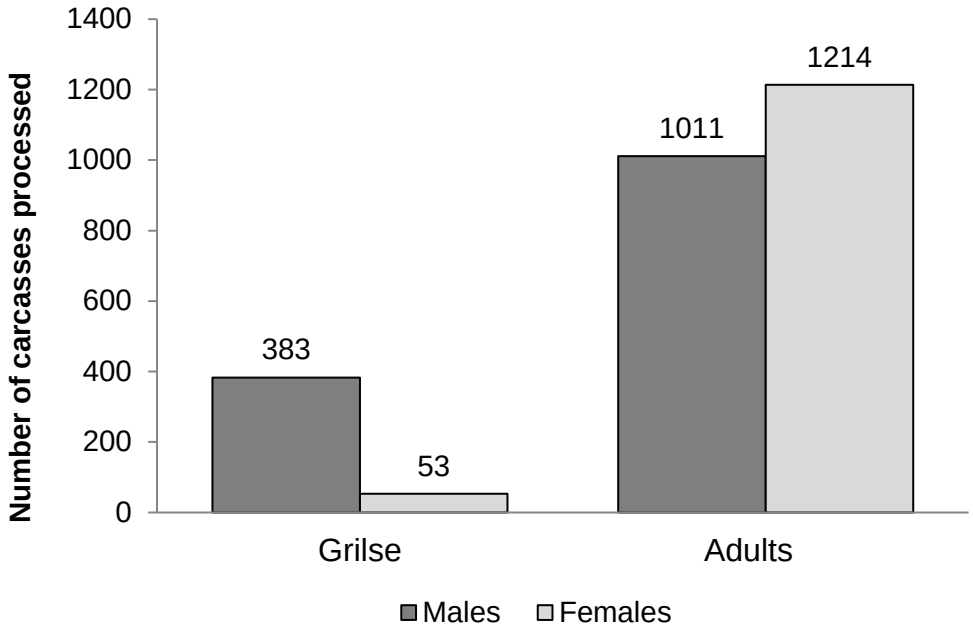

Figure 8. Total salmon carcasses processed by age class and sex during the 2015 lower American River escapement survey.

Table 7. Summary of salmon carcasses processed by age class during the 2015 lower American River escapement survey.

Survey period	Dates	Grilse	Adults
1	Oct 19-22	0	0
2	Oct 26-29	0	2
3	Nov 2-5	0	2
4	Nov 9-13	2	4
5	Nov 16-19	5	26
6	Nov 23-25	18	104
7	Nov 30-Dec 3	39	273
8	Dec 7-11	96	496
9	Dec 14-18	88	550
10	Dec 21-23	108	379
11	Dec 28-31	54	213
12	Jan 4-7	17	104
13	Jan 11-14	7	51
14	Jan 19-22	5	22
	Total	**439**	**2226**
	(%)	(16)	(84)

Egg Retention

A total of 1,224 female carcasses were examined for egg retention (Table 8, Figure 9). Ninety percent (*n*=1,107) of female carcasses were spawned, three percent (*n*=40) partially spawned, and six percent (*n*=77) unspawned.

Table 8. Female egg retention recorded during the 2015 lower American River escapement survey.

Survey period	Dates	Female egg retention			Weekly total
		0 to 29%	30 to 69%	70 to 100 %	
		n	*n*	*n*	
1	Oct 19-22	0	0	0	**0**
2	Oct 26-29	1	0	1	**2**
3	Nov 2-5	0	0	3	**3**
4	Nov 9-13	1	1	1	**3**
5	Nov 16-19	10	1	1	**12**
6	Nov 23-25	38	1	8	**47**
7	Nov 30-Dec 3	124	11	7	**142**
8	Dec 7-11	230	5	7	**242**
9	Dec 14-18	285	10	14	**309**
10	Dec 21-23	206	7	20	**233**
11	Dec 28-31	98	2	9	**109**
12	Jan 4-7	58	1	5	**64**
13	Jan 11-14	40	1	0	**41**
14	Jan 19-22	16	0	1	**17**
	Total	**1,107**	**40**	**77**	**1,224**
	(%)	(90)	(3)	(6)	

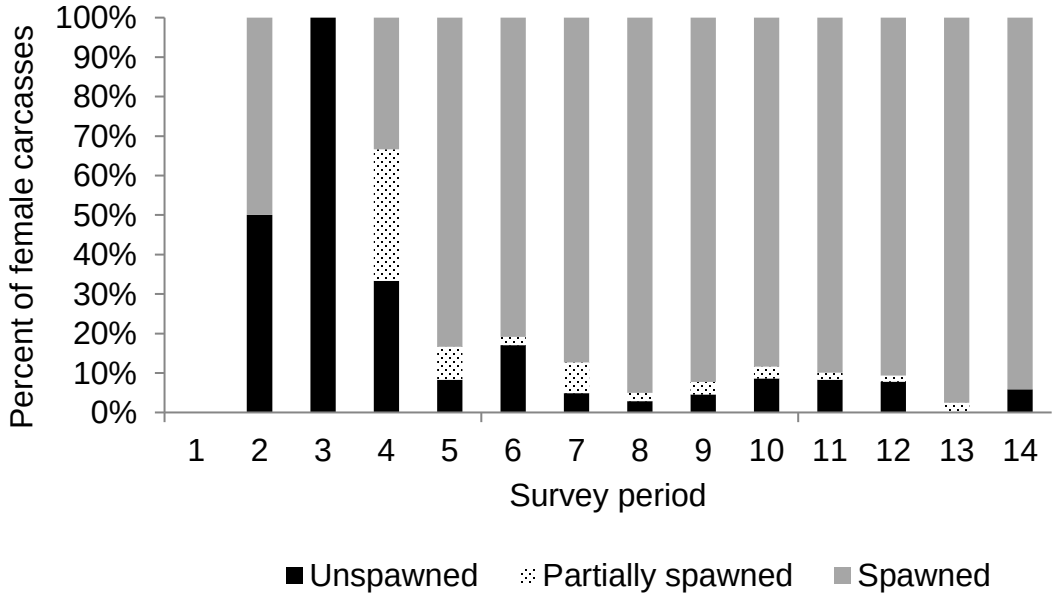

Figure 9. Temporal distribution of female egg retention recorded during the 2015 lower American River escapement survey.

CWT Carcasses[1]

A total of 7,516 carcasses were examined for the presence of an adipose fin. Eighteen percent (*n*=1,374) were missing an adipose fin. From these carcasses, 1,242 heads were collected for CWT extraction. Covariate data were collected for the remaining carcasses before being chopped. Seventy-five percent (*n*=5,652) of carcasses had an intact adipose fin, 4,229 of which were simply chopped and tallied due to advanced decomposition. Adipose presence could not be determined (unknown or skeleton) for seven percent (*n*=490) of carcasses. The largest number of adipose-clipped carcasses were processed during survey period 9 (*n*=338) (Table 9, Figure 10).

Table 9. Summary of adipose fin condition recorded during the 2015 lower American River escapement survey.

Survey period	Dates	Adipose status			No. of head tags
		Intact	Clipped	Skeletons	
1	Oct 19-22	2	0	3	0
2	Oct 26-29	4	0	0	0
3	Nov 2-5	3	0	0	0
4	Nov 9-13	9	1	1	1
5	Nov 16-19	37	6	0	6
6	Nov 23-25	168	30	7	22
7	Nov 30-Dec 3	503	123	27	107
8	Dec 7-11	1198	281	65	261
9	Dec 14-18	1399	338	116	318
10	Dec 21-23	1175	282	67	258
11	Dec 28-31	601	186	107	171
12	Jan 4-7	330	74	49	55
13	Jan 11-14	165	38	37	31
14	Jan 19-22	58	15	11	12
	Total	**5,652**	**1,374**	**490**	**1,242**
	(%)	(75)	(18)	(7)	

[1] All salmon carcass heads collected during Central Valley salmon escapement surveys for CWT removal are processed by the CDFW's Ocean Salmon Project in Santa Rosa, CA. Tag data are finalized and uploaded to the Regional Mark Information System (RMIS) on the Regional Mark Processing Center's website during the summer months following the escapement surveys. To query specific CWT data from this survey, visit www.rmpc.org.

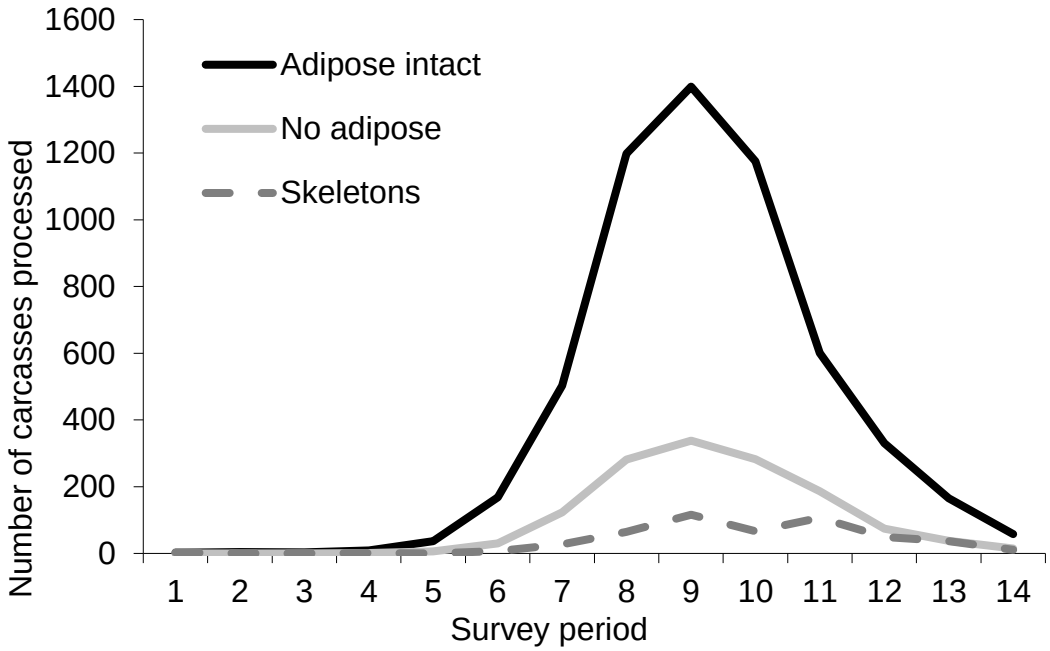

Figure 10. Temporal distribution of salmon processed with adipose fin intact or clipped during the 2015 lower American River escapement survey.

Environmental Conditions

LAR water temperature decreased an average of 0.2°F per day over the duration of the survey. The minimum and maximum water temperatures recorded by the USGS gauge at Fair Oaks during the months of October 2015 to January 2016 were 8.3°C (47°F) (Jan 2-8, 2016) and 20.6°C (69°F) (Oct 1 and 3, 2015), respectively, with a mean temperature of 13.3°C (56°F) (Figure 11).

Flow releases from Folsom and Nimbus dams were generally within the minimum required release of 14.2 cms (500 cfs) from October 1, 2015 through January 24, 2016 for a critically dry water year-type and ranged from a low of 13.6 cubic meters per second (cms), (479 cfs) on November 3 to a high of 21.9 cms (759 cfs) on January 24 (Figure 11) (USGS 2016). Mean flow during the same time period was 14.7 cms (518 cfs).

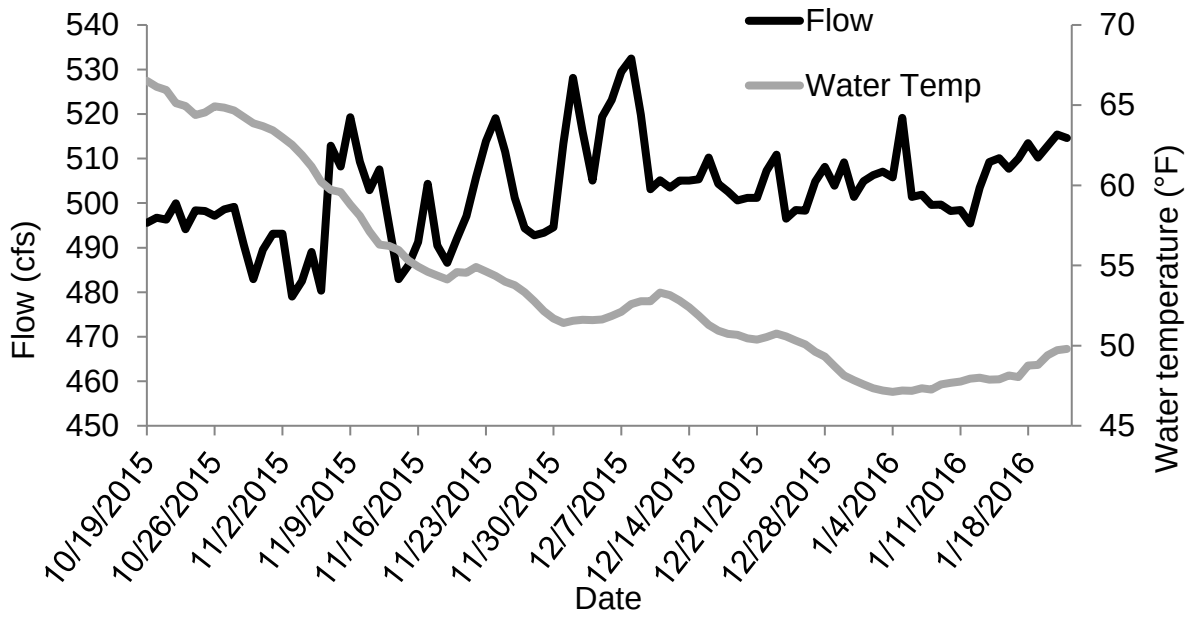

Figure 11. Lower American River average daily flow (cubic feet per second) and average daily water temperature (°F) during the 2015 lower American River escapement survey. Data source: USGS January 2016.

The minimum and maximum recorded secchi depths were 110 cm (Jan 6, 2016) and 555 cm (Nov 19, 2015), respectively, with a mean of 265 cm (Figure 12). Although there were large oscillations in water clarity during the survey, the general trend was a decrease in visibility over the duration of the survey.

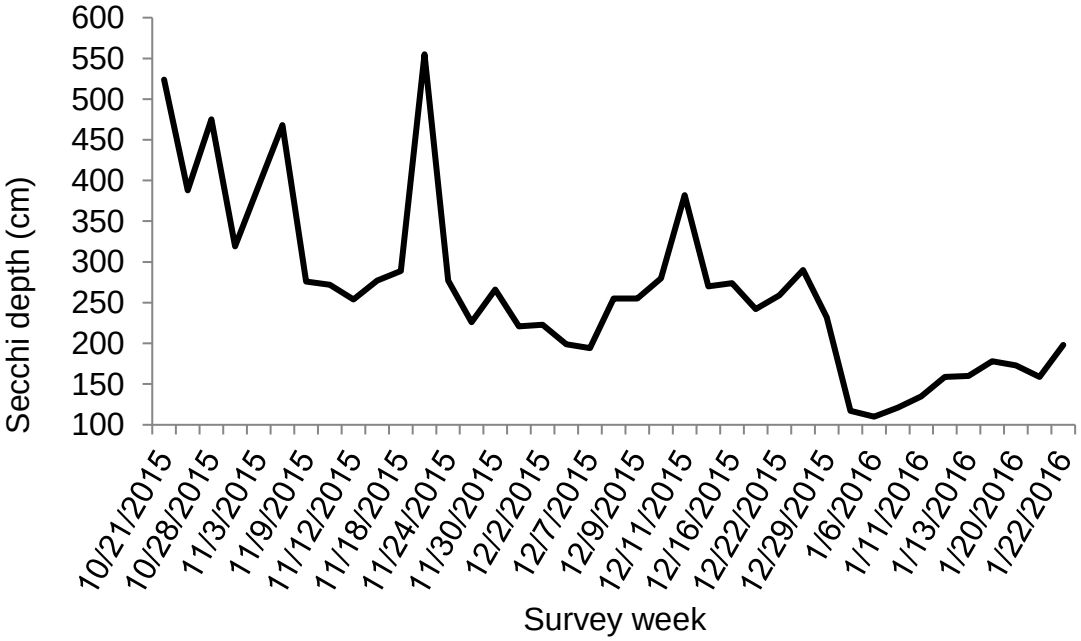

Figure 12. Lower American River water clarity data obtained from secchi measurements (cm) from October 2015 to January 2016.

Escapement Estimate

A total of 1,031 carcasses was disk-tagged and released from October 19, 2015 to January 22, 2016. The total number of disk-tagged carcasses recaptured was 485. The likelihood of recapture was positively related to length. The in-river LAR escapement estimate from the CJS model is 13,793 fall-run Chinook salmon. The bootstrap estimate of the standard error of estimated total escapement is 352 fall-run Chinook salmon. The 90 percent bootstrap (*n*=1,000) percentile confidence interval is 13,106 to 14,251.

In addition to the in-river estimates, 9,821 carcasses were collected at Nimbus Hatchery, and 1,946 carcasses were collected from the Nimbus weir by hatchery personnel. The hatchery uses a standard 68 cm FL as the cutoff for both male and female grilse.

The combined 2015 LAR fall-run Chinook salmon escapement estimate from the in-river survey, Nimbus Hatchery and weir collections is 25,560.

DISCUSSION

Annual LAR escapement estimates and associated data trends are influenced by a number of factors including escapement and spawning success of previous brood years, juvenile survival during emigration, ocean conditions, predation, adult harvest, and LAR flow and water temperature.

The LAR escapement estimate has been steadily increasing since 2008. However, there was a 75 percent reduction in the 2015 estimate compared to the 2013 estimate (Figure 13).

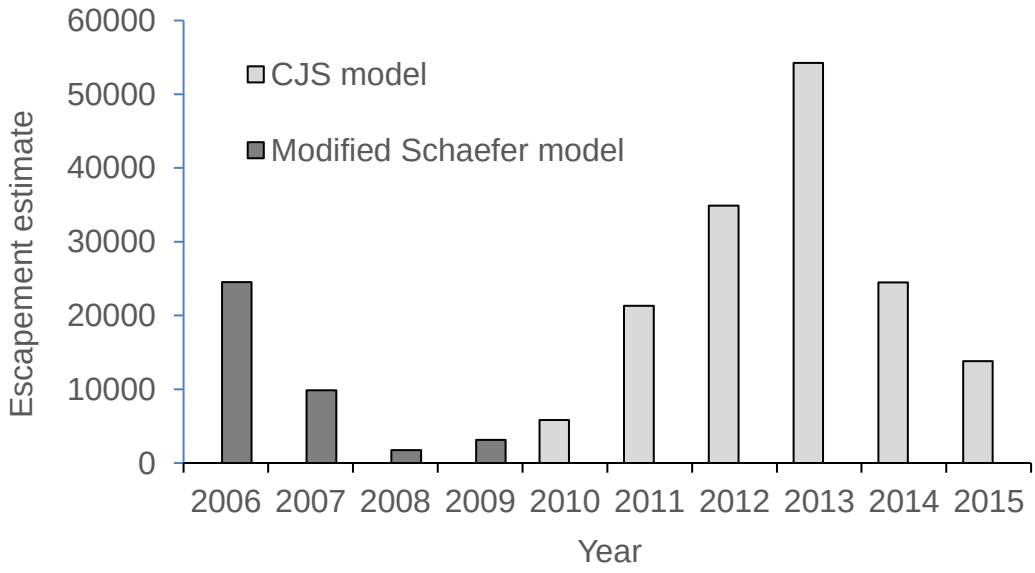

Figure 13. Historical in-river escapement estimates for the lower American River escapement survey from 2006-2015.

During the 2015 survey, less than one percent of carcasses encountered were processed during the first five weeks compared to 47 and 22 percent during the 2012 and 2013 surveys, respectively. The late arrival of the salmon resulted in a delayed peak of carcass detection not seen since 2008, the second year of a four-year period of low adult escapement. The most carcasses processed during a survey period occurred during the second week of December, which is one to two weeks later than average. Over 65 percent of carcasses were processed during periods 8 through 10 (Dec 7-23). The later start of the 2015 season is likely the result of prolonged periods of low flow on the LAR (USGS 2016) and prolonged periods of water temperatures exceeding 57°F during migration and holding periods (Combs and Burrows 1957). Continued drought may cause a continued decrease in escapement in future years.

As observed in previous years, the largest number of carcasses were observed in Section 1, the upper-most section of the survey, with decreasing numbers observed in Sections 2 and 3. In 2015, 95 percent of carcasses were observed in Section 1 which is higher than that observed in the previous seven years (minimum: 72 percent in 2011, maximum: 93 percent in 2008).

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