CALIFORNIA DEPARTMENT OF FISH AND GAME
HABITAT CONSERVATION DIVISION
Native Anadromous Fish and Watershed Branch
Stream Evaluation Program

Lower American River
EMIGRATION SURVEY
October 1996-September 1997

by

Bill Snider
and
Robert G. Titus

Stream Evaluation Program
Technical Report No. 00-2
January 2000

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1/ This work was supported by funds provided by the U.S. Fish and Wildlife Service, Central Valley Anadromous Fish Restoration Program, as part of a cooperative agreement with the California Department of Fish and Game pursuant to the Central Valley Project Improvement Act (PL. 102-575).

2/ Stream Evaluation Program Technical Report 00-2.

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SUMMARY

A rotary screw trap (RST) was used to collect data on emigrating anadromous fishes in the lower American River. The trap was fished near river mile (RM) 9 from 1 October 1996 through 21 June 1997.

Emigrants of four anadromous fishes were collected: chinook salmon, steelhead trout, Pacific lamprey and American shad. We collected 32,064 salmon emigrants between 16 December 1996 and 21 June 1997. Three races of juvenile chinook were collected (race determined by size-at-time criteria): 30,030 fall-run-sized salmon were collected between 16 December 1996 and 21 June 1997; 28 spring-run-sized chinook were collected between 7 February and 16 May 1997; and, six winter-run-sized chinook were collected from 16 December 1996 to 3 March 1997. We also collected 49 young-of-the-year (YOY) steelhead between 14 January and 16 June 1997, 42 in-river produced yearling-sized steelhead between 23 December 1996 and 30 April 1997, and 21 hatchery-produced yearling-sized steelhead between 17 January and 27 May 1997. Also collected were 715 Pacific lamprey, between 4 October 1996 and 16 June 1997, and 145 American shad, between 7 October 1996 and 21 June 1997.

Chinook salmon emigrants were described by life stage as yolk-sac fry, fry, parr, silvery parr and smolts. Most of the fall-run salmon collected were parr (47.7%). Fry comprised 35.8% of the chinook salmon catch, yolk-sac fry comprised 12.5%, silvery parr comprised 3.9%, and smolts comprised less than 0.1%. Yolk-sac fry were collected between 16 December 1996 and 28 March 1997, fry between 23 December 1996 and 2 April 1997, parr between 24 December 1996 and 6 June 1997, silvery parr between 3 February and 21 June 1997, and smolts between 19 and 23 May 1997.

Salmon yolk-sac fry lengths ranged from 26 to 41 mm fork length (FL), fry ranged from 31 to 42 mm FL, parr ranged from 30 to 88 mm FL, silvery parr ranged from 35 to 102 mm FL, and smolts ranged from 77 to 92 mm FL.

Fulton's condition factor (*K)* was determined for juveniles $\geq$45 mm FL.

In the 1997 survey year, the first salmon was caught in late-December 1996, and the salmon catch peaked during late February 1997, essentially the same timing observed in the 1995 survey year (Snider et al. 1997). Migration in both the 1995 and 1997 survey years started 3 weeks later than in the 1996 survey year and 3 weeks earlier than in the 1994 survey year (Snider and Titus 1995, Snider et al. 1997, Snider et al. 1998). Peak catch occurred at essentially the same time of year during 1994, 1995 and 1997, and nearly 1 month later than in 1996. In none of the four survey years was the timing of emigration coincident with the timing of peak spring flows. The end of migration was not determined in 1997 since trapping was ended during week 25 while salmon were still being caught, due to conflicts with recreational use of the trapping area. Migration ended after week 25 in each of the other three survey years.

The estimated total chinook salmon catch of 1997 (32,064) was the lowest observed during the four survey years. An estimated total of 45,478 salmon was caught in 1995, 132,040 in 1996, and 162,089 in 1994. Peak daily catch and overall catch rate were also the lowest observed (3,083 salmon and 54 salmon /h, respectively). Catch rate was less than 50% of that observed in 1995 and less than 10% of the rates observed in 1994 and 1996.

Trapping efficiency was measured using mark-and-recapture techniques. The measured mean efficiency in 1997 was low, (0.75%), but very similar to that measured during 1994 ((0.72%) and 1996 (0.68%)

Flow during the 1997 survey year was substantially different than during the three previous survey years. Flow was extremely high during December and January, averaging over 32,000 cfs during January with a daily high of over 100,000 cfs. In comparison, January flows in 1994 and 1996 were essentially uniform, averaging less than 2,000 cfs. In 1995, January flow ranged from less than 2,000 cfs early in the month to nearly 30,000 cfs late in the month (mean = 8,552 cfs). Comparisons of mean and maximum January flows with an index of survival to emigration (expanded number of emigrants/escapement) indicates that survival may be inversely related to January flow conditions ($r = -0.743$).

INTRODUCTION

Anadromous fish emigration was monitored on the lower American River, Sacramento County, California (Figure 1) from October 1996 through mid-June 1997. This was the fourth, consecutive year that migration was monitored on the lower American River as part of a multi-year effort to evaluate flow and other habitat requirements of anadromous salmonids using the lower American River.

The timing and life-stage composition of emigrating salmonids can directly affect cohort survival and chronic changes in emigration can ultimately affect population persistence (Park 1969). Various abiotic conditions, many induced by human activities, are known to directly or indirectly alter emigration. Flow change (increases and decreases), flow magnitude, water temperature, turbidity, and habitat availability are some conditions that may be altered and affect emigration.

Fall-run chinook salmon *Oncorhynchus tshawytscha* emigration from the lower American River is vulnerable to all such conditions potentially resulting from flow regulation at Folsom Dam. An important objective of our investigations into flow-habitat relationships on the lower American River is to identify relationships between timing, magnitude, and composition of emigrating chinook salmon in the lower American River and flow, temperature, and other factors potentially controlled by operation of the Folsom Project.

Since emigration can be influenced by anthropogenic disturbances in environmental conditions, it is essential that the relationships between such conditions and emigration, and ultimately survival to spawning, be understood if management of altered systems is to accommodate both short- and long-term survival. Evaluation of the emigrating population can also relate production and survival of chinook salmon to precedent conditions of spawning, incubation, and rearing. As such, monitoring salmon emigration in the lower American River has been part of an investigation of the influences of altered flow on chinook salmon habitat requirements.

Our investigation has several objectives. The primary objective is to identify the general attributes of emigration on the lower American River, including timing, abundance, fish size and life stage composition, and fish condition, and to relate these attributes primarily to flow dependent, environmental conditions. We aim to develop an empirically-based model to link emigration with flow through repetitive investigations during years with varying chinook salmon population sizes and/or environmental conditions. Additionally, we plan to develop procedures to quantify or index the size of the emigrating population. Ultimately, we propose to associate production and survival with environmental conditions by combining emigration data with information being collected on spawner population size, numbers and distribution of redds, and the magnitude and dynamics of the rearing phase of chinook salmon precedent to emigration. Emigration evaluations conducted in the lower American River during 1992 and 1993 dealt primarily with overcoming the logistical difficulties innate to such a study (Snider 1992, Fothergill 1994). In 1994, 1995 and 1996 continuous collection of data throughout the emigration period allowed us to achieve certain of the objectives listed above (Snider and Titus

1995; Snider et al. 1997; Snider et al. 1998). This report summarizes data collected during most of the 1997 migration season; our objective in all years is to continuously monitor emigration until no salmon are caught for a continuous two-week period, typically through July, although in 1997 logistical problems required removing the traps in late June, when salmon were still being caught.

Background

Chinook Salmon Emigration

Snider and Titus (1995) outlined some of the key elements determining emigration success of salmonids produced in large river systems.

- Young chinook generally spend their pre-smolt growth and development period in two locations: the natal stream and in the river estuary. The more time spent in the natal stream, the shorter the residence time necessary in the downstream estuary.

- As residence time in the natal stream decreases, it becomes increasingly important to maintain suitable environmental conditions in downstream environs.

- Timing of emigration is crucial if habitat suitability in downstream environs varies over time. The more restricted the period of downstream habitat suitability, the more critical it is to understand the factors that control the timing of emigration.

- Factors which may affect emigration timing and the life stage at which salmon migrate include timing of the spawning run, time of spawning, length of incubation, the time of emergence, flow, intra- and interspecific fish interactions, turbidity and water temperature.

- Salmon that remain in the natal stream for a long period after emerging are more likely to smolt there.

Various schemes have been used to classify the life stages of juvenile chinook salmon (For example, Kjelson and Brandes (1989) and Healey (1991) used a size criterion to distinguish fry and smolts. For the purposes of this study, we characterize fish as yolk-sac fry, fry, parr, silvery parr, and smolt based upon development stages (Titus 1991, Titus and Mosegaard 1992; based primarily on Allan and Ritter 1977). Young chinook are classified as yolk-sac fry in the short period following emergence when the yolk sac is visible and acts as the primary source of nutrition. The fry stage is the short transitional life stage beginning with independence from the yolk sac and ending shortly after dispersal from the redd area. The term “fry” herewith will apply only to this life stage, and unless otherwise indicated, will not include yolk-sac fry. Parr are typically characterized by distinct parr marks and the complete absence of a yolk sac. The silvery parr stage is the transitional life stage between parr and smolt and is characterized by faint or absent parr marks and a silvery appearance. The smolt stage is the life stage at which fish are morphologically, physiologically, and behaviorally prepared to enter the marine environment. A smolt is generally characterized by a bright silvery or whitish appearance, deciduous scales, and a reduced condition factor (i.e., the ratio of weight to length is lower than in previous life stages).

Overview of Lower American River Chinook Salmon Emigration

Emigration has been monitored in the lower American River on a number of occasions (Snider and Titus 1995).

- Emigration was monitored on the American River from 1945-1947 (USFWS 1953). Fry emigrants were detected as early as January, but did not increase in numbers until March, reaching a peak in April. Fingerling (>50 mm FL) emigration began in late May and lasted until mid-June.

- In 1988 and 1989, Beak Consultants, Inc. used Kodiak trawls to sample emigrating salmon on the lower American River. In 1988, sampling began in late April and no fry were caught. In 1989, fry emigration apparently peaked in early March, although sampling did not begin until 1 March. In both years, fingerling emigration peaked in mid-May.

- In 1992 and 1993, various methods were employed by the Stream Evaluation Program of the California Department of Fish and Game (CDFG). It was determined during this period, that the most effective means of capturing emigrants was the rotary screw trap (RST) (Snider and Titus 1995).

In 1994, 1995 and 1996, emigration on the lower American River was continuously monitored throughout the emigration period. In 1994, we caught an estimated 162,089 salmon emigrants with RST's between 13 January 1994 and 13 July 1994. Peak emigration occurred in mid- to late February. The following year, an estimated 51,847 salmon emigrants were caught by RST's between 11 January 1994 and 9 August 1995 (one additional juvenile salmon caught 8 November 1994 was a winter-run-sized salmon). Peak catches again occurred in mid- to late February. In 1996, emigration was somewhat more protracted than in previous years. It started three weeks earlier (week 48), peaked nearly one month earlier (26 January), and ended slightly earlier than in 1995 and slightly later than in 1994. The timing of emigration in both 1994 and 1995 was similar to that observed in the 1988 and 1989 trawling surveys, but much earlier than that observed in emigration studies from 1945 through 1947 (Snider and Titus 1995).

The majority (>70%) of chinook salmon emigrants captured in 1994, 1995 and 1996 were fry or yolk-sac fry, and nearly all (>99%) were pre-smolts. No smolts were captured during 1996. These findings indicate that juvenile salmon must undergo significant development in the river and estuarine environs downstream from the study area prior to ocean entry.

Fulton's condition factor (*K*) was calculated for a subset of emigrating fish in 1994, 1995 and 1996. A decrease in *K* has been associated with the onset of smolting in young salmonids (e.g. Folmar and Dickhoff 1980, Wedemeyer et al. 1980, Titus and Mosegaard 1992). In 1994, 1995 and 1996, however, there was no detectable difference in *K* between chinook salmon classified as smolts and those classified as parr.

RST efficiency was measured in 1994 and 1996 using a mark-recapture method. Efficiency measurements in 1994 ranged from 0.00% to 0.94%. (mean = 0.72%). In 1996, mean efficiency was 0.68% (SD = 0.55), and ranged from 0.00% to 2.06%.

Other Anadromous Fishes

Emigrating anadromous fish species other than chinook salmon that were captured in the lower American River in 1994, 1995 and 1996 included steelhead trout, Pacific lamprey and American shad. Snider and Titus (1995) provide a brief description of the life histories of these species.

STUDY AREA AND METHODS

Anadromous fishes are restricted to the lowermost 23 miles of the American River, from Nimbus Dam to the Sacramento River (Figure 1). Flow in this reach is regulated by Folsom Dam, which is operated by the U.S. Bureau of Reclamation (USBR) to provide water supplies, flood protection, hydroelectric power production, and to maintain fish and wildlife habitats. Flow during the migration period can range from less than 1,000 cubic feet per second (cfs) to more than 100,000 cfs. Large amounts of debris typically accompany flow changes as increased stage picks up debris along the river margins. Urban runoff from several flood control drains also introduces a variety of debris into the river.

In 1997, one 8 ft diameter RST was fished immediately downstream of the Watt Avenue bridge (Figure 1) on the north side of a large, mid-channel bar (Figure 2). This same location was fished during the previous three survey years. The trap was deployed on 29 September 1995 and was fished nearly continuously up to and through the 1997 reporting period (1 October 1996–21 June 1997). Trapping was terminated on 21 June 1997 due to unavoidable conflicts with heavy recreational use of the trapping area. Fishing was essentially continuous through 3 April 1997 when heavy concentrations of algae began fouling the traps requiring constant cleaning. The traps were fished less than 4 h per day between 4 and 14 April 1997; trapping was halted altogether between 14 and 23 April 1997 before the algae problems abated. Trapping then continued uninterrupted from 23 April through 21 June 1997.

Servicing of the RST was conducted two to three times a week in October and November 1996. The trap was serviced at least every weekday, and sometimes on weekends, from late December 1996 through 21 June 1997, except as noted above.

At each servicing, fish were removed from the trap, sorted, and counted by species and race for chinook salmon[1]. Up to 300 of each species were measured and weighed (length to the nearest 0.5 mm, and weight to the nearest 0.1 g). All captured salmon appearing to be outside the fall-run size criteria for the time of capture were measured. *K* was calculated as 10^5(weight, g)/(FL, mm)^3. All measured salmonids were visually classified as yolk-sac fry, fry, parr, silvery parr, or smolts. Yolk-sac fry were defined as newly-emerged fish with a visible yolk sack ("unzipped"). Fry were defined as recently-emerged fish whose yolk sac was fully absorbed ("zipped-up") and whose pigmentation was largely undeveloped. Parr were defined as darkly pigmented fish with characteristic dark, oval-to-round parr marks on their sides, no silvery coloration, and firmly set scales. Silvery parr were defined as fish having faded parr marks and a sufficient accumulation of purine to produce a silvery, but not fully smolted, appearance. Salmon lacking or having highly faded parr marks, a bright silver or nearly white color, a pronounced fusiform body shape (i.e., lower condition), and deciduous scales were classified as smolts. The total weekly number of each life stage captured was calculated by multiplying the weekly percentage of each life stage by the weekly count when the total number of salmon measured and classified was less than the number counted.

Flow data were obtained from USBR release records for Nimbus Dam. The City of Sacramento provided turbidity data (Nephelometric Turbidity Units, NTU) from measurements taken at the City's Fairbairn Water Treatment Plant at RM 7. Water temperature was continuously measured at the trap site throughout the survey period at two-hour intervals using an Onset Stowaway thermograph affixed to the RST. Water temperature was measured at Nimbus Dam, also using a Stowaway, through 1 February 1997, when equipment failure terminated the measurements. Water transparency as measured by Secchi depth, water and air temperatures, and trapping effort (hours fished since last service) were recorded at each servicing of the trap.

Between 19 January 1997 (week 4) and 29 March 1997 (week 13), all captured salmon and steelhead were marked using Bismarck Brown Y stain (Deacon 1961), then released approximately 3,000 ft upstream of the trap. The percentage of marked fish recaptured in the trap provided a measure of trap efficiency.

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[1]/ Chinook salmon race was determined using the size-at-time criteria developed by Frank Fisher, California Department of Fish and Game, Inland Fisheries Division.

RESULTS

General

Flow was remarkably high and variable from early December 1996 through mid-February 1997 (Figure 3). Flow was well above 5,000 cfs during most of this period, exceeding 25,000 cfs on several occasions in December before peaking at a near record high of 115,000 cfs in early January 1997. Flow remained high through mid-February, after which time it rapidly decreased from over 30,000 cfs to 4,000 cfs then fluctuated between 4,000 and 6,500 cfs through mid-March. Flow then decreased further, fluctuating between 2,000 and 3,000 cfs through the remainder of the survey period.

Mean daily water temperature decreased from 55 ºF in early December 1996 to a period low of 45 ºF during late January (Figure 3). It then increased to 48 ºF during the final storm of the season, and remained below 50 ºF through February and most of March. Temperature began to steadily increase on 20 March 1997, climbing to 55 ºF by 13 April 1997, 60 ºF by 14 May 1997, and 65 ºF by 6 June 1997.

Turbidity averaged 84.9 NTUs during the survey period, and peaked at 610 NTUs on 4 January 1997 (Figure 4). Peaks in turbidity in early January and February corresponded to peak discharges (Figures 3 and 4). Turbidity was relatively high in 1996–1997; turbidity rarely exceeded 10 NTUs during any of the three preceding survey periods (1994–1996).

Twenty-three fish species were collected in the RST (Table 1). Juvenile chinook salmon accounted for the majority of fish caught (n = 32,064), followed by Japanese smelt (n = 1,920), Sacramento squawfish (n = 761), Pacific lamprey (n = 702), threadfin shad (n = 329), Sacramento sucker (n = 165), American shad (n = 145) and steelhead (n = 112).

Fall-run-sized Chinook Salmon

Fall-run chinook salmon emigration spanned 27 weeks, from 16 December 1996 (week 51 of 1996) through 21 June 1997 (week 25 of 1997) (Table 2). A total of 32,030 fall run was caught in 4,303 hours of fishing effort (overall average = 7.4 fish/h). The highest daily catch occurred on 25 February 1997 (3,083 fish, 54 fish/h) (Figures 5 and 6), essentially the same date when the peak catches were observed in 1994 and 1995, but approximately one month later than in 1996 (Snider and Titus 1995; Snider et al. 1997, Snider et al. 1998). The highest weekly catch (6,100 fish, 37 fish/h) also occurred in week 9 (23 February–1 March 1997) (Figures 7 and 8).

Fall-run salmon were caught each week beginning 12 December 1996 (week 51 of 1996) through 21 June 1997 (week 25 of 1997) with the exception of week 16 (13–19 March 1997) (Figure 7). Substantial amounts of algae that started to collect in the traps beginning in week 14 (4 April 1997) forced drastic reductions in sampling effort through week 17. The trap was fished only 3.25 h during week 15, with one salmon caught, and 3.0 h during week 16 with no salmon

Table 1. Summary of fish species collected during the lower American River emigration survey, October 1996 through September1997. The species are listed in alphabetical order, by common name

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	1996			1997						
Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total
American shad	4	1	0	0	0	0	0	8	132	145
Bullhead	0	0	0	1	0	0	0	1	1	3
Bluegill	3	22	0	2	0	0	0	6	2	35
Chinook salmon[2/] (fall run)	0	0	319	1,515	14,908	14,115	63	996	114	32,030
Chinook salmon[2/] (spring run)	0	0	0	0	7	9	8	4	0	28
Chinook salmon[2/] (winter run)	0	0	2	1	2	1	0	0	0	6
Gambusia	1	0	6	20	3	0	0	0	0	30
Golden shiner	1	0	3	15	1	2	1	0	0	23
Green sunfish	0	0	0	0	0	1	0	1	0	2
Hardhead	0	0	0	0	1	0	0	0	1	2
Japanese smelt	0	5	58	640	713	464	5	17	28	1920
Lamprey (ammocoete)	4	34	32	114	299	62	11	25	21	602
Lamprey (subadult)	0	4	14	4	5	3	9	10	5	54
Lamprey (adult)	0	2	0	1	2	1	11	37	5	59
Largemouth bass	0	0	4	17	0	0	2	0	7	30
Mississippi silverside	0	0	8	0	0	0	0	0	0	8
Sculpin	0	1	17	10	15	15	2	3	7	70
Smallmouth bass	0	0	1	1	0	0	0	0	0	2
Splittail	0	0	0	0	0	0	0	2	0	2
Squawfish	18	424	28	166	30	7	1	8	79	761
Steehead (YOY)	0	0	0	1	0	6	2	36	4	49
Steelhead (yearling)	0	0	1	50	9	1	1	1	0	63
Striped bass	0	0	0	0	0	0	0	0	1	1
Sucker	1	2	5	19	3	1	2	22	110	165
Threadfin shad	0	2	5	68	232	22	0	0	0	329
Tule perch	1	0	0	0	0	0	0	0	0	1
Warmouth	0	1	0	0	0	0	0	0	0	1
White catfish	0	0	1	1	1	0	0	0	1	4

2/ Chinook salmon race based upon size criteria (F. Fisher, CA Department of Fish and Game).

Table 2. Weekly catch statistics for juvenile fall-run chinook salmon caught during the 1997 lower American River emigration survey, October 1996 through September1997.

Week	Beginning date	Hours fished	Total catch	Catch/h	Size statistics (FL in mm)			
					Mean	Min	Max	SD
51	15 Dec 1996	335	50	0.15	31.9	26	37	2.18
52	22 Dec 1996	263	215	0.82	33.9	28	39	2.16
1	29 Dec 1996	168	123	0.73	33.9	28	40	2.35
2	5 Jan 1997	114.5	275	2.40	33.1	28	41	2.30
3	12 Jan 1997	262.5	427	1.63	35.0	27	41	2.18
4	19 Jan 1997	90.25	203	2.25	35.9	30	42	1.69
5	26 Jan 1997	167.75	541	3.23	36.1	32	43	1.49
6	2 Feb 1997	120.25	1100	9.15	36.3	30	43	1.48
7	9 Feb 1997	190.75	2569	13.47	36.6	27	50	1.56
8	16 Feb 1997	171.5	5139	29.97	36.5	31	53	1.70
9	23 Feb 1997	165	6100	36.97	36.8	30	57	2.25
10	2 Mar 1997	167	5725	34.28	36.9	31	57	2.06
11	9 Mar 1997	143.75	3877	26.97	36.9	31	63	2.63
12	16 Mar 1997	191.75	3036	15.83	36.8	31	66	3.01
13	23 Mar 1997	163.5	1477	9.03	36.8	32	68	2.93
14	30 Mar 1997	170.75	8	0.05	37.0	35	39	1.22
15	6 Apr 1997	3.25	1	0.31	37.0	37	37	0
16	13 Apr 1997	3	0	0.00				
17	20 Apr 1997	67.75	24	0.35	66.4	49	82	9.64
18	27 Apr 1997	166.75	48	0.29	75.6	58	88	7.90
19	4 May 1997	169.75	115	0.68	76.6	60	91	6.44
20	11 May 1997	166.5	320	1.92	76.6	57	94	5.76
21	18 May 1997	169	434	2.57	76.4	55	94	5.85
22	25 May 1997	166.75	109	0.65	77.7	64	102	6.19
23	1 Jun 1997	168.75	74	0.44	80.6	61	93	5.45
24	8 Jun 1997	169.25	25	0.15	80.6	76	88	3.19
25	15 Jun 1997	167	15	0.09	85.3	76	94	6.02
	Total	4303	32030	7.44	40.2	26	102	12.21

caught. The catch-rate increased from 0.15 fish/h in week 51 (of 1996) to 37 fish/h during week 9 (23 February–1 March 1997) (Figure 8). After week 9, catch-rate decreased to less than 10 fish/h by week 13, and then to mostly less than 1 fish/h for the remainder of the sampling period when catch rate only exceeded 1 fish/h during weeks 20 (1.92 fish/h) and 21 (2.57 fish/h) (11–24 May 1997).

Salmon length ranged from 26 to 102 mm FL (Table 2). Mean weekly length ranged from 31.9 to 85.3 mm FL (Table 2, Figure 9). Most (>99%) of the fish collected through March (week 14) were <40 mm FL (Figures 9 and 10). Between 15 December 1996 (week 51) and 5 April 1997 (week 14) mean length increased very gradually from 31.9 mm to 37.0 mm (Figure 9 and 10). Mean length then increased sharply to 66.4 mm FL when trapping effort was increased to normal in week 17 (following the periods of heavy algae), then increased only 18.9 mm in 8 weeks, with the greatest increase occurring between weeks 17 and 18 (9.2 mm).

The length frequency distribution for all fall run exhibited two modes (Figure 11). The first mode ranged from 26 mm to 44 mm FL, peaking at 37 mm FL. This mode contained the majority of salmon caught. The second mode ranged from 46 mm to 98 mm FL, peaking at 78 mm FL.

Life Stage Distribution

The fall-run chinook salmon RST catch in the 1997 survey year comprised 12.5% yolk-sac fry, 35.8% fry, 47.7% parr, 3.9% silvery parr, and 0.01% smolt (Table 3). Life stage distribution in 1997 differed substantially from that observed in 1994, 1995 and 1996 (Table 4). Notably, the proportion of parr caught in 1997 (47.7%) was much greater than in the three previous years, nearly twice as great as the next highest proportion, 25.5% in 1995.

Similarly, the proportion of yolk-sac fry and fry was lower than in previous years. The combined proportion of yolk-sac fry and fry was 48.8% in 1997 compared to 96.7% in 1994, and about 73% in both 1995 and 1996 (Table 4).

Fall-run yolk-sac fry were caught from 16 December 1996 (week 51) to 28 March 1997 (week 13) (Figures 12 and 13). Yolk-sac fry were caught every week between week 51 (1996) and week 13 (1997). The peak yolk-sac fry catch occurred in week 10 (n = 593) with a secondary peak occurring in week 3 (n = 320) (Figure 13). Yolk-sac fry lengths were fairly uniform in 1997 (Figures 13 and 14). Lengths ranged from 26 to 41 mm FL (mean = 34.5 mm FL, SD = 2.05); 95% of yolk-sac fry were between 31 mm and 38 mm FL (Figure 13). Mean weekly length increased from 31.9 mm to 35.6 mm FL between week 51 and week 4 (Figure 13), then leveled off thereafter to about 35 mm.

Fall-run fry were caught from 23 December 1996 (week 52) through 2 April 1997 (week 14); 91% of the catch occurred from week 3 through week 12 (Figure 12). Fry numbers peaked in week 10 (n = 3,784; Figure 13). The fry length distribution was nearly normal (Figure 14); 99% were between 33 mm and 39 mm FL. Fry length ranged from 31 to 42 mm FL (mean = 36.3, SD = 1.41). Mean weekly fry length was relatively constant, ranging from 35.4 to 36.6 mm FL (Figure 13).

Table 3. Weekly life stage distribution of fall-run chinook salmon caught during the 1997 lower American River emigration survey, October 1996 through September1997.

Week	Yolk-sac fry	Fry	Parr	Silvery parr	Smolt	Total
51	50	0	0	0	0	50
52	209	5	1	0	0	215
1	114	9	0	0	0	123
2	252	21	2	0	0	275
3	320	106	1	0	0	427
4	134	69	0	0	0	203
5	95	392	54	0	0	541
6	138	682	279	2	0	1,100
7	334	296	1,937	2	0	2,569
8	475	392	4,267	4	0	5,139
9	553	1,002	4,520	25	0	6,100
10	593	3,784	1,319	29	0	5,725
11	369	2,688	791	29	0	3,877
12	271	1,426	1,295	44	0	3,036
13	110	607	739	22	0	1,477
14	0	2	6	0	0	8
15	0	0	1	0	0	1
16	0	0	0	0	0	0
17	0	0	7	17	0	24
18	0	0	0	48	0	48
19	0	0	2	113	0	115
20	0	0	0	320	0	320
21	0	0	0	429	4	434
22	0	0	40	69	0	109
23	0	0	3	71	0	74
24	0	0	0	25	0	25
25	0	0	0	15	0	15
Total	4,017	11,482	15,263	1,263	4	32,030
Percent	12.5%	35.8%	47.7%	3.9%	0.01%	100%

Table 4. Comparisons of life stage composition of chinook salmon captured during emigration surveys made on the lower American River between 1994 and 1997.

Life stage	1994	1995	1996	1997
Yolk-sac fry		3.5%	22.6%	12.5%
Fry	96.7%	70.5%	59.6%	35.8%
Parr	1.6%	25.5%	17.4%	47.7%
Silvery parr	1.4%	0.1%	4.0%	3.9%
Smolt	0.3%	0.4%	0.00%	<.01%

Fall-run parr were caught from 24 December 1996 (week 52) through 6 June 1997 (week 23) (Figure 12); 99% of the catch occurred between weeks 5 and 13. Parr length ranged from 30 mm to 88 mm FL (mean = 37.4 mm FL, SD = 3.89) (Figures 13 and 14). A strong positive skew in parr length distribution (Figure 14) suggests that the length at which salmon change from parr to silvery parr is more variable than the length at which they change from fry to parr. Nonetheless, >95% of measured parr were between 35 mm and 41 mm FL (Figure 14). Mean weekly parr length varied only slightly through week 15 (mean FL = 37.7, SD = 1.99), although the size range through week 15 was quite variable owing to a few, large parr being captured during weeks 8 through 12 (Figure 13). Mean weekly parr length steadily increased after week 15 through week 23, from 37 mm to 79 mm FL (Figure 13).

Fall-run silvery parr were caught from 2 February 1997 (week 6) to 21 June 1997 (week 25) (Figure 12). Catch peaked in week 21 (n = 429) (Figure 13). There appeared to be two groups of emigrating silvery parr: the first group (n = 157) consisted of early (weeks 6 through 13), relatively small (mean <55 mm FL) migrating fall run; the second group generally increased in both number (n = 1,136) and size (mean >75 mm FL) starting in week 17. Silvery parr ranged in length from 35 mm to 98 mm FL (mean = 76.2 mm FL, SD = 7.83) (Figure 14). Unlike in previous years, there was a distinct peak in the length frequency distribution. A trend toward increasing mean weekly length was exhibited (Figure 13). Mean weekly length increased from <45 mm FL in weeks 6, 7, and 8 to over 80 mm FL in weeks 22 through 25.

Fall-run smolts were only caught during week 21 (Figure 12). Four fall-run smolts were collected, ranging in size from 77 mm to 92 mm FL (Figures 13 and 14).

The length distribution for each life stage was distinct (ANOVA, $p<0.05$).

Condition Factor

As in previous survey years (1994–1996), there was no indication that condition factor in American River chinook salmon declined prior to emigration. K of silvery parr (1.08) and smolts (1.09) was significantly higher than that of fry (0.75) and parr (0.92); K of silvery parr and smolts were not significantly different (Table 5) (ANOVA, $p<0.001$).

Table 5. Condition factor (*K*) statistics by life stage for chinook salmon (>45 mm FL) collected during the lower American River emigration survey, October 1996 through September1997.

K Factor	Fry	Parr	Silvery parr	Smolt
Minimum	0.63	0.47	0.11	1.05
Maximum	0.87	2.86	1.95	1.18
Mean	0.75	0.92	1.08	1.09
Standard deviation	0.08	0.38	0.11	0.05
Sample size	14	127	909	4

Overall, *K* increased with increasing length (Figure 15); the slope of the regression line was significantly different from zero ($p<0.001$). To remove excessive heteroscedasticity introduced by the inclusion of yolk-sac fry and fry not fully metamorphosed, only *K* factors of salmon ≥ 45 mm FL were used in the regression. Further, outlier values of *K* within this group were removed by including only values within ± 2 SD of the mean of the distribution of *K* values.

Mean *K* varied slightly between years (Appendix I). *K* calculated for parr was significantly lower in 1997 (0.92) than in 1994 (1.02) but was significantly higher than in 1995 (0.78) and 1996 (0.77). *K* calculated for silvery parr was lower in 1997 than in 1996, but not significantly different than that calculated in 1994 and 1995 (ANOVA, $p<0.001$). *K* calculated for smolts in 1997 (1.09) was comparable to the *K* values calculated for smolts in 1994 (1.14) and 1995 (1.15).

Mark-recapture/ Trap Efficiency

Trap efficiency was measured from week 4 through 13 (19 January and 29 March 1997). A total of 27,755 salmon was marked; 156 were recaptured for an overall trap efficiency of 0.56%. Percent recapture (efficiency) ranged from 0% (week 4) to 2.4% (week 13) (Figure 16; Table 6). Mean weekly trap efficiency was 0.75%. Percent recapture showed no relationship to flow (r^2 = 0.004), Secchi depth (r^2 = 0.190), trap rotation velocity (r^2 = 0.016), number of fish marked (r^2 = 0.149), number of total fish caught (r^2 = 0.098), average FL of fish caught (r^2 = 0.002), or trapping effort (r^2 = 0.067).

Estimated Abundance of Emigrating Fall-run Chinook Salmon

The total number of fall-run chinook salmon emigrating from the lower American River in 1997 was estimated using the mean trap efficiency of 0.75%. The total number of captured fall run (*n* = 32,030) was divided by mean efficiency to yield an estimated 4.3 million salmon. This number is intended to be used as an index of emigration rather than an absolute measurement.

Table 6. Results of rotary screw trap efficiency evaluation conducted with marked chinook salmon during the lower American River emigration survey, October 1996 through September1997.

Week	Number salmon marked	Number salmon recaptured	Efficiency (% recaptured)
4	151	0	0
5	450	7	1.56
6	1,042	6	0.58
7	2,482	11	0.44
8	5,090	25	0.49
9	5,338	29	0.54
10	5,664	24	0.42
11	3,820	20	0.52
12	2,926	15	0.51
13	792	19	2.40
Total	27,755	156	0.56 (mean = 0.75%)

Spring-run-sized Chinook Salmon

Spring-run-sized chinook salmon were periodically captured from week 6 to week 20 (Table 7). Overall, 28 spring-run-sized chinook were collected. Nine of the 28 were marginally larger (within 2 mm FL) than the minimum size defining spring run for the date captured. Three of the 28 were adipose clipped. The data obtained from the coded wire tags collected from these three fish identified the salmon as fall run produced at Feather River Hatchery and planted on 15 April 1997 in the Sacramento River, immediately downstream from the mouth of the American River, at Miller Park. The fish were planted as part of a trawling survey evaluation conducted by the U.S. Fish and Wildlife Service.

Twenty-five spring run were classified as silvery parr; three were classified as smolts. Two smolts were collected during week 18 and one during week 20.

Winter-run-sized Chinook Salmon

Six winter-run-sized chinook salmon were collected by RST (Table 8). These fish were captured between 16 December 1996 (the first date that salmon were captured in this survey year) and 2 March 1997. All winter run were well within the size range defining winter-run juveniles for the dates of capture. The first two winter run collected (16 December 1996) were classified as silvery parr. The other four winter run were all classified as smolts.

Table 7. Summary of catch statistics for spring-run-sized chinook salmon collected during the 1997 lower American River emigration survey, October 1996 through September1997.

			Size statistics			
Week	Beginning date	Total catch	Mean	Min	Max	SD
6	2 Feb 1997	1	59.0	-	-	-
8	16 Feb 1997	5	60.2	57.0	64.0	2.56
9	23 Feb 1997	1	74.0	-	-	-
10	2 Mar 1997	5	63.2	62.0	65.0	1.47
11	9 Mar 1997	3	68.7	67.0	71.0	1.70
12	16 Mar 1997	1	68.0	-	-	-
17	20 Apr 1997	3	91.0	85.0	98	5.35
18	27 Apr 1997	5	96.4	90.0	106	6.71
19	4 May 1997	2	97.5	96.0	99.0	1.50
20	11 May 1997	2	108.0	105.0	111.0	3.00
	Total	28	78.2	57.0	111.0	17.49

Table 8. Summary of catch statistics for winter-run-sized chinook salmon collected during the 1997 lower American River emigration survey, October 1996 through September1997.

			Size statistics			
Week	Beginning date	Total catch	Mean	Min	Max	SD
51	15 Dec 1996	2	74.0	72	76	1.0
3	12 Jan 1997	1	97	-	-	-
6	2 Feb 1997	1	96	-	-	-
8	16 Feb 1997	1	104	-	-	-
10	2 Mar 1997	1	115	-	-	-
	Total	6				

Steelhead Trout

Juvenile steelhead captured in the RST represented three different groups: young-of-the-year (typically <100 mm FL), and both in-river and hatchery-produced yearlings (typically 100–300 mm FL) (Table 9).

The first YOY steelhead was captured during week 3 (12 January 1997). This is the earliest that a YOY steelhead has been captured since emigration monitoring on the lower American River was initiated in 1993. Previously, the earliest capture of a YOY steelhead occurred during early March, in 1996 (Snider et al. 1998). Forty-eight more YOY steelhead were subsequently captured in 1997 between week 13 (23 March 1997) and the end of the survey (21 June 1997) (Figure 17). Most YOY (86%) were captured after week 16. Mean length increased steadily from 31 mm FL in week 13 to 78 mm FL in week 25 (Figure 18).

YOY steelhead lengths ranged from 28 mm FL to 96 mm FL (Table 9). The largest YOY steelhead was captured during week 25 (96 mm FL).

Life stage was identified for 45 of the 49 YOY steelhead (Table 10). Five were classified as fry, 36 as parr, and four as silvery parr.

In-river produced yearling steelhead (*n* = 42) were caught from week 52 (22 December 1996) through week 18 (3 May 1997) (Table 9; Figure 17). Fish length ranged from 137 mm to 267 mm FL (Figure 18). The smallest yearling steelhead (137 mm FL) was collected during week 52 of 1996. The majority (34 fish, 81%) of these fish was collected during weeks 2 and 3 (5–18 January 1997).

Life stage was determined for 14 of the 42 in-river produced yearling steelhead (Table 10). Two of these yearlings were classified as parr, four as silvery parr and eight as smolts.

Twenty-one hatchery-produced yearling steelhead were collected between week 3 (12 January 1997) and week 18 (3 May 1997) (Figure 17). The majority (20 fish, 95%) of these fish was collected from week 3 through week 7 (12 January–15 February 1997). All of the hatchery-produced steelhead were classified as smolts (Table 10).

Table 9. Catch statistics for steelhead caught during the 1997 lower American River emigration survey, October 1996 through September1997.

	Young of the year		Yearling (in-river)		Yearling (hatchery)	
Week	Count	Mean FL (mm) and range	Count	Mean FL (mm) and range	Count	Mean FL (mm) and range
51						
52			1	137.0		
1						
2			20	228.1 (220–250)		
3	1	31	14	204.2 (140–255)	10	216.0 (172–262)
4					4	236.8 (216–251)
5			2	220 (173–267)		
6					1	201
7					5	235.6 (212–258)
8						
9			3	227.3(189–248)		
10						
11						
12						
13	3	33.2 (28-33)	1	160		
14						
15						
16						
17	1	36				
18	3	42 (39-45)	1	195	1	237
19	2	53.5 (51-56)				
20	6	45.8(39-45)				
21	20	55.1 (44-64)				
22	6	59.3 (48-72)				
23						
24	1	84.0				
25	3	78.0 (51-96)				
26						
Total	49	52.0 (28-96)	42	215.1 (137–267)	21	225.0 (172–262)

Table 10. Life stage composition by age and origin for steelhead caught during the 1997 lower American River emigration survey, October 1996 through September1997.

	Young of the year		Yearling (wild)		Yearling (hatchery)	
Life stage	Count	Mean FL (mm) and range	Count	Mean FL (mm) and range	Count	Mean FL (mm) and range
Fry	5	34.2 (28–39)	0		0	
Parr	36	52.9 (33–84)	2	186.5 (185–188)	0	
Silvery parr	4	72.8 (51–96)	4	164.3 (137–207)	0	
Smolts	0		8	213 (160–267)	20	224.5 (172–262)

Comparison with Concurrent Seine Survey

Chinook Salmon

Seining surveys in the lower American River were conducted in weeks 3 through 10, 13, 15, 18, 19, 21 and 26 of 1997. The trend in catch distributions between seining and trapping was distinctly different (Figures 19 and 20). Catches in the trapping survey were bimodal, with a large peak in week 9 consisting mostly of fry and parr, and a secondary peak in week 21 consisting of silvery parr and smolts. In contrast, catches in the seining survey were trimodal, with peaks in weeks 4, 7, and 15. The greatest peak was that during week 7 (9–15 February 1997). Trapping effort during weeks 15 and 16 was near zero, owing to debris problems, as discussed above. The reduced effort would account for the low trap catches during week 15.

Size-at-time statistics for seine and RST caught salmon also differed (Figure 20). The mean size of RST caught salmon remained fairly constant through week 15 as the RST catch was dominated by recently-emerged fish. In contrast, the mean size of seine caught salmon during this period showed an increase between weeks 3 and 6 then a slight decline during weeks 10 and 13. Seine caught salmon during this period were consistently larger than RST caught salmon. The mean size of seine caught fish showed a consistent, gradual increase from week 10 through week 26; the mean size of RST caught fish showed a sharp increase after week 15 when recently emerged-sized fish disappeared from the RST catch, but not from the seine catch.

The weekly life-stage distribution differed slightly between seine and RST catches (Table 12, Figures 21 and 22). Yolk-sac fry and fry disappeared from the RST catch after week 13. Some yolk-sac fry and fry were captured by seine after week 13, although the proportion declined substantially after week 13 and dropped to nearly zero by week 18. (The reduced effort in trapping in week 15 would explain the apparent earlier cessation of these life stages in the RST catches). Relative composition of fry and parr differed slightly between the two surveys. During the earlier weeks (weeks 3-6) fry were more abundant in the RST while parr were more abundant in the seine catches. The reverse was true during weeks 7-9.

Table 12. Weekly life-stage compositions of chinook salmon caught concurrently by seine and rotary screw trap during the 1997 lower American River emigration survey, October 1996 through September 1997.

	Week	Catch (*n*)	Percent distribution				
			Yolk-sac fry	Fry	Parr	Silvery parr	Smolt
Seine	3	35	97.1	2.9	0	0	0
	4	452	86.5	11.3	2.2	0	0
	5	117	18.0	35.0	45.3	1.7	0
	6	331	1.8	2.4	95.8	0	0
	7	1,362	2.9	16.8	80.3	0	0
	8	940	2.0	59.6	38.4	0	0
	9	163	3.1	40.5	56.4	0	0
	10	151	15.9	72.9	11.2	0	0
	13	471	2.6	56.8	40.6	0	0
	15	1,213	0.5	8.2	91.3	0	0
	18	723	0.3	0.6	50.2	48.9	0
	19	100	0	0	1	99	0
	21	131	0	0	1.5	985	0
	26	6	0	0	0	100	0
	Total	6,195	9.1	23.2	58.2	9.5	0
Rotary screw trap	3	397	75.3	24.2	0.3	0	0.3
	4	203	68.0	32.0	0	0	0
	5	541	18.9	71.3	9.8	0	0
	6	1,102	14.2	60.6	24.8	0.3	0.1
	7	2,171	13.0	11.5	75.4	0.1	0
	8	1,250	9.2	7.6	82.7	0.4	0.1
	9	993	9.1	16.4	74.0	0.5	0
	10	1,000	10.3	65.8	22.9	1	0
	13	748	8.4	40.6	49.4	1.5	0
	15	1	0	0	100	0	0
	18	53	0	0	0	96.2	3.8
	19	101	0	0	2.0	98.0	0
	21	329	0	0	0	99.1	0.9
	26	0	0	0	0	0	0
	Total	8,889	15.2	30.2	48.8	5.7	0.1

Steelhead Trout

The age (size) composition of both the seine and trap catches were comparable throughout the survey period (Table 9 and 13, Figure 23). Yearling steelhead dominated both the trap and seine catches through week 9 (1 March 1997). YOY steelhead dominated both the trap and seine catches after week 10. The seine catches were substantially greater than the trap catches for all ages throughout the survey. A total of 869 yearling steelhead (440 hatchery produced and 429 in-river produced steelhead) were captured by seine between weeks 3 and 9. In contrast, only 63 yearling steelhead were collected by RST during the entire survey. Similarly, over 1,000 YOY steelhead were collected by seine, 49 by RST. Comparison of the two gear type's results indicate that the RST appears to represent the temporal distribution of migration (emigration for yearlings, in-river migration for YOY), but does not appear to adequately reflect the relative abundance of yearling migrants.

Pacific Lamprey

Three lamprey life stages were collected: ammocoetes, the blind, filter-feeding larval stage; juveniles, recently metamorphosed from the ammocoete stage to a small, eyed form; and relatively large (>300 mm total length, TL) adults returning from the ocean to spawn (Table 1).

Ammocoetes (n = 602) were periodically collected from week 40 of 1996 (4 October 1996) through week 25 (16 June 1997, the last week of sampling) (Figure 24). The greatest weekly catch (n = 144) was during week 7 (9–16 February 1997). Juvenile lamprey (n = 54) were periodically collected from week 46 (13 November1996) through week 25 (Figure 24). Fifty-nine adult lamprey appeared in the trap from week 45 (7 November 1996) through week 23 (9 June 1997).

American Shad

A total of 145 American shad were trapped in the 1997 survey year (Figure 25).

Table 13. Catch and size statistics for steelhead collected by seine during the 1997 lower American River emigration survey, October 1996 through September 1997.

				Size data (FL in mm)	
Week	Seine hauls	Catch	Catch/haul	Mean	Range
3	13	114	8.8	228.6	115-390
4	23	636	27.7	225.8	138-339
5	26	2	0.08	182.0	166-198
6	31	3	0.01	175.0	122-212
7	27	4	0.15	190.0	190.0
8	28	321	11.5	222.8	118-294
9	26	140	5.4	226.7	25-288
10	26	4	0.15	163.5	29-225
13	46	2	0.04	121.5	23-220
15	54	9	0.17	111.8	22-230
18	40	241	6.0	30.5	21-45
19	11	36	3.3	33.9	21-42
21	49	626	12.8	39.1	21-69
26	48	149	3.1	69.2	38-103
Total	448	2,287	5.1		

DISCUSSION

Several significant findings are contained in the emigration data above.

- The timing of both fry, or recently-emerged salmon (<50 mm FL), and fingerling (>50 mm FL) emigration was substantially different from that recorded before construction of the Folsom Complex (1945–1947), and somewhat different from that observed in 1994 and 1996.

  The only data on salmon emigration in the lower American River prior to construction of the Folsom Project detected fry and fingerling emigration substantially later than post-Folsom Project evaluations (i.e., the 1988 and 1989 trawling surveys and the 1994, 1995, 1996 and 1997 trapping surveys). The 1944–1946 brood stocks had access to the upper reaches of the American River. Thus, the 1945–1947 emigration timing may have been due to possible differences in spawning and adult migration timing, longer incubation, later emergence, and slower growth associated with typically colder, more oligotrophic conditions found in the upper reaches of the American River. Relatively earlier emergence and emigration currently observed in the lower river is also likely a result of the temperature-moderating effect of lakes Folsom and Natoma.

- Emigration in 1997 was substantially later than in 1996 and somewhat earlier than observed in 1994. It was comparable to that observed in 1995.

  Emigration in 1997 began and peaked approximately three weeks earlier than in 1994 and one month later than in 1996; it was nearly identical to that observed in1995. Water temperature during incubation may have played a role. Average water temperature in December 1996, prior to the 1997 emigration, was 51.4 ºF, comparable to that observed in December 1994, prior to the 1995 emigration, (52.0 ºF) when timing was very similar. However, it was substantially cooler than in December 1995, prior to the 1996 emigration (55.7 ºF), when timing was substantially earlier, and somewhat warmer than in December 1993 (48.9 ºF), prior to the 1994 emigration, when timing was relatively later.

- Using length as the sole criterion for distinguishing life stages is unreliable.

  Hoar (1976) speculated that smolt characteristics such as decreased condition and silvering were associated with length. Our results indicate that such length criteria should be applied with caution. Condition factor actually increased with FL in 1997, and silvering occurred over a range of lengths (silvery parr were as small as 38 mm, and parr as large as 113 mm FL).

Condition factor (K) increased with FL in all size classes in 1997. Since smolting is typically associated with a drop in lipid content and a decrease in K, it is apparent that all the fish caught in 1997 required further growth and development in the downstream environs of the Delta and estuary before fully transforming into smolts. This finding is consistent with those for the three previous survey years.

The proportion of fry, parr, silvery parr and smolt emigrants is variable from year to year. Notably, the proportion of parr in 1997 (47.7%) was considerably higher than in the three previous survey years. The combined fry and yolk-sac fry fraction in 1997 (48.3%) was the lowest observed during the three survey years (Appendix I). The early high flows may have killed many of the salmon that would have otherwise emerged early and emigrated as fry, resulting in a smaller number, thus smaller proportion of the catch.

- The estimated number of juvenile emigrants appears to be strongly influenced by flow during the incubation period (primarily January) (Figure 26).

Mean flow in January 1997 (32,617 cfs) was substantially greater than that observed during any of the previous three survey years (1,755 cfs in 1994, 2,186 cfs in 1996, and 8,576 cfs in 1995). Those years when January flows were stable and flood events were absent (flow <25,000 cfs) also produced the highest, estimated total emigration population (total catch/mean efficiency) (Appendix II).

The estimated total emigration population was not related to spawner population ($r^2 = 0.0001$) (Appendix II). The highest estimated spawner escapement (68,000 salmon in 1995) yielded the second highest emigration population estimate (1996 survey year); the second highest estimated spawner escapement estimate (67,000 salmon in 1996) yielded the lowest emigration population estimate (1997 survey year). The highest estimated emigration population occurred in the 1994 survey year following the second lowest spawner escapement population (28,754 in 1993).

An index of survival to emigration (estimated emigration population/escapement estimate) was negatively correlated with both mean January flow and peak January flow ® = –0.743) (Appendix II; Figure 26).

- RST efficiency appears to be consistently low in large rivers.

Efficiencies of less than 1% are extremely low, but are consistent with other efficiency rates for similar traps in similarly large rivers (Snider and Titus 1998; C. Hanson, Hanson Environmental, Inc., pers. comm.). Efficiencies in the Trinity River, California, reported by Goldsmith (1993) ranged from 0.3 to 5.6%. Thedinga et al. (1994) reported 24% efficiencies for chinook salmon using RST with fences that fished 6–11% of the cross section of a 24 m wide stream. Kennen et al. (1994) reported efficiency estimates ranging from 11.2 to 17.3% for chinook salmon smolts in a small, 7–9 m wide stream.

A mark-recapture study of the lower American River RST in 1994 revealed a mean trap efficiency of 0.72%, comparable to that observed in 1996 (0.68%) and 1997 (0.75). Increasing the number of traps or using additional capture methods (e.g., Kodiak trawl, round-fyke traps) could increase the cumulative efficiency. Improving marking techniques could improve our ability to measure efficiency.

- The downstream environs are very important to the survival of lower American River fall-run chinook salmon.

As in the previous three survey years, nearly all (>99%) emigrating chinook salmon observed in 1997 were pre-smolts. These findings suggest that the smolting process is not completed in the lower American River, but will continue downstream, likely in the Delta and the estuary. These facts point to the importance of the downstream environs to ultimate survival of American River chinook salmon.

ACKNOWLEDGMENTS

Survey data were gathered by: Katherine Berry, Brigid Payne, Mike Stiehr, Shawn Oliver, Tiffany Meyer, Doug Post, Al Daniel, and Patrick Garrison. A special thank you is given to Katherine Berry and Brigid Payne for their assistance in management and analysis of the survey data and preparation of this report.

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APPENDICES

Appendix I. Comparison of results from lower American River emigration surveys conducted 1994 through 1997.

	Year			
	1994	1995	1996	1997
Salmon emigration start date	Week 2 (of 1994)	Week 51 (of 1994)	Week 48 (of 1995)	Week 51 (of 1996)
Salmon emigration end date	Week 28	Week 32	Week 29	week 25[1/]
Date of peak salmon catch	23 Feb	24 Feb	26 Jan	25 Feb
Maximum daily salmon catch	14,887	3,371	12,285	3,083
Maximum daily salmon catch rate	677 fish/h	141 fish/h	614 fish/h	54 fish/h
Total estimated salmon catch	162,089	45,478	132,040	32,064
Total estimated steelhead catch	43	30	145	112
Total estimated American shad catch	91	522	46	145
Total estimated Pacific lamprey catch	321	247	499	715
Average juvenile salmon catch	30.4 fish/h	9.6 fish/h	25.6 fish/h	7.44
<u>Salmon life stage composition</u>				
Yolk-sac fry	96.7%[2/]	3.5%	22.3%	12.5%
Fry		70.5%	50.7%	35.8%
Parr	1.6%	25.5%	20.6%	47.7%
Silvery parr	1.4%	0.1%	2.3%	3.9%
Smolt	0.3%	0.4%	--	0.01%
<u>Salmon condition factors (mean)</u>				
Yolk-sac fry	0.79 [2/]	0.93	0.74	0.87[3/]
Fry		0.74	0.69	0.75
Parr	1.02	0.78	0.77	0.92
Silvery parr	1.07	1.05	1.11	1.08
Smolt	1.14	1.15	--	1.09

1/ Trapping was ended before catches reached zero.
2/ Yolk-sac fry and fry combined as one life stage in 1994.
3/ Only includes fish ≥ 40 mm FL

Appendix II. Comparison of results from lower American River emigration surveys conducted 1994 through 1997 and corresponding spawner escapement and incubation flows.

	Year			
	1994	1995	1996	1997
Total catch	162,089	45,478	132,040	32,064
Mean efficiency	0.72	0.72[1/]	0.68	0.75
Estimated emigration population	18.2 million	5.9 million	19.4 million	4.3 million
Spawner escapement	28,754	27,733	68,000	67,000
Emigration survival index	633.4	213.0	285.6	63.8
Mean January flow	1,755	8,552	2,186	32,617

1/ Estimated as the mean efficiency observed during 1994, 1996 and 1997.

FIGURES