State of California
The Resources Agency
Department of Water Resources
Environmental Services Office

FEATHER RIVER STUDY
CHINOOK SALMON EMIGRATION SURVEY

March – June 1996

November 1999

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Summary

This report presents the results of the first season (March through June 1996) of the Feather River Study salmon emigration survey. This emigration survey served as a pilot study for sampling, operation, and mooring of the rotary screw fish traps (RSTs).

Two RSTs were used to collect salmon emigration data from the lower Feather River. One RST was deployed at the downstream end of the low flow channel (approximately river mile (rm) 60), hereafter referred to as the Thermalito RST. A second RST was deployed downstream of Honcut Creek (the lower end of the study area) at approximately rm 42, hereafter referred to as the Live Oak RST. The intent was to fish the RSTs from January through June 1996, but delays in delivery of the RSTs from the manufacturer and high flow conditions in February prevented RST deployment until early March.

Data were collected on chinook salmon and steelhead, as well as other fish species captured in the RSTs. A total of twenty-four species was caught. A total of 17,078 juvenile salmon was caught between 3 March and 30 June 1996. Of the total catch, 14,514 salmon were captured in the Thermalito RST and 2,564 were captured in the Live Oak RST. Salmon size ranged from 25 to 121 mm fork length. Salmon emigration probably peaked sometime in January or February, but the peak could not be identified since RSTs were not deployed until the beginning of March. A total of 83 young-of-the-year and 15 juvenile steelhead of other age classes were captured between 8 March and 30 June 1996.

Despite the small 1996 Feather River data set, there were some similarities with 1996 salmon emigration data from lower American River. RST efficiencies were similar as were the overall and weekly numbers, mean fork lengths, and size ranges of salmon caught during weeks 10 through 26 of both surveys. The 1996 data were also comparable to historical Feather River salmon catch, mean sizes (fork length), and size ranges.

Introduction

In 1991, the California Department of Water Resources (DWR), in cooperation with the California Department of Fish and Game (DFG), began the Feather River study to examine the effects of temporary water transfers between the State Water Project and Yuba County Water Agency on chinook salmon and other fish. The initial study sought to determine the effect of flow on fish habitat. Study objectives included the development of a flow model using Instream Flow Incremental Methodology (IFIM) and a temperature model.

In 1995, the study was expanded to gather fishery data in support of the Federal Energy Regulatory Commission (FERC) relicensing of the State Water Project's Oroville Complex and to address issues raised by the Central Valley Project Improvement Act's (CVPIA) Anadromous Fish Restoration Program (USFWS 1997). To this end, DWR initiated a number of studies in the lower Feather River consisting of five major elements: (1) chinook salmon spawning; (2) chinook salmon emigration; (3) chinook salmon spawning gravel evaluation; (4) hatchery tagging program; and (5) a Feather River literature database.

One of the primary elements of the Feather River study is the salmon emigration survey. This element examines the timing and magnitude of emigration of naturally produced salmon relative to different physical conditions and spawning activity during the previous fall. Although the main focus is salmon, useful data are also collected on steelhead, splittail, and other fish species.

Emigration is monitored primarily using rotary screw fish traps (RSTs). RSTs are sturdy, relatively easy to move within the stream, relatively easy to operate and maintain, are able to capture fish without harm in fast-moving water, and can sample continuously. Two RSTs are installed, one at the lower end of each of the two study reaches, and operated for approximately six months (mid-December through June). Two RSTs are necessary because flow is more strictly regulated in the low flow channel flow than in the reach below Thermalito Outlet, and therefore emigration cues and species composition may be different for the two reaches.

The emigration of salmonids and other species has not been monitored in the Feather River since the 1970s (Painter and others 1977). The US Fish and Wildlife Service and the DFG have recently increased their fish monitoring activities (using RSTs and other gear) in the Sacramento River and San Joaquin River systems. This study will make a valuable contribution to the increasing pool of knowledge about fish populations in the Central Valley and provide useful information about fish movement in the Feather River. Other relevant salmon monitoring on the lower Feather River consists of a chinook salmon spawning survey (carcass counts) and an angler survey conducted by the DFG.

The emigration survey objectives aim to achieve the following:

1. Document general salmon emigration attributes, such as timing and abundance.

2. Investigate the influence of factors thought to initiate emigration, such as flow, turbidity, and water temperature.

3. Develop annual juvenile salmon production indices by relating information on spawning intensity to emigration data. The indices will be used to examine the effects of different physical and biological factors on Feather River salmon production.

Methods

Study Area

The lower Feather River (Figure 1) is located within the Central Valley of California, draining an extensive area of the western slope of the Sierra Nevada. The reach between Oroville Dam and the confluence with the Sacramento River is of low gradient. Above Lake Oroville, the river has three forks, the North Fork, Middle Fork and South Fork, which converge at the lake. Lake Oroville, created by the completion of Oroville Dam in 1967, has a capacity of approximately 3.5 million acre-feet (maf) of water and is a multi-use reservoir providing flood control, water supply, power generation, and recreation. Flow in the lower Feather River below the reservoir is regulated through releases from Oroville Dam, Thermalito Diversion Dam, and the Thermalito Afterbay Outlet. Under normal operations, the majority of water released from Lake Oroville is diverted at Thermalito Diversion Dam into the Power Canal and Thermalito Forebay (Figure 2). The remainder of the flow, typically 600 cubic feet per second (cfs), flows through the historical river channel, typically referred to as the “low flow channel.” Water released from the forebay is used to generate power as it is discharged into Thermalito Afterbay. Water is returned to the Feather River through Thermalito Afterbay Outlet, then flows southward through the lower reach to the confluence with the Sacramento River at Verona. The Feather River study area (Figure 2) is 23 river miles long and consists of the low flow channel, which extends from the Fish Barrier Dam (river mile [rm] 67.25) to Thermalito Outlet (rm 59), and a lower reach from Thermalito Outlet to Honcut Creek (rm 44). The confluence with the Yuba River (rm 27.5) is 16.5 river miles further downstream from Honcut Creek. The study is focused on the upper 23 river miles (rm 44 to 67) of the lower river because it is the portion of the river where salmonid spawning occurs. River miles 0 to 44 are comprised mostly of flatwater habitat with substrates consisting mostly of fines.

The Fish Barrier Dam, just downstream of the Thermalito Diversion Dam, is the upper limit for upstream migrating fish. The base of the Fish Barrier Dam is where the fish ladder begins, guiding fish into Feather River Hatchery. The hatchery was built by DWR to mitigate for loss of chinook salmon and steelhead spawning and rearing habitat resulting from construction of Oroville Dam.

Data Collection

The primary sampling devices used for the emigration survey were two eight-foot RSTs. An RST operates in the following manner to capture fish: with the trapping cone lowered into flowing water, water strikes the baffles on the inside of the trapping cone, causing the cone to rotate. Fish enter the upstream end of the rotating trapping cone, become trapped inside the trapping cone, and are carried rearward into a livebox. One RST was placed at the downstream end of the low flow channel at approximately rm 60, just upstream of the Thermalito Outlet (Figure 2). The other was placed in the lower reach near the town of Live Oak (approximately RM 42) (see Figure 2). Separate RSTs are needed because the operation of the Oroville Complex results in two substantially different flow regimes: flow in the low flow channel is more strictly regulated and is generally relatively low and constant; the lower reach (below Thermalito Outlet), is subject to flow fluctuations and flows usually range from 750 to 40,000+ cfs during emigration. Because the flows can be so different in the two reaches, emigration cues and species composition may differ. The RST sites were selected based on the following criteria for RST installation, operation, and maintenance: (1) suitable depth (greater than six feet at minimum flow); (2) suitable velocity (greater than two feet per second at minimum flow); (3) suitable anchoring point(s); and (4) relatively limited public access.

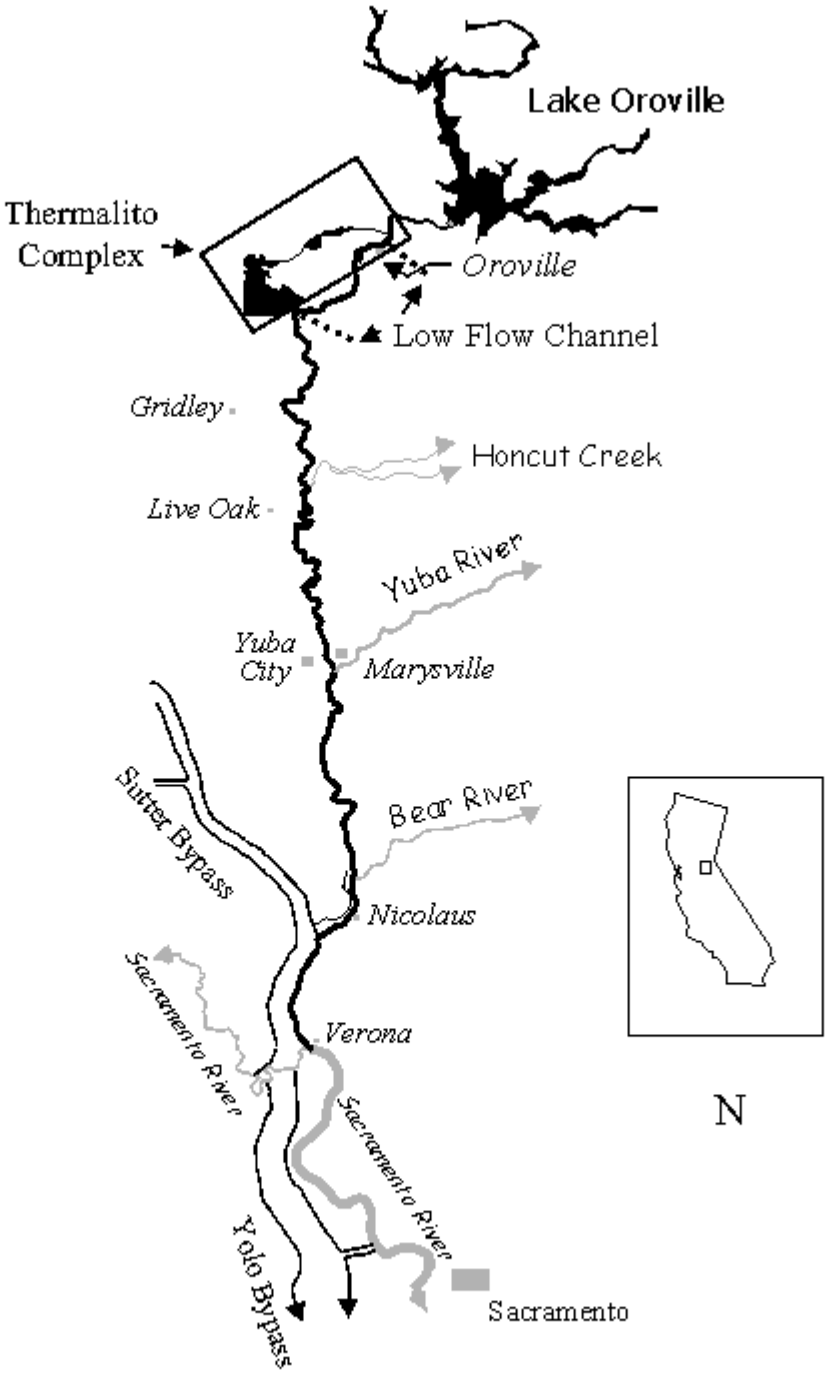


Figure 1 Lower Feather River and associated tributaries between Oroville Dam and the confluence with the Sacramento River

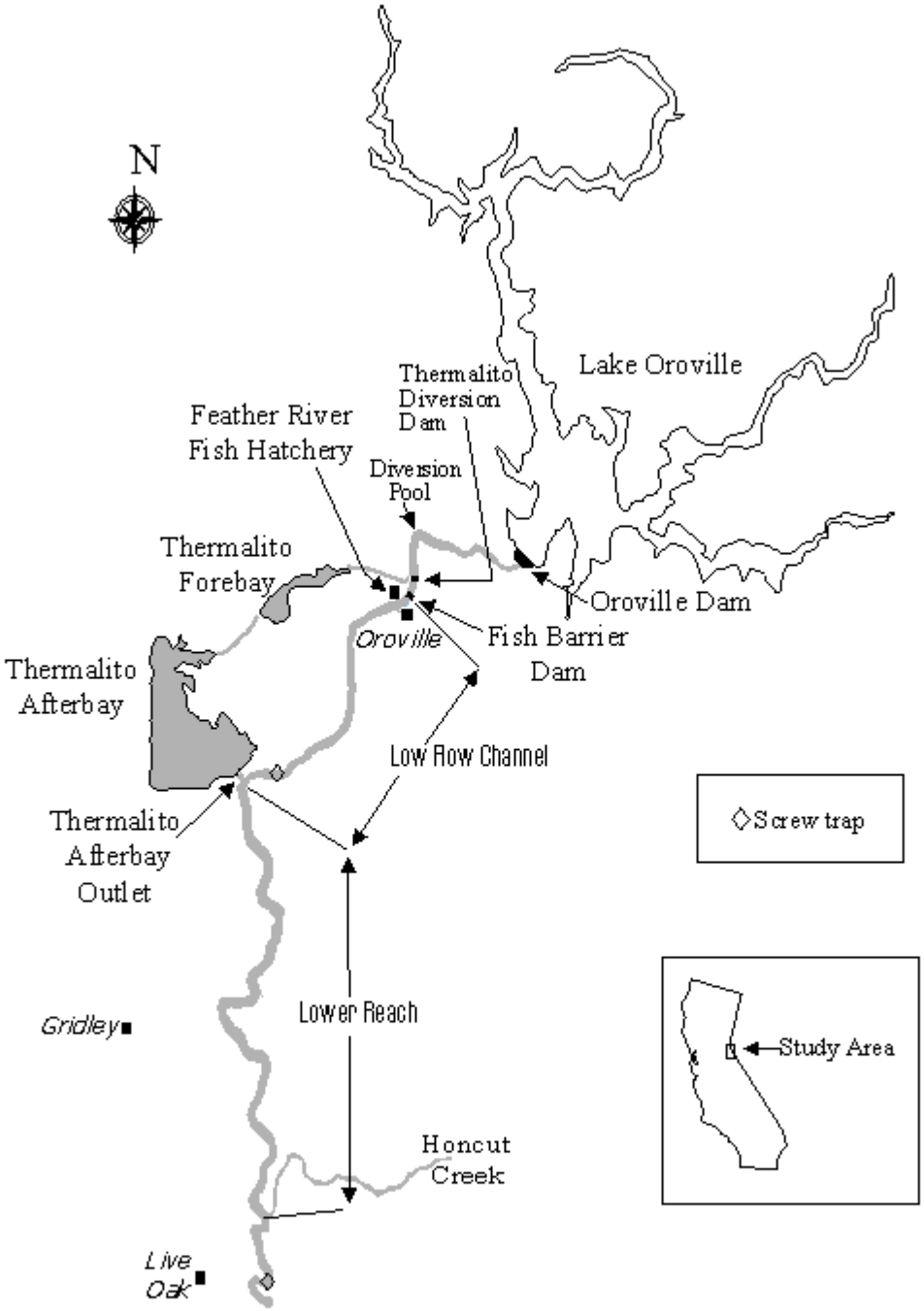


Figure 2 Feather River study area

The intent was to fish the RSTs continuously for six months (January through June) during the expected period of chinook salmon emigration. Delays in delivery of the RSTs from the manufacturer during January and high flow conditions in the river during February delayed RST deployment until March. The RSTs were deployed 3 March 1996 at Live Oak and 7 March 1996 at Thermalito and fished continuously for four months (March through June 1996), except for short periods when river conditions became unsafe. Both RSTs were serviced at least once a day in the morning and more often when the amount of debris warranted it. During servicing, trapped fish were removed from the livebox, identified to species, and counted. Fork length (FL) was measured to the nearest millimeter for up to 50 individuals of each species.

Other data were also collected daily at each RST: water clarity (secchi depth), water temperature, the length of time the RST fished during the sample period (number of hours fished since last service), average trapping cone revolutions per minute, and the total number of trapping cone revolutions during the sampling period. These parameters were selected to increase consistency of this project with other fish monitoring projects occurring in the Sacramento River system. Flow data came from DWR records of releases from Oroville Dam and Thermalito Afterbay Outlet.

RST efficiency was evaluated mostly using fish collected in the RST or by supplemental seining, however one set of evaluations was conducted with spray-dyed hatchery salmon. Fish collected from the river were marked by clipping a lobe of the caudal fin and released approximately one kilometer upstream of each RST. RST catch was monitored for four days after marked fish were released to obtain the number of recaptures. Two evaluations were attempted for the Thermalito RST, but only one was successful. One successful evaluation was conducted for Live Oak RST. An additional evaluation was attempted at both RSTs using spray-dyed hatchery fish, but was unsuccessful due to dye-retention problems and consequent difficulties in detecting recaptures.

RST efficiency values were used to calculate a “partial” estimate of the number of fish emigrating from the low flow channel and the lower reach. This “partial emigration estimate” was calculated by dividing the total salmon catch in a RST by the RST efficiency value for that RST:

$$\text{Emigration Estimate} = \text{Total catch in RST} \div \text{RST efficiency value}$$

Results

Sampling Period

The Thermalito RST was deployed from 3 March through 30 June 1996. It fished continuously except for one eight-day period in May (17 to 24 May 1996) when it was not fished due to flood control releases (1,800 to 10,000 cfs) in the low flow channel. The Live Oak RST was deployed from 4 March through 30 June 1996 and was fished continuously for the three months the RSTs were deployed.

Flows

During the emigration survey, low flow channel flows stayed at the typical level of 600 cfs except for the flood control release in May. Lower reach flows ranged from 1,500 to 23,000 cfs (Figure 3). Prior to RST deployment, January and February flows ranged from 600 to 21,500 cfs in the low flow channel and from 2,550 to 44,000 cfs in the lower reach.

Water Temperature

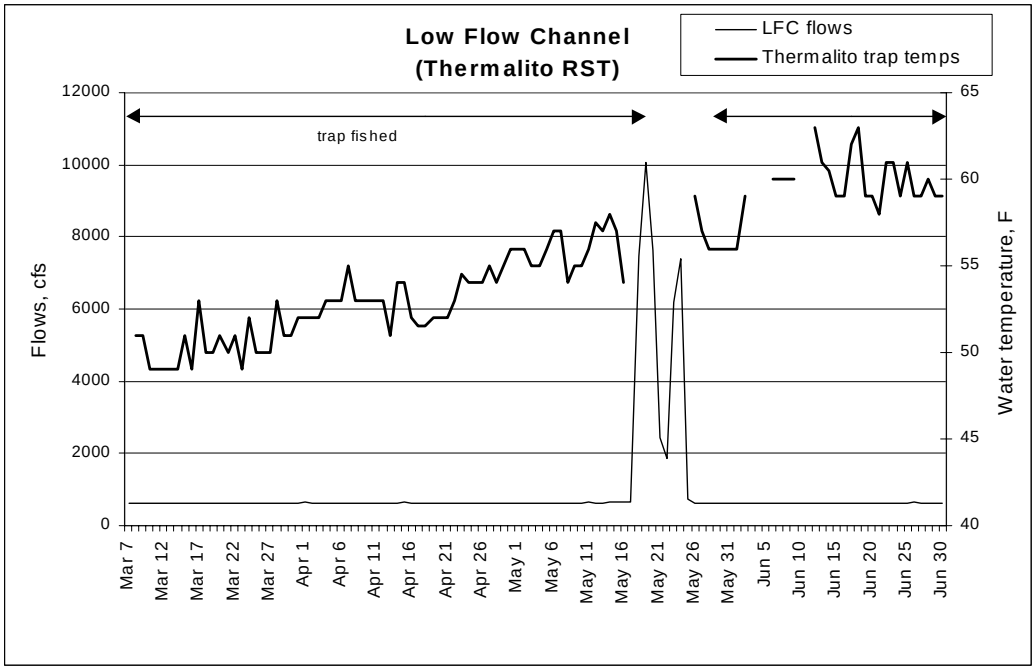
From March through June, water temperature (see Figure 3) ranged from 49 to 63 °F at the Thermalito RST and 49 to 71 °F at the Live Oak RST. In the lower reach there was a gradual increase in water temperature throughout the sampling season with some indication of an inverse correlation with river flow (r = -0.6, P = 0.05).

Water Clarity

Water clarity typically varied with flows and rain events. Secchi depth ranged from 0.89 to 6.6+ feet (2.00+ meters) at the Thermalito RST and 1.8 to 6.6+ feet (0.55 to 2.00+ meters) at the Live Oak RST (Figure 4). It is typical for low flow channel water clarity to remain high because flows are usually constant and low. Lower reach water clarity can be influenced by flow fluctuations, water quality in the afterbay, and discharges from agricultural land adjacent to the river.

RST Catch

Of the 24 species caught, 11 were native species and 13 were introduced species (Table 1). The ten species or species groups in highest abundance were as follows (in order of prevalence): chinook salmon (*Oncorhynchus tshawytscha*), Sacramento sucker (*Catostomus occidentalis*), juvenile cyprinids, wakasagi (*Hypomesus nipponensis*), largemouth bass (*Micropterus salmoides*), prickly sculpin (*Cottus asper*), juvenile lamprey (ammocetes, most likely Pacific lamprey, *Lampetra tridentata*), juvenile centrarchids (non-*Micropterus* species), bluegill (*Lepomis macrochirus*), and Sacramento squawfish (*Ptychocheilus grandis*). Total catch (both RSTs combined) was dominated by chinook salmon (59% of total catch). Thermalito RST total catch was 83% salmon and Live Oak RST total catch was 23% salmon.



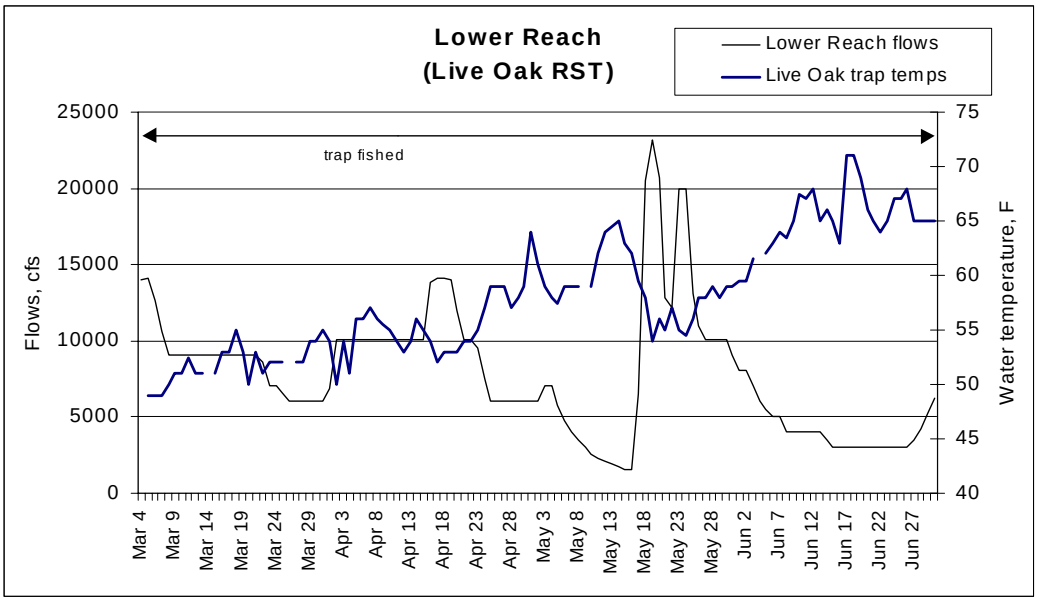
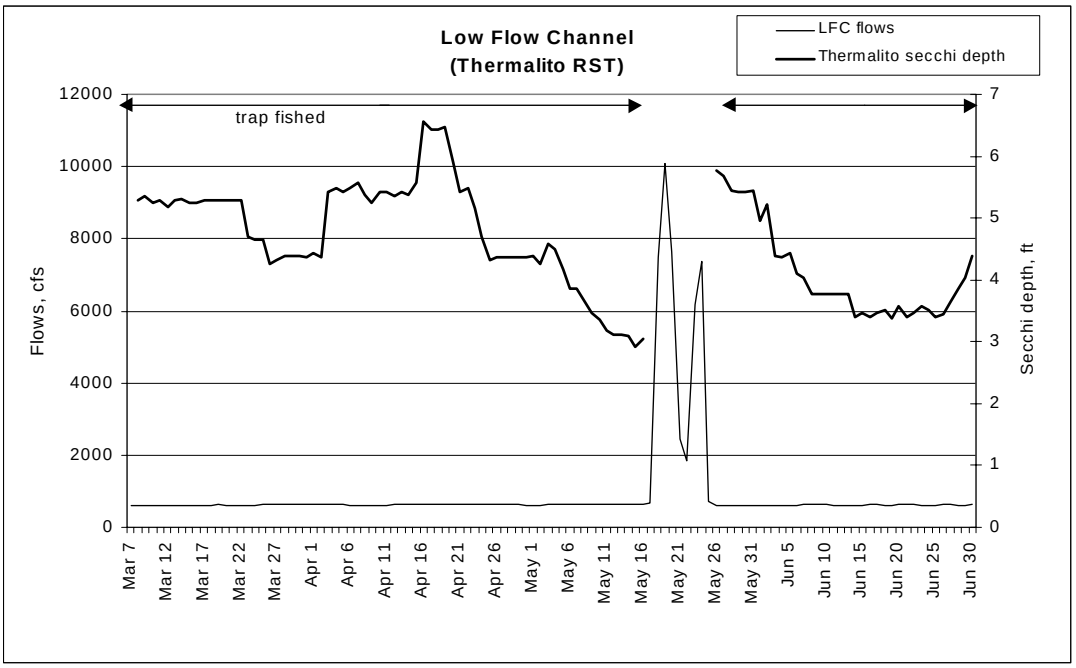


Figure 3 Flows and water temperature during the lower Feather River chinook salmon emigration survey from March through June 1996



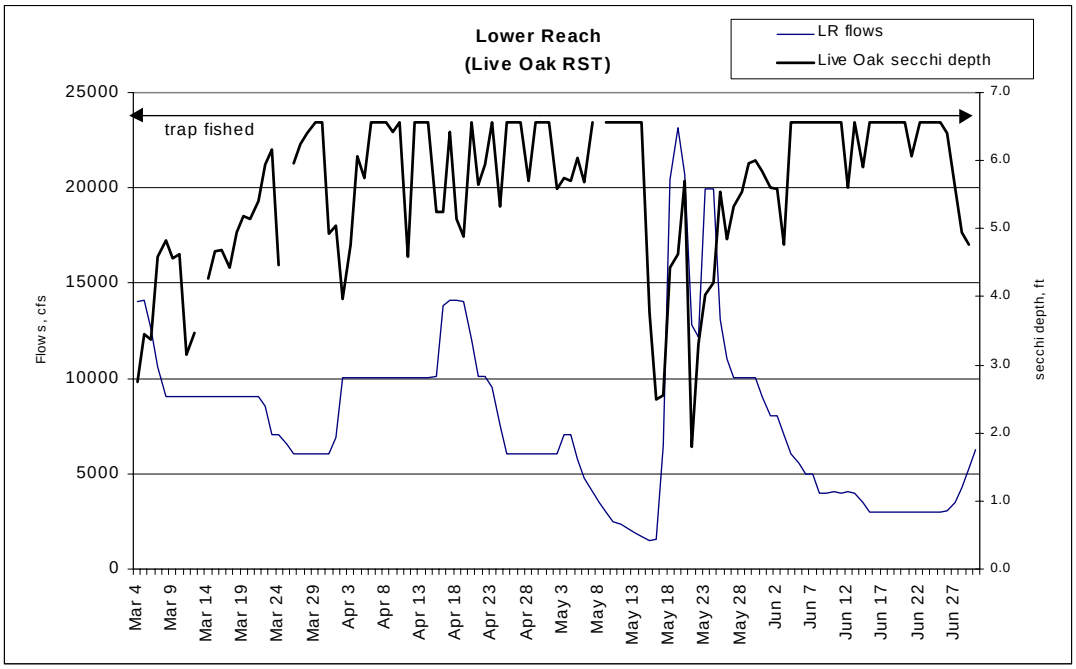


Figure 4 Flows and water clarity (secchi depth) during the lower Feather River chinook salmon emigration survey from March through June 1996

Table 1 Summary of fish species caught (both RSTs) during the lower Feather River chinook salmon emigration survey from March through June 1996

Species	*Origin*	*March*	*April*	*May*	*June*	*Total*
American shad	Introduced	0	0	1	6	7
bluegill	Introduced	3	13	31	53	100
brown bullhead	Introduced	0	0	2	0	2
carp	Introduced	0	1	1	0	2
chinook salmon	Native	15999	651	249	179	17078
golden shiner	Introduced	0	1	1	7	9
hardhead	Native	0	0	1	0	1
hitch	Native	0	0	0	5	5
largemouth bass	Introduced	1	0	394	149	544
mosquitofish	Introduced	2	8	25	7	42
Pacific lamprey	Native	2	12	5	3	22
prickly sculpin	Native	104	122	54	194	474
redear sunfish	Introduced	0	1	3	1	5
river lamprey	Native	0	1	1	3	5
Sacramento splittail	Native	0	0	2	0	2
Sacramento squawfish	Native	1	18	44	28	91
Sacramento sucker	Native	0	5	1064	4904	5973
smallmouth bass	Introduced	0	1	3	0	5
steelhead (young-of-the-year)	Native	60	9	10	4	83
steelhead (juveniles of other age classes)	Native	7	4	1	3	15
striped bass	Introduced	0	0	0	1	1
threadfin shad	Introduced	0	0	3	2	5
tule perch	Native	0	1	2	12	15
wakasagi	Introduced	96	35	19	1717	1867
warmouth	Introduced	0	2	5	5	12
juvenile bass (Micropterus sp.) [a]	Introduced	1	0	1	0	2
juvenile lamprey (ammocete) [a]	Native	96	25	44	16	181
juvenile cyprinid [a]	Mixed	4	96	2125	16	2241
juvenile centrarchid (non-Micropterus sp.) [a]	Introduced	4	5	7	113	129
unidentified juvenile [b]	Mixed	1	3	6	6	16
Total						28934

[a] individuals not identified to species (usually identified to genus or family).
[b] small (<45 mm, often larval-sized) fish which could not be identified in the field.

Salmon Emigration

Chinook salmon emigration was detected throughout all 17 weeks of RST sampling (3 March to 30 June 1996) (Table 2, Figure 5). A season total of 17,078 salmon was caught in 5,165 hours of fishing effort (3.3 fish/h). Peak catch occurred at both RSTs in early March and catch numbers steadily declined for the duration of sampling, indicating that peak emigration likely occurred before the RSTs were deployed (see Figure 5).

Salmon catch at the Thermalito RST totaled 14,514 fish in 2,464 hours of fishing effort (5.9 fish/h). Salmon catch at the Live Oak RST totaled 2,564 fish in 2,701 hours of fishing effort (0.9 fish/h). The highest daily salmon catch at Thermalito was 2,222 fish on 8 March 1996 (Figure 6). The highest daily salmon catch at Live Oak was 366 fish on 6 March 1996 (Figure 7). The highest weekly catches (see Figure 5) were as follows: Thermalito, 7,515 fish during week 11 (10 to 16 March 1996); Live Oak, 1,112 fish during week 10 (3 to 9 March 1996). Salmon catch declined steadily at both RSTs during March, but leveled off somewhat in April. Four coded-wire-tagged juvenile salmon were caught at Live Oak in May in weeks 19 (5 to 11 May) and 21 (19 to 25 May). These were assumed to be fall-run salmon that were tagged at Feather River Hatchery and released at the Live Oak boat ramp in early May. Because of their size (80 to 84 mm FL), these fish could not have been “inland salmon” (DFG salmon planting program in reservoirs) which would have been in the 200-mm size range. The CWT fish were not kept for tag recovery.

Salmon size ranged from 25 to 121 mm FL at Thermalito and 30 to 110 mm FL at Live Oak (see Table 2). Overall mean weekly length ranged from 36.5 to 93.3 mm FL at Thermalito and 37.1 to 82.0 mm FL at Live Oak (see Table 2, Figure 8). Mean fork length was approximately the same (about 37 mm) at both RSTs during the first two weeks of RST sampling, then increased steadily through the rest of the season (Figures 9 and 10). Over 75% of the entire 1996 survey salmon catch (both RSTs) occurred by the end of the second week of RST sampling (Figures 11 and 12). Approximately 71% of the Live Oak catch (n = 1,312) and 81% of the Thermalito catch (n = 2,362) was comprised of fish less than 50 mm FL, indicating that the majority of emigrating salmon were pre-smolt.

Three RST efficiency evaluations were attempted for the Thermalito RST and two were conducted for the Live Oak RST, but only one evaluation at each trap provided useful results. Trap efficiencies were as follows: 1.1% at Thermalito and 0.4% at Live Oak. An emigration index was not calculated because sampling was not conducted during the whole emigration period.

Emigration does not appear to be related to flows, water clarity, or water temperature. The following table gives the correlation coefficients between the number of salmon emigrants and flows, water clarity, and water temperature at the RSTs.

	r values (P = 0.05)	
	Thermalito	*Live Oak*
Flows	0.12	0.03
Water clarity	0.07	0.21
Water temperature	0.22	0.21

Table 2 Summary of chinook salmon catch statistics for the lower Feather River chinook salmon emigration survey from March through June 1996

		Size statistics (FL in mm)			
Week and Date	*Total Catch*	*Mean*	*Minimum*	*Maximum*	*Standard Deviation*
Thermalito RST					
(10) 03 - 09 Mar	3291	36.5	32	43	1.84
(11) 10 - 16 Mar	7515	36.5	27	58	2.47
(12) 17 - 23 Mar	2109	36.6	25	70	3.52
(13) 24 - 30 Mar	821	37.8	32	75	5.27
(14) 31 Mar - 06 Apr	281	38.5	32	68	5.32
(15) 07 - 13 Apr	63	43.0	32	89	11.14
(16) 14 - 20 Apr	39	64.7	33	95	18.31
(17) 21 - 27 Apr	59	68.3	39	98	13.65
(18) 28 Apr - 04 May	37	71.8	41	93	11.40
(19) 05 - 11 May	86	77.8	52	98	8.58
(20) 12 - 18 May	2	86.0	85	87	1.41
(21) 19 - 25 May		(trap not fished due to flood control releases)			
(22) 26 May - 01 Jun	43	82.9	35	93	12.02
(23) 02 - 08 Jun	63	88.0	67	103	6.61
(24) 09 - 15 Jun	39	90.7	67	101	6.50
(25) 16 - 22 Jun	43	91.9	72	103	6.88
(26) 23 - 30 Jun	23	93.3	81	121	7.90
Total or Average	14514	65.3	47	87	7.68
Size Range (mm)	25 - 121				
Mean weekly FL (mm)	36.5 - 93.3				
Live Oak RST					
(10) 03 - 09 Mar	1112	37.1	31	59	3.56
(11) 10 - 16 Mar	841	38.6	30	63	4.96
(12) 17 - 23 Mar	220	42.9	31	72	9.63
(13) 24 - 30 Mar	48	40.7	32	78	10.14
(14) 31 Mar - 06 Apr	75	52.0	34	83	11.70
(15) 07 - 13 Apr	28	60.7	35	91	13.55
(16) 14 - 20 Apr	25	65.8	51	96	10.26
(17) 21 - 27 Apr	55	69.5	50	84	7.69
(18) 28 Apr - 04 May	74	74.6	58	110	8.76
(19) 05 - 11 May	69	74.4	46	90	7.85
(20) 12 - 18 May	9	76.4	64	84	5.68
(21) 19 - 25 May	6	78.0	36	92	20.78
(22) 26 May - 01 Jun	0				
(23) 02 - 08 Jun	2	82.0	76	88	8.49
(24) 09 - 15 Jun	0				
(25) 16 - 22 Jun	0				
(26) 23 - 30 Jun	0				
Total or Average	2564	61.0	44	84	9.47
Size Range (mm)	30 - 110				
Mean weekly FL (mm)	37.1 - 82.0				

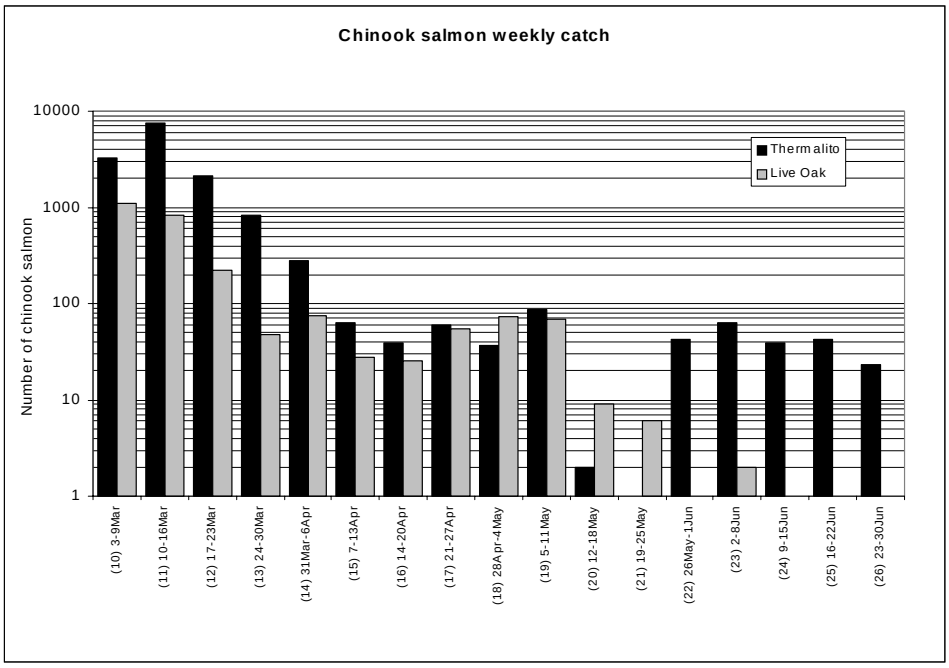


Figure 5 Weekly catch of chinook salmon caught by RSTs during the lower Feather River chinook salmon emigration survey from March through June 1996. ( ) = week number. The Thermalito RST was not fished from 17 to 24 May 1996 due to high flows (10,000 cfs) in the low flow channel.

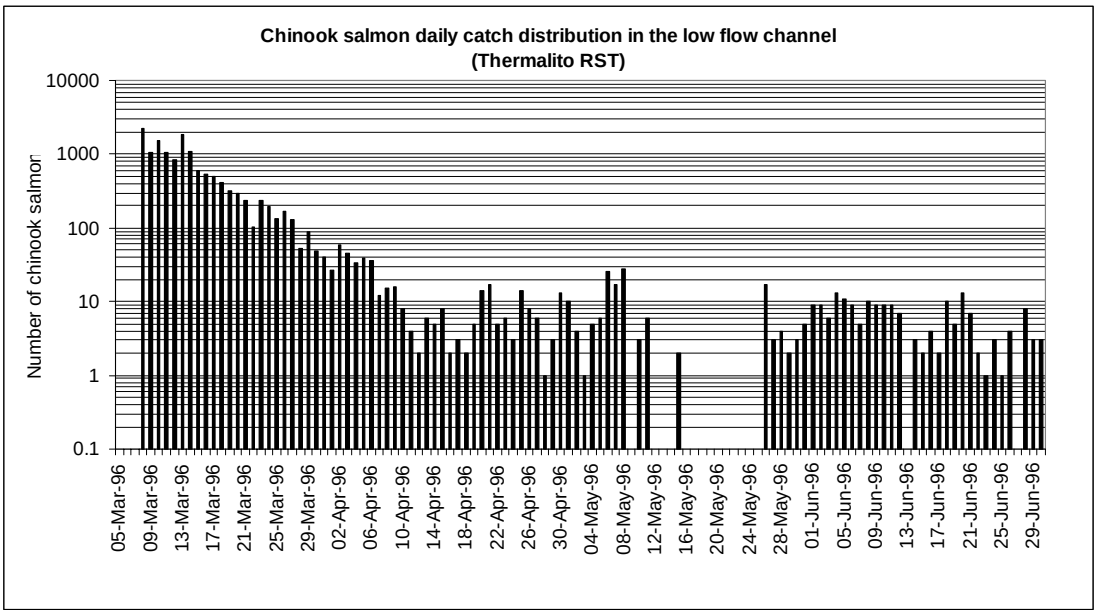


Figure 6 Daily catch distribution of chinook salmon caught by the Thermalito RST during the lower Feather River chinook salmon emigration survey from March through June 1996. The Thermalito RST was not fished from 17 to 24 May 1996 due to high flows (10,000 cfs) in the low flow channel.

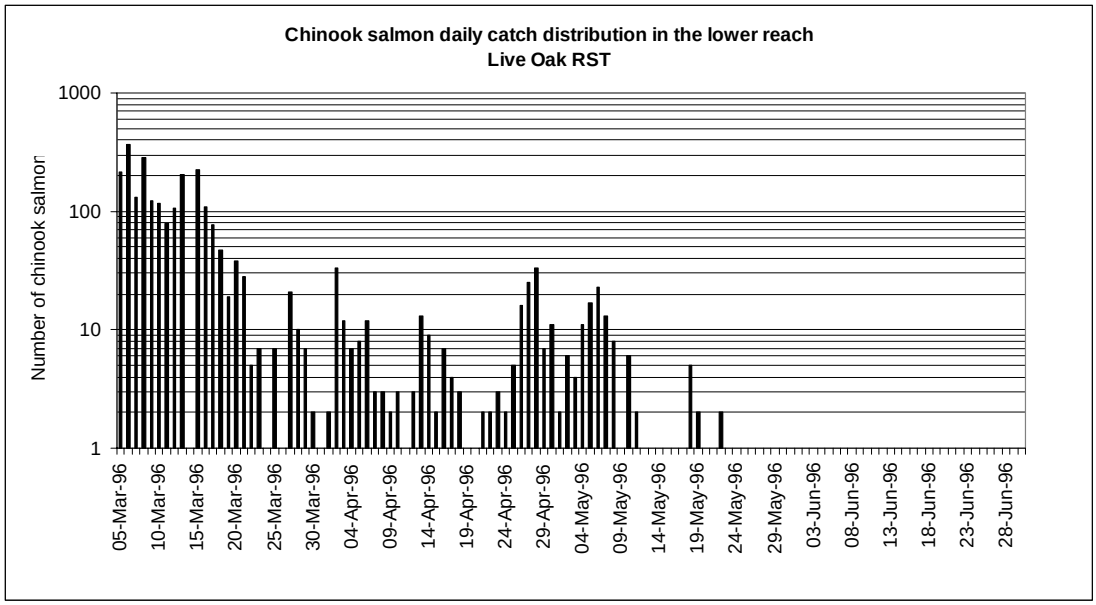


Figure 7 Daily catch distribution of chinook salmon caught by the Live Oak RST during the lower Feather River chinook salmon emigration survey from March through June 1996

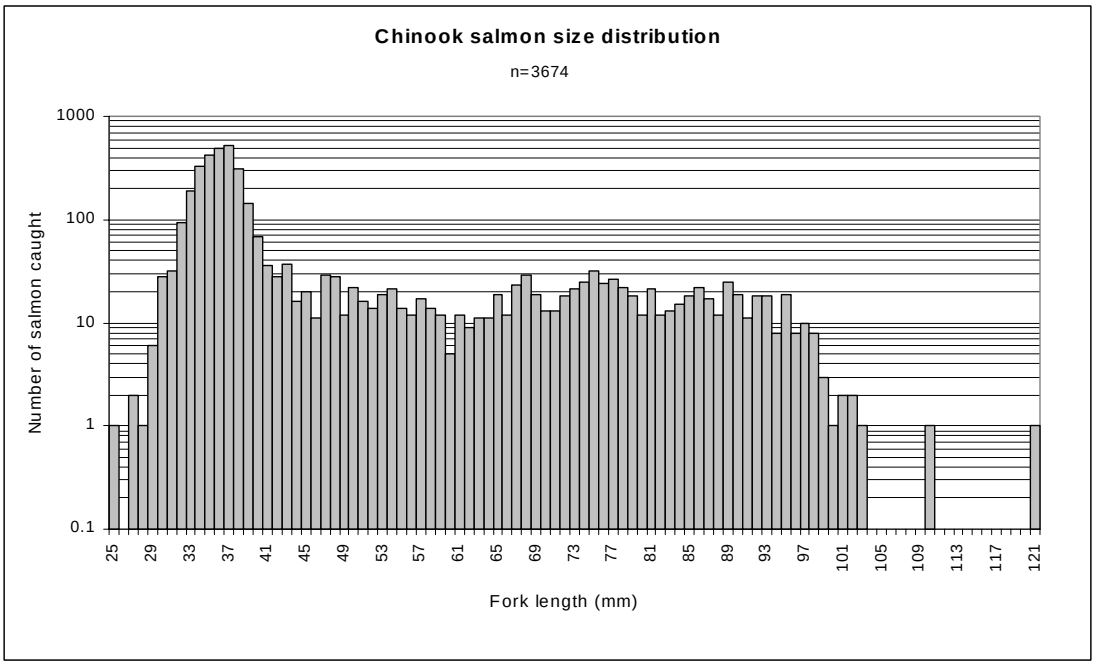


Figure 8 Length-frequency distribution of chinook salmon caught by RSTs during the lower Feather River chinook salmon emigration survey from March through June 1996. (Combined data from both RSTs.)

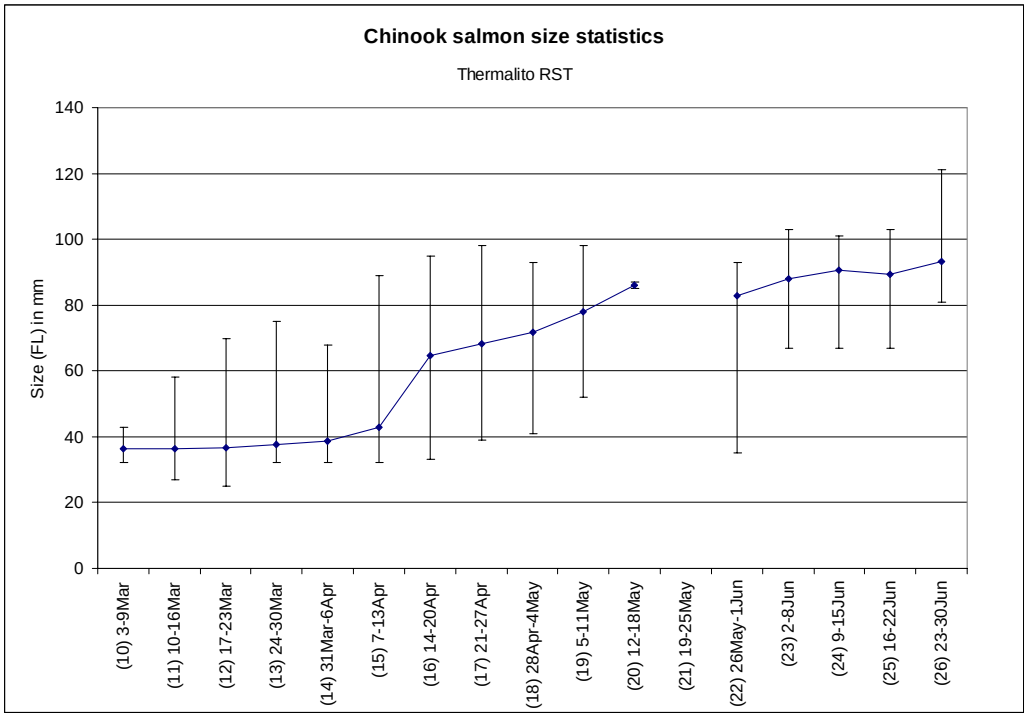


Figure 9 Mean length and size range of chinook salmon caught by RST during the lower Feather River chinook salmon emigration survey from March through June 1996. ( ) = week number. The Thermalito RST was not fished from 17 to 24 May 1996 due to high flows (10,000 cfs) in the low flow channel.

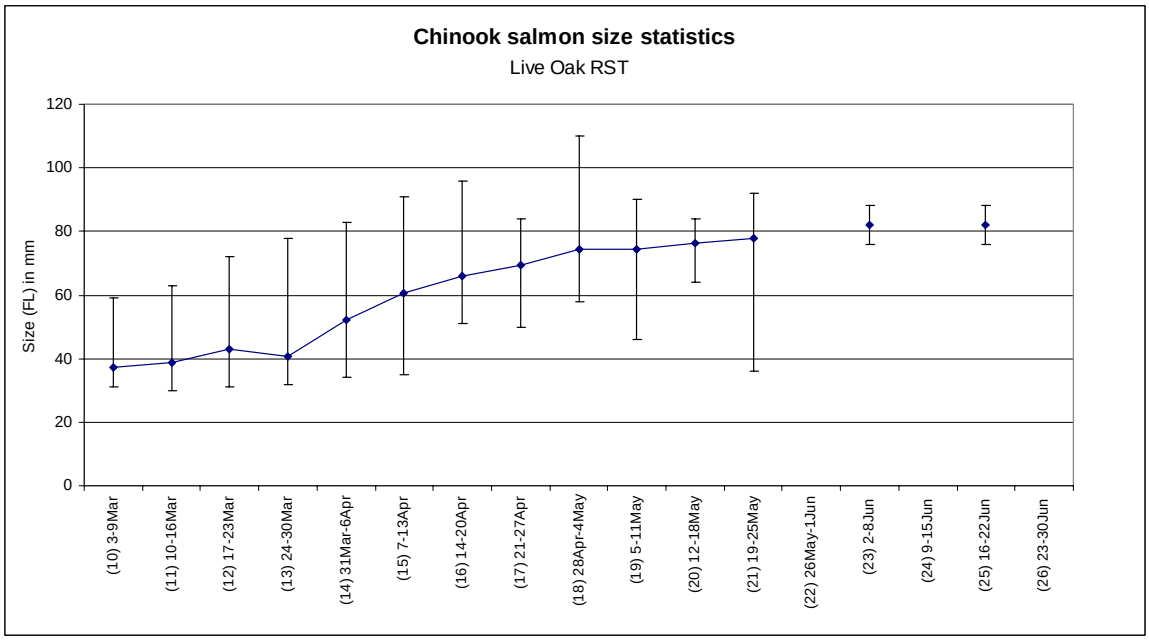


Figure 10 Mean length and size range of chinook salmon caught by RST during the lower Feather River chinook salmon emigration survey from March through June 1996. ( ) = week number.

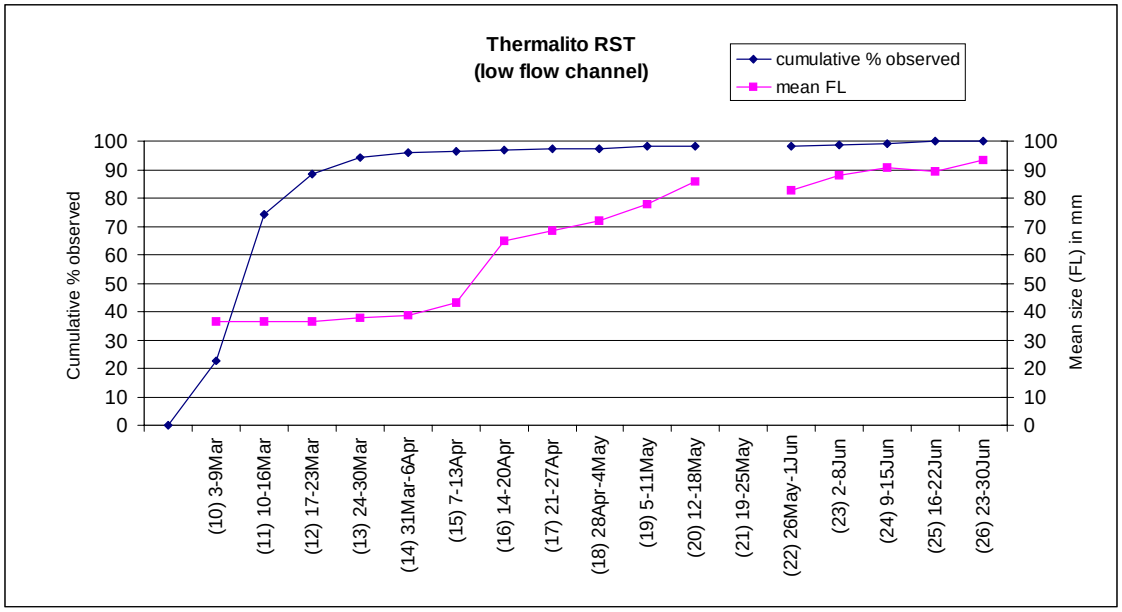


Figure 11 Cumulative catch compared to weekly average size during the lower Feather River chinook salmon emigration survey from March through June 1996. ( ) = week number. The Thermalito RST was not fished from 17 to 24 May 1996 due to high flows (10,000 cfs) in the low flow channel.

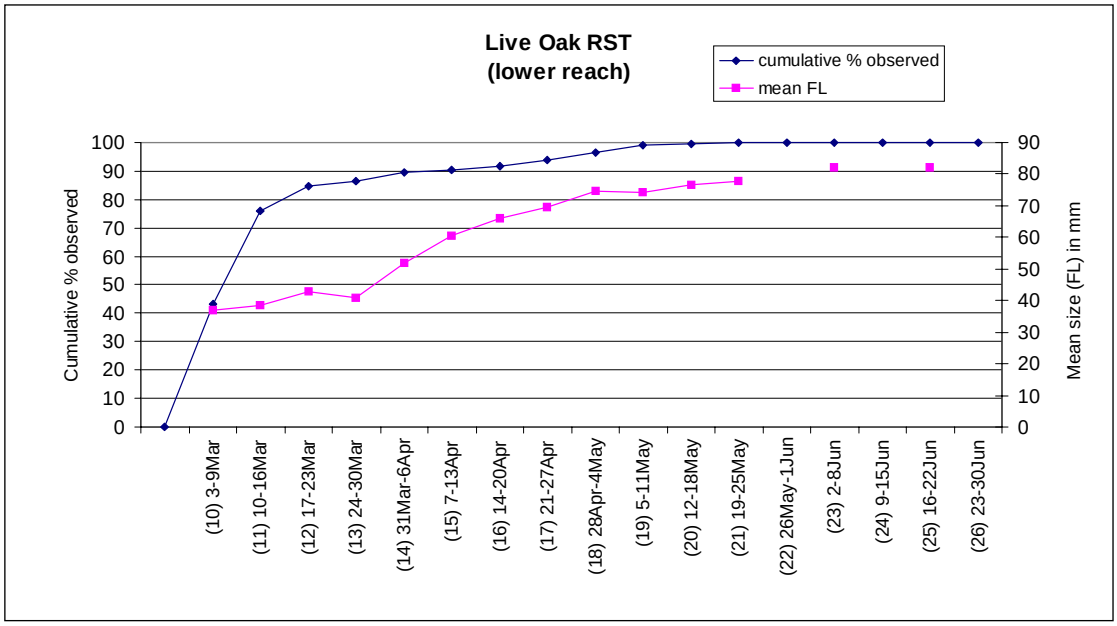


Figure 12 Cumulative catch compared to weekly average size during the lower Feather River chinook salmon emigration survey from March through June 1996. ( ) = week number.

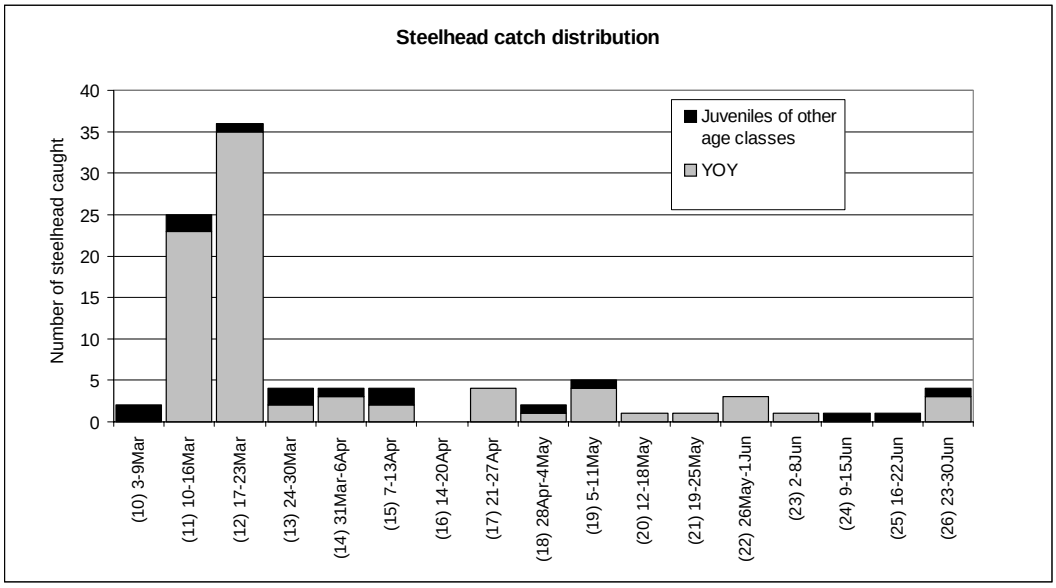


Figure 13 Catch distribution of juvenile steelhead caught by RSTs during the lower Feather River chinook salmon emigration survey from March through June 1996. ( ) = week number.

Steelhead Emigration

Steelhead emigration was detected throughout the 17 weeks of RST sampling (3 March to June 30 1996). Steelhead catch in both RSTs consisted of young-of-the-year (YOY) fish (typically <100 mm FL) and juvenile steelhead of other age classes (typically 100 to 300 mm FL). No adults were captured. YOY fish were caught from weeks 11 (10 to 16 March 1996) through 26 (23 to 30 June 1996) (Figure 13). A total of 83 YOY fish was caught (78 at Thermalito and five at Live Oak). YOY size ranged from 22 to 114 mm FL (mean = 34.4 mm) (Table 3; Figure 14). One 114 mm fish caught is thought to have been a YOY.

The larger juveniles of other age classes were caught from weeks 10 through 15 (3 March to 13 April 1996), week 18 (24 April to 4 May 1996), week 19 (5 to 11 May 1996), and weeks 24 through 26 (9 to 30 June 1996) (see Table 3, see Figure 13). The size of these fish was 171 to 311 mm FL (mean = 233.6 mm) (see Table 3, see Figure 14). A total of 15 juvenile steelhead of other age classes was captured (seven at Thermalito and eight at Live Oak).

Table 3 Summary of steelhead catch statistics for the lower Feather River chinook salmon emigration survey from March through June 1996

	Thermalito RST				*Live Oak RST*			
	Young-of-the-year		*Juveniles of Other Age Classes*		*Young-of-the-year*		*Juveniles of Other Age Classes*	
Week and Dates	*Count*	*Mean FL (mm) and Range*	*Count*	*Mean FL (mm) and Range*	*Count*	*Mean FL (mm) and Range*	*Count*	*Mean FL (mm) and Range*
(10) 03 - 09 Mar	0		0		0		2	246 (237 - 255)
(11) 10 - 16 Mar	22	26.7 (23 - 29)	0		1	37	2	191 (171 - 211)
(12) 17 - 23 Mar	34	27.3 (22 - 77)	0		1	38	1	185
(13) 24 - 30 Mar	2	27.5 (27 -28)	2	202 (195 - 209)	0			
(14) 31 Mar - 06 Apr	2	36.3 (35 - 38)	0		1	35	1	200
(15) 07 - 13 Apr	1	24	2	228 (225 - 231)	1	35		
(16) 14 - 20 Apr	0		0		0			
(17) 21 - 27 Apr	4	35.3 (30 - 42)	0		0			
(18) 28 Apr - 04 May	1	61	0		0		1	240
(19) 05 - 11 May	4	55 (43 - 63)	1	311	0			
(20) 12 - 18 May	1	73	0		0			
(21) 19 - 25 May	(trap was not fished from 17 to 24 May)				1	37		
(22) 26 May - 01 Jun	3	52.3 (39 - 61)	0		0			
(23) 02 - 08 Jun	1	78	0		0			
(24) 09 - 15 Jun	0		1	267	0			
(25) 16 - 22 Jun	0		1	285	0			
(26) 23 - 30 Jun	3	83 (60 - 114)	0		0		1	282
Total	78	34.4 (22 - 114)	7	246.1 (195 - 311)	5	36.4 (35 - 38)	8	222.6 (171 - 282)

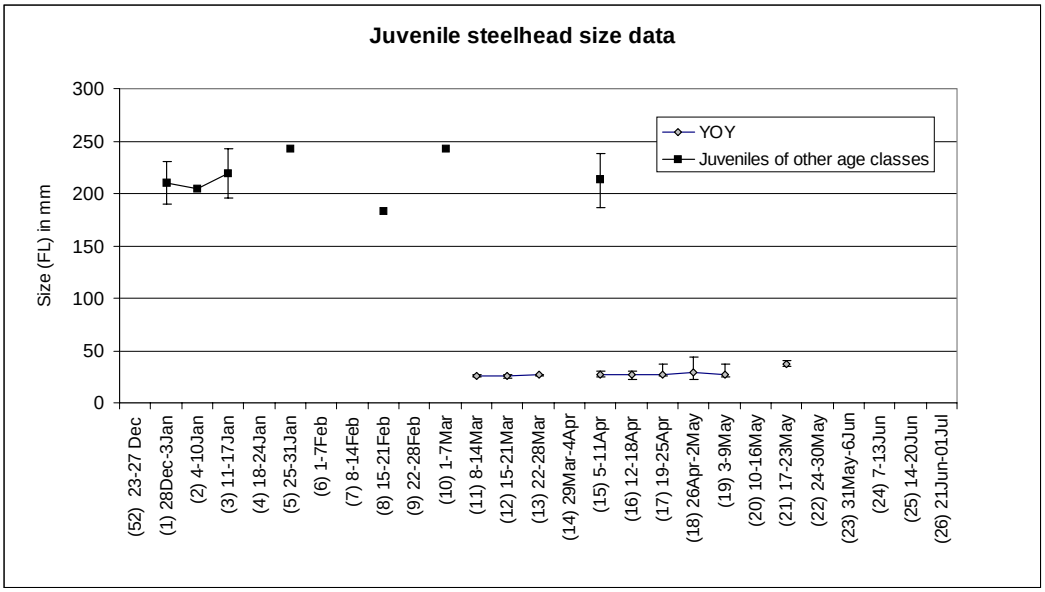


Figure 14 Mean fork length and size range of juvenile steelhead caught by RSTs during the lower Feather River chinook salmon emigration survey from March through June 1996. ( ) = week number.

Discussion

Although sampling was completed for only four of the six months scheduled for the 1996 survey, some important information was obtained on species composition and salmonid emigration in the river. Many lessons were learned about the deployment and operation of RSTs. Additional ideas originated for improving RST sampling in subsequent seasons.

RST Performance

The Thermalito RST caught substantially more fish than the Live Oak RST. This is reflected in the higher Thermalito RST efficiency: 1.1% compared to the Live Oak RST efficiency of 0.4%. A higher efficiency value was expected at Thermalito because the channel is much narrower at Thermalito than it is at Live Oak, and stream width at the Thermalito RST does not vary as much because low flow channel flows are usually a constant 600 cfs. Stream width at the Live Oak RST site varies depending on lower reach flows. During the 1996 emigration survey flows varied from 1,500 to 24,000 cfs, and the stream width at the Live Oak RST varied from approximately 266 to 359 feet (calculated from measurements on aerial photos). Thus, the Thermalito RST fishes approximately 10% of the stream width while the Live Oak RST fishes approximately 2% to 3% of the stream width. The Feather River RST efficiency values were similar to the 1996 the lower American River efficiency value of 0.68% (Snider and others 1998).

Obviously, it would have been more informative to have more than one set of RST efficiency results, but the many difficulties experienced with efficiency evaluation logistics, and low salmon catch numbers in the RSTs as the season progressed prevented us from attempting more evaluations. Results of three (out of five) of the evaluations were discarded because of problems with holding fish, marking methods, and detection of recaptured marked fish. Spray-dyed hatchery fish were used for an additional set of evaluations, but the results were discarded because of difficulties with detection of marked fish and problems associated with applying efficiency results for hatchery fish to wild fish (Roper and Scarnecchia 1996). In future emigration surveys, Bismarck brown-dyed or adipose-fin-clipped (CWT) in-channel produced salmon will be used for multiple RST efficiency evaluations.

RST Catch and Species Composition

There was a notable dominance of native species. The finding that the proportion of native to introduced species was higher in the lower reach (95% native:5% introduced) than in the low flow channel (87% native:13% introduced) was unexpected. On average, temperatures tended to be warmer in the lower reach, and therefore, it was surprising that such a high proportion of natives were observed in that reach. The overall high proportion of natives reflects the relatively cool conditions during the survey.

Species composition has not changed much since the last fish survey in the Feather River. Painter and others (1977) reported 35 species collected during their seven year (1967 to 1975) study. The 1996 emigration survey collected mostly the same species, but there are some notable differences. Species reported by Painter and others (1977) but not caught in the 1996 survey were western brook lamprey (*Lampetra richardsoni*), coho salmon (*Onchorhynchus kisutch*), chum salmon (*O. keta*), pink salmon (*O. gorbuscha*), sockeye salmon (*O. nerka*), brown trout (*Salmo trutta*), channel catfish (*Ictalurus punctata*), and white sturgeon (*Acipenser transmontanus*). The 1996 emigration survey captured three species not found during the 1967-1975 surveys: redear sunfish (*Lepomis microlophus*), river lamprey (*Lampetra ayresi*), and

wakasagi (*Hypomesus nipponensis*). It is possible that either survey may have misidentified the western brook and river lampreys due to the difficulty in distinguishing lamprey species. Wakasagi dispersed into the Feather River system via the North Fork of the river after introduction into Lake Almanor in 1972 (Dill and Cordone 1997). Wakasagi have apparently successfully expanded their distribution downstream as indicated by their presence as the fourth most abundant in overall catch numbers (see Table 1). It is likely that redear sunfish dispersed into the lower river from Lake Oroville introductions.

Salmonid Emigration

Timing

Salmon emigration was detected throughout the period sampled. The incomplete data set prevented determination of overall abundance of emigrants, however it did provide a set of data for the March through June period that will be useful for making comparisons in future years. Because total catch declined steadily during sampling at both RSTs, it is likely that the peak of emigration was missed due to the late deployment of the RSTs. Peak catch at both RSTs occurred in early March (6 March at Live Oak and 8 March at Thermalito). Painter and others (1977) found that the peak of salmon emigration occurred in January or February.

Effects of Flow, Water Clarity, Water Temperature on Emigration

There appears to be no relationship between salmon emigration and flows in the low flow channel because low flow channel flows are generally constant. However, because the Thermalito RST was not fished during the 10,000-cfs flood control release in May, there are no data to use to determine whether the increased low flow channel flows influenced emigration during that period. Flow and emigration trends should be reviewed after emigration data is collected during a full range flow fluctuations in the low flow channel. However, the Live Oak RST was fished continuously throughout the sampling period in a variety of flows and no relation between flows and emigration was detected.

Emigration Index

Differences in fish abundance may also partially account for catch trends at the Thermalito and Live Oak sampling sites. Seasonal emigration estimates could not be calculated because of the absence of data for January and February, however it may still be instructive to calculate “partial” emigration estimates for each reach. The “partial” emigration estimates were calculated to be 1.3 million fish for the low flow channel (Thermalito RST) and 641,000 fish for the lower reach (Live Oak RST). The estimates were consistent with the fact that approximately 70% of adult spawners were located in the low flow channel as opposed to the lower reach (Sommer and others forthcoming). Note that the actual production differences between the two reaches may be even greater than suggested by the “partial” emigration estimates. The Live Oak estimate included fish from both the low flow channel and the lower reach, while it is assumed that the Thermalito estimate is based primarily on fish from the low flow channel. If a large proportion of the Live Oak catch is from the low flow channel, salmon production for the lower reach could be substantially lower than the 641,000 estimate.

Comparison With Other Emigration Studies

The Feather River 1996 salmon emigration data were similar to the 1996 salmon emigration period for the lower American River and the Feather River salmon emigration patterns of the 1970s, but differed slightly

from pre-Oroville project patterns. The 1996 Feather River emigration survey caught salmon through the last day of the RST sampling period (30 June 1996, week 26). Snider and others (1998) found that emigration on the lower American River ended in mid-July (week 29). Painter and others (1977) found that the length of the Feather River emigration period was variable, but could occur at the end of June (when they sampled that late). Although the 1996 and 1970s Feather River emigration periods ended at approximately the same time, Warner (1955) found that emigration ended around 1 June, a month earlier than the more recent surveys. Painter and others (1977) concluded that the differences in emigration timing they saw during several years of sampling was attributed to the difference in sampling locations or normal, year-to-year variation, which could also be the reason for the differences between results of the various surveys discussed here.

The incomplete set of 1996 Feather River emigration data precludes making detailed comparisons with emigration patterns in other streams or with historical patterns in the Feather River; however, it is interesting to note that the results of 1996 Feather River survey showed some similarities to the results of the 1996 American River emigration survey.

- In weeks 10 to 29 the Feather River RSTs caught a total of 17,078 salmon in 1996 compared to the American River RSTs 1996 catch of 15,512 salmon (Snider and others 1998).

- Chinook salmon size ranges in the 1996 emigration survey were comparable to those in the 1996 lower American River emigration survey and earlier DFG emigration surveys. In the 1996 Feather River emigration survey, salmon ranged from 25 to 121 mm FL compared to the 35 to 95 mm FL size range of the salmon catch in 1970s surveys (Painter and others 1977) and the 1996 lower American River salmon size range of 25 to 98 mm FL (Snider and others 1998). Warner (1955) found that emigrating salmon ranged from 32 to 65 mm FL; however, the smaller size range could be attributable to the gear type (3-feet by 5-feet fyke net). Painter and others (1977) found that the smaller, 3-feet by 5-feet fyke nets tended to not be effective for catching salmon larger than 60 mm.

- Nearly all the emigrating chinook salmon were pre-smolt. The high percentage of fish less than 50 mm FL (81% at Thermalito and 71% at Live Oak) suggests that fish are not smolting in the upper half of lower Feather River and are likely undergoing smoltification in the Feather River downstream of Live Oak, in the Sacramento River, or in the Sacramento-San Joaquin Estuary or San Francisco Bay. Based on life stage classification and size data, Snider and others (1977) concluded that all the salmon emigrating from the lower American River in 1996 were pre-smolt (about 98% were smaller than 50 mm). Painter and others (1977) and Warner (1955) did not make any conclusions about the life stage of emigrating Feather River salmon, but because the gear they used (3-feet by 5-feet fyke nets) limited their catch to fish smaller than 60 mm FL they likely were not collecting smolts and therefore lacked the information needed to determine what the proportions were between the different life stages.

Steelhead

There was a notable presence of steelhead. Although not captured in large numbers, the presence of YOY steelhead indicates that there is at least modest natural production in the Feather River. The lower catch numbers of juvenile steelhead is probably attributable to their low abundance in the Feather River and also to the fact that steelhead emigrate at a larger size, mostly as two and three year old fish (Hallock and others 1961). The larger size of emigrating steelhead enables them to avoid the RSTs (Thedinga and others 1994) much more readily than the smaller emigrating salmon juveniles.

Acknowledgments

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