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CHINOOK SALMON SPAWNER STOCKS IN CALIFORNIA'S CENTRAL VALLEY, 1991

Edited by

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Inland Fisheries Division

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ABSTRACT

This report covers the 39th annual inventory of chinook salmon, Oncorhynchus tshawytscha, spawner populations in the Sacramento-San Joaquin River system. It is a compilation of reports estimating the fall-, winter-, late-fall-, and spring-run salmon spawner populations for streams which were surveyed.

Estimates were made from counts of fish entering hatcheries and migrating past dams, from surveys of dead and live fish and redds on spawning areas, and from aerial counts.

The estimated 1991 total escapement of chinook salmon in the Central Valley was 147,080 fish. This total consisted of 132,571 fall-, 5,921 spring-, 190 winter-, and 8,398 late-fall-run spawners. All of the spring-, late-fall-, and winter-run salmon were estimated to be in the Sacramento River system, while 1,176 fish of the fall run were in the San Joaquin River system.

Spawner populations in all individual tributaries (except the American River) and the Sacramento River mainstem were lower than in 1990; but it should be noted that fall run populations in the Feather and Yuba rivers, two of the larger tributaries, were not surveyed that year. The winter run in the mainstem Sacramento River was at a record low level.

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INTRODUCTION

The Sacramento-San Joaquin River system (Figure 1), which flows through California's Central Valley, is the principle producer of chinook salmon caught in the state's ocean fisheries; its salmon runs also contribute to the ocean fisheries of Oregon and Washington. This report is the 39th compilation of chinook salmon spawner stock surveys. The spring and fall runs have been monitored since 1953, and late-fall and winter runs since 1971. The four runs are distinguished as follows:

1) Late-fall run. These salmon spawn mainly in the upper Sacramento River and its tributaries near and upstream of Red Bluff. They arrive in this area in early November through February, with spawning occurring from January through early April. Adults of this run are usually larger in physical size than fall- and winter-run salmon spawning in the same area.

2) Winter run. These salmon spawn almost entirely in the Sacramento River and its tributaries upstream of Red Bluff, arriving there in late December through mid-July, and spawning from April to early August.

3) Spring run. Once widespread in Central Valley tributaries, this run has disappeared from many of the streams in which dam construction has blocked access to spawning habitat. Spring-run spawners return to the system from the ocean in March through June, oversummer in holding pools, and spawn from late August through early October.

4) Fall-run. These are presently the most numerous and widely distributed salmon in the Central Valley. They enter the river from the ocean in June through November and spawn from early October through early January.

Monitoring of salmon spawner escapement in Central Valley tributaries is an important component of the California Department of Fish and Game's (CDFG) fishery management effort. The primary objectives of this work are to determine size and composition of spawner populations. Any changes in spawning distribution and habitat conditions that may adversely affect salmon are noted to determine if corrective action is necessary.

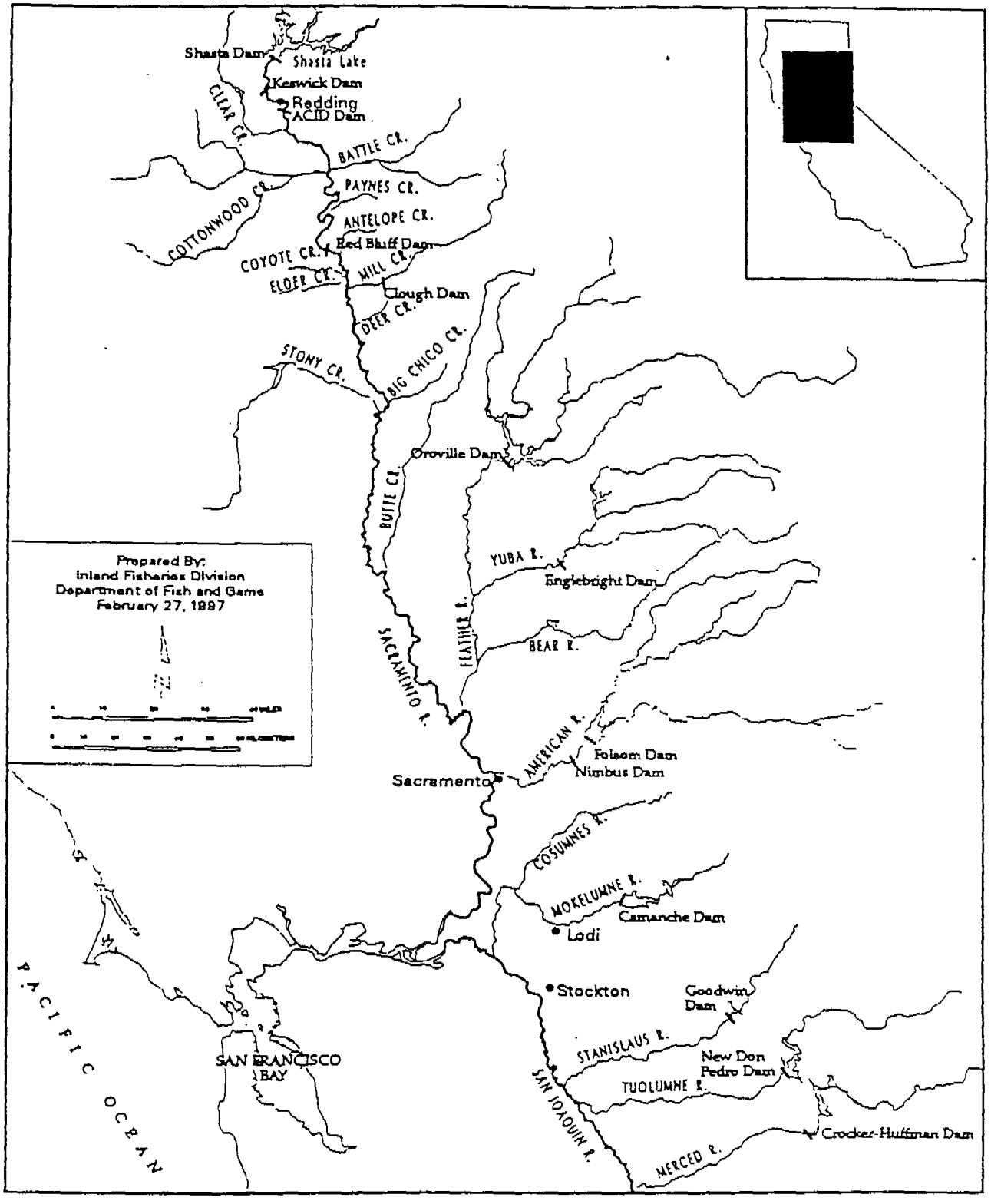

FIGURE 1. Sacramento-San Joaquin River system of California's Central Valley.

GENERAL METHODS

During 1991, spawner stock data were collected in most Central Valley tributaries known to support chinook salmon runs by: monitoring fish entering hatcheries and migrating past dams; conducting stream surveys in spawning areas for live fish, carcasses, and redds; or making aerial counts.

The data collected usually represented only a sampling of the tributaries' spawners. For some tributaries, although surveys were conducted, data were not sufficient to calculate an estimate of the spawner population size. In other streams, carcasses were marked throughout a series of survey periods. Upon recovery during subsequent trips, discrete marks applied to the carcasses allowed identification with individual surveys. All counted carcasses were either marked or cut in half to prevent recounting. Estimated spawner numbers were derived from this type of mark-and-recovery data using appropriate biometric calculations (Appendix 1).

Specific details of surveys (e.g. timing, duration, location), or other estimation methods are presented under the following individual tributary sections.

CHINOOK SALMON SPAWNER POPULATIONS FOR THE SACRAMENTO RIVER SYSTEM

Keswick Dam to Red Bluff Diversion Dam

by Richard E. Painter, CDFG-Inland Fisheries Division (IFD)

Spawner population sizes were estimated for all four runs of chinook salmon in the Sacramento River mainstem (Figure 2) upstream of Red Bluff Diversion Dam (RBDD). Clear, Cottonwood, and Battle creeks were the only tributaries in this area for which individual fall-run population estimates were made. Spawning distribution in the mainstem was determined from aerial redd counts.

In 1991, 48,012 salmon were estimated for the Sacramento River system between Keswick Dam and Red Bluff, consisting of 40,178 fall-, 6,882 late-fall-, 190 winter- and 762 spring-run fish (Appendix 2). The mainstem portions of the fall- and late-fall-run spawner population were 20,235 and 6,721 fish, respectively. The mainstem totals which are reported include fish from tributaries in which a run might have occurred, but where no surveys were made; e.g. the late-fall run in Clear Creek, the spring run in Cottonwood Creek, and the late-fall, winter, and spring runs in Battle Creek.

Sacramento River Mainstem

Estimates of the total numbers of salmon using the Sacramento River system upstream from RBDD during 1991 were based on daily counts made by the U.S. Fish and Wildlife Service and CDFG at the dam. Counts were obtained through closed-circuit television monitoring of salmon passing through the RBDD fishways.

Total numbers of fish counted each week were adjusted for those periods when the fishways remained open but no counts were possible, such as when river turbidity was high, during flood conditions when the dam gates were temporarily opened, and when no observations were made at night. Adjustments to lapses in daytime counts were made by interpolation. Adjustments for the non-monitored nighttime hours were made by multiplying the 14-h day counts by a "night-factor", generated from weekly night counts. The adjusted weekly number of fish was apportioned among the four runs based on their relative proportions seen that week in random samples of salmon taken from the dam's east-bank trapping facility; salmon were assigned to a run based on their relative degree of ripeness (an indication of when it was believed that they would spawn).

The numbers of spring- and fall-run salmon passing RBDD in a calendar year account for the entire annual run of these races.

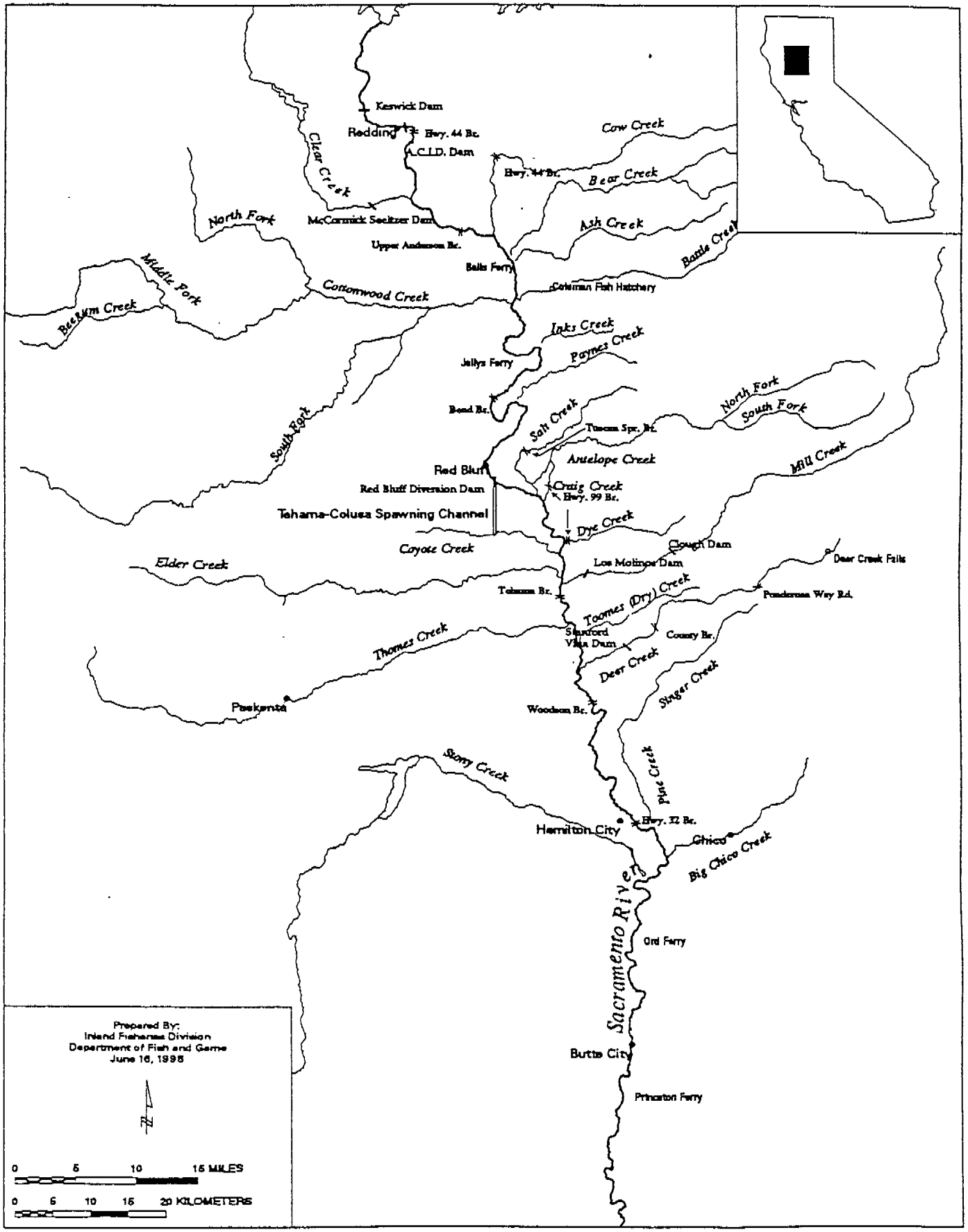

FIGURE 2. Sacramento River system from Keswick Dam downstream to Princeton Ferry.

However, the late-fall and winter runs for a calendar year usually include the latter part of one annual run during the beginning of the year, and the first part of the next annual run at the end of that year. Approximately half of the late-fall annual run occurs in each portion of the calendar year, while most of the winter annual run usually occurs early in the year, with the smaller part of the following annual winter run at the end of the year. The total 1991 potential spawners for each of these two runs was obtained by adding the appropriate estimated numbers of fish from the 1990 calendar year that would spawn in 1991, and not including that portion of the 1991 calendar year estimated numbers that would spawn in 1992.

The RBDD gates were raised, during periods from 3 December 1990 through 1 May 1991 and from 1-31 December 1991, to facilitate upstream migration of the winter run of chinook salmon. When the dam gates are open the fishways are essentially inoperable, and counts are not possible. Estimated numbers of salmon for these periods were calculated based on historical data. The number of 1991 salmon estimated from counts made when the gates were closed was expanded to determine the remainder of the run, using each run's average of proportional distributions seen during 1968-1985, when the gates were closed year-round.

For each of the four runs, the estimated spawner population upstream of RBDD was further defined by reducing the number of potential spawners by the estimated number of fish landed in the sport fishery between Keswick Dam and Red Bluff; no attempt was made to account for any other prespawning mortality in the upper river. The numbers of sport-caught salmon were estimated from an angler survey conducted by CDFG-IFD.

To obtain the late-fall- and fall-run populations for only the mainstem upper Sacramento River, the numbers of potential spawners was reduced by the numbers for the appropriate run in Clear, Cottonwood, and Battle creeks.

Late-fall run. An estimated 7,091 late-fall 1991 potential spawners passed RBDD in 1990 and 1991 (Table 1). The late-fall sport-catch was estimated to be 209 salmon, leaving 6,882 fish (Table 2) as a spawner population upstream of Red Bluff. Coleman National Fish Hatchery (CNFH) in Battle Creek took in 161 late-fall salmon, leaving 6,721 fish as the mainstem spawner population (Appendix 2). Although some late-fall-run salmon may have used other tributaries of the upper Sacramento River, no spawner surveys were made in those streams. Numbers of those fish are included in the upper mainstem population, along with 118 late-fall-run salmon trapped at Keswick Dam that were hauled to CNFH for spawning.

TABLE 1. Adjusted chinook salmon counts and estimated numbers of each run at Red Bluff Diversion Dam from 30 September 1990 through 28 December 1991. a/

Count period	Adjusted salmon count b/	Number of salmon examined c/	Distribution of runs: Late-fall % of fish examined	Late-fall Estimated number d/	Winter % of fish examined	Winter Estimated number d/	Spring % of fish examined	Spring Estimated number d/	Fall % of fish examined	Fall Estimated number d/
30 Sept. – 29 Dec '90 e/	--	--	--	3,468	--	3	--	--	--	--
1991										
30-Dec-89 – 05-Jan	--	--	--	461 f/	--	3 f/				
06-Jan – 12-Jan	--	--	--	448 f/	--	3 f/				
13-Jan – 19-Jan	--	--	--	218 f/	--	1 f/				
20-Jan – 26-Jan	--	--	--	206 f/	--	2 f/				
27-Jan – 02-Feb	--	--	--	254 f/	--	5 f/				
03-Feb – 09-Feb	--	--	--	289 f/	--	6 f/				
10-Feb – 16-Feb	--	--	--	297 f/	--	6 f/				
17-Feb – 23-Feb	--	--	--	310 f/	--	2 f/				
24-Feb – 02-Mar	--	--	--	233 f/	--	12 f/				
03-Mar – 09-Mar	--	--	--	152 f/	--	15 f/				
10-Mar – 16-Mar	--	--	--	123 f/	--	18 f/				
17-Mar – 23-Mar	--	--	--	240 f/	--	15 f/	--	1 f/		
24-Mar – 30-Mar	--	--	--	147 f/	--	9 f/	--	2 f/		
31-Mar – 06-Apr	--	--	--	129 f/	--	15 f/	--	5 f/		
07-Apr – 13-Apr	--	--	--	99 f/	--	16 f/	--	7 f/		
14-Apr – 20-Apr	--	--	--	17 f/	--	17 f/	--	11 f/		
21-Apr – 27-Apr	--	--	--	--	--	7 f/	--	13 f/		
28-Apr – 04-May	--	--	Total g/:	7,091 h/	--	3 f/	--	21 f/		
05-May – 11-May	64	29			6.9	4	93.1	60		
12-May – 18-May	53	14			7.1	4	92.9	49		
19-May – 25-May	83	25			0.0	0	88.0	73	12.0	10
26-May – 01-Jun	94	33			6.1	6	54.5	51	39.4	37
02-Jun – 08-Jun	141	36			5.6	8	69.4	98	25.0	35
09-Jun – 15-Jun	163	43			4.7	8	20.9	34	74.4	121
16-Jun – 22-Jun	117	30			0.0	0	23.3	27	76.7	90
23-Jun – 29-Jun	211	66			1.5	3	18.2	38	80.3	169
30-Jun – 06-Jul	439	123			Total g/:	191 i/	8.1	36	91.9	403
07-Jul – 13-Jul	341	56					7.1	24	92.9	317
14-Jul – 20-Jul	161	--					3.4 j/	5	96.6 j/	156
21-Jul – 27-Jul	907	--					3.4 j/	31	96.6 j/	876
28-Jul – 03-Aug	636	62					0.0	0	100.0	636
04-Aug – 10-Aug	374	38					2.6	10	97.4	364
11-Aug – 17-Aug	1,974	180					1.1	22	98.9	1,952
18-Aug – 24-Aug	1,882	159					1.9	36	98.1	1,846
25-Aug – 31-Aug	1,719	143					2.8	48	97.2	1,671
01-Sep – 07-Sep	3,278	132					1.5	49	98.5	3,229
08-Sep – 14-Sep	2,048	120					0.0	0	100.0	2,048
15-Sep – 21-Sep	5,999	222					0.9	54	99.1	5,945
22-Sep – 28-Sep	5,617	242					Total g/:	805	100.0	5,617
29-Sep – 05-Oct	4,238	230							100.0	4,238
06-Oct – 12-Oct	4,130	203							100.0	4,130
13-Oct – 19-Oct	4,057	104	3.8	154					96.2	3,903
20-Oct – 26-Oct	3,030	152	9.9	300					90.1	2,730
27-Oct – 02-Nov	1,693	113	17.7	300					82.3	1,393
03-Nov – 09-Nov	1,269	102	31.4	398					68.6	871
10-Nov – 16-Nov	1,109	138	15.2	169					84.8	940
17-Nov – 23-Nov	1,721	131	44.3	762					55.7	959
24-Nov – 30-Nov	770	51	60.8	468					39.2	302
01-Dec – 07-Dec	--	--								
08-Dec – 14-Dec	--	--		2,520 f/		22 f/				845 f/
15-Dec – 21-Dec	--	--							Total g/:	45,833
22-Dec – 28-Dec	--	--								
Total for 1991 calendar year k/:	48,318	2,977		8,694		210		805		45,833

a/ Red Bluff Diversion Dam gates were raised from 3 December 1990 through 3 May 1991, and from 1-31 December 1991.

b/ Actual weekly counts were expanded to adjust for periods when the fishways were open and no observations were made.

c/ Salmon in the fishway trapping facility which were examined to determine the run composition, based on relative spawning readiness.

d/ Adjusted count x Proportion of examined fish assigned to run.

e/ Estimated numbers represent salmon passing the dam during this period in 1990 that were expected to spawn in 1991 (Kano 1998a).

f/ Due to the dam gates being raised, no counts were possible. Estimated numbers based on historical (1968-1985) average proportional run distribution.

g/ Total estimated number of potential spawners for the 1991 run.

h/ Includes 118 fish trapped at Keswick Dam and trucked to Coleman National Fish Hatchery.

i/ Includes 18 fish trapped at Keswick Dam and 5 fish at Red Bluff Dam that were trucked to Coleman National Fish Hatchery.

j/ Fishway trap was not operated. Percentage based on previous and following week's proportions.

k/ Including late-fall- and winter-run 1992 potential spawners.

TABLE 2. Calculation of the 1991 spawner population for each run of chinook salmon upstream of Red Bluff Diversion Dam.

Run	Number of fish passing dam in calendar year: 1990		1991		Number of potential spawners		Estimated sport catch		Estimated 1991 spawner population
Late-fall a/	3,468	+	3,623 b/	=	7,091	-	209	=	6,882
Winter a/	3	+	188 b/	=	191	-	1	=	190
Spring			805	=	805	-	43	=	762
Fall			45,833	=	45,833	-	5,655	=	40,178
Totals:	**3,471**	**+**	**50,449**	**=**	**53,920**	**-**	**5,908**	**=**	**48,012**

a/ Estimated numbers of these runs from 3 Dec. 1990 through 1 May 1991 were calculated using the historical (1968-1985) average proportional distribution.

b/ Totals of 5,071 late-fall- and 22 winter-run salmon passed RBDD in the latter part of 1991 (Table 1), and were not included in these counts; these fish were considered 1992 spawners.

The estimated 6,721 fish late-fall spawner population for the upper Sacramento River mainstem was 5.8% lower than the 1990 population of 7,136 fish, and 71% of the race's average run size from 1981 through 1990 (Appendix 3).

Winter run. An estimated 191 winter-run 1991 potential spawners passed RBDD in 1990 and 1991 (Table 1). The winter-run sport-catch was estimated to be one salmon, leaving a spawner population of 190 fish (Table 2) upstream of Red Bluff. Some winter-run salmon may have used Battle Creek, but no spawner surveys were made in that stream for this run. Numbers of those fish are included in the upper mainstem population, along with 18 winter-run salmon trapped at Keswick Dam and five fish from RBDD that were hauled to CNFH for spawning.

The 1991 winter-run spawner population upstream of RBDD was the lowest ever recorded, 56% lower than the 1990 population, and only 5% of the average run size for the previous 10 years (Appendix 3).

Spring run. An estimated 805 spring-run potential spawners passed RBDD in 1991 (Table 1). The spring-run sport-catch was estimated to be 43 salmon, leaving 762 fish as a spawner population upstream of Red Bluff (Table 2). No spring-run salmon were taken into CNFH, and although some spring-run fish may have spawned in Battle Creek, no surveys were made for this run; any of these fish were assigned to the mainstem portion of the run.

The 1991 spring-run spawner population upstream of RBDD was a decrease of 80% from the 1990 population, and only 7% of the average run size for the previous 10 years (Appendix 3).

Fall run. An estimated 45,833 fall-run potential spawners passed RBDD in 1991 (Table 1). The fall-run sport-catch was estimated to be 5,655 salmon, leaving 40,178 fish as a spawner population upstream of Red Bluff (Table 2). A total of 19,943 spawners was estimated for Clear, Cottonwood, and Battle creeks, leaving 20,235 salmon as the upper mainstem population (Appendix 2). This population included fall-run salmon which used other tributaries to the upper mainstem that were not surveyed.

The fall run in the Sacramento River system upstream of Red Bluff was a decrease of 37% from the 1990 population, and was 44% of the average 1981-1990 population (Appendix 3).

Mainstem spawning distribution. The 1991 relative redd distribution of the four runs of salmon in the mainstem Sacramento River from Keswick Dam downstream to RBDD was determined from data collected by airplane during each run's spawning season. All of the winter-, and the majority of the late-fall- and spring-run mainstem spawning (81.6% and 92.9%, respectively) occurred upstream from RBDD (Table 3). Fall-run spawning in this area constituted 67.0% of the entire mainstem.

Clear Creek

Late-fall. No spawner surveys were conducted for this run in this tributary during 1991.

Fall run. Nine weekly mark-and-recovery surveys of Clear Creek were made between 17 October and 10 December 1991, in the 6.4-km (4-mi) stretch of river downstream from McCormick-Saeltzer Dam. A total of 241 fresh salmon carcasses was marked with colored tape attached to the jaw with a hog ring. One-hundred-twenty-six of the marked carcasses were subsequently recovered. A Schaefer estimate (Appendix 1.B) of 2,026 salmon was calculated as the 1991 spawner population (Table 4).

Based on examination of 1,020 salmon carcasses, the spawner population consisted of 36.0% male adults (fork length [FL] > 64 cm [25.2 in]), 51.0% female adults, and 13.0% grilse (FL ≤ 64 cm). The observed prespawning mortality was less than 1%.

TABLE 3. Chinook salmon relative redd distribution during 1991 in the mainstem Sacramento River from Keswick Dam to Princeton Ferry.

River section	Late-fall run		Winter run		Spring run		Fall run	
	Redds counted a/	Proportional distribution	Redds counted b/	Proportional distribution	Redds counted c/	Proportional distribution	Redds counted d/	Proportional distribution
Keswick Dam to A.C.I.D. Dam e/	37	32.5%	0	0.0%	0	0.0%	41	1.9%
A.C.I.D. Dam to Highway 44	8	7.0%	8	72.7%	5	35.7%	261	11.8%
Highway 44 to Upper Anderson Bridge	16	14.0%	3	27.3%	4	28.6%	467	21.1%
Upper Anderson Bridge to Balls Ferry	22	19.3%	0	0.0%	3	21.4%	354	16.0%
Balls Ferry to Jellys Ferry	6	5.3%	0	0.0%	0	0.0%	277	12.5%
Jellys Ferry to Bend Bridge	2	1.8%	0	0.0%	1	7.1%	65	2.9%
Bend Bridge to Red Bluff Dam	2	1.8%	0	0.0%	0	0.0%	17	0.8%
Red Bluff Dam to Tehama Bridge	5	4.4%	0	0.0%	1	7.1%	334	15.1%
Tehama Bridge to Woodson Bridge	3	2.6%	0	0.0%	0	0.0%	231	10.4%
Woodson Bridge to Hamilton City (Hwy. 32)	6	5.3%	0	0.0%	0	0.0%	102	4.6%
Hamilton City to Ord Ferry	7	6.1%	0	0.0%	0	0.0%	58	2.6%
Ord Ferry to Princeton Ferry	0	0.0%	0	0.0%	0	0.0%	5	0.2%
Totals:	114		11		14		2,212	

a/ Total count made during one aerial survey on 13 February 1991.
b/ Total count made for eight aerial surveys from 8 May through 24 July 1991.
c/ Total count made for two aerial surveys on 12 September and 3 October 1991.
d/ Total count made for five aerial surveys from 18 October through 10 December 1991.
e/ Anderson-Cottonwood Irrigation District Dam.

TABLE 4. Chinook salmon carcass mark–and–recovery data used to estimate the 1991 fall–run spawner population in Clear Creek from McCormick–Saeltzer Dam to 6.4 km (4.5 mi) downstream. a/

Recovery period (j)	Number of marked carcasses recovered from marking period (i): 1	2	3	4	5	6	7	Total marked carcasses recovered (Rj)	Total carcasses observed (Cj) b/	Population estimate (N) c/
2	6	--	--	--	--	--	--	6	74	211
3	0	13	--	--	--	--	--	13	75	127
4	0	7	10	--	--	--	--	17	260	468
5	1	2	5	21	--	--	--	29	336	703
6		1	1	10	12	--	--	24	177	322
7				9	5	9	--	23	128	223
8				1	3	2	8	14	75	143
9								0	50	50
Total recovered (Ri):	7	23	16	41	20	11	8		Total:	2,247
Total carcasses marked (Mi):	20	39	30	88	31	16	17			
								Adjusted estimate d/:		**2,026**

a/ Surveys were conducted from 17 October to 10 December 1991.

b/ Includes salmon carcasses which were marked and marked carcasses that were recovered.

c/ Schaefer (1951) estimate equation: $N = \Sigma (Rij \times (Mi/Ri) \times (Cj/Rj))$.

d/ Adjusted estimate reflects the modified Schaefer equation (Hoopaugh 1978), where marked carcasses (Mi) from the second marking period on were subtracted from the total estimate, i.e. 2,247 – 221 = 2,026.

Cow Creek

Spring Run. Surveys were conducted from 22-29 July 1991 in a 13.6-km (8.5-mi) stretch of South Cow Creek starting 31.3 km (19.5 mi) upstream from its confluence with North Cow Creek. Pools in this reach of the creek that were deeper than 1.2 m (4 ft) and with water temperatures of less than 20.5°C (69°F) were snorkeled. No salmon were observed, and a population estimate was not made.

Fall Run. Surveys were made on 7 and 19 November 1991 starting 3.2 km (2 mi) upstream from the mouth of Cow Creek and extending 9.6 km (6 mi) into South Cow Creek. A total of 59 salmon carcasses, 63 live fish, and 126 redds was observed.

Aerial redd surveys were also made of the creek on 18 October and 1 November 1991, from its mouth to 14.5 km (9 mi) upstream, following the north fork. Twenty-eight redds were counted.

No estimate of the Cow Creek fall-run population was made.

The spawner population of Cow Creek consisted of 41% male adults (FL > 64 cm [25.2 in]), 48% female adults, and 11% grilse (FL ≤ 64 cm), based on a sampling of 54 carcasses. No pre-spawning mortality was observed.

Bear Creek

Fall run. Surveys were conducted on 1 and 7 November 1991 from the mouth of Bear Creek to 4.8 km (3 mi) upstream. A total of 7 salmon carcasses, only one live fish, and 29 redds was observed. A population estimate for this run was not made.

Cottonwood Creek

Spring run. Cottonwood Creek was not surveyed for this run in 1991.

Fall run. An aerial redd survey from the creek's mouth to the confluence with the south fork was made on 18 October 1991, during which 32 redds were counted.

Seven weekly surveys were made between 16 October and 26 November 1991 covering the 16.9-km (10.5-mi) stretch of Cottonwood Creek upstream from its mouth; the presence of several beaver dams probably prevented salmon migration past this point. A total of 229 salmon carcasses was counted. Thirty carcasses were marked by attaching colored tape to the jaw with a hog ring, and 10 were subsequently recovered. A Petersen estimate (Appendix 1.A.2) of 676 fish was calculated as the spawner population for 1991.

The spawner population of Cottonwood Creek consisted of 33% male adults (FL > 64 cm [25.2 in]), 31% female adults, and 36% grilse (FL ≤ 64 cm), based on a sampling of 205 carcasses. No pre-spawning mortality was observed.

Battle Creek

Late-fall, winter, and spring runs. No spawner surveys were conducted for these runs during 1991 in Battle Creek. The only available spawner data were for 161 late-fall run salmon taken into CNFH.

Fall run. Ten weekly surveys were conducted from 7 October through 9 December 1991. Surveys covered the 5.6-km (3.5-mi) stretch of river between CNFH and the old hatchery location. The first six surveys also included 0.4 km (0.25 mi) of Gover's Ditch from the bypass entrance to the fish screen. Salmon carcasses were marked by attaching colored tape to the jaw with a hog ring; fresh carcasses were marked on the upper jaw, while decayed carcasses were marked on the lower jaw.

Using fresh carcass mark-and-recovery data with the Schaefer calculations (Appendix 1.B), 6,558 salmon were estimated as the spawner population in Battle Creek downstream of CNFH (Table 5). Combined with an additional 10,683 fish which entered CNFH, the total Battle Creek fall-run population was 17,241 salmon.

The composition of fall-run salmon in Battle Creek was 39% male adults (FL > 64 cm [25.2 in]), 56% female adults, and 5% grilse (FL ≤ 64 cm), based on an examination of 3,500 carcasses. In comparison, fish entering CNFH consisted of 46.7% male adults, 47.2% female adults, and 6.1% grilse. Pre-spawning mortality of fall-run salmon in Battle Creek averaged 3.0% in 1991.

The 1991 fall spawner population for Battle Creek of 17,241 fish was 18% lower than the 1990 run, and 57% of the average run size for 1981 through 1990 (Appendix 3).

Ash, Inks, and Paynes creeks

Fall Run. During a normal year of rainfall, these creeks support small fall runs. However, drought conditions prevailed in 1991, with these streams remaining dry or with insufficient flow to attract salmon. No spawner surveys were conducted.

TABLE 5. Chinook salmon carcass mark–and–recovery data used to estimate the 1991 fall–run spawner population in Battle Creek downstream from Coleman National Fish Hatchery to the old hatchery site, including Gover's Ditch. a/

Recovery period (j)	Number of marked carcasses recovered from marking period (i): 1	2	3	4	5	6	7	8	Total marked carcasses recovered (Rj)	Total carcasses observed (Cj) b/	Population estimate (N) c/
2	1	--	--	--	--	--	--	--	1	148	888
3		37	--	--	--	--	--	--	37	590	856
4		13	71	--	--	--	--	--	84	887	1,933
5		1	6	97	--	--	--	--	104	1,016	1,236
6			2	15	92	--	--	--	109	999	1,445
7			1	4	30	42	--	--	77	359	500
8					1	4	10	--	15	104	181
9					3	3	5	10	21	73	127
10						2		2	4	56	89
Total recovered (Ri):	1	51	80	116	126	51	15	12		Total:	7,255
Total carcasses marked (Mi):	6	74	185	133	186	68	29	22			
									Adjusted estimate d/:		**6,558**

a/ Surveys were conducted from 7 October to 9 December 1991.

b/ Includes salmon carcasses which were marked and marked carcasses that were recovered.

c/ Schaefer (1951) estimate equation: $N = \Sigma (Rij \times (Mi/Ri) \times (Cj/Rj))$.

d/ Adjusted estimate reflects the modified Schaefer equation (Hoopaugh 1978), where marked carcasses (Mi) from the second marking period on were subtracted from the total estimate, i.e. 7,255 – 697 = 6,558.

Red Bluff Diversion Dam to Princeton Ferry
by Richard E. Painter, CDFG-IFD

A total of 12,308 chinook salmon spawners was estimated for 1991 in the Sacramento River system between Red Bluff and Princeton Ferry (Figure 2). This total consisted of 1,516 late-fall-, 856 spring-, and 9,936 fall-run salmon (Appendix 2).

Tributaries in this area that were individually surveyed were Antelope, Mill, and Deer creeks. Population estimates were made only for the mainstem, and Mill and Deer creeks. Due to the RBDD gates being opened, the Tehama-Colusa Spawning Channel was not operated, and no salmon entered that facility.

Sacramento River Mainstem

Late-fall run. Based on an aerial survey made on 13 February 1991, an estimated 1,516 late-fall-run salmon were in the mainstem Sacramento River downstream of Red Bluff to Ord Bend.

Winter run. No redds were observed in the mainstem Sacramento River downstream of Red Bluff during eight aerial surveys between 8 May and 24 July 1991, and it was assumed that no winter-run salmon spawned in this stretch of the river.

Spring run. Based on two aerial surveys between 12 September and 3 October 1991, an estimated 58 spring-run salmon were in the mainstem Sacramento River downstream of Red Bluff to Tehama Bridge.

Fall run. Based on five aerial surveys from 18 October through 10 December 1991, 9,936 fall-run salmon were estimated for the mainstem Sacramento River between RBDD and Princeton Ferry. This run size was 38% lower than the 1990 population, and only 36% of the average run size from 1981 to 1990 (Appendix 3).

Mainstem spawning distribution. Redd counts made during the aerial surveys in 1991 were used to determine the relative spawning distribution of the four runs of salmon in the mainstem Sacramento River between Red Bluff and Princeton Ferry (Table 3). In proportion to the entire mainstem (including upstream of RBDD) spawning activity, 18.4% of the late-fall-, none of the winter-, 7.1% of the spring-, and 33.0% of the fall-run redds were observed this section of the river.

Antelope Creek

Spring run. A survey of upper Antelope Creek was made on 12 August 1991. Snorkeling to count salmon was conducted from the confluence of the north and south forks to 3.2 km (2 mi) downstream. No spring-run salmon were observed. A population estimate was not made.

Fall run. A survey was conducted on 31 October 1991 in the 1.6-km (1-mi) stretch of Antelope Creek upstream of Cone Grove Bridge. No salmon were observed, and due to low water conditions further surveys were not made. An estimate of the fall-run spawner population was not made.

Mill Creek

Spring run. During the spring-run spawning period, ten surveys were made of upper Mill Creek from 14 August to 3 October 1991. Sections of the creek from 6.4 km (4 mi) upstream of the HWY.36 Bridge to 42.6 km (26.5 mi) downstream were snorkeled or walked. Totals of four salmon carcasses, 24 adult fish, and 45 redds were observed.

Prior to these surveys, spring-run salmon were monitored immigrating past Clough Dam from 10 April through 13 June 1991. Passage through a 1.2-m long by 0.45-m diameter (4-ft L x 1.5-ft D) tunnel located at the upstream end of the fish ladder, was recorded by a Smith-Root Model 602 electronic fish counter. Through this method a total of 319 salmon was determined as the 1991 spring-run population.

Fall run. Three surveys were made in the 11.3-km (7-mi) stretch of Mill Creek upstream of its mouth. A total of 37 salmon carcasses and 69 redds was counted. An estimate of the fall-run spawner population was not made.

Deer Creek

Spring run. During twelve surveys made from 23 May through 8 October 1991, spring-run salmon were counted by snorkeling or walking sections of the creek downstream from Deer Creek Falls. The actual length of stream surveyed was shorter than the "indicator reach" used to develop a relationship between salmon observed and Stanford-Vina dam ladder counts for estimating the run size in 1987[2/]; in that relationship, the indicator reach count was assumed to represented 31% of the run. This year's

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[2/] E. Eckman. 1986 and 1987 spring-run salmon surveys. File report to the Lassen National Forest Resource Office, U.S. Forest Service, 17 November 1987.

stream section was assumed to represent 29% of the run, and the total snorkeling count of 139 salmon was expanded to 479 fish for the 1991 spring run.

Fall run. A 3.5-km (2.2-mi) stretch of lower Deer Creek was surveyed on 18 November and 5 December 1991 from the railroad trestle located 3.2 km (2 mi) from its mouth to Stanford-Vina Dam. No live salmon, carcasses, or redds were observed; salmon may not have been able to ascend the creek due to low water conditions. An estimate of the spawner population was not made.

Salt, New, Craig, Dye, Coyote, Elder, Thomes, Toomes, Stoney, and Singer creeks

Fall run. During a normal year of rainfall, these creeks support small fall runs. However, drought conditions prevailed in 1991, with these streams remaining dry or with insufficient flow to attract salmon. No spawner surveys were conducted.

Big Chico Creek to the American River

A total of 85,584 chinook salmon was estimated in 1991 for the Sacramento River tributaries from Butte Creek to the American River (Figure 3). This total consisted of 4,303 spring-run and 81,281 fall-run fish (Appendix 2).

Big Chico Creek

Spring run. No surveys were conducted for this run in 1991.

Fall run. No surveys were conducted for this run in 1991.

Butte Creek

Spring run. No surveys were conducted for this run in 1991.

Fall run. No surveys were conducted for this run in 1991.

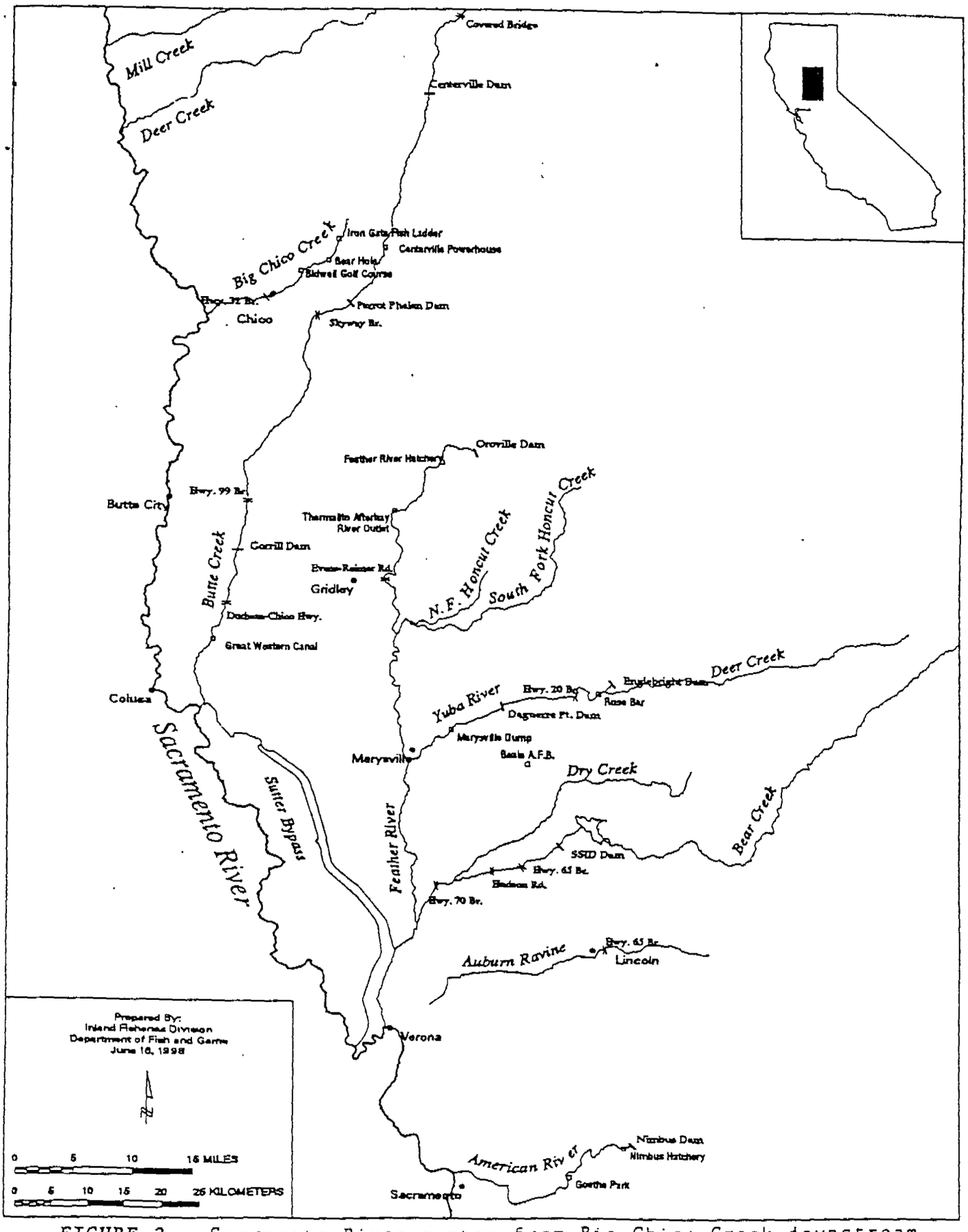

FIGURE 3. Sacrameto River system from Big Chico Creek downstream to the American River.

Feather River - by Fred Meyer, CDFG-Region 2

Spring run. From 7 September to 1 October 1991 at Feather River Hatchery (FRH) 3,448 salmon were classified as spring-run fish (Schlicting 1993); an additional 855 mortalities occurred in the holding ponds for a total of 4,303 which entered FRH. These fish consisted of 56.5% male adults (FL ≥ 65 cm [25.5 in]), 39.9% female adults, and 3.6% grilse (FL < 65 cm). In the river itself, the period of spring-run spawning could not be distinguished from the fall-run spawning period, and no attempt was made to estimate numbers of in-river spring-run salmon.

The 4,303 spring-run salmon at FRH in 1991 was more than twice the 1990 run, and 45% higher than the average number observed in the past 10 years (Appendix 3).

Fall run. Salmon carcass mark-and recovery surveys were conducted in the Feather River between the hatchery barrier dam and the Gridley boat ramp. This stretch of river was surveyed in two sections, characterized by different flow regimes. The stream section between the hatchery barrier dam and Thermalito Afterbay Outlet, a "low-flow section", had constant flows of 17 m^3/s (600 cfs) throughout the survey period of 7 October through 2 December 1991. No surveys were made in this section during the week of 5 November. Flow downstream of Thermalito Afterbay to the Gridley boat ramp ranged from 22.6 m^3/s (800 cfs) to 28.3 m^3/s (1000 cfs) during the survey period of 13 November through 3 December. Visibility through the water was 1.2 m to 1.8 m (4-6 ft) in the upstream section, and 0.9 m to 1.2 m (3-4 ft) in the downstream section.

Only fresh adult carcasses were marked, with a colored ribbon attached to the lower jaw by a hog ring, and released into flowing water for later recovery. Fresh carcasses were distinguished by having at least one clear eye, while the adult distinction was a FL ≥ 66 cm (26 in); this length separation was based on early season recoveries of coded-wire-tagged salmon. All other carcasses, including recovered marks, were chopped in half.

Schaefer (Appendix 1.B) estimates, calculated from the mark-and-recovery data, were 24,623 adult salmon for the upstream section, and 3,901 adults for the downstream section (Table 6, Table 7). Combining these numbers and expanding for a 9% grilse proportion gave a total in-river estimate of 31,345 fish. A total of 10,717 fall-run salmon entered FRH (including 1,215 mortalities which occurred in the holding ponds) bringing the 1991 fall run in the Feather River to 42,062 fish.

The composition of fall-run salmon in the river, based on examination of 1,420 fresh carcasses, was 30% male adults (FL ≥ 66 cm [26 in]), 61% female adults, and 9% grilse. In comparison,

TABLE 6. Chinook salmon carcass mark–and–recovery data used to estimate the 1991 fall–run adult spawner population in the Feather River from Feather River Hatchery to Thermalito Afterbay Outlet. a/

Recovery period (j)	Number of marked carcasses recovered from marking period (i): 1	2	3	4	5	6	7	8	Total marked carcasses recovered (Rj)	Total carcasses observed (Cj) b/	Population estimate (N) c/
2	1	--	--	--	--	--	--	--	1	161	1,234
3	2	23	--	--	--	--	--	--	25	673	2,592
4		2	58	--	--	--	--	--	60	780	3,634
5			--	--	--	--	--	--	0	0	0
6			0	13	--	--	--	--	13	934	13,660
7			4	3	--	22	--	--	29	413	2,429
8			1		--	9	19	--	29	211	1,067
9					--		1	5	6	115	923
Total recovered (Ri):	3	25	63	16	0	31	20	5		Total:	25,539
Total carcasses marked (Mi):	23	88	296	234	0	152	103	43			
									Adjusted estimate d/:		**24,623**

a/ Surveys were conducted from 7 October to 2 December 1991, except no survey was made during the fifth week.

b/ Includes salmon carcasses which were marked and marked carcasses that were recovered.

c/ Schaefer (1951) estimate equation: $N = \leq (Rij \times (Mi/Ri) \times (Cj/Rj))$.

d/ Adjusted estimate reflects the modified Schaefer equation (Hoopaugh 1978), where marked carcasses (Mi) from the second marking period on were subtracted from the total estimate, i.e. 25,539 – 916 = 24,623.

TABLE 7. Chinook salmon carcass mark–and–recovery data used to estimate the 1991 fall–run adult spawner population in the Feather River from the Thermalito Afterbay Outlet to Gridley. a/

Recovery period (j)	Number of marked carcasses recovered from marking period (i): 1	2	3	4	5	Total marked carcasses recovered (Rj)	Total carcasses observed (Cj) b/	Population estimate (N) c/
2	52	--	--	--	--	52	380	830
3	7	29	--	--	--	36	378	1,005
4	1	2	9	--	--	12	274	2,140
5					--	0	117	117
Total recovered (Ri):	60	31	9	--	--		Total:	4,092
Total carcasses marked (Mi):	131	86	86	19	--			
						Adjusted estimate d/:		**3,901**

a/ Surveys were conducted from 13 November to 3 December 1991.

b/ Includes salmon carcasses which were marked and marked carcasses that were recovered.

c/ Schaefer (1951) estimate equation: $N = \sum (Rij \times (Mi/Ri) \times (Cj/Rj))$.

d/ Adjusted estimate reflects the modified Schaefer equation (Hoopaugh 1978), where marked carcasses (Mi) from the second marking period on were subtracted from the total estimate, i.e. 4,092 – 191 = 3,901.

salmon entering FRH consisted of 34.4% male adults, 51.7% female adults, and 13.9% grilse.

The 1991 Feather River population of 42,062 salmon was 13% lower than the 1989 run (this tributary was not surveyed in 1990), and 79% of the average population from 1981 to 1989 (Appendix 3).

Yuba River

Spring Run. No surveys were conducted for this run in 1991.

Fall run. The 1991 fall-run salmon spawner surveys were conducted by consultants Jones & Stokes Associates, Inc. under contract to the Yuba County Water Agency (Mitchell 1992).

Weekly salmon carcass mark-and-recovery surveys were conducted from 1 October through 12 December 1991 in the Yuba River from the Parks Bar bridge (Hwy.20) downstream to the E Street bridge in Marysville. In the river stretch upstream of Hwy.20 to Englebright Dam, a single survey was conducted on 29 October to examine the amount of spawning occurring there.

Yuba River flows and water clarity during the surveys provided excellent conditions for sampling and recovery of salmon carcasses. Flows at Marysville were approximately 59.5 m^3/s (2100 cfs) for the first week of the surveys, and decreased steadily to about 16.7 m^3/s (600 cfs) by mid-October, where they remained for the remainder of the survey period. Visibility through the water in the survey areas ranged from 1.5 to 3 m (5-10 ft).

This season fresh carcasses of both adult and grilse were marked to estimate the numbers of each in the population. This was the only change in procedure from that used by CDFG in recent past seasons; in those surveys only adult carcasses, regardless of their state of decomposition, were marked. A carcass was determined to be fresh if it had at least one clear eye or had firm flesh and a shiny appearance. The CDFG length criteria of 66 cm FL (26 in) was used to separate adult from grilse carcasses. Marks consisted of pieces of surveyor's tape attached to the lower jaws of carcasses, and different colors of tape were used to identify carcasses with specific marking periods. Marked carcasses were returned into running water for subsequent recovery. Decayed carcasses were counted and chopped in half.

Using carcass mark-and-recovery data with the Schaefer model (Appendix 1.B), separate estimates were made for adult and grilse populations (9,500 and 2,337, respectively) in the Yuba River between the Hwy.20 bridge and Marysville (Table 8, Table 9). The population for the area upstream of Hwy.20 to Rose Bar was also calculated assuming that spawners in this section constituted a 15.5% proportion of the total river's population. Including this

TABLE 8. Chinook salmon carcass mark–and–recovery data used to estimate the 1991 fall–run adult spawner population in the Yuba River between the Highway 20 bridge and Marysville. a/

Recovery period (j)	Number of marked carcasses recovered from marking period (i): 1	2	3	4	5	6	7	8	9	Total marked carcasses recovered (Rj)	Total carcasses observed (Cj) b/	Population estimate (N) c/
2	3	--	--	--	--	--	--	--	--	3	267	1,001
3	0	37	--	--	--	--	--	--	--	37	645	1,703
4	1	17	93	--	--	--	--	--	--	111	1,042	2,542
5		10	25	91	--	--	--	--	--	126	922	2,018
6			7	12	67	--	--	--	--	86	689	1,190
7			1	3	8	36	--	--	--	48	472	1,049
8					1	11	22	--	--	34	215	514
9						1	1	9	--	11	106	298
10							2	0	6	8	61	220
Total recovered (Ri):	4	64	126	106	76	48	25	9	6		Total:	10,535
Total carcasses marked (Mi):	15	169	301	221	119	114	61	26	24			
										Adjusted estimate d/:		9,500

a/ Surveys were conducted from 8 October to 12 December 1991.

b/ Includes salmon carcasses which were marked and marked carcasses that were recovered.

c/ Schaefer (1951) estimate equation: $N = \sum(Rij \times (Mi/Ri) \times (Cj/Rj))$.

d/ Adjusted estimate reflects the modified Schaefer equation (Hoopaugh 1978), where marked carcasses (Mi) from the second marking period on were subtracted from the total estimate, i.e. 10,535 – 1,035 = 9,500.

TABLE 9. Chinook salmon carcass mark–and–recovery data used to estimate the 1991 fall–run grilse spawner population in the Yuba River between the Highway 20 bridge and Marysville. a/

Recovery period (j)	Number of marked carcasses recovered from marking period (i): 1	2	3	4	5	6	7	8	9	Total marked carcasses recovered (Rj)	Total carcasses observed (Cj) b/	Population estimate (N) c/
2	0	--	--	--	--	--	--	--	--	0	13	13
3		4	--	--	--	--	--	--	--	4	84	98
4		2	13	--	--	--	--	--	--	15	262	588
5			2	10	--	--	--	--	--	12	206	884
6			1	4	12	--	--	--	--	17	181	523
7			1	1	2	9	--	--	--	13	104	238
8					1	3	2	--	--	6	42	128
9						2	1	2	--	5	23	55
10								0	0	0	12	12
Total recovered (Ri):	0	6	17	15	15	14	3	2	0		Total:	2,539
Total carcasses marked (Mi):	0	7	41	70	35	28	15	3	3			

Adjusted estimate d/: 2,337

a/ Surveys were conducted from 8 October to 12 December 1991.

b/ Includes salmon carcasses which were marked and marked carcasses that were recovered.

c/ Schaefer (1951) estimate equation: $N = \sum (Rij \times (Mi/Ri) \times (Cj/Rj))$.

d/ Adjusted estimate reflects the modified Schaefer equation (Hoopaugh 1978), where marked carcasses (Mi) from the second marking period on were subtracted from the total estimate, i.e. 2,539 – 202 = 2,337.

section's population of 2,171 salmon, the total estimated 1991 Yuba River spawner population was 14,008 fish.

The composition of the run based on examination of 110 fresh carcasses was 42.0% male adults (FL ≥ 66 cm [26 in]), 37.7% female adults, and 20.3% grilse (FL < 66 cm).

The 1991 Yuba River run of 14,008 salmon was almost double the population of 1989 (this tributary was not surveyed in 1990), and 87% of the average run size from 1981 to 1989 (Appendix 3).

American River - by Maury Fjelstad, CDFG-Region 2

Fall run. Weekly salmon carcass mark-and-recovery surveys were conducted between 14 November and 20 December 1991 in the 11.2-km (7-mi) reach of the American River from Goethe Park upstream to the Nimbus Hatchery racks. River flows averaged 41 m^3/s (1,448 cfs) during the survey period, but varied greatly, ranging from 22.7 m^3/s to 74.6 m^3/s (800-2679 cfs). Higher flows were more prevalent during the later surveys, and possibly reduced carcass recoveries.

Only adult carcasses, regardless of their state of decomposition, were marked for use in estimating the population. While all the fresh (clear-eyed) carcasses were marked, at times it was only possible to mark about half of the decayed carcasses seen. Marked carcasses were either replaced into running water when possible, or left in place in backwater areas.

The adult salmon spawner population of the Goethe Park to Nimbus racks section, estimated from mark-and-recovery data using the Schaefer model was 14,616 fish. This adult estimate was expanded to include a 9% grilse proportion, for a total of 16,061 fish in this section. Upstream of the Nimbus racks, 2,022 spawners were estimated. The two combined estimates gave 18,083 salmon within the river. An additional 7,128 salmon entered Nimbus Hatchery (Ducey 1992), bringing the total American River 1991 fall-run population to 25,211 fish.

The composition of 760 fresh salmon carcasses examined was 50% male adults (FL ≥ 68 cm [26.8 in]), 41% female adults, 8% male grilse (FL < 68 cm), and 1% female grilse. In comparison, fall-run salmon entering the Nimbus Hatchery in 1991 consisted of 45.5% male adults, 49.5% female adults, and 5.0% grilse.

The 1991 run of 25,211 salmon was 2½ times the size of the previous year's population, but still only 60% of the average run size from 1981 through 1990 (Appendix 3).

CHINOOK SALMON SPAWNER POPULATIONS FOR THE SAN JOAQUIN RIVER SYSTEM

The Mokelumne, Stanislaus, Tuolumne, and Merced rivers of the San Joaquin River system (Figure 4) were surveyed for chinook salmon spawners. A total of 1,176 salmon, consisting entirely of fall-run fish, was estimated for 1991 (Appendix 2).

Cosumnes River

Fall run. This tributary was not surveyed.

Mokelumne River

Fall run. A cooperative program (between CDFG, Woodbridge Irrigation District, and East Bay Municipal Utility District [EBMUD]) to benefit fall-run salmon spawning in the Mokelumne River was again implemented during 1991. Releases were made from Camanche Dam to maintain an attraction flow of 14.2 m^3/s (500 cfs) from 1-10 November. Flows were decreased to 5.7 m^3/s (200 cfs) until 15 December, then further decreased to 4.5 m^3/s (160 cfs) for the remainder of the spawning season. Water temperatures in the spawning areas ranged from 18.8°C (66°F) in early October to 13.3°C (56°F) in late November.

Spawner surveys were conducted in the stretch of river from Camanche Dam to Elliot Road between 20 November and 6 December 1991, but very few salmon carcasses were recovered.

EBMUD also contracted with Biosystems, Inc. to monitor salmon at Woodbridge Dam from 1 October through 29 December 1991 (Hartwell 1992). A total of 410 salmon was counted migrating past the dam by using video equipment and a fish trap. Of these salmon, 41 fish entered the Mokelumne River Fish Installation (Estey 1992), and the 1991 fall-run in-river spawner population was assumed to be 369 fish.

The run at Woodbridge Dam consisted of 38.4% male adults (FL ≥ 61 cm [24 in]), 47.4% female adults, 10.8% male grilse (FL < 61 cm), and 3.4% female grilse. The composition of the salmon entering the hatchery was 53.7% male adults, 26.8% female adults, and 14.5% grilse.

The 1991 spawner population of 410 fish in the Mokelumne River was 18% lower than the previous year's run, and only 7% of the average population size estimated from 1981 through 1990 (Appendix 3).

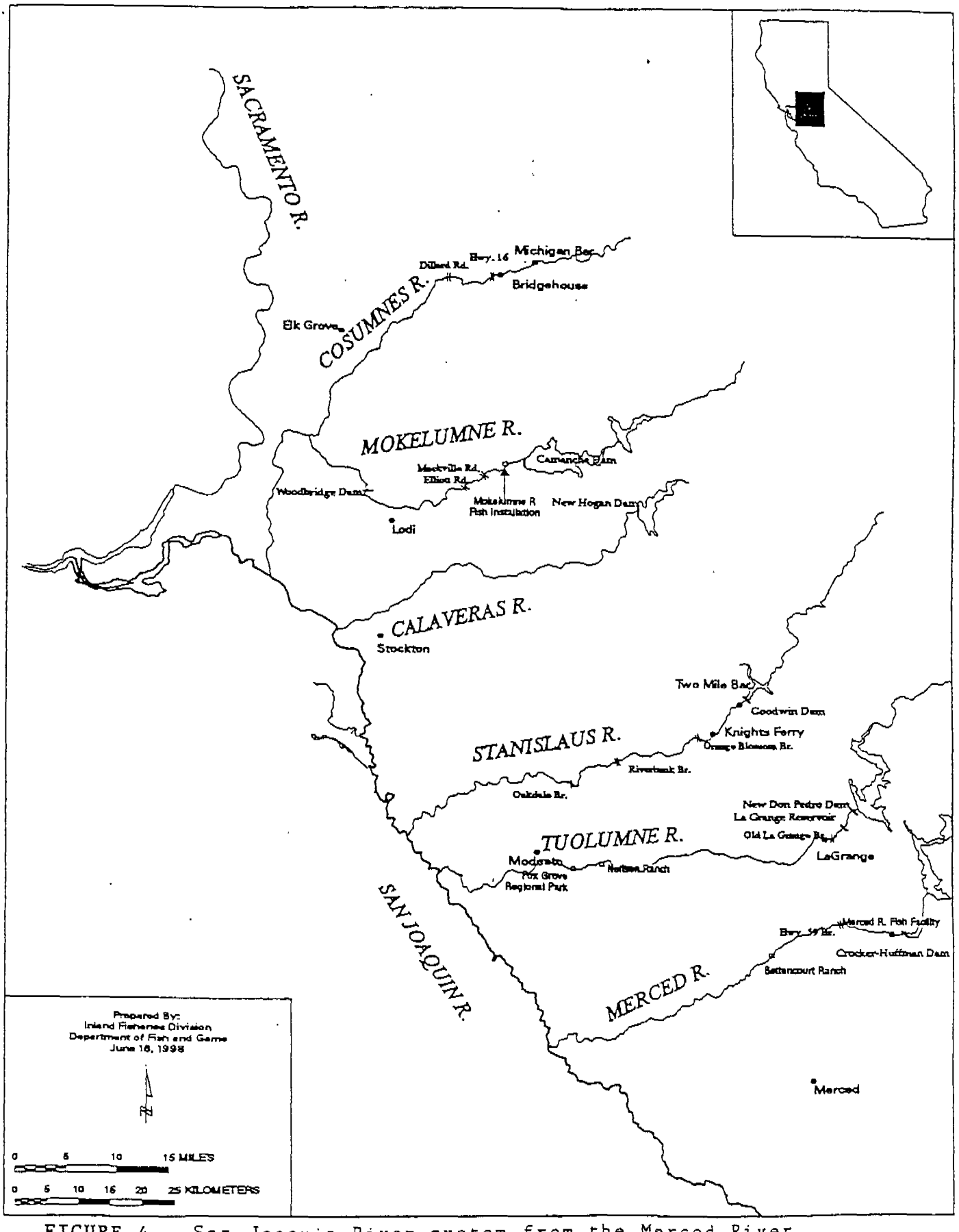

FIGURE 4. San Joaquin River system from the Merced River downstream to the Cosumnes River.

Calaveras River

This tributary was not surveyed in 1991.

Stanislaus River - by Steven J. Baumgartner, CDFG-Region 4

Fall run. A cooperative program (between CDFG, South San Joaquin and Oakdale irrigation districts, Tri-Dam, and U.S. Bureau of Reclamation) to attract fall-run salmon to the Stanislaus River was again implemented during 1991. From 12 October through 10 December, water releases from Goodwin Dam kept river flows at about 5.7 m^3/s (200 cfs). An additional 5.6 m^3/s (196 cfs) was released from the South San Joaquin Irrigation District into the Stanislaus River at Riverbank. A temporary weir and fish-trap just upstream of the Orange Blossom Bridge was operated from 12 October to 7 December to collect eggs from the anticipated increased numbers of salmon; these eggs were hatched and the young reared at Merced River Fish Facility.

Spawner surveys were conducted from 24 October 1991 through 3 January 1992, with actual mark-and-recovery starting on 21 November. Surveys were made on-foot in the Goodwin Dam and Two Mile Bar areas, while the 30.9-km (19.2-mi) stretch from Knights Ferry downstream to Riverbank was covered by boat. During the surveys, river flows at Orange Blossom Bridge ranged from 2.2 to 4.9 m^3/s (79-173 cfs), while water temperatures ranged from 13.3°C (55.9°F) in early November to 9.4°C (48.9°F) in early January. Visibility through the water was always greater than 3 m (10 ft).

This season, both fresh and decayed adult salmon carcasses, regardless of age-class, were marked using serially-numbered brass tags attached to a jaw with a hog-ring. Marked carcasses were released into running water for subsequent recovery. Carcasses of decayed grilse salmon and skeletons were only counted and chopped in half to prevent recounting.

The carcass marking protocol and use of numbered tags was intended to allow post-season distinction of age-class and condition, so the data could be better compiled for estimating the population through several biometric models (Appendix 1). Analysis of the data indicated that the Schaefer estimation was the most appropriate technique.

The salmon population of the Knights Ferry to Riverbank section was estimated at 335 fish using the fresh adult and grilse mark-and-recovery data in the Schaefer calculations (Table 10). Based on redd counts, about 15 salmon were present in the Goodwin Dam and Two-Mile Bar areas. A total of 44 salmon was trapped at Orange Blossom Bridge from 12 October to 10 December 1991.

TABLE 10. Chinook salmon carcass mark–and–recovery data used to estimate the 1991 fall–run spawner population in the the Stanislaus River from Knights Ferry to Riverbank. a/

Recovery period (j)	Number of marked carcasses recovered from marking period (i): 1	2	3	4	5	6	Total marked carcasses recovered (Rj)	Total carcasses observed (Cj) b/	Population estimate (N) c/
2	0	--	--	--	--	--	0	24	24
3	1	5	--	--	--	--	6	30	70
4		1	2	--	--	--	3	38	152
5				1	--	--	1	13	56
6				1	0	--	1	11	48
7				1	1	0	2	8	25
Total recovered (Ri):	1	6	2	3	1	0		Total:	375
Total carcasses marked (Mi):	4	12	10	13	2	3			
							Adjusted estimate d/:		**335**

a/ Surveys were conducted from 23 October 1991 to 3 January 1992; marking started on 21 November.

b/ Includes salmon carcasses which were marked and marked carcasses that were recovered.

c/ Schaefer (1951) estimate equation: $N = \sum (Rij \times (Mi/Ri) \times (Cj/Rj))$.

d/ Adjusted estimate reflects the modified Schaefer equation (Hoopaugh 1978), where marked carcasses (Mi) from the second marking period on were subtracted from the total estimate, i.e. 375 – 40 = 335.

The combined numbers for fall-run salmon from Goodwin Dam to Riverbank, and from the fish spawned at the trap gave a run of 394 fish for the Stanislaus River in 1991.

The run consisted of 38% male adults (FL ≥ 67 cm [26.4 in]), 46% female adults, 8% male grilse (FL < 67 cm), and 8% female grilse, based on examination of 105 salmon carcasses (both fresh and decayed). The length separating grilse and adults was determined from data collected in the entire San Joaquin basin surveys.

The 1991 Stanislaus River fall-run spawner population of 394 salmon was a decrease of 18% from the previous year's population, and only 7% of the average run size for the past ten years (Appendix 3).

Tuolumne River - by Mark M. Pisano, CDFG-Region 4

Fall run. The 1991 fall-run chinook salmon spawner surveys in the Tuolumne River were conducted from 22 October 1991 through 3 January 1992; actual carcass mark-and-recovery began on 26 November. Surveys covered the river stretch from Old LaGrange Bridge downstream to Fox Grove Regional Park, a distance of 38.5 km (24 mi). The average flow during the survey period was 3.2 m^3/s (114 cfs), and visibility was never less than 3 m (10 ft). In the upstream-most survey area, water temperature decreased from 14.0°C (57.2°F) in October to 9.5°C (49.1°F) in December.

This season, both fresh and decayed adult salmon carcasses, regardless of age-class, were marked using serially-numbered brass tags attached to a jaw with a hog-ring. Marked carcasses were released into running water for subsequent recovery. Carcasses of decayed grilse salmon and skeletons were only counted and chopped in half to prevent recounting.

The carcass marking protocol and use of numbered tags was intended to allow post-season distinction of age-class and condition, so the data could be better compiled for estimating the population through several biometric models (Appendix 1). Analysis of the data indicated that the Petersen estimation was the most appropriate technique.

The population in the river section between Old LaGrange Bridge and Fox Grove Regional Park was 52 salmon, estimated from a total of 24 carcasses, 12 of which were marked, and 7 subsequently recovered. Turlock Irrigation District personnel counted three redds in the river stretches up- and downstream of the mark-and-recovery survey area, and from this redd count a total of six salmon was estimated to be in those areas. An additional 19 live salmon were counted after the surveys were completed, bringing the total 1991 fall-run spawner population for the Tuolumne River to 77 salmon.

Based on a sample of 22 carcasses, the run consisted of 36.4% male adults (FL ≥ 67 cm [26.4 in]), 36.4% female adults, and 27.2% male grilse (FL < 67 cm); no female grilse were among the salmon sampled for length and sex determinations. The length separating grilse and adults was determined from data collected in the entire San Joaquin basin surveys.

The 1991 fall run of 77 salmon was a decrease of 20% from the previous year's population (Appendix 3), and the lowest population ever recorded.

Merced River

Fall run. Weekly carcass mark-and-recovery surveys were conducted in the 17.4-km (10.8-mi) stretch of the Merced River from Crocker-Huffman Dam to 1.2 km (0.75 mi) downstream of the Hwy.59 bridge (at Da Sylva's gate). Surveys began on 24 October 1991 and were completed on 3 January 1992; the first salmon were observed on 14 November, about three weeks later than they were seen in surveys prior to 1989. No surveys were made of the river downstream of Hwy.59. Water temperatures decreased from 16°C (60.8°F) in October to 11°C (51.8°F) in January. Visibility through the water was greater than 1.5 m (5 ft) throughout the survey period.

This season, both fresh and decayed adult salmon carcasses, regardless of age-class, were marked using serially-numbered brass tags attached to a jaw with a hog-ring. Marked carcasses were released into running water for subsequent recovery. Carcasses of decayed grilse salmon and skeletons were only counted and chopped in half to prevent recounting.

The carcass marking protocol and use of numbered tags was intended to allow post-season distinction of age-class and condition, so the data could be better compiled for estimating the population through several biometric models (Appendix 1). Analysis of the data indicated that the Petersen estimation was the most appropriate technique.

An estimate of 78 fish was calculated for the river stretch from the Crocker-Huffman Dam to Da Sylva's gate, based on 15 carcasses observed, of which 12 were marked and two subsequently recovered. A total of 41 salmon was taken into the Merced River Fish Facility (M. Cozart, CDFG-Reg. 4, pers. comm.). The total 1991 fall-run spawner population for the Merced River was 119 salmon.

Only 11 carcasses were measured and sexed during the surveys. These consisted of one male adult (FL ≥ 67 cm [26.4 in]), seven female adults, and three female grilse (FL < 67 cm). Salmon which entered the Merced River Fish Facility consisted of 78.1% adults (FL ≥ 61 cm [24 in]), and 21.9% grilse (FL < 61 cm). The

length separating the in-river grilse and adults was determined from data collected in the entire San Joaquin basin surveys.

Eighty-eight salmon which had strayed from the San Joaquin River were "rescued" from the San Luis Canal and Los Banos Wildlife Area bypass channel. The total number of fish present in the western Merced County drainage system was judged to be about twice as many as rescued.

The 1991 Merced River fall run of 119 salmon was an increase of 45% from the previous year's run size, but still only 1% of the average population size from 1981 through 1990 (Appendix 3).

SUMMARY

The total estimated 1991 Central Valley chinook salmon spawner population was 147,080 fish (Table 11).

This was 29% lower than the 1989 total of 205,990 salmon (Kano 1998b). Direct comparison of the 1991 total to the previous year's total was not made, since in-river spawners were not estimated for the Feather and Yuba rivers in 1990. However, 1991 populations in all other individual surveyed tributaries (except for the American River) and the Sacramento River mainstem were lower than during 1990.

Almost all (99.2%) of the 1991 fall run occurred in the Sacramento River system. The Stanislaus, Tuolumne, and Merced rivers of the San Joaquin River system again contributed only a small portion of the fall-run spawners, with a combined total of 590 fish (Appendix 2); this was 10% lower than the combined total estimated in 1990. The winter run in the mainstem Sacramento River was a record low with only 190 salmon.

TABLE 11. Summary of the 1991 Sacramento-San Joaquin river system chinook salmon spawner populations.

Spawning area	Late-fall run	Winter run	Spring run	Fall run	Total
Sacramento mainstem	8,237	190	820	30,171	39,418
Sacramento tributaries	161a/	--	5,101	101,224	106,486
San Joaquin tributaries	--	--	--	1,176	1,176
Totals:	**8,398**	**190**	**5,921**	**132,571**	**147,080**

a/ Consists only of fish which entered Coleman Hatchery (Battle Creek).

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APPENDIX 1. Calculation methods used with carcass mark-and-recovery data to estimate chinook salmon spawner populations.

A. The Petersen equation:

1.

$$N = \frac{M \times C}{R}$$

or,

2. Chapman's version in Ricker (1975);

$$N = \frac{(M+1) \times (C+1)}{(R+1)}$$

where N = estimated spawner population,

M = number of carcasses marked,

C = number of carcasses observed, including those marked and those recovered with marks, and

R = number of marked carcasses recovered.

B. A modification of the Schaefer (1951) equation, which was initially used in the 1976 Central Valley spawner stock report (Hoopaugh 1978);

$$N = \sum \left(R_{ij} \times \frac{M_i}{R_i} \times \frac{C_j}{R_j}\right) - \sum_2^i M_i$$

where N = the estimated spawner population,

R_{ij} = carcasses marked in the ith marking period which were recovered in the jth recovery period,

M_i = carcasses marked in the ith marking period,

R_i = total marked carcasses recovered from the ith marking period,

R_j = total marked carcasses recovered during the jth recovery period,

C_j = total carcasses observed in the jth recovery period, including those with marks, and

$\sum_2^i M_i$ = total carcasses marked from the second marking period on. Subtraction of this factor adjusted for replacement of recovered marked fish.

C. The Jolly-Seber calculations as modified by Boydstun (1994):

$E = N_1 + D_1 + D_2 + \ldots D_j$, where

E = the estimated spawner population

N_1 = number of carcasses in the surveyed population in period 1, the first "week" of spawning, and

D_i = number of carcasses joining the population between period *i* and *i*+1, with *j* being the last survey period.

Three basic quantities are first calculated:

1) An estimate of the number of marked carcasses available for recovery during each survey (B_i):

$$B_i = \frac{(T_i+1) \times (K_i)}{(R_i+1)} + (M_i+1)$$

- To estimate B_j, the number of marked carcasses in the population just before the last survey, it is assumed that the proportion of marked carcasses in the last survey is the same as the estimated proportion in the previous survey, and:

$$B_j = \frac{B_{j-1} \times M_j}{M_{j-1}}$$

2) An estimate of the number of carcasses in the population immediately before each survey (N_i):

$$N_i = \frac{B_i \times (C_i+1)}{M_i+1}$$

and,

3) An estimate of the "survival rate" of marked carcasses from the *i*th to the *i*th+1 periods (S_i):

$$S_i = \frac{b_{i+1}}{b_i - m_i + T_i}$$

- to estimate survival of carcasses from period 1 to period:

$$S_1 = \frac{B_2}{T_1}$$

In the above equations, the variables are defined as:

T_i = number of carcasses marked in the *i*th period,

K_i = total marked carcasses recovered after the *i*th period that were marked before the *i*th period,

R_i = total recovered marked carcasses that were marked in the *i*th period,

M_i = total recovered marked carcasses for the *i*th period, and

C_i = number of carcasses examined for marks during the *i*th period, including those marked and recovered marks in the period.

D_i can then be calculated:

$$D_i = \frac{(N_{i+1} - S_i) \times (N_i - C_i + T_i)}{\sqrt{S_i}}$$

and,

N_1 can also be calculated, assuming equal sampling efficiency between weeks 1 and 2:

$$N_1 = \frac{N_2 \times C_1 \div C_2}{\sqrt{S_1}}$$

(The use of the square root of *Si* in the denominator of the above two equations is a further modification by Frank Fisher, CDFG, personal comm.)

APPENDIX 2. 1991 chinook salmon spawner population estimates for the Central Valley river system.

River area / Tributary	Estimated number of fish: Late-fall run	Winter run	Spring run	Fall run	Total
Sacramento River System:					
Keswick Dam to Red Bluff					
Sacramento River mainstem a/	6,721 b/	190 c/	762	20,235	27,908
Clear Creek	-- d/	--	--	2,026	2,026
Cottonwood Creek	--	--	-- d/	676	676
Battle Creek					
Coleman National Fish Hatchery	161	--	--	10,683	10,844
Downstream of hatchery	-- d/	-- d/	-- d/	6,558	6,558
(Totals for tributary):	(161)	--	(--)	(17,241)	(17,402)
Totals for area:	6,882	190	762	40,178	48,012
Sacramento River System:					
Red Bluff to Princeton Ferry					
Sacramento River mainstem					
Red Bluff to Tehama Bridge	362	0	58	4,560	4,981
Tehama Bridge to Woodson Bridge	214	0	0	3,141	3,355
Woodson Br. to Hamilton City	437	0	0	1,389	1,826
Hamilton City to Ord Bend	502	0	0	785	1,288
Ord Bend to Princeton Ferry	0	0	0	60	60
(Totals for tributary):	(1,516)	(0)	(58)	(9,936)	(11,510)
Mill Creek	--	--	319	-- e/	319
Deer Creek	--	--	479	-- e/	479
Totals for area:	1,516	0	856	9,936	12,308
Sacramento River System:					
Butte Creek to American River					
Feather River					
Feather River Hatchery	--	--	4,303	10,717	15,020
In-river	--	--	-- d/	31,345	31,345
(Totals for tributary):	--	--	(4,303)	(42,062)	(46,365)
Yuba River	--	--	-- d/	14,008	14,008
American River					
Nimbus Hatchery	--	--	--	7,128	7,128
In-river	--	--	--	18,083	18,083
(Totals for tributary):	--	--	--	(25,211)	(25,211)
Totals for area:	--	--	4,303	81,281	85,584
Sacramento River System Totals:	8,398	190	5,921	131,395	145,904
San Joaquin River System:					
Mokelumne River					
Mokelumne River Fish Installation	--	--	--	41	41
In-river	--	--	--	369	369
(Totals for tributary):	--	--	--	(410)	(410)
Stanislaus River	--	--	--	394	394
Tuolumne River	--	--	--	77	77
Merced River					
Merced River Fish Facility	--	--	--	41	41
In-river	--	--	--	78	78
(Totals for tributary):	--	--	--	(119)	(119)
San Luis/Los Banos trap	--	--	--	176	176
San Joaquin River system totals:	--	--	--	1,176	1,176

a/ Includes numbers of fish for tributaries in this river area that were not surveyed or for which an estimate was not made.

b/ Includes 118 fish from Keswick Dam that were transported to and spawned at Coleman Hatchery.

c/ Includes 18 fish from Keswick Dam and 5 fish from Red Bluff Diversion Dam that were transported to Coleman Hatchery.

d/ Tributary was not surveyed for this run.

e/ An estimate of the run size was not made.

APPENDIX 3. Chinook salmon spawner population estimates from 1981 through 1991 in California's Central Valley tributaries.

Tributary / Race	Estimated number of fish											1981–1990 average
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	
Sacramento River system upstream of Red Bluff (excluding Battle Creek)												
Late–fall run	6,423	4,899	14,984	7,140	8,136	7,811	15,393	11,324	11,351	7,136	**6,721**	9,460
Winter run	19,795	1,233	1,827	2,662	3,684	2,394	1,978	2,075	527	437	**190**	3,661
Spring run	20,655	23,156	3,854	7,823	10,200	15,824	10,972	9,568	5,139	3,856	**762**	11,105
Fall run	33,289	20,567	27,326	41,805	52,820	67,940	75,958	64,170	48,526	32,013	**20,235**	46,441
Battle Creek												
Fall run a/	17,205	26,795	13,983	29,893	39,808	31,252	24,249	67,475	31,048	21,088	**17,241**	30,280
Sacramento River mainstem downstream of Red Bluff												
Fall run	42,724	23,833	32,018	19,166	46,780	34,372	32,588	21,250	10,056	16,127	**9,936**	27,891
Feather River												
Spring run b/	469	1,910	1,702	1,562	1,632	1,433	1,213	6,833	5,078	1,893	**4,303**	2,373
Fall run a/	53,020	55,519	30,522	51,056	56,002	55,471	77,846	49,036	48,119	6,126 b/	**42,062**	52,955
Yuba River												
Fall run	14,025	39,367	13,756	9,665	13,042	19,328	18,518	9,000	7,622	c/	**14,008**	16,036
American River												
Fall run a/	64,055	43,898	35,300	39,696	65,213	55,067	46,143	33,514	28,923	10,239	**25,211**	42,205
Mokelumne River												
Fall run a/	4,954	9,372	15,861	8,298	7,682	7,167	1,630	528	281	499	**410**	5,627
Stanislaus River												
Fall run	1,000	d/	500	11,439	13,473	6,497	6,292	10,212	1,510	480	**394**	5,711
Tuolumne River												
Fall run	14,253	7,126	14,836	13,689	40,322	7,404	14,751	5,779	1,275	96	**77**	11,953
Merced River												
Fall run a/	10,415	3,263	18,248	29,749	16,052	7,439	4,126	4,592	427	82	**119**	9,439

a/ Estimate includes numbers of salmon at the tributary's hatchery.

b/ Numbers are only those salmon which entered Feather River Hatchery, in–river spawner estimates were not made.

c/ Tributary was not surveyed.

d/ No estimate made.