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CHINOOK SALMON SPAWNER STOCKS IN CALIFORNIA'S CENTRAL VALLEY, 1993

Edited by

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Habitat Conservation Division
Wildlife & Habitat Data Analysis Branch

Inland Fisheries

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ABSTRACT

This report covers the 41st 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 some 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 1993 total escapement of chinook salmon in the Central Valley was 171,315 fish. This total consisted of 163,638 fall-, 6,070 spring-, 340 winter-, and 1,267 late-fall-run spawners. All of the spring-, late-fall-, and winter-run salmon were estimated to be in the Sacramento River system, while 5,983 fish of the fall run were in the San Joaquin River system.

The 1993 total salmon population was 39% larger than in 1992. Despite the higher population, late-fall- and winter-run salmon numbers in the Sacramento River mainstem decreased from 1992. The mainstem spring run was similar in size to 1992's population, which was the lowest ever recorded.

San Joaquin tributary fall runs also increased over those for 1992. However, the San Joaquin system still only contributed a small portion (3.5%) of the total Central Valley escapement.

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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 41st 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 return 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.

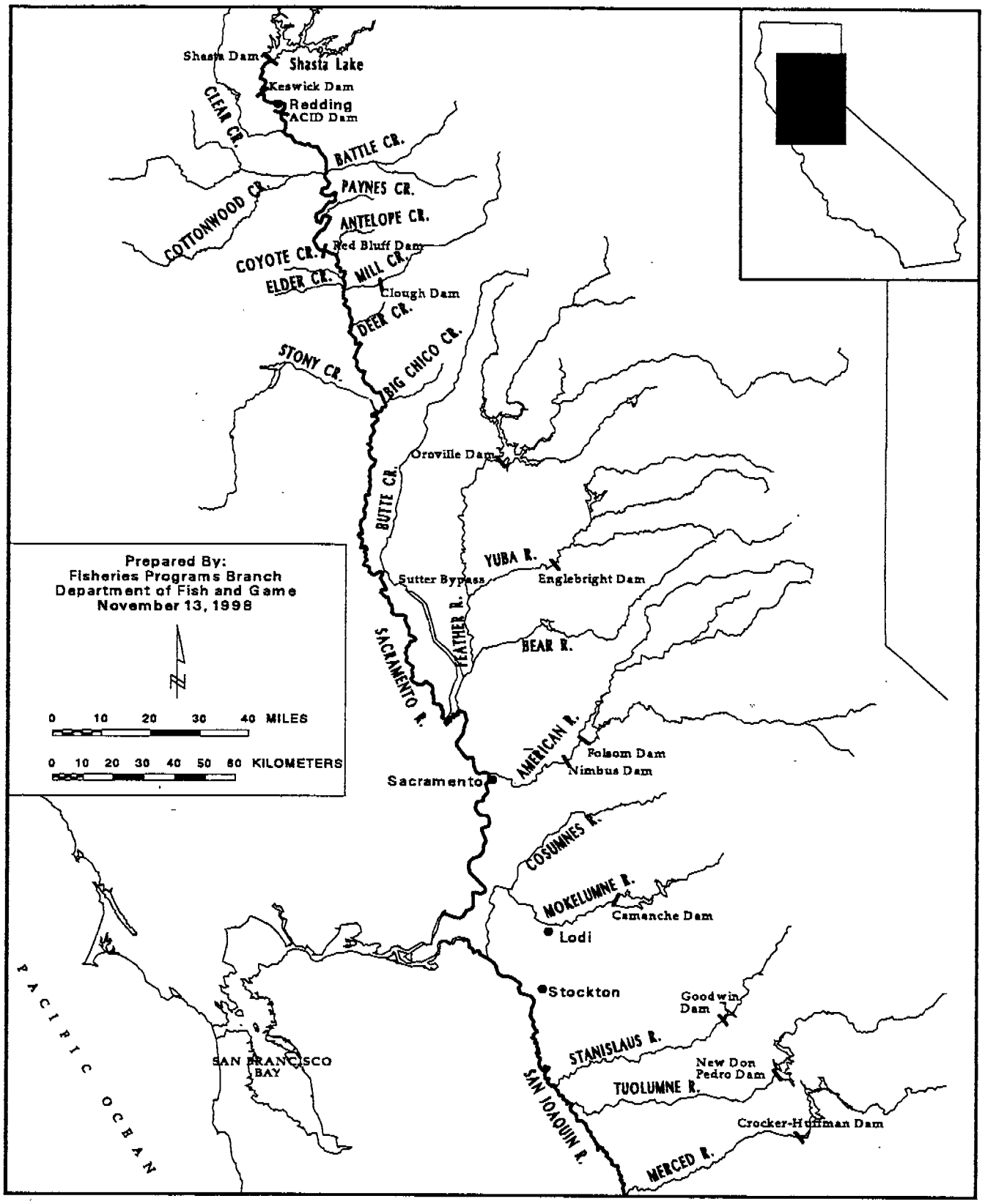

Figure 1. Sacramento-San Joaquin River system of California's Central Valley

GENERAL METHODS

During 1993, 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 some such cases, a decision of the number of spawners present was arrived at by "best professional judgement".

In other streams, salmon 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 Frank W. Fisher and Colleen D. Harvey-Arrison
CDFG-Northern California and North Coast Region (Region 1)

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 and Battle creeks were the only tributaries in this area for which individual fall-run population estimates were calculated. Spawning distribution in the mainstem was determined from aerial redd counts.

In 1993, 55,673 salmon were estimated for the Sacramento River system between Keswick Dam and Red Bluff, consisting of 53,686 fall-, 1,267 late-fall-, 333 winter- and 387 spring-run fish (Appendix 2). The mainstem portions of the fall- and late-fall-run spawner population were 33,824 and 739 fish, respectively. The mainstem totals which are reported include fish for tributaries in which a run might have occurred, but where no estimates were possible; 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 1993 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 fishways.

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 assessment of when they would spawn as indicated by coloration, scale absorption, secondary sexual characteristics, and relative degree of ripeness.

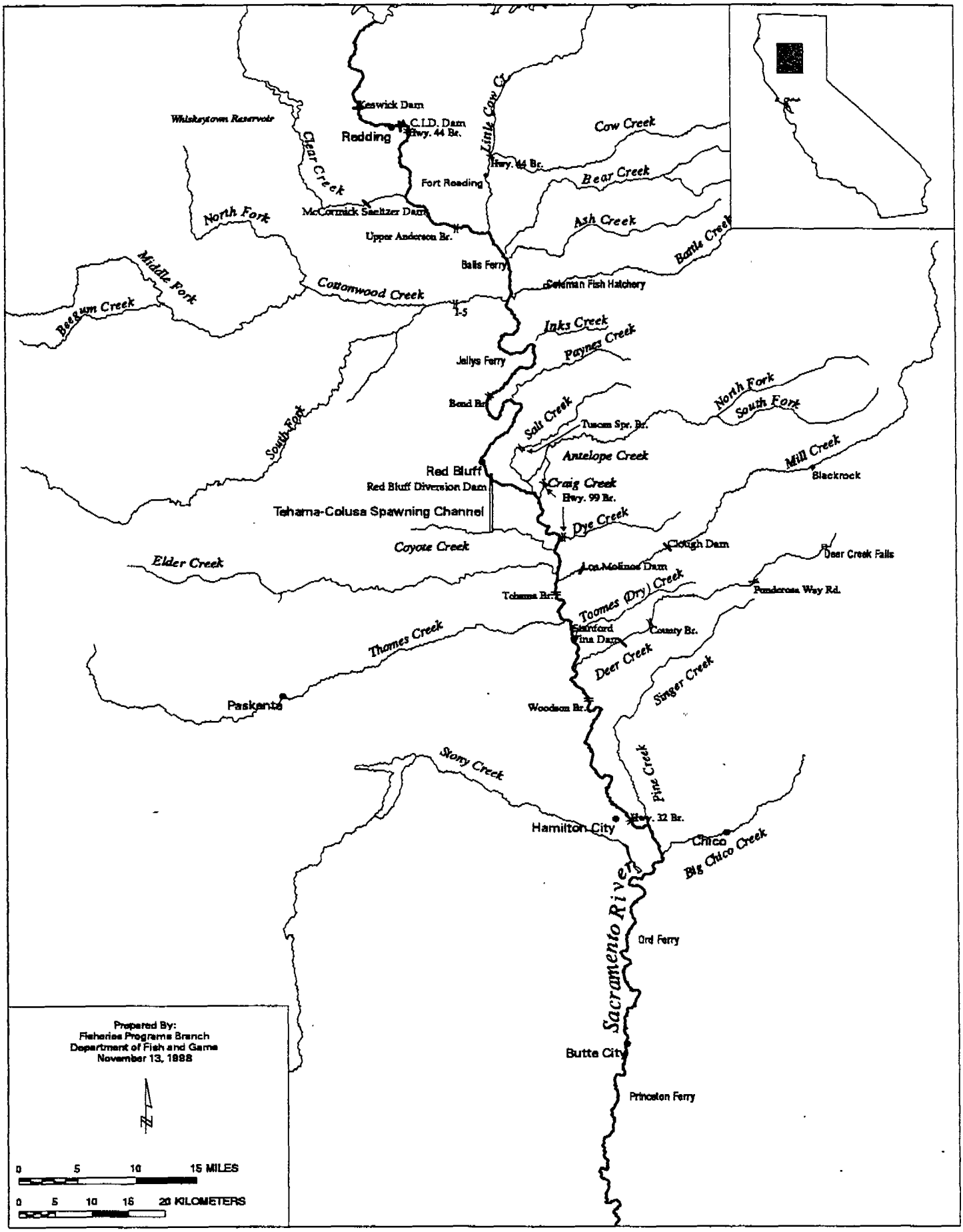

Figure 2. Sacramento River system from Keswick Dam downstream to Princeton Ferry

The numbers of spring- and fall-run salmon passing RBDD in a calendar year account for the entire annual run of these races. However, the late-fall and winter runs in 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 1993 potential spawners for each of these two runs was obtained by adding the appropriate estimated numbers of fish from the 1992 calendar year that would spawn in 1993, and not including that portion from the 1993 calendar year estimated numbers that would spawn in 1994.

The RBDD gates were raised from 1 November 1992 through 1 May 1993, and from 17 October 1993 through 1 January 1994, 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. Numbers of salmon passing the dam for these periods were calculated, from the numbers estimated through actual counts when the gates were closed, using migrational distributions based on historical data. The distributions represented an average timing derived from RBDD data for the 1970-1986 late-fall run, the 1982-1986 winter run, and the 1970-1988 spring and fall runs (Table 1).

For each of the four runs, the estimated potential spawner population upstream of RBDD was reduced by the number of fish taken 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. Numbers of sport-caught salmon were calculated using monthly estimated catches from an angler survey conducted by CDFG.

Finally, to obtain only the upper Sacramento River mainstem populations, the numbers of potential spawners of each run were reduced by the populations of the appropriate run in those tributaries where estimates were made.

Late-fall run. An estimated 1,514 late-fall 1993 potential spawners passed RBDD in 1992 and 1993 (Table 2); due to the RBDD gates being open, only 8% of this estimate was derived from actual counts at the dam. The late-fall sport-catch was estimated to be 247 salmon, leaving 1,267 fish as a spawner population upstream of Red Bluff (Table 3). Coleman National Fish Hatchery (CNFH) in Battle Creek took in 528 late-fall-run salmon, leaving 739 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

TABLE 1. Distribution of migration for chinook salmon runs past Red Bluff Diversion Dam, used to estimate numbers of fish passing the dam during periods when actual counts were not possible.

Approximate monthly period	Julian week	Proportion of run (%) 1/			
		Late-fall run	Winter run	Spring run	Fall run
	1	6.50	1.70		
January	2	6.32	1.78		
	3	3.07	0.35		
	4	2.91	1.28		
	5	3.58	2.38		
February	6	4.08	3.12		
	7	4.19	3.08		
	8	4.38	0.97		
	9	3.29	6.35		
March	10	2.14	7.72		
	11	1.74	9.23		
	12	3.39	7.79	0.10	
	13	2.08	4.91	0.25	
	14	1.82	7.64	0.59	
April	15	1.39	8.26	0.96	
	16	0.24	9.19	1.38	
	17		3.47	1.63	
	18		2.02	1.60	
May	19		1.60	1.71	
	20		2.17	2.16	
	21		3.09	2.63	
	22		2.03	2.86	0.01
June	23		1.63	2.61	0.00
	24		1.84	2.93	0.01
	25		0.51	3.50	0.03
	26		0.76	3.10	0.08
	27		1.60	3.67	0.10
July	28		0.31	6.02	0.29
	29		1.04	4.75	0.49
	30		0.44	3.21	0.70
	31		0.01	4.12	0.96
August	32			6.97	1.68
	33			9.07	2.95
	34			6.75	3.53
	35			5.74	3.91
	36			7.22	4.54
September	37			6.68	5.59
	38			5.23	8.58
	39			3.70	9.24
	40			1.19	10.49
October	41	0.26		0.69	10.59
	42	2.06			8.97
	43	2.33			6.99
	44	3.27			6.70
November	45	4.24			4.67
	46	3.42			2.71
	47	3.65			2.23
	48	5.37			1.68
December	49	5.27	0.17		0.90
	50	5.27	0.38		0.66
	51	6.94	0.49		0.51
	52	6.81	0.71		0.19

1/ Distributions are averages based on the following years of data:
- Late-fall-run, 1970 through 1986.
-Winter-run, 1982 through 1986.
-Spring-run, 1970 through 1988.
-Fall-run, 1970 through 1988.

TABLE 2. Adjusted chinook salmon counts and estimated numbers of each run at Red Bluff Diversion Dam from 11 October 1992 through 1 January 1994. 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/
11 Oct '92 - 2 Jan '93 e/	--	--	--	740	--	6	--	--	--	--
1993										
03-Jan - 09-Jan	--	--	--	98 f/	--	6 f/				
10-Jan - 16-Jan	--	--	--	96 f/	--	6 f/				
17-Jan - 23-Jan	--	--	--	47 f/	--	1 f/				
24-Jan - 30-Jan	--	--	--	44 f/	--	4 f/				
31-Jan - 06-Feb	--	--	--	54 f/	--	8 f/				
07-Feb - 13-Feb	--	--	--	62 f/	--	11 f/				
14-Feb - 20-Feb	--	--	--	63 f/	--	11 f/				
21-Feb - 27-Feb	--	--	--	66 f/	--	3 f/				
28-Feb - 06-Mar	--	--	--	50 f/	--	22 f/				
07-Mar - 13-Mar	--	--	--	32 f/	--	26 f/				
14-Mar - 20-Mar	--	--	--	26 f/	--	31 f/				
21-Mar - 27-Mar	--	--	--	51 f/	--	27 f/				
28-Mar - 03-Apr	--	--	--	32 f/	--	17 f/	--	1 f/		
04-Apr - 10-Apr	--	--	--	28 f/	--	26 f/	--	2 f/		
11-Apr - 17-Apr	--	--	--	21 f/	--	28 f/	--	4 f/		
18-Apr - 24-Apr	--	--	--	4 f/	--	31 f/	--	6 f/		
25-Apr - 01-May	--	--	Total g/.	1,514 h/	--	12 f/	--	6 f/		
02-May - 08-May	62	22			18.2	11	81 8	51		
09-May - 15-May	52	15			13.3	7	86.7	45		
16-May - 22-May	60	19			15.8	9	84.2	51		
23-May - 29-May	34	12			25.0	9	75 0	25		
30-May - 05-Jun	38	8			25.0	10	62.5	24	12.5	5
06-Jun - 12-Jun	32	12			8.3	3	41.7	13	50.0	16
13-Jun - 19-Jun	50	11			9.1	5	36.4	18	54 5	27
20-Jun - 26-Jun	122	35			2.8	3	42.9	52	54.3	67
27-Jun - 03-Jul	201	56			1.8	4	28.6	57	69.6	140
04-Jul - 10-Jul	153	47			0.0	0	8.5	13	91.5	140
11-Jul - 17-Jul	145	63			1.6	2	1.6	2	96.8	141
18-Jul - 24-Jul	92	32			3.1	3	3 1	3	93.8	86
25-Jul - 31-Jul	82	40			Total g/.	342 i/	5.0	4	95 0	78
01-Aug - 07-Aug	71	19					0.0	0	100.0	71
08-Aug - 14-Aug	156	39					2.6	4	97 4	152
15-Aug - 21-Aug	467	122					1.6	7	98.4	460
22-Aug - 28-Aug	239	72					Total g/.	388	100.0	239
29-Aug - 04-Sep	952	121							100 0	952
05-Sep - 11-Sep	2,385	136							100.0	2,385
12-Sep - 18-Sep	2,996	160							100.0	2,996
19-Sep - 25-Sep	5,707	150							100.0	5,707
26-Sep - 02-Oct	9,659	85							100 0	9,659
03-Oct - 09-Oct	7,164	137							100.0	7,164
10-Oct - 16-Oct	5,940	43	2.3	137					97.7	5,803
17-Oct - 23-Oct	--	--	--						--	5,109 f/
24-Oct - 30-Oct	--	--	--						--	3,977 f/
31-Oct - 06-Nov	--	--	--						--	3,812 f/
07-Nov - 13-Nov	--	--	--						--	2,657 f/
14-Nov - 20-Nov	--	--	--						--	1,542 f/
21-Nov - 27-Nov	--	--	--	j/					--	1,269 f/
28-Nov - 04-Dec	--	--	--						--	956 f/
05-Dec - 11-Dec	--	--	--		--				--	512 f/
12-Dec - 18-Dec	--	--	--		--				--	376 f/
19-Dec - 25-Dec	--	--	--		--	3 f/			--	290 f/
26-Dec - 01-Jan-94	--	--	--		--				--	108 f/
									Total g/.	56,896
Total for 1993 calendar year k/.	36859	1,456		911		336		388		56,896

a/ Red Bluff Diversion Dam gates were raised from 1 November 1992 through 1 May 1993, and from 17 October 1993 through 1 January 1994.

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 1992 that were expected to spawn in 1993 (Kano 1998).

f/ Due to the dam gates being raised, no counts were possible Estimated numbers based on historical average proportional run distributions

g/ Total estimated number of potential spawners for the 1993 run.

h/ Includes 400 fish trapped at Keswick Dam and trucked to Coleman National Fish Hatchery.

i/ Includes 20 fish trapped at Keswick Dam that were trucked to Coleman National Fish Hatchery.

j/ It was not posssible to make estimates for the late-fall run during this period.

k/ Including late-fall- and winter-run 1994 potential spawners

TABLE 3. Calculation of the 1993 spawner population for each run of chinook salmon upstream of Red Bluff Diversion Dam.

Run	Number of fish passing dam in calendar year: 1992		1993		Number of potential spawners		Estimated sport catch		Estimated 1993 spawner population
Late-fall	740	+	774 a/	=	1,514 b/	-	247	=	1,267
Winter	6	+	336 a/	=	342 b/	-	9	=	333
Spring			388	=	388 b/	-	1	=	387
Fall			56,896	=	56,896 b/	-	3,210	=	53,686
Totals:	**746**	**+**	**58,344**	=	**59,090**	-	**3,467**	=	**55,623**

a/ A total of 137 late-fall- and three winter-run salmon passed RBDD in the latter part of 1993 (Table 2), and were not included in these counts; these fish were considered 1994 spawners.
b/ Due to the RBDD gates being open, only portions of these numbers were calculated from actual counts. These portions were: late-fall 8%, winter 19%, spring 95%, and fall 64%.

included in the upper mainstem population, along with 400 late-fall-run salmon trapped at Keswick Dam that were hauled to CNFH for spawning.

The estimated 739 fish late-fall spawner population for the upper Sacramento River mainstem was a decrease of 92% from the 1992 population (Appendix 3); this was the lowest run size ever recorded.

Winter run. An estimated 342 winter-run 1993 potential spawners passed RBDD in 1992 and 1993 (Table 2); due to the RBDD gates being open, only 19% of this estimate was derived from actual counts at the dam. The winter-run sport-catch was estimated to be nine salmon, leaving a spawner population of 333 fish upstream of Red Bluff (Table 3). 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 20 winter-run salmon trapped at Keswick Dam that were hauled to CNFH for spawning.

The 1993 winter-run spawner population upstream of RBDD was a decrease of 72% from the 1992 population, and only 20% of the average run size for the previous 10 years (Appendix 3).

Spring run. An estimated 388 spring-run potential spawners passed RBDD in 1993 (Table 2); 95% of this estimate was derived from actual counts at the dam. The spring-run sport-catch was

estimated to be only one salmon, leaving 387 fish as a spawner population upstream of Red Bluff (Table 3). The Clear Creek spring run was only one fish, leaving 386 fish as the mainstem spawner population (Appendix 2). No spring-run salmon were taken into CNFH, and no surveys were made for this run in Battle Creek itself; these fish are reported as part of the mainstem portion of the run.

The 1993 spring-run spawner population of 387 fish upstream of RBDD was a increase of 4% from the 1992 population of 372 fish, but still only 6% of the average run size for the previous ten years (Appendix 3).

Fall run. An estimated 56,896 fall-run potential spawners passed RBDD in 1993 (Table 2); due to the RBDD gates being open, only 64% of this estimate was derived from actual counts at the dam. The fall-run sport-catch was estimated to be 3,210 salmon, leaving 53,686 fish as a spawner population upstream of Red Bluff (Table 3). A total of 19,862 spawners was estimated for Clear and Battle creeks, leaving 33,824 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 an increase of 25% from the 1992 population, and was 74% of the average 1983-1992 population (Appendix 3).

Mainstem spawning distribution. The 1993 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 flights during the winter-, spring-, and fall-run spawning seasons. No surveys were made for the late-fall run. All of the spring- and the majority (97.9%) of the winter-run mainstem spawning occurred upstream from RBDD (Table 4). Fall-run spawning in this area constituted 72.4% of the entire mainstem.

Clear Creek

Late-fall run. A single survey on 15 March 1993 was conducted from McCormick-Saeltzer Dam to 7.2 km (4.5 mi) downstream. Seventeen salmon carcasses, four live fish, and eight redds were observed. An estimate of the late-fall-run population was not made.

Spring run. Nine snorkeling surveys of the 1.6-km (1-mi) creek section downstream of McCormick-Saeltzer Dam were conducted between 20 April and 6 July 1993; only one adult salmon was seen.

TABLE 4. Chinook salmon relative redd distribution during 1993 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/	--	--	2	4.2%	0	0.0%	564	12.3%
A.C.I.D. Dam to Highway 44	--	--	31	64.6%	1	100.0%	640	14.0%
Highway 44 to Upper Anderson Bridge	--	--	11	22.9%	0	0.0%	612	13.4%
Upper Anderson Bridge to Balls Ferry	--	--	1	2.1%	0	0.0%	475	10.4%
Balls Ferry to Jellys Ferry	--	--	1	2.1%	0	0.0%	640	14.0%
Jellys Ferry to Bend Bridge	--	--	1	2.1%	0	0.0%	252	5.5%
Bend Bridge to Red Bluff Dam	--	--	0	0.0%	0	0.0%	125	2.7%
Red Bluff Dam to Tehama Bridge	--	--	1	2.1%	0	0.0%	795	17.4%
Tehama Bridge to Woodson Bridge	--	--	0	0.0%	0	0.0%	242	5.3%
Woodson Bridge to Hamilton City (Hw	--	--	--	--	0	0.0%	171	3.7%
Hamilton City to Ord Ferry	--	--	--	--	0	0.0%	52	1.1%
Ord Ferry to Princeton Ferry	--	--	--	--	0	0.0%	4	0.1%
Totals:			48		1		4,572	

a/ No aerial surveys were made during the late-fall-run spawning period.

b/ Total count made for 14 aerial surveys from 21 April through 12 August 1993.

c/ Count made during an aerial survey on 14 September 1993.

d/ Total count made for five aerial surveys from 1 October through 1 December 1993.

e/ Anderson-Cottonwood Irrigation District Dam.

During the same period as the surveys downstream, monitoring of spring-run salmon immigrating past the dam was attempted. Fish 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. A single upstream passage was counted, but could not be verified as a salmon.

The Clear Creek spring run was at least one fish.

Fall run. Six surveys of Clear Creek were made from 15 October through 6 December 1993 in the 7.2-km (4.5-mi) stretch downstream from McCormick-Saeltzer Dam. Salmon carcasses were marked by attaching colored tape to the jaw with a hog ring, and replacing them back into running water for recovery during following surveys. Using fresh carcass mark-and-recovery data with the Schaefer model (Appendix 1.B), the spawner population in Clear Creek downstream of the dam was estimated to be 1,246 fish (Table 5).

During the same period as the surveys downstream, monitoring of salmon immigrating past the dam was attempted. Fish 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. No passage was recorded and it was assumed that fall-run salmon did not spawn upstream of the dam.

The fall-run spawner population of Clear Creek consisted of 41% male adults (fork length [FL] > 64 cm [25.2 in]), 53% female adults, 4% male grilse (FL ≤ 64 cm), and 2% female grilse. Adults were considered to be those fish which were three years old and older, while grilse were 2-year-olds.

No pre-spawning mortality was observed in Clear Creek this season.

Cow Creek

Spring run. No surveys for this run in this tributary were made in 1993.

Late-fall run. A survey of South Cow Creek was made on 9 March 1993, from the confluence of Old Cow Creek to 4.8 km (3 mi) downstream. Only two salmon carcasses, one live fish, and one redd were observed. An estimate of the run size was not made.

Fall run. Surveys were made on 10 and 23 November 1993 in Cow Creek from Fort Reading extending 3.2 km (2 mi) upstream. A total of 37 salmon carcasses, 21 live fish, and 74 redds was observed.

TABLE 5. Chinook salmon carcass mark-and-recovery data used to estimate the 1993 fall-run spawner population in Clear Creek downstream of McCormick-Saeltzer Dam. 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	6	--	--	--	--	6	64	104
3	2	10	--	--	--	12	79	219
4	0	3	5	--	--	8	32	199
5	0	0	1	1	--	2	69	696
6	0	1	0	0	6	7	26	175
Total recovered (Ri):	8	14	6	1	6		Total:	1,393
Total carcasses marked (Mi):	13	42	49	12	44			
						Adjusted estimate d/:		**1,246**

a/ Surveys were conducted from 15 October through 6 December 1993.

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. 1,393 - 147 = 1,246.

Aerial redd surveys were also made on 19 October, and 1 and 12 November 1993, from the creek's mouth to 21.9 km (13.6 mi) upstream, and over 10.5 km (6.5 mi) of North Fork Cow Creek and 12.1 km (7.5 mi) of South Fork Cow Creek. Forty-eight redds were counted in the mainstem, two redds were seen in the North Fork, and 64 redds in the South Fork.

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

Cottonwood Creek

Late-fall run. Surveys for this run were not made in this tributary due to high water flows and turbidity.

Spring run. Beegum Creek, a tributary to Cottonwood Creek, was surveyed on 3 August 1993. Sections of a 4.2-km (2.5-mi) stretch from its confluence with the north and south forks to Beegum Falls were surveyed by snorkeling. Only one adult salmon was seen.

A snorkeling survey of a 1.6-km (1-mi) stretch of the South Fork Cottonwood Creek upstream of Maple Gulch was conducted on 5 August, but no salmon were observed.

An estimate of the spring run in Cottonwood Creek was not made.

Fall run. Three surveys were made during 1 November to 8 December 1993 from the mouth of Cottonwood Creek to the Interstate-5 bridge 8.8 km (5.5 mi) upstream. A total of 40 salmon carcasses, 57 live fish, and 111 redds was counted. Eighteen carcasses were marked with colored tape attached to the jaw with a hog ring, but none were ever recovered.

Aerial surveys to determine spawning distribution were also made over a 31.4-km (19.5-mi) stretch from the creek's mouth into North Fork Cottonwood Creek. A maximum of 191 redds was observed.

A fall-run spawner population estimate was not made.

Battle Creek

Late-fall run. No surveys were made of this run's in-river spawner population. A total of 528 late-fall-run salmon entered CNFH in 1993, consisting of 32% male adults, 35% female adults, and 33% grilse.

Winter and spring runs. No spawner surveys were conducted for these runs in Battle Creek during 1993.

Fall run. Nine weekly surveys were conducted from 5 October through 20 December 1993, covering the 5.6-km (3.5-mi) stretch of river between CNFH and the old hatchery location. 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 model (Appendix 1.B), the spawner population in Battle Creek downstream of CNFH was estimated to be 11,029 fish (Table 6). Combined with an additional 7,587 fish which entered CNFH, the total Battle Creek fall-run population was 18,616 salmon (Appendix 2).

The composition of the fall run in Battle Creek was 33% male adults (FL > 64 cm [25.2 in]), 66% female adults, 1% grilse (FL ≤ 64 cm), based on an examination of 3,716 carcasses. In comparison, fall-run fish entering CNFH consisted of 43% male adults, 50% female adults, and 7% grilse.

Pre-spawning mortality of fall-run salmon in Battle Creek averaged 0.5% in 1993.

The 1993 fall-run spawner population for Battle Creek of 18,616 fish was 32% higher than the 1992 run, and 65% of the average run size for 1983 through 1992 (Appendix 3).

TABLE 6. Chinook salmon carcass mark-and-recovery data used to estimate the 1993 fall-run spawner population in Battle Creek downstream from Coleman National Fish Hatchery to the old hatchery site. 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	7	--	--	--	--	--	--	--	7	557	1,323
3	1	85	--	--	--	--	--	--	86	1,111	2,434
4		21	115	--	--	--	--	--	136	1,667	3,636
5			12	125	--	--	--	--	137	1,265	2,051
6			1	28	57	--	--	--	86	650	1,281
7				2	7	29	--	--	38	257	718
8					3	5	11	--	19	139	517
9								1	1	13	130
Total recovered (Ri):	8	106	128	155	67	34	11	1		Total:	12,090
Total carcasses marked (Mi):	19	232	279	243	145	103	49	10			
									Adjusted estimate d/:		**11,029**

a/ Surveys were conducted from 5 October through 20 December 1993.

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. 12,090 - 1,061 = 11,029.

Red Bluff Diversion Dam to Princeton Ferry

by Frank W. Fisher and Colleen D. Harvey-Arrison, CDFG-Region 1

A total of 15,272 chinook salmon spawners was estimated for 1993 in the Sacramento River system between Red Bluff and Princeton Ferry (Figure 2). This total consisted of 7 winter-, 323 spring- and 14,942 fall-run salmon (Appendix 2).

Tributaries in this area for which individual estimates were made included Antelope, 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. No aerial surveys were made during the late-fall-run spawning period in the mainstem Sacramento River downstream of Red Bluff to Princeton Ferry.

Winter run. During 14 aerial surveys between 21 April and 12 August 1993, evidence of winter-run spawning in the mainstem Sacramento River downstream of Red Bluff was observed only from RBDD to Tehama Bridge (Table 4). It was estimated that seven winter-run salmon were in this stretch of river.

Spring run. No redds were observed in the mainstem Sacramento River downstream of Red Bluff during an aerial survey on 14 September 1993, and it was assumed that no spring-run salmon spawned in this stretch of the river.

Fall run. Based on five aerial surveys from 1 October through 1 December 1993, 12,895 fall-run salmon were estimated for the mainstem Sacramento River between RBDD and Princeton Ferry (Appendix 2). This run size was 37% higher than the 1992 population, and 56% of the average run size from 1983 to 1992 (Appendix 3).

Mainstem spawning distribution. Redd counts made during the aerial surveys in 1993 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. In proportion to the entire mainstem (including upstream of RBDD) spawning activity, 2.1% of the winter-, none of the spring-, and 27.6% of the fall-run redds were observed this section of the river (Table 4).

Antelope Creek

Late-fall run. Surveys were made of the lower Antelope Creek system during 1-12 February 1993 for late-fall-run salmon. Antelope Creek itself was covered from the mouth of New Creek downstream 8.4 km (5.2 mi). The entire length of New and Craig creeks, and the lower 3.9 km (2.4 mi) of Butler Slough were also surveyed. No salmon carcasses, adult fish, or redds were observed. An estimate of the late-fall run was not made.

Spring run. The creek was surveyed on 17 August 1993 by snorkeling from the confluence of the north and south forks to 6.4 km (4 mi) downstream. Three adult salmon were counted. Another survey was made during the spawning season on 27 September from 4 km (2.5 mi) upstream of the north and south fork confluence (McClure Place) to 3.2 km (2 mi) downstream of the confluence (Paynes Place). No salmon carcasses, live fish, or redds were observed.

A minimum of three spring-run salmon were in Antelope Creek in 1993.

Fall run. A survey during the fall-run spawning season was made of the 0.8-km (0.5 mi) stretch of the creek downstream from Cone Grove Park. Only one salmon carcass, four live fish, and eight redds were seen. An estimate of the fall-run spawner population was not made.

Mill Creek

Spring run. During the spring-run spawning period, nine surveys were made of approximately 24 km (15 mi) of upper Mill Creek from 7 September to 6 October 1993. No salmon carcasses, only four live fish, and 12 redds were observed in total.

Prior to these surveys, spring-run salmon were visually counted immigrating past Clough Dam beginning on 13 April 1993. Due to high spring runoff, it was not possible to install the electronic fish counter at Clough Dam this year, and because of the poor visibility through the water here, the counting location was moved farther downstream to Ward Dam during 12 May through 2 July. A total of 25 adult salmon was counted past the dams during the periods when observations were made. This total was expanded for non-counting periods resulting in 61 fish as the 1993 spring run in Mill Creek, the smallest spawner population ever recorded.

Based on subjective length distinctions during visual observations, the spring run consisted of 92% adults and 8% grilse.

Fall run. Three surveys were made from 25 October through 24 November 1993 in the 7.2-km (4.5-mi) stretch of Mill Creek upstream of its mouth to Clough Dam. A total of 67 salmon carcasses, 46 live fish, and 87 redds was counted. Thirteen of the carcasses were marked by attaching colored tape to the jaw with a hog ring, and only two were subsequently recovered. A Petersen estimate (Appendix 1.A.2) of 317 spawners was calculated for the section of Mill Creek downstream of Clough Dam.

Monitoring of fall-run salmon immigrating past the dam was also conducted to determine an upstream spawner population. Fish 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. Electronic counts were supplemented by visual observations twice each week. The 1,112 recorded or visually counted upstream passages from 8 October through 9 December 1993 were expanded for those periods when no counts were made for an estimate of 1,658 salmon upstream of the dam.

The fall-run spawner population up- and down-stream of Clough Dam in 1993 was 1,975 fish.

Deer Creek

Spring run. Seventeen surveys were made in upper Deer Creek from 8 August through 22 October 1993. Totals of 19 salmon carcasses, 88 live fish, and 119 redds were observed in 17.7 km (11 mi) of the spawning area.

During snorkeling surveys of the known holding habitat for spring-run salmon made on 18-19 August, 259 fish were counted. This count was felt to be the minimum spring-run spawner population for 1993.

Fall run. Monitoring of fall-run salmon immigrating past the Stanford-Vina Dam was conducted from 12 October through 8 December 1993. Fish 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. Electronic counts were supplemented by visual observations. Using these counts, 72 fish were estimated as the 1993 fall-run spawner population.

Big Chico Creek to the American River

A total of 94,387 chinook salmon was estimated in 1993 for the Sacramento River tributaries from Big Chico Creek to the American River (Figure 3). This total consisted of 5,360 spring-run and 89,027 fall-run fish (Appendix 2).

Big Chico Creek

Spring run. Based on snorkeling observations made during a survey of the creek, the 1993 spring run was felt to be about 38 fish.

Fall run. No surveys were conducted for this run in 1993.

Butte Creek

Spring run. Surveys were made of the creek between DeSabla Powerhouse to Parrot-Phelan Dam from 16 September through 21 October 1993. Totals of 44 salmon carcasses, 108 live fish, and 354 redds were observed. Based on these observations, the 1993 spring run was felt to be about 650 fish.

Fall run. No surveys were conducted for this run in 1993.

Feather River - by Fred Meyer, CDFG
Sacramento Valley and Central Sierra Region (Region 2)

Spring run. A total of 4,672 salmon classified as spring-run fish entered Feather River Hatchery (FRH) in 1993 (B. Barngrover, CDFG-Region 2, pers. comm.). These fish consisted of 37.6% male adults (FL > 55.9 cm [22 in]), 46.8% female adults, and 15.6% grilse (FL ≤ 55.9 cm). In the river itself, the spring-run spawning period could not be distinguished from that of the fall-run, and no attempt was made to estimate numbers of in-river spring-run salmon.

The 4,672 spring-run salmon at FRH in 1993 was three times higher than that for 1992, and almost 1¾ times that of the average run size observed in the past ten 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 1 October through 2 December 1993. Flow downstream of Thermalito Afterbay

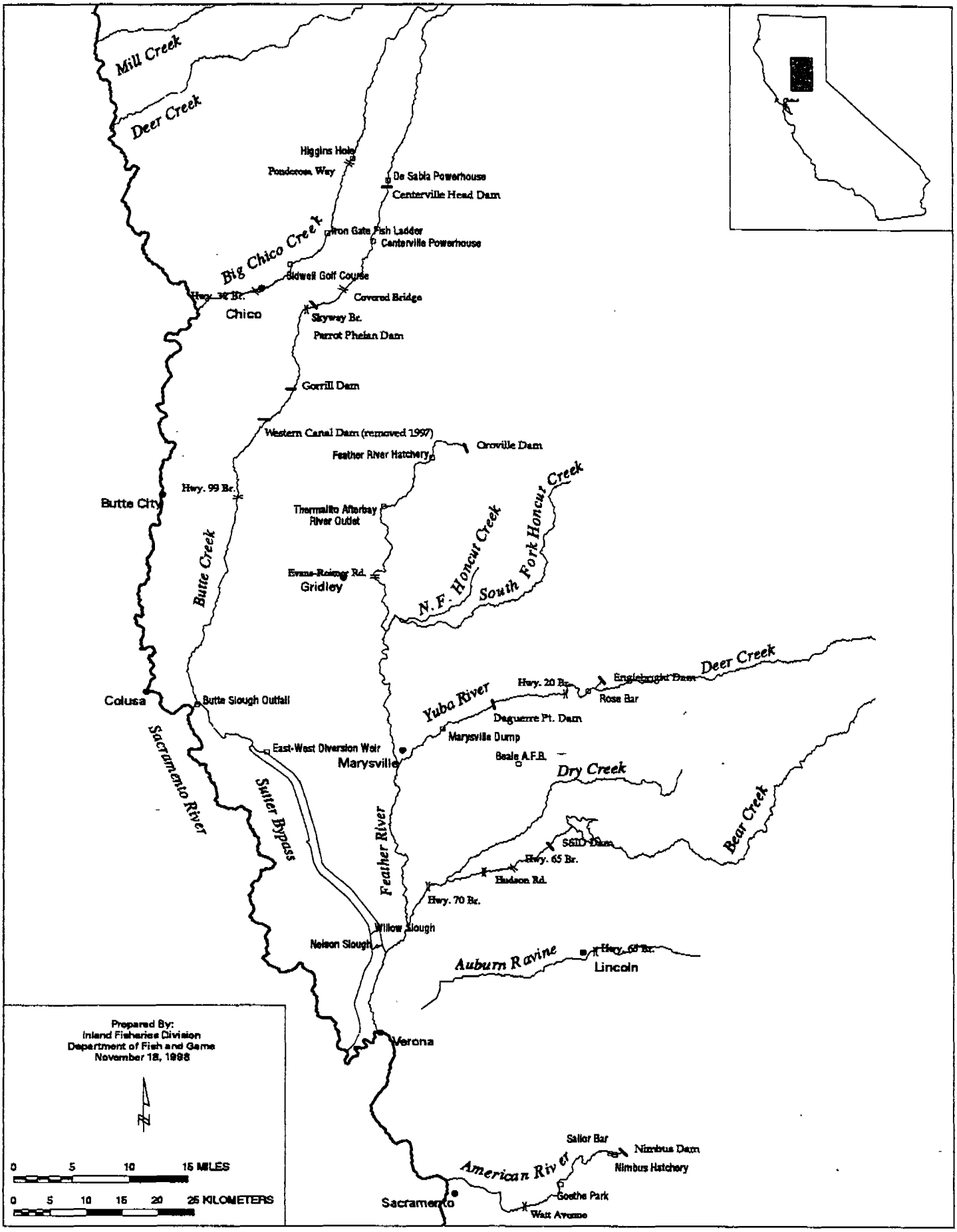

Figure 3. Sacramento River system from Big Chico Creek downstream to American River.

to the Gridley boat ramp was about 56.6 m^3/s (2,000 cfs) during the beginning part of the survey period, but nearly doubled in December; surveys in this section were conducted from 15 October through 3 December. Visibility through the water was 1.5 to 1.8 m (5-6 ft) in the upstream section, and 1.2 m to 1.5 (4-5 ft) in the downstream section.

Only fresh adult salmon carcasses were marked, with a colored ribbon attached to the lower jaw by a hog ring, and released into flowing water for later recovery; for each marking period a different ribbon color was used. Fresh carcasses were distinguished by having at least one clear eye, while the adult distinction was a fish having a FL ≥ 66 cm (26 in). The length used to separate adults from grilse was the same as for the 1992 fall run; length frequency analysis of salmon measured at FRH this year did not provide an adequate length-separation between two- and three-year-olds. Fresh grilse (FL < 66 cm) carcasses were counted to determine the grilse proportion in the population and then chopped in half, as were all other carcasses including those that were recovered with marks.

Schaefer (Appendix 1.B) estimates, calculated from the mark-and-recovery data, were 23,442 adult salmon for the upstream section, and 3,925 adults for the downstream section (Table 7, Table 8). Combining these numbers and expanding for a 11.5% grilse proportion gave a total in-river estimate of 30,923 fish. A total of 11,991 fall-run salmon entered FRH (B. Barngrover CDFG-Region 2, pers. comm.), bringing the 1993 fall run in the Feather River to 42,914 fish (Appendix 2).

The composition of fall-run salmon in the river, based on examination of 3,158 fresh carcasses, was 29.1% male adults (FL ≥ 66 cm [26 in]), 59.4% female adults, 6.2% male grilse (FL < 66 cm), and 5.3% female grilse. In comparison, salmon entering FRH consisted of 31.9% male adults (FL ≥ 55.9 cm [22 in]), 53.4% female adults, and 14.7% grilse (FL < 55.9 cm).

The 1993 Feather River population of 42,914 salmon was 6% larger than the 1992 run, but still 15% below the average population from 1983 to 1992 (Appendix 3); that period's average excludes the 1990 run size, when no estimate was made of the in-river population.

Yuba River - by John Nelson, CDFG-Region 2

Spring Run. No surveys were conducted for this run in 1993.

Fall run. The 1993 fall-run salmon spawner surveys were conducted jointly by CDFG and staff of Jones & Stokes Associates, Inc., which was contracted by the Yuba County Water Agency.

Weekly salmon carcass mark-and-recovery surveys were made from

TABLE 7. Chinook salmon carcass mark-and-recovery data used to estimate the 1993 fall-run spawner population in the Feather River from the hatchery barrier dam to the Thermalito Afterbay outlet. 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	1	--	--	--	--	--	--	--	--	1	122	580
3	2	19	--	--	--	--	--	--	--	21	605	1,252
4	0	12	54	--	--	--	--	--	--	66	1,447	3,421
5	0	2	5	168	--	--	--	--	--	175	2,168	3,805
6	1		6	57	207	--	--	--	--	271	2,869	5,646
7				7	34	178	--	--	--	219	2,330	6,442
8						24	141	--	--	165	954	2,821
9							21	36	--	57	394	1253
10							7	19	13	26	178	669
Total recovered (Ri):	4	33	65	232	241	202	169	55	13		Total:	25,889
Total carcasses marked (Mi):	19	59	162	402	483	596	500	182	63			
										Adjusted estimate d/:		**23,442**

a/ Surveys were conducted from 1 October through 2 December 1993.

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. 25,889 - 2,447 = 23,442.

TABLE 8. Chinook salmon carcass mark-and-recovery data used to estimate the 1993 fall-run spawner population in the Feather River from the Thermalito Afterbay outlet to the Gridley boat ramp. 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	1	--	--	--	--	--	--	1	51	204
3		4	--	--	--	--	--	4	179	1,074
4			7	--	--	--	--	7	205	794
5			1	11	--	--	--	12	176	864
6				1	13	--	--	14	166	632
7					1	16	--	17	104	348
8						6	4	10	47	291
Total recovered (Ri):	1	4	8	12	14	22	4		Total:	4,207
Total carcasses marked (Mi):	4	24	31	60	52	73	42			
								Adjusted estimate d/:		**3,925**

a/ Surveys were conducted from 15 October through 3 December 1993.

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. 4,207 - 282 = 3,925.

12 October through 7 December 1993 in the Yuba River from the Parks Bar bridge (Hwy.20) downstream to Marysville. Surveys were not made of the river stretch upstream of Hwy.20 to Englebright Dam.

Mean daily flows during the surveys ranged from 34.5 to 42.8 m^3/s (1282-1511 cfs) at the Smartville gage, and from 28.0 to 45.5 m^3/s (990-1606 cfs) at the Marysville gage. Visibility through the water in the survey areas ranged from 0.6 to 1.8 m (2-6 ft), averaging approximately 1.2 m (4 ft).

This season, only fresh adult salmon carcasses were marked; carcasses were considered fresh if they were clear-eyed, while the adult designation was a FL $\geq$ 65 cm (25.6 in). Marks consisted of pieces of surveyor's tape attached to the upper jaws with hog rings; different colors of tape were used to identify carcasses with distinct marking periods. Marked carcasses were returned into flowing water for subsequent recovery. Fresh grilse (FL < 65 cm) carcasses were counted for determining the overall grilse proportion in the population, and then chopped in half, as were all other carcasses including those recovered with marks.

Using carcass mark-and-recovery data with the Schaefer model (Appendix 1.B), estimates of 2,099 and 2,817 adults were calculated for the sections from Hwy.20 to Daguerre Point Dam and from the dam downstream to Marysville, respectively (Table 9, Table 10). The adult estimates were adjusted to include a 13.1% grilse proportion for the upstream section and 13.3% for the downstream section (316 and 432 fish, respectively), for an estimated 5,664 total fish in the mark-and-recovery area. The population for the area upstream of Hwy.20 to Rose Bar was estimated by assuming that spawners in this section constituted a 15.5% proportion of the total river's population. Including this section's 1,039 salmon, the total estimated Yuba River 1993 fall run was 6,703 fish.

The composition of the run based on examination of fresh carcasses was 37.2% male adults (FL $\geq$ 65 cm), 49.6% female adults, and 13.2% grilse (FL < 65 cm).

The 1993 Yuba River run of 6,703 salmon was 5% higher than the 1992 population, but still only 54% of the average run size from 1983 to 1992 (Appendix 3); that period's average excludes the 1990 run size, when no estimate was made of the population.

TABLE 9. Chinook salmon carcass mark-and-recovery data used to estimate the 1993 fall-run spawner population in the Yuba River from Parks Bar (Hwy. 20) to Daguerre Point Dam. 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	0	--	--	--	--	--	--	--	0	51	51
3		0	--	--	--	--	--	--	0	68	68
4		0	3	--	--	--	--	--	3	78	449
5		1	2	5	--	--	--	--	8	102	634
6			2	6	7	--	--	--	15	110	392
7			1	2	3	5	--	--	11	59	322
8					1		2	--	3	42	218
9								3	3	26	182
Total recovered (Ri):	0	1	8	13	11	5	2	3		Total:	2,316
Total carcasses marked (Mi):	1	24	46	37	39	38	12	21			
									Adjusted estimate d/:		**2,099**

a/ Surveys were conducted from 12 October through 6 December 1993.

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. 2,316 - 217 = 2,099.

TABLE 10. Chinook salmon carcass mark-and-recovery data used to estimate the 1993 fall-run spawner population in the Yuba River from Daguerre Point Dam to Marysville. 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	0	--	--	--	--	--	--	0	37	37
3	1	4	--	--	--	--	--	5	62	322
4			4	--	--	--	--	4	74	400
5			1	2	--	--	--	3	81	1,091
6					0	--	--	0	22	22
7					0	1	--	1	35	455
8					1		1	2	23	644
Total recovered (Ri):	1	4	5	2	1	1	1		Total:	2,971
Total carcasses marked (Mi):	3	23	27	35	45	13	11			
								Adjusted estimate d/:		**2,817**

a/ Surveys were conducted from 19 October through 7 December 1993.

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. 2,971 - 154 = 2,817.

American River

Fall run. Weekly salmon carcass mark-and-recovery surveys in the American River were conducted between 17 October 1993 and 23 January 1994, covering the 22.5-km (14-mi) reach from Watt Avenue upstream to Sailor Bar (Snider et al. 1995). Average river flow during days when surveys were made ranged from 49.5 to 106.2 m^3/s (1,747-3,752 cfs); flows of greater than 85 m^3/s (3,000 cfs) only occurred during the first and ninth week of the surveys. Water clarity, measured by secchi disk, averaged from 2.9 to 4.2 m (9.5-14 ft). Average water temperature was 17.8°C (64°F) at the start of the surveys, decreasing to 9.4°C (49°F) towards the end.

Fresh salmon carcasses were marked by attaching a color-coded hog ring to the upper jaw; different colors were used each weekly marking period. A carcass was considered fresh if it had at least one clear eye or pink gills. Marked carcasses were replaced into running water immediately upstream of where originally found, or left in place in backwater areas. Non-fresh carcasses were counted and cut in half. Length, sex, and degree of egg-retention were recorded for fresh carcasses.

A total of 1,491 fresh carcasses (all but 12 of which were marked) and 10,231 non-fresh carcasses were observed. The salmon spawner population of the Watt Avenue to Sailor Bar section of the river, estimated from mark-and-recovery data using the Schaefer model (Appendix 1.B), was 28,754 fish (Table 11). An additional 10,656 salmon entered Nimbus Hatchery (B. Barngrover, CDFG-Region 2, pers. comm.), bringing the total American River 1993 fall-run population to 39,410 fish (Appendix 2).

Based on examination of 1,465 fresh carcasses, the run consisted of 30.1% male adults (FL > 70 cm [27.6 in]), 47.2% female adults (FL > 60 cm [23.6 in]), 18.6% male grilse (FL ≤ 70 cm), and 5.6% female grilse (FL ≤ 60 cm). The general size criteria distinguishing adults from grilse was determined from length frequency distributions for both sexes separately. Salmon entering Nimbus Hatchery consisted of 29.8% male adults (FL ≥ 60 cm), 39.1% female adults, and 31.1% grilse (FL <60 cm).

The 1993 run of 39,410 salmon was 3½ times larger than the previous year's population, and 12% higher than the average run size from 1983 through 1992 (Appendix 3).

TABLE 11. Chinook salmon carcass mark-and-recovery data used to estimate the 1993 fall-run spawner population in the American River from Watt Avenue to Sailor Bar. a/

Recovery period (j)	Number of marked carcasses recovered from marking period (i): 1	2	3	4	5	6	7	8	9	10	11	12	Total marked carcasses recovered (Rj)	Total carcasses observed (Cj) b/	Population estimate (N) c/
2	0	--	--	--	--	--	--	--	--	--	--	--	0	14	14
3		0	--	--	--	--	--	--	--	--	--	--	0	49	49
4			1	--	--	--	--	--	--	--	--	--	1	153	1,836
5				11	--	--	--	--	--	--	--	--	11	636	1,789
6				4	75	--	--	--	--	--	--	--	79	2,694	6,802
7				1	25	179	--	--	--	--	--	--	205	3,347	6,951
8					1	56	138	--	--	--	--	--	195	2,803	6,098
9					1	1	14	29	--	--	--	--	45	942	2,572
10					2	8	9	25	25	--	--	--	69	1,032	2,534
11						2	2	8	5	7	--	--	24	348	838
12								2	2	0	4	--	8	127	274
13								0		2		1	3	114	273
14								1		2			3	83	199
Total recovered (Ri):	0	0	1	16	104	246	163	65	32	11	4	1			Total: 30,229
Total carcasses marked (Mi):	1	1	12	45	261	495	365	195	68	23	7	3			
													Adjusted estimate d/:		**28,754**

a/ Surveys were conducted from 17 October 1993 through 23 January 1994..

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. 30,229 - 1,475 = 28,754.

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 5,983 salmon, consisting entirely of fall-run fish, was estimated for 1993 (Appendix 2).

Cosumnes River

Fall run. This tributary was not surveyed in 1993.

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 continued during 1993. In conjunction with increased flows from the draining of Lodi Lake, releases from Camanche Dam of 36.8 m^3/s (1300 cfs) were made from 19-25 October. Flows were decreased to 11.3 m^3/s (400 cfs) thereafter for the remainder of the spawning season. Water temperatures in the spawning areas ranged from 13.3°C (56°F) in early November to 11.4°C (52.5°F) in late December. Water clarity, measured by secchi dish was always greater than 1.7 m (5.5 ft).

EBMUD also contracted with Vogel Environmental Services to monitor salmon at Woodbridge Dam from 14 October 1993 through 2 January 1994 (Hartwell 1994); the salmon immigration was already underway when the monitoring began. A total of 3,157 salmon was counted migrating past the dam by using video equipment and a fish trap. Of these salmon, 2,164 fish entered the Mokelumne River Fish Installation (B. Barngrover, CDFG-Region 2, pers. comm.), so the 1993 fall-run in-river spawner population was assumed to be 993 fish (Appendix 2).

The run at Woodbridge Dam consisted of 29.4% male adults, 28.8% female adults, 36.8% male grilse, and 5.0% female grilse. The composition of the salmon entering the hatchery was 36.7% male adults (FL > 61 cm [24 in]), 34.6% female adults, and 28.7% grilse (FL < 61 cm).

The 1993 spawner population of 3,157 fish in the Mokelumne River was almost twice the size of the previous year's run, and 72% of the average population size estimated from 1983 through 1992 (Appendix 3).

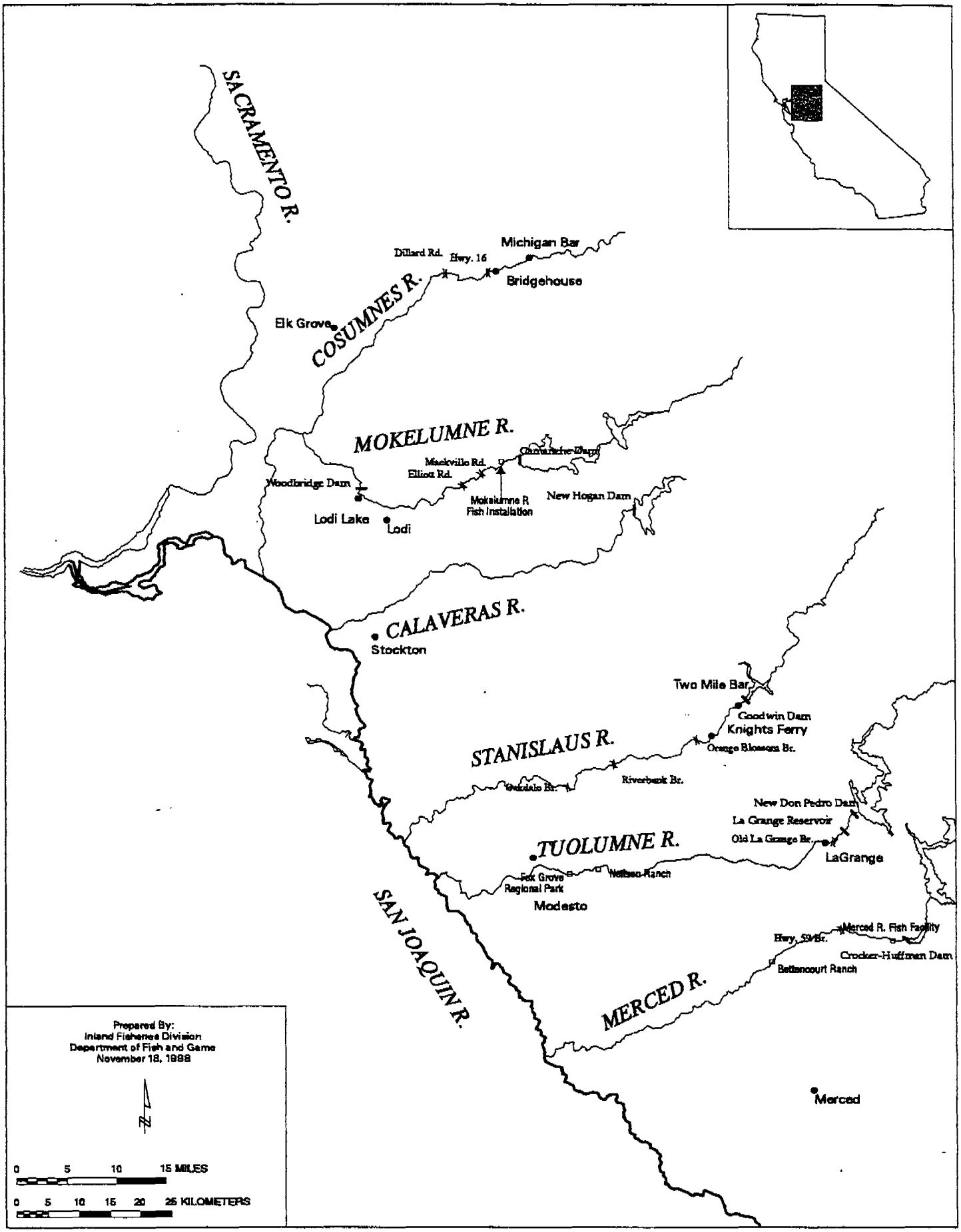

Figure 4. San Joaquin River system from the Merced River to the Cosumnes River.

Calaveras River

This tributary was not surveyed in 1993.

Stanislaus River

Fall run. Spawner surveys were conducted from 20 October through 23 December 1993, with mark-and-recovery starting on 27 October. This season the carcasses of fresh and decayed adult and fresh grilse salmon were marked using serially-numbered tags attached to a jaw with a hog-ring. Marked carcasses were released into running water for subsequent recovery. Carcasses of decayed grilse 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. Analysis of the data indicated that the Petersen estimate (Appendix 1.A.2) was the most appropriate technique. From a total of 87 carcasses marked, of which 12 were recovered, the salmon population of the Knights Ferry to Riverbank section was estimated at 677 fish. The population was not estimated in the Goodwin Dam and Two-Mile Bar areas.

The run consisted of 32.6% male adults (FL $\geq$ 65 cm [25.6 in]), 46.1% female adults, 11.2% male grilse (FL $<$ 65 cm), and 10.1% female grilse

The 1993 Stanislaus River fall-run spawner population of 677 salmon was over 2½ times larger the previous year's run, but still only 13.3% of the average run size for 1983-1992 (Appendix 3).

Tuolumne River

Fall run. The 1993 fall-run chinook salmon spawner surveys in the Tuolumne River were conducted from 14 November through 12 December 1993. Surveys covered the river stretch from Old LaGrange Bridge downstream to Fox Grove Regional Park, a distance of 38.5 km (24 mi). Visibility through the water was never less than 3.9 m (13 ft), with the bottom of the river visible during most surveys. In the upstream-most survey area, water temperature ranged from 12.0°C (53.6°F) in October to 10°C (50°F) in December.

This season all salmon carcasses, regardless of condition or age-class, were marked using serially-numbered tags attached to a jaw with a hog-ring. Marked carcasses were released into running water for subsequent recovery.

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. Analysis of the data indicated that the Petersen estimate (Appendix 1.A.2) was the most appropriate technique.

The population in the river section between Old LaGrange Bridge and Fox Grove Regional Park was 471 salmon, estimated from a total of 170 carcasses marked and 96 subsequently recovered. The population up- and down-stream of the mark-and-recovery survey area was not estimated.

The run consisted of 28.5% male adults (FL ≥ 65 cm [25.6 in]), 41.5% female adults, 15% male grilse (FL < 65 cm), and 16% female grilse.

The 1993 fall run of 471 salmon was 3½ times larger than the previous year's population, but still only 5% of the average run size for the past ten years (Appendix 3).

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 downstream to Hwy.59. Surveys were conducted from 20 October 1993 through 6 January 1994; actual carcass mark-and-recovery began on 27 October. Water temperatures ranged from 16°C (59°F) to 8°C (41.8°F), and visibility through the water was greater than 2.7 m (9 ft) throughout the survey period.

This season all salmon carcasses, regardless of condition or age-class, were marked using serially-numbered tags attached to a jaw with a hog-ring. Marked carcasses were released into running water for subsequent recovery.

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. Analysis of the data indicated that the Schaefer estimate (Appendix 1.B) was the most appropriate technique.

An estimate of 1,269 fish was calculated for the river stretch from Crocker-Huffman Dam to Hwy.59 (Table 12). A total of 409 salmon was taken into the Merced River Fish Facility (M. Cozart, CDFG-San Joaquin Valley & Southern Sierra Region [Reg. 4], pers. comm.). The total 1993 fall-run spawner population for the Merced River was 1,678 salmon.

The in-river run consisted of 51.8% male adults, 33.4% female adults, 8.2% male grilse, and 6.6% female grilse. The lengths separating in-river grilse and adults, as determined from length frequency analysis, was 57 cm FL (22.4 in) for adipose-clipped salmon and 61 cm FL (24 in) for non-adipose-clipped fish. Salmon which entered the Merced River Fish Facility consisted of 57.2% adults (FL $\geq$ 61 cm), and 42.8% grilse (FL $<$ 61 cm).

The 1993 Merced River fall run of 1,678 salmon was almost twice the previous year's run size, but still only 21% of the average population size from 1983 through 1992 (Appendix 3).

TABLE 12. Chinook salmon carcass mark-and-recovery data used to estimate the 1993 fall-run spawner population in the Merced River from Crocker-Huffman Dam to Hwy. 59. 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	47	82
3	0	10	--	--	--	--	--	--	--	10	109	211
4	1	3	17	--	--	--	--	--	--	21	90	227
5		3	3	13	--	--	--	--	--	19	114	262
6			0	2	21	--	--	--	--	23	103	192
7			0	2	5	21	--	--	--	28	138	266
8			1		1	2	14	--	--	18	72	254
9					2	1	0	14	--	17	44	80
10							0	0	3	3	3	10
11							1	0		1	1	4
12								1		1	1	2
Total recovered (Ri):	4	16	21	17	29	24	15	15	3		Total:	1,590
Total carcasses marked (Mi):	7	31	56	39	53	46	59	27	10			
										Adjusted estimate d/:		**1,269**

a/ Surveys were conducted from 20 October 1993 through 6 January 1994.

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. 1,590 - 321 = 1,269.

SUMMARY

The total estimated 1993 Central Valley chinook salmon spawner population was 171,315 fish (Table 13). This was 39% higher than the 1992 total of 123,197 salmon (Kano 1998).

Despite the higher 1993 total population, Sacramento River mainstem late-fall- and winter-run salmon decreased in numbers; these runs have been decreasing in size since 1989. The mainstem spring run was similar in size to that of 1992, which was the lowest population recorded.

The total of all runs in Sacramento River tributaries was 1½ times greater than in 1992, with the largest increase seen in the American River.

The San Joaquin River tributary fall runs also increased over those of 1992. However, this system still only contributed a small portion (3.5%) of the total Central Valley escapement. The Stanislaus, Tuolumne, and Merced rivers had a combined 2,826 fall-run salmon (Appendix 2), less than half of this system's spawners.

TABLE 13. Summary of the 1993 Sacramento-San Joaquin river system chinook salmon spawner populations.

Spawning area	Late-fall run	Winter run	Spring run	Fall run	Total
Sacramento mainstem	739 a/	340	386	46,719	48,184
Sacramento tributaries	528 b/	--	5,684	110,936	117,148
San Joaquin tributaries	--	--	--	5,983	5,983
Totals:	**1,267**	**340**	**6,070**	**163,638**	**171,315**

a/ Estimated run size upstream of Red Bluff only; the mainstream downstream of Red Bluff was not surveyed.
b/ 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);

$$N=\sum (R_{ij}\times\frac{M_i}{R_i}\times\frac{C_j}{R_j})-\sum_{2}^{i} M_i$$

where N = the estimated spawner population,

R_{ij} = carcasses marked in the *i*th marking period which were recovered in the *j*th recovery period,

M_i = carcasses marked in the *i*th marking period,

R_i = total marked carcasses recovered from the *i*th marking period,

R_j = total marked carcasses recovered during the *j*th recovery period,

C_j = total carcasses observed in the *j*th recovery period, including those with marks, and

$\Sigma_2^i M_i$ = 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 for period 1, the following equation was used:

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

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:

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

(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. 1993 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 for all runs
Sacramento River System:					
Keswick Dam to Red Bluff					
Sacramento River mainstem a/	739 b/	333 c/	386	33,824	35,282
Clear Creek	d/	--	1	1,246	1,247
Battle Creek					
Coleman National Fish Hatchery	528	--	--	7,587	8,115
Downstream of hatchery	e/	e/	e/	11,029	11,029
(Totals for tributary)	(528)			(18,616)	19,144)
Totals for area:	1,267	333	387	53,686	55,673
Sacramento River System:					
Red Bluff to Princeton Ferry					
Sacramento River mainstem					
Red Bluff to Tehama Bridge	e/	7	0	8,129	8,136
Tehama Bridge to Woodson Bridge	e/	--	0	2,476	2,476
Woodson Br. to Hamilton City	e/	--	0	1,729	1,729
Hamilton City to Ord Bend	e/	--	0	514	514
Ord Bend to Princeton Ferry	e/	--	0	47	47
(Totals for tributary):		(7)		(12,895)	(12,902)
Antelope Creek	d/	--	3	d/	3
Mill Creek	--	--	61	1,975	2,036
Deer Creek	--	--	259	72	331
Totals for area:	--	7	323	14,942	15,272
Sacramento River System:					
Big Chico Creek to American River					
Big Chico Creek	--	--	38	e/	38
Butte Creek	--	--	650	e/	650
Feather River					
Feather River Hatchery	--	--	4,672	11,991	16,663
In-river	--	--	e/	30,923	30,923
(Totals for tributary):	--	--	(4,672)	(42,914)	(47,586)
Yuba River	--	--	e/	6,703	6,703
American River					
Nimbus Hatchery	--	--	--	10,656	10,656
In-river	--	--	--	28,754	28,754
(Totals for tributary):	--	--	--	(39,410)	(39,410)
Totals for area:	--	--	5,360	89,027	94,387
Sacramento River System Totals:	**1,267**	**340**	**6,070**	**157,655**	**165,332**
San Joaquin River System:					
Mokelumne River					
Mokelumne River Fish Installation	--	--	--	2,164	2,164
In-river	--	--	--	993	993
(Totals for tributary):	--	--	--	(3,157)	(3,157)
Stanislaus River	--	--	--	677	677
Tuolumne River	--	--	--	471	471
Merced River					
Merced River Fish Facility	--	--	--	409	409
In-river	--	--	--	1,269	1,269
(Totals for tributary):	--	--	--	(1,678)	(1,678)
San Joaquin River system totals:	--	--	--	**5,983**	**5,983**

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 400 fish from Keswick Dam that were transported to and spawned at Coleman Hatchery.

c/ Includes 20 fish from Keswick Dam that were transported to Coleman Hatchery.

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

e/ Tributary was not surveyed for this run.

APPENDIX 3. Chinook salmon spawner population estimates from 1983 through 1993 in California's Central Valley tributaries.

Tributary / Race	Estimated number of fish											1983-1992
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	**1993**	average
Sacramento River mainstem upstream of Red Bluff												
Late-fall run	14,879	6,540	8,136	7,811	15,393	11,324	11,351	7,136	6,721	9,733	**739**	9,902
Winter run	1,827	2,662	3,684	2,394	1,978	2,075	527	437	190	1,177	**333**	1,695
Spring run	3,854	7,823	10,200	15,824	10,972	9,568	5,139	3,856	762	372	**386**	6,837
Fall run	26,226	36,965	52,120	67,940	75,958	68,623	50,679	33,024	22,937	25,391	**33,824**	45,986
Battle Creek												
Fall run a/	13,983	29,893	39,808	31,252	24,249	67,475	31,048	21,088	17,241	12,708	**18,616**	28,875
Sacramento River mainstem downstream of Red Bluff												
Fall run	32,018	19,166	46,780	34,372	32,588	21,250	10,056	16,127	9,936	8,101	**12,895**	23,039
Feather River												
Spring run b/	1,702	1,562	1,632	1,433	1,213	6,833	5,078	1,893	4,303	1,497	**4,672**	2,715
Fall run a/	30,522	51,056	56,002	55,471	77,846	49,036	48,119	6,126 b/	42,062	40,545	**42,914**	50,073 c/
Yuba River												
Fall run	13,756	9,665	13,042	19,328	18,518	9,000	7,622	d/	14,008	6,362	**6,703**	12,367
American River												
Fall run a/	35,300	39,696	65,213	55,067	46,143	33,514	28,923	10,239	25,211	11,267	**39,410**	35,057
Mokelumne River												
Fall run a/	15,861	8,298	7,682	7,167	1,630	528	281	499	410	1,645	**3,157**	4,400
Stanislaus River												
Fall run	500	11,439	13,473	6,497	6,292	10,212	1,510	480	394	255	**677**	5,105
Tuolumne River												
Fall run	14,836	13,689	40,322	7,404	14,751	5,779	1,275	96	77	132	**471**	9,836
Merced River												
Fall run a/	18,248	29,749	16,052	7,439	4,126	4,592	427	82	119	986	**1,678**	8,182

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/ Average does not include the 1990 estimate.

d/ Tributary was not surveyed.