Status of Winter-Run Chinook Salmon, *Oncorhynchus tshawytscha,* in the Sacramento River

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INTRODUCTION

Winter-run chinook salmon, Oncorhynchus tshawytscha, spawning populations in the Sacramento River have been declining at least since 1967. Since 1979 (except for 1981} the populations have remained at an alarmingly low level. Considerable data relative to winter-run salmon that utilize the Sacramento River have been generated during the past 20-years, but has not been published.

The purpose of this report is to summarize some of the things that are known about winter-run salmon, and to suggest some possible reasons for their decline.

LIFE HISTORY NOTES

Adult Migration

Time

Winter-run chinook salmon, Oncorhynchus tshawytscha, -start their annual Spawning migration in the Sacramento River past Red Bluff Diversion Dam in mid-December, and the run continues into early August. The bulk of the run passes Red Bluff between January and May, with the peak in mid-March (Figure 1).

Number

The counts of adult winter-run salmon passing Red Bluff Diversion Dam from 1967 through 1984 range from a high of 117,800 in 1969 to a low of 1,156 in 1980. The average count for the three year period 1982-84 is only 2,056. The calculated (from regression) populations or runs indicate an average decline of 51% per generation during the 1967-84 period (Table 1 and Figure 2).

Ocean Hook Scars

Adult winter-run salmon are examined regularly in the fish trapping facility at Red Bluff Diversion Dam.

During the 15-year period, 1970-71 through 1984-85, the annual percent of ocean hook scars noted while examining winter-run salmon ranged from a high of 33.2% in 1976-77 to a low of 7.5% in 1980-81, and averaged 20.6%. This average is less than that noted in the other three runs of salmon (Table 2).

A True Run

In the three year period 1969-71, approximately 720,000 juvenile salmon were seined from the Sacramento River near Red Bluff in September and October.

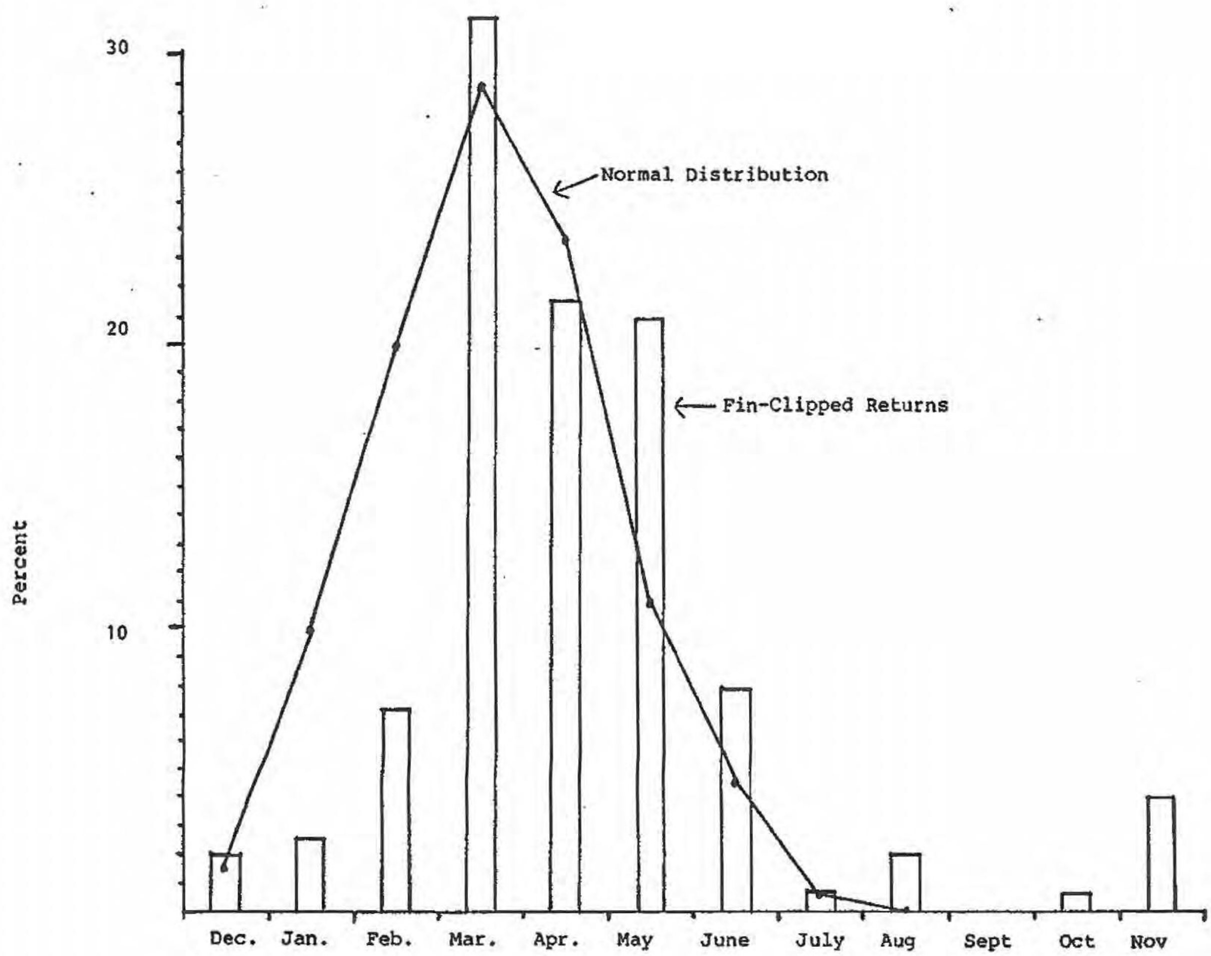

FIGURE 1. Normal distribution of adult winter-run salmon migrating past Red Bluff Diversion Dam (1970-81 average), and monthly percent of all returning fin-clipped winter-run salmon (from the 1969-71 releases) observed at Red Bluff Diversion Dam.

Table 1. Winter-Run Salmon Spawning Runs Past Red Bluff Diversion Dam Showing Decline Per Generation (3-years) Based on Regression, 1967-84 [7].

Adjusted Counts [7]		Calculated Counts From Regression Log Y= 5.19 – 0.10x r= -.85 p= .01		
			Decline Per Generation	
Year	Number	Number	Number	Percent
1967	49,533 [1,2]	123,16 x	One Generation	
1968	84,414 [2,3]	96,942		
1969	117, 800 [3,4]	76,300 x		
1970	81, 159 [2,3]	60,053	63,116	51
1971	53,089	47,265	49,677	51
1972	37,133	37,201	39,099	51
1973	24,079	29,279	30,774	51
1974	19,116	23,044	24,221	51
1975	23,430	18,137	19,064	51
1976	35,096	14,276	15,003	51
1977	17,214	11,236	11,808	51
1978	24,862	8,843	9,294	51
1979	2,364	6,960	7,316	51
1980	1,156	5,478	5,758	51
1981	20,041	4,311	4,532	51
1982	1,242	3,394	3,566	51
1983	2,262 [6]	2,671	2,807	51
1984	2,663	2,102	2,209	51

1 8-hour counts, adjusted for 14-hour counting period (x1.75).
2 Counts reconstructed by adjusting actual counts to their respective run
3 Adjusted for missing counts (actual count 61,369).
4 Adjusted for missing counts (actual count 80,934).
5 Adjusted for missing counts (actual count 52,185).
6 Adjusted for missing counts (actual count 405)
7 Counts represent at least 95% of the total run.

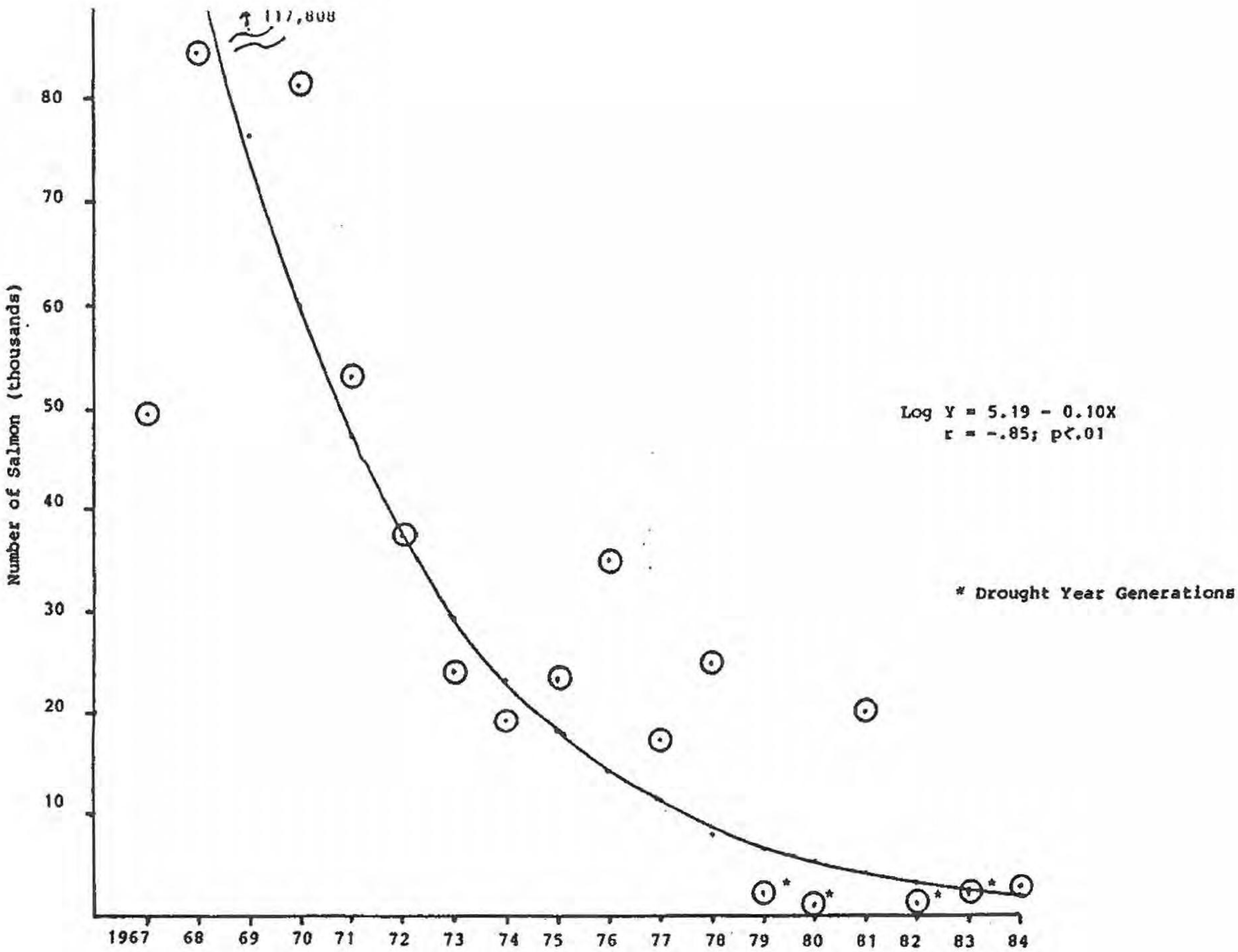

Figure 2. Number of Adult Winter-Run Chinook Salmon Counted Passing Red Bluff Diversion Dam, 1967-84.

TABLE 2. Ocean Hook Scars (in percent) Observed Among the Four Runs of Adult Salmon Examined in the Fish Trapping Facility at Red Bluff Diversion Dam.

Year	Run			
	Late-Fall	Winter	Spring	Fall
1970-71	- - - - - - 20.3% - - - - - - - Combined		27.2%	35.6%
1971-72	34.4%	23.1%	28.7%	28.4%
1972-73	26.3%	24.9%	28.9%	32.6%
1973-74	30.8%	24.9%	30.2%	33.5%
1974-75	38.6%	20.2%	28.5%	30.7%
1975-76	35.2%	20.6%	33.0%	33.5%
1976-77	39.3%	33.2%	30.1%	45.3%
1977-78	29.7%	12.7%	25.4%	32.5%
1978-79	27.5%	21.4%	28.9%	28.3%
1979-80	28.3%	21.9%	24.7%	27.6%
1980-81	28.0%	7.5%	21.0%	33.6%
1981-82	30.3%	24.5%	27.5%	34.2%
1982-83	27.0%	22.6%	23.1%	27.6%
1983-84	16.2%	17.9%	15.2%	21.9%
1984-85		13.5%		
Average	30.1%	20.6%	26.6%	29.5%

They were marked (fin-clipped) at Coleman National Fish Hatchery and released at Red Bluff (Table 3). It was believed that winter-run salmon juveniles (from the May-June spawning period) would be 46 mm or less in length at the time of the seining, so most juvenile salmon longer than 46 mm were returned directly to the river upon capture i.e., they were not marked. Of those that were marked, 94% were between 26 mm and 46 mm in length; six percent ranged between 47 mm and 84 mm in length, and were thought to be late-fall-run salmon juveniles. The time pattern of adult returns of the marked salmon to the Upper Sacramento (Red Bluff Diversion Dam) coincided well with that of the normal winter-run (Figure 1). Of the total marked fish observed at Red Bluff, 95.4% passed the dam during the normal winter-run salmon migration period and 4.6% passed the dam within the migration time pattern of late-fall-run salmon.

Seining in the Sacramento River at Red Bluff in September and October, 1973 resulted in the capture of juvenile salmon which also revealed a size distribution similar to that obtained in 1969-71 (Table 4).

Spawning

Historic

Historic information is scarce, but it appears that prior to construction of Shasta Dam the principal spawning area for winter-run salmon was in the Sacramento River system upstream from Redding.

On the Upper McCloud River between Lower Falls and Big Springs, in May and June, 1939, chinook salmon were observed spawning. On May 26, 25 adult salmon were seen on nests (most at Big Springs). On August 5, eyed eggs and

TABLE 3. Size Distribution of Chinook Salmon Juveniles Seined from the Sacramento River at Red Bluff, 1969-71.

Brood Year (BY)	Date	Size (Fork Length in mm) Number Measured	Range	Average
	9-29-69	495	28-53	36.20
	10-01-69	485	30-49	35.20
	10-02-69	246	29-55	36.02
	10-03-69	211	29-57	37.58
	10-06-69	237	30-59	36.31
1969	10-10-69	246	30-57	36.88
	10-14-69	225	30-57	37.64
	10-15-69	201	30-51	37.29
	10-17-69	437	32-63	39.66
	10-20-69	301	31-63	38.69
	BY Totals	3,178	23-63	Av. 37.16
	9-15-70	206	31-61	37.31
	9-18-70	221	31-59	37.53
	9-24-70	298	31-64	38.16
1970	9-30-70	158	31-59	39.37
	10-07-70	248	31-70	36.56
	10-16-70	126	31-51	37.68
	10-22-70	212	33-84	41.12
	11-04-70	117	35-75	49.70
	BY Totals	1,586	31-84	Av. 39.05
	9-22-71	227	33-55	40.92
	9-23-71	271	30-55	38.01
	9-24-71	215	32<»50	38.00
	9-27-71	300	31-55	37.19
1971	9-27-71	240	32-49	37.35
	9-29-71	248	31-45	37.00
	9-30-71	263	32-50	37.41
	10-01-71	203	31-45	36.64
	10-04-71	271	26-55	35.96
	10-06-71	222	31-46	36.72
	10-07-71	248	32-53	37.02
	10-07-71	365	29-78	38.26
	10-12-71	373	31-48	36.10
	10-13-71	261	31-53	36.24
	10-14-71	272	30-47	36.34
	BY Totals	3,989	26-78	Av. 37.10

TABLE 4. Size Frequency Distribution of Chinook Salmon Juveniles Seined from the Sacramento River at Red Bluff, 1973.

Fork Length in mm	#1 9/13-9/14	#2 9/27-9/28	#3 10/11-10/12	#4 10/22-10/23	#5 10/29-10/30
30		1			
<30-31.9	8	12	6	3	6
32-33.9	115	185	115	52	97
34-35.9	310	477	505	203	405
36-37.9	219	407	431	164	411
38-39.9	138	300	342	153	335
40-41.9	50	185	172	133	311
42-43.9	54	246	131	94	262
44-45.9	46	169	66	72	233
46-47.9	30	96	33	52	195
48-49.9	19	73	22	24	112
50-51.9	18	61	12	15	93
52-53.9	8	41	13	11	51
54-55.9	1	21	5	3	33
56-57.9	1	8	3	1	27
58-59.9	1	4	1	4	11
60-61.9		1	1	5	11
> 61.9				7	24
	N=1018	N=2287	N=1358	N=996	N=2617
	• =37.9	• =39.7	• =38.2	• =40.0	• =41.5

alevins were taken from two nests, and on September 29 several juvenile salmon were seined from the river at Big Springs. On April 24, 1902 a pair of salmon were observed spawning in the McCloud River opposite Baird Hatchery (Slater, 1963).

Time

Winter-run salmon spawn from mid-April through mid-August with the bulk of the spawning occuring in May and June.

Area

Winter-run salmon now spawn in the Sacramento River from the Redding area downstream at least as far as Tehama. They spawn in greatest numbers upstream from Red Bluff. Although primarily a main stem of the Sacramento River spawner, they have been observed spawning in small numbers in tributary streams including Battle and Mill Creeks as well as in the Calavaras River, a tributary to the lower San Joaquin River.

Age

Winter-run salmon spawn primarily as 3-year old fish. Recoveries of marked 1969-71 brood year winter-run salmon from 1971 through 1975 in the fish trapping facility at Red Bluff Diversion Dam indicate that 25% returned to spawn as 2-year old fish, 67% as 3-year old fish and 8% as 4-year old fish (Table 5).

Fecundity

Between 1956 and 1982, a total of 234 winter-run salmon were spawned at Coleman National Fish Hatchery. The number of eggs per female ranged from 2,500 to 4,453 and averaged 3,353 (Table 6).

TABLE 5. Age Composition of Marked Adult Winter-Run Salmon Recovered at Red Bluff Diversion Dam.

Releases	Returns 1/ Year					
Year	1971	1972	1973	1974	1975	Totals
1969 (BY)	9	24	7			40
1970 (BY)		14	49	2		65
1971 (BY)			14	27	3	44
			37 (2 yr) 25%	100 (3yr) 67%	12 (4 yr) 8%	149 100%

_1/ Actual numbers observed.

TABLE 6. Fecundity of Winter-Run Salmon Spawned at Coleman National Fish Hatchery.

Year	Females Spawned	Total Eggs	Eggs Per Female
1956	2	6,000	3,000
1958	136	381,000	2,801
1963	53	236,000	4,453
1967	7	17,500	2,500
1978	29	121,000	4,172
1982	3	11,175	3,725
1982	2	7,168	3,584
1982	2	5,872	2,936
Totals Average	234	784,715	3,353

The seaward migration of juvenile winter-run salmon in the Sacramento River at Red Bluff starts in the early part of August and continues at least through October. The peak of the migration is from mid-September to mid-October. Data are lacking as to whether or not the migration period at Red Bluff extends much beyond October.

Trawling by the Department of Fish and Game in Sacramento River at Clarksburg in 1973 showed that juvenile winter-run salmon (35-45 mm) were present there during the September-November period (Schaffter, 1980).

SOME FACTORS CONTRIBUTING TO THE DECLINE

Drought

Two year classes of winter-run salmon were lost due to drought conditions in 1976-1977. Year classes have failed to recover in subsequent generations. In addition, the last strong year class (1981) failed to return well in 1984, and at present no dominant year class exists. Low fecundity would contribute to the difficulty of "bouncing back" after any particular disaster.

Red Bluff Diversion Dam

Adult Salmon Delay and Blockage

Between 1979 and 1981 radio tagged winter-run salmon were monitored in the vicinity of Red Bluff Diversion Dam (put in operation in 1966). Of the radio tagged salmon that approached the dam 37.5% did not migrate past it. Delay time of these tagged salmon that did pass the dam ranged from 1 to 40 days and averaged 18 days (Table 7). Delay time immediately below the dam, for those salmon from all four runs that eventually passed it, was related to flow i.e., the greater the flow, between 4,000 and 16,000 cubic feet per second, the longer the delay (Figure 3). From 1967 through 1983, during the period when most adult winter-run salmon pass Red Bluff (January-May), the average monthly flow of the Sacramento River near Red Bluff ranged from a low of 12,743 to a high of 23,535 cfs (Table 8).

River Temperature Below Red Bluff

During most years, winter-run salmon are not able to spawn successfully downstream from Red Bluff.

TABLE 7. Red Bluff Diversion Dam Blockage and Delay of Adult Salmon

RUN	of Fish Blocked	Delay time of Fish Not Blocked (Days)	Estimated Effect 1/ Relative	Reason
Late-Fall	30.0	Av. 3.9 (Rn 1-7)	1	Delay of ripe fish
Fall	14.3	Av. 3.5 (Rn 1-15)	3	Delay of ripe fish. Crowded spawning area below dam.
Spring	33.3	Av. 11 (Rn 1-22)	5	Delay of ripe fish. High summer temp., below Red Bluff.
Winter	37.5	Av. 18.2 (Rn 1-40)	10	High spawning temps. some years below Red Bluff.

1_/ On a scale of 1 to 10.

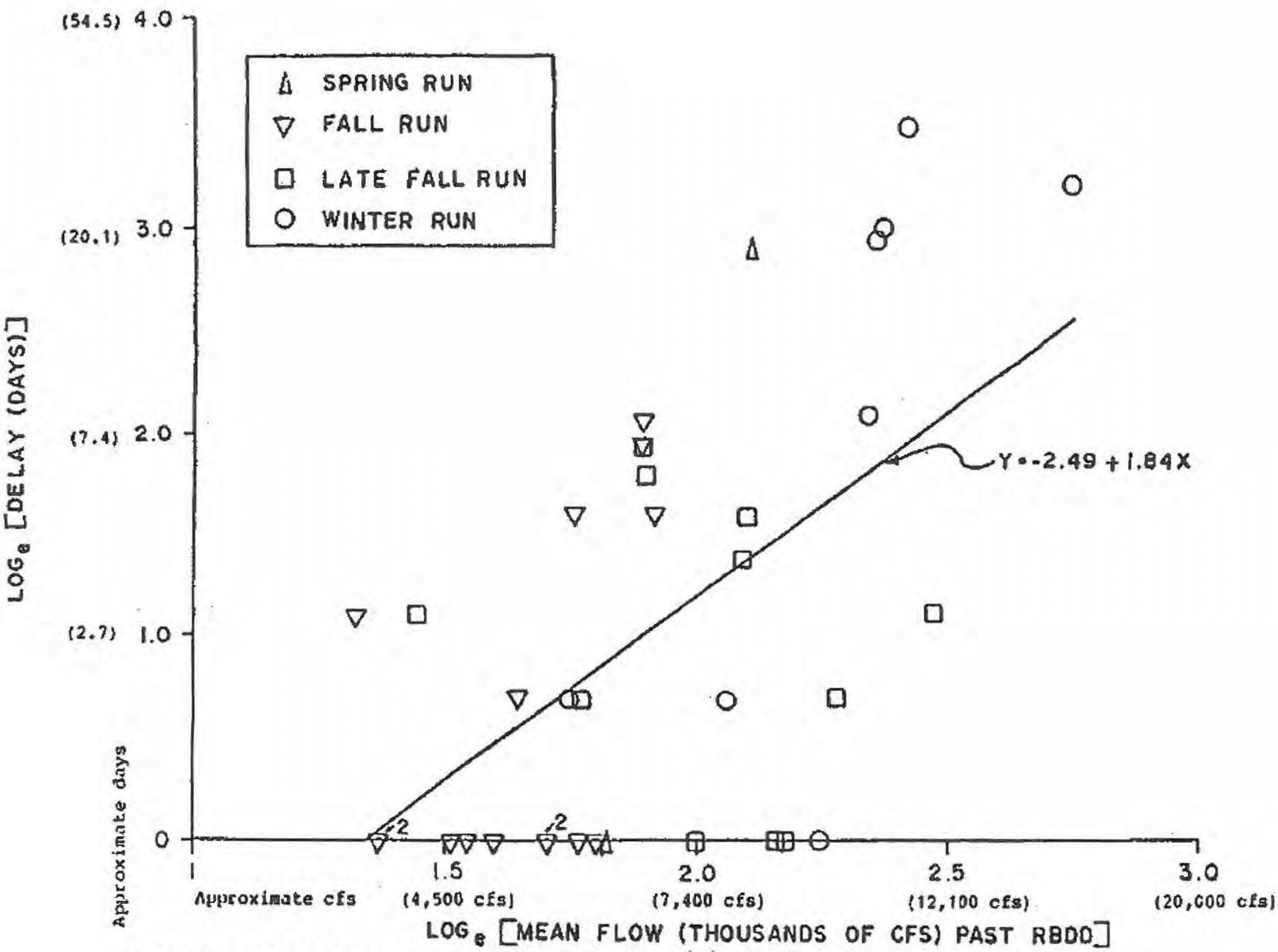

FIGURE 3. Relationship between delay (in Area One) of radio tagged salmon that passed Red Bluff Diversion Dam (RBD and mean flow (all data transformed to natural logarithms). From: Hallock, R.J., D.A. Vogel and R.R. Reisenbichler, 1982.

TABLE 8. Average Monthly Flow of the Sacramento River Near Red Bluff (cubic feet per second).

Year	January	February	March	April	May
1967	17,240	23,220	9,882	19,760	19,600
1968	11,940	24,240	13,830	9,606	9,763
1969	34,030	39,990	14,280	11,840	16,090
1970	61,060	38,870	12,760	9,465	9,520
1971	25,820	14,080	11,780	16,520	17,190
1972	8,909	9,750	14,350	10,950	11,140
1973	30,140	28,440	17,320	9,187	11,220
1974	52,860	22,180	29,830	35,110	14,860
1975	8,186	19,860	29,760	13,710	16,710
1976	7,335	9,129	8,447	11,060	12,790
1977	6,693	6,117	6,390	8,442	8,330
1978	21,550	17,800	27,380	15,880	11,060
1979	8,897	10,370	8,291	8,133	9,386
1980	26,190	36,220	23,350	8,849	8,623
1981	9,791	9,273	12,930	9,977	12,120
1982 1/	22,240	32,200	22,000	29,790	15,720
1983 1/	23,920	58,190	75,830	22,910	22,510
Average	22,164	23,525	19,906	14,776	12,743

1/ Preliminary

TABLE 9. Average Monthly High Sacramento River Temperatures at Red Bluff Diversion Dam (°F).

Year	Month			
	May	June	July	August
1967	56	57	58	57
1968	56	57	56	57
1969	58	58	59	58
1970	57	59	60	61
1971	56	56	56	56
1972	55	59	59	59
1973	57	58	57	57
1974	57	59	61	58
1975	54	57	56 1/	56 1/
1976	-	58	60	64
1977	57	64	68	70
1978	60	61	61	60
1979	61	59	58	59
1980	59	58	59	61
1981	56	59	58	60
1982	55	58	58	56
1983	55	55	-	56
1984	55	57	57	59

1/ Partial temperature record.

The range of suitable salmon hatching temperatures is from 42.5° F to 57.5°F (Combs and Burrows, 1957). According to Slater (1963) the habits of winter-run salmon adapt it to "situations where temperatures of 50°F to 57°F can be maintained during the May through August spawning and incubation period".

During the 18-year period 1967-84 Sacramento River temperatures downstream from Red Bluff would have been suitable for winter-run salmon spawning and egg incubation only 4-years (Table 9). In addition, between 1949 and 1956 average river temperatures at Woodson Bridge during June and July averaged greater than 61°F (Azevedo and Parkhurst, 1957). It is probable that Sacramento River temperatures are never suitable for winter-run salmon spawning downstream from Woodson Bridge, and are only suitable downstream from Red Bluff 22% of the time.

Data relative to the effect of water temperature on winter-run salmon eggs and young fish as presented by Slater (1963) indicate that temperature tolerances of winter-run salmon are similar to those of other races of salmon (Table 10)

Juvenile Salmon Mortality

Although no specific studies relative to the survival of juvenile winter-run salmon passing Red Bluff Diversion Dam have been conducted, studies of this type have been conducted with fall and late-fall run juveniles as well as with yearling steelhead. Since the results of these studies indicate that losses occur among juvenile salmon that pass the dam in the spring as well as in winter, it is probable that winter run juveniles also suffer mortality to some degree when passing the dam in the fall. This

TABLE 10 . Mortality of Winter-Run Chinook Salmon Eggs and Young Fish with Related Water Temperatures at Coleman National Fish Hatchery, 1958-59 3/.

(Compiled by Harry D. Baer from records of Coleman National Fish Hatchery)

Month	Monthly Mortality Rate	Accumulated Mortality	Average Water Temperature
	Percent	Percent	°F
May	11. 5 1/	6.4 2/	56.5
June	49.1	51.5	59.7
July	97.6	98.8	63.3
August	13.6	99;o	59.4
September	11.1	99.1	57.1
October	4.3	99.1	53.9
November	1.1	99.2	48.5
December	3.2	99.2	47.3
January	2.8	99.2	45.7

1/ Approximate, based on derived number on hand at beginning of month comprised of actual number on hand, 47,227, plus half of those added during month, 328,362 or a total of 211,408.

2/ Referred to total of 381,065 eggs ultimately collected during the period April 30-June 13, 1958.

3/ From Slater, 1963.

assumption becomes even more probable when it is noted that the studies with fall-run salmon indicate a juvenile loss of 23% just from passing under a dam gate (Table 11).

HARVEST

Sacramento River Sport Catch

Data are scarce relative to the inland sport catch of adult winter-run salmon. During the eight year period 1968-75 (not including 1974) the estimated percent of the total run caught by Sacramento River sport fishermen ranged from 4% in 1970 to 18% in 1971, and averaged 10% (Table 12). Catch figures are not available for other years, but the run size is re-recored from 1967 through 1984 (Table 1).

Ocean Sport and Commercial Catch

Based on returns from marked (fin-clipped) naturally produced juvenile winter-run salmon seined from and released in the Sacramento River at Red Bluff (1969-71 BY), most winter-run salmon caught in the ocean are landed between Monterey and Ft. Bragg. Mark duplication of Trinity River Hatchery salmon made it difficult to tell if any winter-run salmon were landed north of Ft. Bragg.

Of the total ocean catch (commercial plus sport), 71% are caught by the sport fishery and 29% are caught by the commercial fishery. The sport caught salmon are 95% 2-year old and 5% 3-year old fish. The commercially caught salmon are 25% 2-year old and 75% 3-year old fish. Very few 4-year old salmon are caught in the ocean because most winter-run salmon leave the ocean on their spawning migration prior to the time the ocean fishery starts in the spring (Table 13).

TABLE 12. Estimated Sport Catch, in Numbers and Percent of Total Run, of Winter-Run Salmon in the Sacramento River.

Year	Total Run	Catch					
		Above Red Bluff		Below Red Bluff		Total	
		Number	Percent	Number	Percent	Number	Percent
1962	-					11,000	
1963	-					2,436	
1964	—					4,882	
1965	-					4,328	
1966	-					3,935	
1967	49,533	—	-	—	-	—	-
1968	84,414	4,851	6	3,663	4	8,514	10
1969	117,80	3,447	3	3,125	3	6,572	6
1970	81,159	1,965	2	1,212	2	3,177	4
1971	53,089	3,865	7	5,842	11	9,707	18
1972	37,133	1,054	3	3,962	11	5,016	14
1073	24,079	1,439	6	1,318	5	2,757	11
1974	19,116	—	-	—	-	—	-
1975	23,430	696	3	871	4	1,567	7
			Av. 4		Av. 6		Av. 10

TABLE 11. Survival[1] of Salmon Released Above and Below Red Bluff Diversion Dam.

Release Area	(on going study) Late-Fall-Run Salmon					(on going study) Fall-Run Salmon			(completed study) Fall-Run Salmon				(completed study) Steelhead
	Returns by Release Year					Returns by Release Year			Returns by Release Year				Returns by Release Year
Release Year	1979	1980	1981	1982	Totals	1981	1982	Totals	1975	1976	1977	Totals	1973-75 Total
Battle Creek	199	554	196	81	1,030	193	398	591					273
2 mi. above Dam									91	98	50	239	
Above Dam gate										117	146	263	
Below Dam gate										141	203	344	
¼ mi. below Dam	281	781	351	74	1,487	265	415	680	456		21	477	372

[1] Marked salmon recovered in the ocean fishery landings of California, Oregon, and Washington and marked adult steelhead recoveries at Coleman Hatcher.

Summary				
Species	Total Released		Survival	Mortality Attributed to Releasing above Dam
Salmon	Above Dam	1,257,654	2,123 (.17%)	
	Below Dam	1,134,934	2,988 (.26%)	35%
Steelhead	Above Dam	301,948	273 (.09%)	25%
	Below Dam	302,864	372 (.12%)	

1/4/85

Of the total catch (ocean commercial and sport plus Sacramento River sport), 85% are landed in the ocean and 15% in the Sacramento River (Table 13).

Catch to Escapement Ratio

Based on the estimated returns of marked winter-run salmon in Table 8, the average catch to escapement ratio for 1969-71 brood year winter-run salmon was .66 to 1 (890 ÷ 1,353). This represents a harvest of 40% (890 ÷ 2,243)

Other Contributing Factors

A. Habitat Destruction

1. Lack of gravel recruitment due to dams.
2. Lack of gravel recruitment due to gravel mining.
3. Armouring of gravel due to controlled flows.
4. Decrease in spawning habitat due to construction of Shasta and Keswick Dams.

B. Mining Pollution near Keswick Dam

C. Industrial Pollution

1. At Anderson
2. At Red Bluff
3. Other

D. Increased Predation

1. Due to concentration of predators below Red Bluff Diversion Dam.
2. Due to releasing larger fish from hatcheries in the fall.

E. Increased Pumping in the Delta

1. Pumping later in the fall than previously.

F. Straying by Adults

1. Spawning in streams such as Mill and Battle Creeks where temperatures become too high for production of juveniles.

TABLE 13. Estimated Returns of Marked Winter-Run Salmon 1/

Broodyear Released[2]	Location	1971	1972	1973	1974	1975	Total
		Returns					
		Year					
1969	Sacramento River						
	Red Bluff Diversion Dam	90	305	19			414
	Sport Catch	9	30	2			41
	Ocean						
	Commercial Catch	14	95				109
	Sport Catch	239	27				266
	Brood Year Total						830
1970	Sacramento River						
	Red Bluff Diversion Dam		200	114	46		360
	Sport Catch		20	11	5		36
	Ocean						
	Commercial Catch		35	35			70
	Sport Catch		151	0			151
	Brood Year Total						617
1971	Sacramento River						
	Red Bluff Diversion Dam			314	256	9	579
	Sport Catch			31	26	1	58
	Ocean						
	Commercial Catch			7	35		42
	Sport Catch			117	0		117
	Brood Year Total						796
Grand Total							2,243

1/ Returns from Monterey, San Francisco and Ft. Bragg only, because of duplicate mark on 1968 BY spring-run salmon from Trinity River Hatchery.
2/ BY numbers released; 1969 = 301,643, 1970 = 109,110, 1971 = 309,266.

SUMMARY

At Red Bluff, the adult winter-run salmon migration occurs between December and August, and peaks in March. Since 1967 the adult population has declined an average of 51% per generation. The adult counts at Red Bluff Diversion Dam have ranged from a high of 117,800 in 1969 to a low of 1,156 in 1980. Ocean hook scars noted on winter-run salmon at Red Bluff are less than for the other three salmon runs. Marked salmon returns indicate that the winter run is a true run.

Spawning formerly occurred in the Sacramento River system upstream from Redding; it now occurs from Redding downstream to at least Tehama, but primarily upstream from Red Bluff. The peak spawning period is May and June. Sixty-seven percent spawn as 3-year old fish followed by 25% as 2-year old fish and 8% as 4-year old fish. Fecundity is comparatively low, with the females averaging only 3,353 eggs.

At Red Bluff, the seaward juvenile migration peaks in September and October. Winter run juveniles have also been observed in the Sacramento River at Clarksburg in the September-November period.

The 1976 and 1977 year classes of winter-run salmon were lost due to drought conditions in the Sacramento River.

At Red Bluff Diversion Dam, 37.5% of the radio tagged winter-run salmon that approached the dam did not pass. Delay of those that did pass ranged from 1 to 40 days. Delay time was related to flow i.e., the greater the flow the longer the delay. Because of high river temperatures, winter-run salmon would have been able to spawn successfully below Red Bluff only 22% of the time, or 4 out of 18-years between 1967 and 1984. Mortality

among winter-run salmon juveniles passing Red Bluff Diversion Dam is thought to occur (since it occurs among juvenile fall and late-fall salmon), but has not been demonstrated by specific studies.

In the Sacramento River, sport fishermen land an average of 10% of the adult winter-run salmon each year. Between 1968 and 1975 the total number caught ranged from a high of 9,707 in 1971 to a low of 1,567 in 1975.

In the ocean, most winter-run salmon are landed between Monterey and Ft. Bragg; 71% are caught by sport fishermen and 29% are caught by commercial fishermen. In the ocean sport fishery, 95% are landed as 2-year old fish and 5% as 3-year old fish. In the ocean commercial fishery, 25% are landed as 2-year old fish and 75% as 3-year old fish.

The average catch to escapement ratio (ocean commercial and sport catch plus Sacramento River sport catch) is .66 to 1. This represents an average annual harvest of 40%.

Factors contributing to the decline of winter-run salmon, other than the 1976-77 drought, low female fecundity, Red Bluff Diversion Dam and -related fish passage problems, and harvest include, (1) habitat destruction, (2) mining pollution, (3) industrial pollution, (4) increased predation due to releasing large fish from hatcheries in the fall, (5) increased Delta water diversion in the fall and (6) straying by adults into tributaries unsuitable for production.

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