A DESCRIPTION OF THE CALIFORNIA DEPARTMENT OF FISH AND GAME MANAGEMENT PROGRAM AND GOALS FOR THE SACRAMENTO RIVER SYSTEM SALMON RESOURCE

By

Richard J. Hallock[1/]

SACRAMENTO RIVER SYSTEM

The Sacramento River system is the principal salmon spawning area in the Central Valley (Figure 1). For the purposes of this report the system is divided into four major spawning areas; 1) the Sacramento River system above its confluence with the Feather River and referred to as the upper Sacramento River system, 2) the Feather River, 3) the Yuba River, and 4) the American River.

Salmon Runs

King salmon (Oncorhynchus tshawytscha) are the only salmon of any importance in the Sacramento River system. The other four North American Pacific Salmon have been recorded in the Sacramento River system but their numbers are small. Four different runs or races of king salmon spawn in the Sacramento River each year, but not in all tributaries. They are called spring, fall, late fall and winter runs. Spring-run salmon enter the river system between March and July and spawn from late August through early October, but primarily in September. Spawning occurs in the Sacramento River as well as in the upper reaches of several suitable tributaries. Fall-run salmon migrate into the Sacramento from July through

---

1/ Associate Marine Biologist, Salmon and Steelhead Program, Anadromous Fisheries Branch.

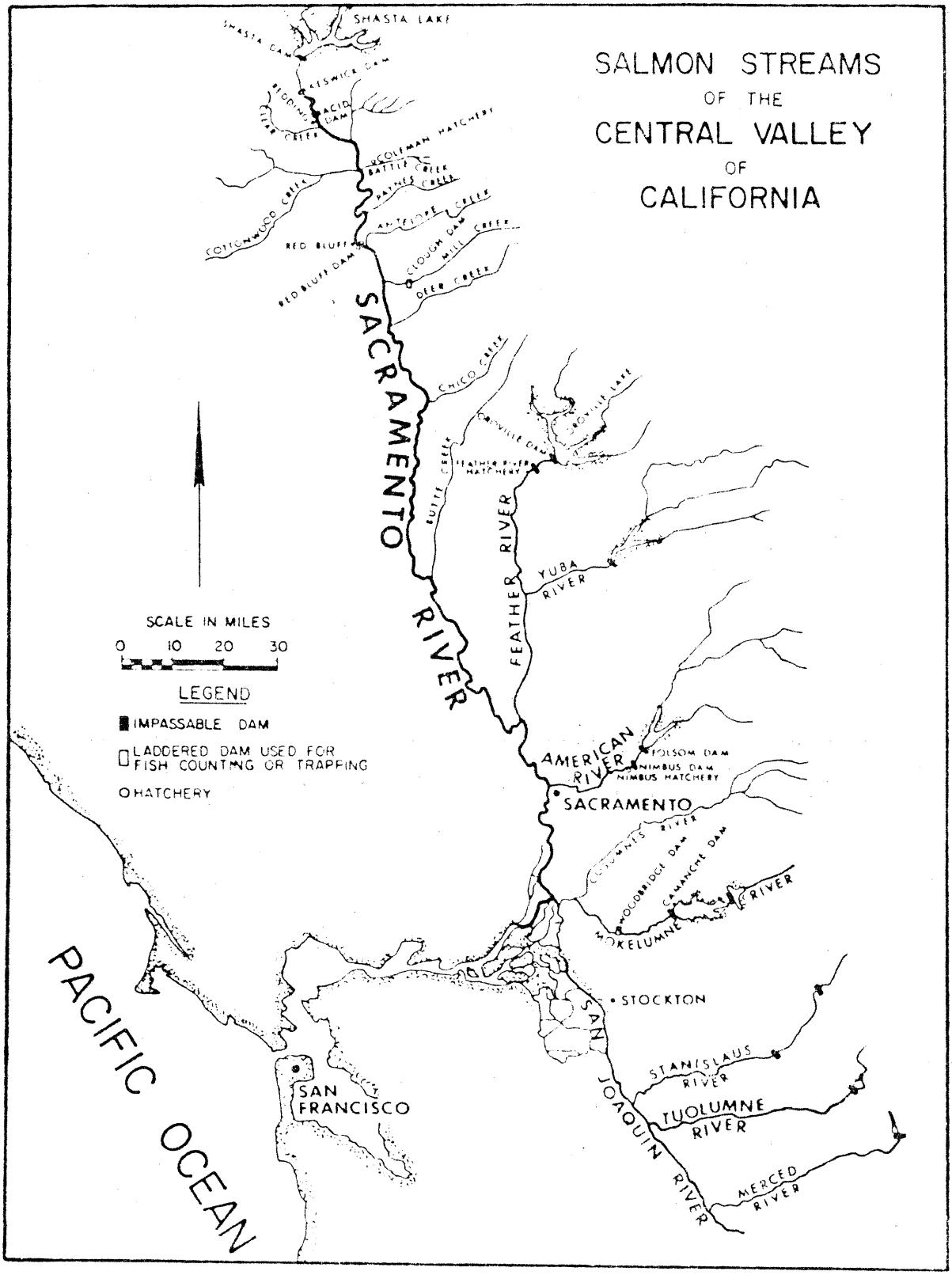


Figure 1. Salmon streams of the Central Valley, indicating salmon hatcheries, impassable dams, and those laddered dams used for fish counting or trapping.

November and spawn from early October through December. Spawning takes place in the Sacramento River, and in the lower reaches of most tributaries. For convenience, these two runs are termed "fall spawners" in this report. Late fall-run salmon migrate into the Sacramento from early November through February and spawn from January through March, primarily in the Sacramento River, but also in small numbers in some tributaries. Winter-run salmon enter the Sacramento River from early January through mid-June and spawn primarily in the upper reaches of the Sacramento between mid-April and mid-July. A few winter-run salmon occasionally spawn in tributaries. These latter two runs are called "spring spawners" in this report.

Salmon Spawning Populations

Methods

Most of the spawning stock estimates presented in this report are attributable to the California Department of Fish and Game; the remainder to the U. S. Fish and Wildlife Service. The salmon spawning escapement figures were obtained in most instances through "spawning stock surveys", i.e., by counting spawned-out carcasses, estimating the proportion of the total carcasses counted, and then calculating the probable number of spawners in the stream. Spawning stock surveys were often supplemented by aerial redd counts and/or tag and recovery programs.

Since 1966 the numbers of salmon that spawned in the Sacramento River system upstream from Red Bluff have been counted in Red Bluff Diversion Dam

fishways. In some instances these counts are incomplete because of lake drawdowns, floods or murky water. Spawning escapements presented for fall spawning salmon are minimums since the spring-run salmon figures included are incomplete.

Since 1953, spawning escapement data have been complete enough to enable estimates of fall- and spring-run salmon for the entire Sacramento River system. However, not until 1970 was a breakdown of total counts into the four runs at Red Bluff Diversion Dam possible.

Spawning Escapement Goals

Defining spawning escapement levels to serve as management goals is a difficult and largely subjective process. In some streams, field surveys of spawning areas have resulted in estimates of the maximum number of spawners that could be accommodated under various stream flows. These estimates, however, are undoubtedly too high, for they assume that the spawning run will spread out uniformly over every square yard of gravel, a condition which, in California, has yet to occur.

Furthermore, a fixed ideal spawning escapement does not exist, for environmental conditions which govern each year's spawning success and survival subsequent to spawning are not fixed. In the San Joaquin system, significant correlations exist between spring outflow and adult fall-run escapement 2-1/2 years later; significant correlations do not exist between size of escapement in 1 year and escapement size 3 and/or 4 years later.

An additional relationship has been demonstrated between ocean fishery catch and escapement. Size of the spawning run is positively correlated with the size of the immediately preceding season's catch; a large catch is followed by a large escapement, a small catch by a small escapement.

Taken together these relationships suggest that factors limiting long-term escapement size operate after spawning occurs and prior to the time that the population is recruited to the ocean fisheries. Because we do not know the degree to which these factors will operate on any given year class, we have no basis on which to establish a "maximum" or a "minimum" escapement goal. We have therefore suggested an "average" escapement goal, which is a desirable level around which the escapement will fluctuate.

Numbers of Salmon

In the presentation of numbers of salmon in the spawning populations a history of the estimated runs is included first, followed by an estimate of the average escapement goal (Table 1).

History of Runs

The 24 years of data on fall spawning salmon escapements in the entire Sacramento River system indicate a peak of 528,000 fish in 1953, and a low of 104,000 in 1957 (Table 2). During the 8 years from 1953 through 1960 these runs averaged 340,000, and five times during this period the combined populations totaled approximately 400,000 or more. However, during the following 16 years (1961-76) there has been an overall gradual but steady decline in the fall spawning populations. During the 10-year period, 1967-76 the fall spawning populations averaged 213,400 fish.

TABLE 1

Sacramento River System
Average Spawning Populations, 1967-76,
and Average Spawning Population Goals (in Thousands)

Run	Upper Sacramento River System		Feather River		Yuba River		American River		Totals	
	Average		Average		Average		Average		Average	
	Present	Goal	Present	Goal	Present	Goal	Present	Goal	Present	Goal
Fall	98	150	49	40	12	25	44	30	203	245
Spring	10	29	.4	1					10.4	30
Late Fall[1/]	19	25							19	25
Winter[1/]	31	40							31	40
Av. Pres.	158		49.4		12		44		263.4	
Av. Goal		244		41		25		30		340

1/ Six year average only (1971-76).

Estimates of spring-spawning salmon have fluctuated considerably since 1970 when the first counts became available, from a low of 25,000 in 1974 to a high of 70,000 in 1971, and averaged about 50,000. During most years, however, these are minimum population estimates based on incomplete counts at Red Bluff Diversion Dam. At times (as in 1970) the water was too turbid for counting for several consecutive weeks, but the fishways were open.

A "least-squares line" was computed for the 24 years of fall-spawning salmon data to mathematically represent the overall population trend. These data indicate a 60% decline. However, the overall decline is due entirely to a decreasing population in the upper Sacramento River (Sacramento River above the Feather River), whereas the American, Feather and Yuba Rivers spawning populations have remained fairly constant or increased (Figure 2).

A least-squares line fitted to the 7 years of spring-spawning salmon population data indicates a 33% decline.

Sacramento River System Above the Feather River

The upper Sacramento River system is the principal spawning area in the Sacramento Valley, as well as in the entire Central Valley. Keswick Dam, located on the main stem of the Sacramento a few miles upstream from Redding is a complete block to migrating salmon. A fish trap at the dam is used to secure salmon for Coleman National Fish Hatchery on Battle Creek. King salmon migrate year-round into this section of the river system and they include all four of the recognized runs.

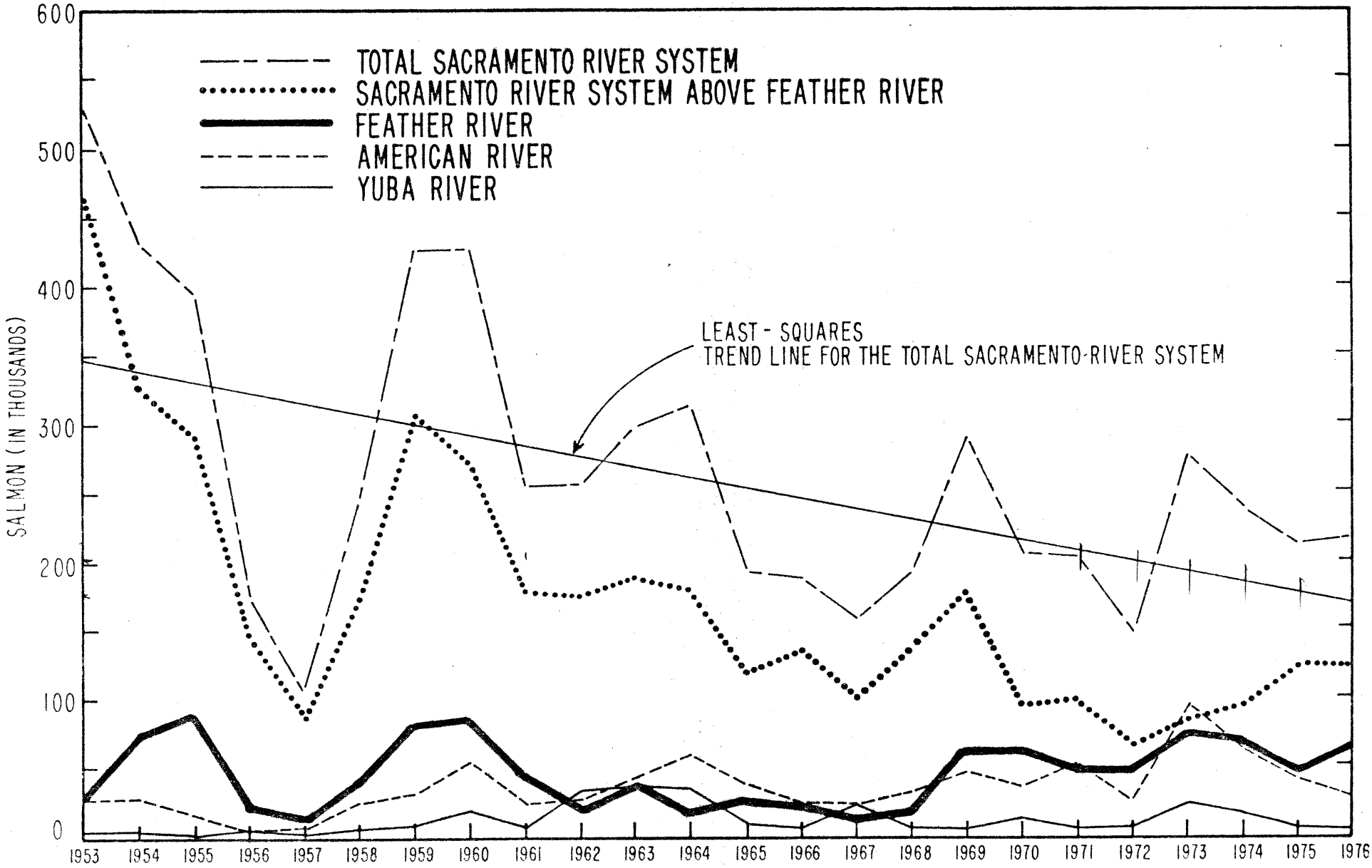


Figure 2. Sacramento River system (Sacramento River system above the Feather River, Feather River, Yuba River and American River) fall spawning king salmon populations, 1953-76, showing the overall downward trend and illustrating how this trend is due almost entirely to declining runs, in upper Sacramento River system.

Estimates of salmon spawning populations from 1953 through 1976 are presented for fall- and spring-run fish, and from 1970 through 1976 for late fall- and winter-run fish (Table 2).

Fall and Spring Runs

Spawning Population Estimates

The combined total annual spawning populations of fall- and spring-run salmon in the upper Sacramento River system averaged 257,000 fish during the 8 years from 1953 through 1960. Five times during this period the combined populations totaled 270,000 or more. However during the following 16 years (1961-76) there has been a gradual but steady decline in the total, to 121,000 fish (Figure 3). The total fall spawning populations (spring and fall runs) have fluctuated between a high of 466,000 in 1953 to a low of 66,400 in 1962. Average for the 24 years is 171,500 fall-run and 9,000 spring-run fish.

Average Spawning Escapement Goal

The average escapement goal under present environmental conditions is 179,000 fall spawners. This would include the main stem of the Sacramento, Battle Creek (including those spawned at Coleman Hatchery) and the remaining tributaries. The total would include 150,000 fall-run and 29,000 spring-run salmon.

Late Fall and Winter Runs

Spawning Population Estimates

The Red Bluff Diversion Dam counts, which have only become available since 1970, indicate considerable fluctuation in the annual numbers of spring-spawn-

TABLE 2

SACRAMENTO RIVER SYSTEM KING SALMON SPAWNING STOCKS, 1953 1976
(In Thousands of Fish)

	Fall-and Spring-Run (Spawn August - December)								Late Fall-and Winter-Run (Spawn January - July)
	Sacramento System Above Feather River								
Year	Sacramento River	Battle Creek	Other Tribs.	Total	Feather River	Yuba River	American River	Total Sacto. River System	Total Sacto. River (Sacto. R. System)
1953	408F+ 8S	16F+2S	27 F+5 S	451 F+15 S=466	28F+0 S	6F	28F	513 F+15 S=528	
1954	276F+ 9S	12F+2S	22 F+4 S	310 F+15 S=325	68F+3 S	5F	29F	412 F+18 S=430	
1955	231F+17S	26F+2S	7 F+6.4S	264 F+25.4S=289.4	86F+1 S	2F	17F	369 F+26.4S=395	
1956	94F+ 7S	21F+2S	10 F+8 S	125 F+17 S=142	18F+2 S	5F	6F	154 F+19 S=173	
1957	68F+ -S	5F+-S	9.4F+3.1S	82.4F+ 3.1S= 85.5	10F+0.5S	1F	8F	101.4F+ 3.6S=105	
1958	128F+ -S	29F+-S	11.3F+4 S	168.3F+ 4 S=172.3	31F+3 S	8F	27F	234.4F+ 7 S=241	
1959	267F+ -S	30F+-S	6.3F+2.3S	303.3F+ 2.3S=305.6	76F+4 S	10F	31F	420.3F+ 6.3S=427	
1960	233F+ -S	24F+-S	4 F+9 S	261 F+ 9 S=270	80F+4 S	20F	54F	415 F+13 S=428	
1961	150F+ -S	20F+-S	4.2F+4 S	174.2F+ 4 S=178.2	44F+0 S	9F	25F	252.2F+ 4 S=256	
1962	139F+ -S	13F+-S	19.3F+4.2S	171.3F+ 4.2S=175.5	19F+0 S	34F	27F	251.3F+ 4.2S=256	
1963	146F+ -S	17F+-S	17.3F+6.5S	180 F+ 6.5S=186.5	34F+0.6S	37F	41F	292.3F+ 7.1S=299	
1964	148F+ -S	16F+-S	7.7F+5.3S	171.7F+ 5.3S=177	38F+3 S	35F	59F	303.7F+ 8.3S=312	
1965	103F+ -S	9F+-S	5 F+1.1S	117 F+ 1.1S=118.1	23F+0.7S	10F	39F	189 F+ 1.8S=191	
1966	115F+ -S	3F+-S	13.4F+0.2S	131.4F+ 0.2S=131.6	21F+0.3S	8F	27F	187.4F+ 0.5S=188	
1967	92F+ -S	5F+-S	2.1F+0.4S	99.1F+ 0.4S= 99.5	12F+0.1S	24F	23F	158.1F+ 0.5S=159	
1968	110F+ -S	6F+-S	18.4F+0.5S	134.4F+ 0.5S=134.9	18F+0.2S	7F	31F	190.4F+ 0.7S=191	
1969	133F+20S	6F+-S	16.6F+1 S	155.6F+21 S=176.6	61F+0.3S	5F	47F	268.6F+21.3S=290	
1970	71F+ 4S	7F+-S	6.6F+3.8S	84.6F+ 7.8S= 92.4	62F+0.2S	14S	37F	197.6F+ 8 S=206	-L+46W
1971	82F+ 6S	5F+-S	2.1F+3 S	89.1F+ 9 S= 98.1	47F+0.5S	6F	52F	194.1F+ 9.5S=204	17L+53W
1972	51F+ 7S	5F+-S	2.3F+1.1S	58.3F+ 8.1S= 66.4	47F+0.3S	9F	25F	139.3F+ 8.4S=148	32L+36W
1973	61F+ 7S	8F+-S	6 F+ -S	75 F+ 7 S= 82	74F+0.2S	24F	95F	268 F+ 7.2S=275	22L+22W
1974	77F+ 4S	4F+-S	8 F+ -S	89 F+ 4 S= 93	66F+0.2F	18F	62F	235 F+ 4.2S=239	6L+19W
1975	92F+10S	5F+-S	2 F+12 S	99 F+22 S=121	43F+1 F	6F	40F	188 F+23 S=211	19L+23W
1976	90F+25S	5F+-S	1 F+ -S	96 F+25 S=121	62F+1 F	4F	28F	190 F+26 S=216	16L+33W

F Fall-run fish
S Spring-run fish
L Late fall-run fish

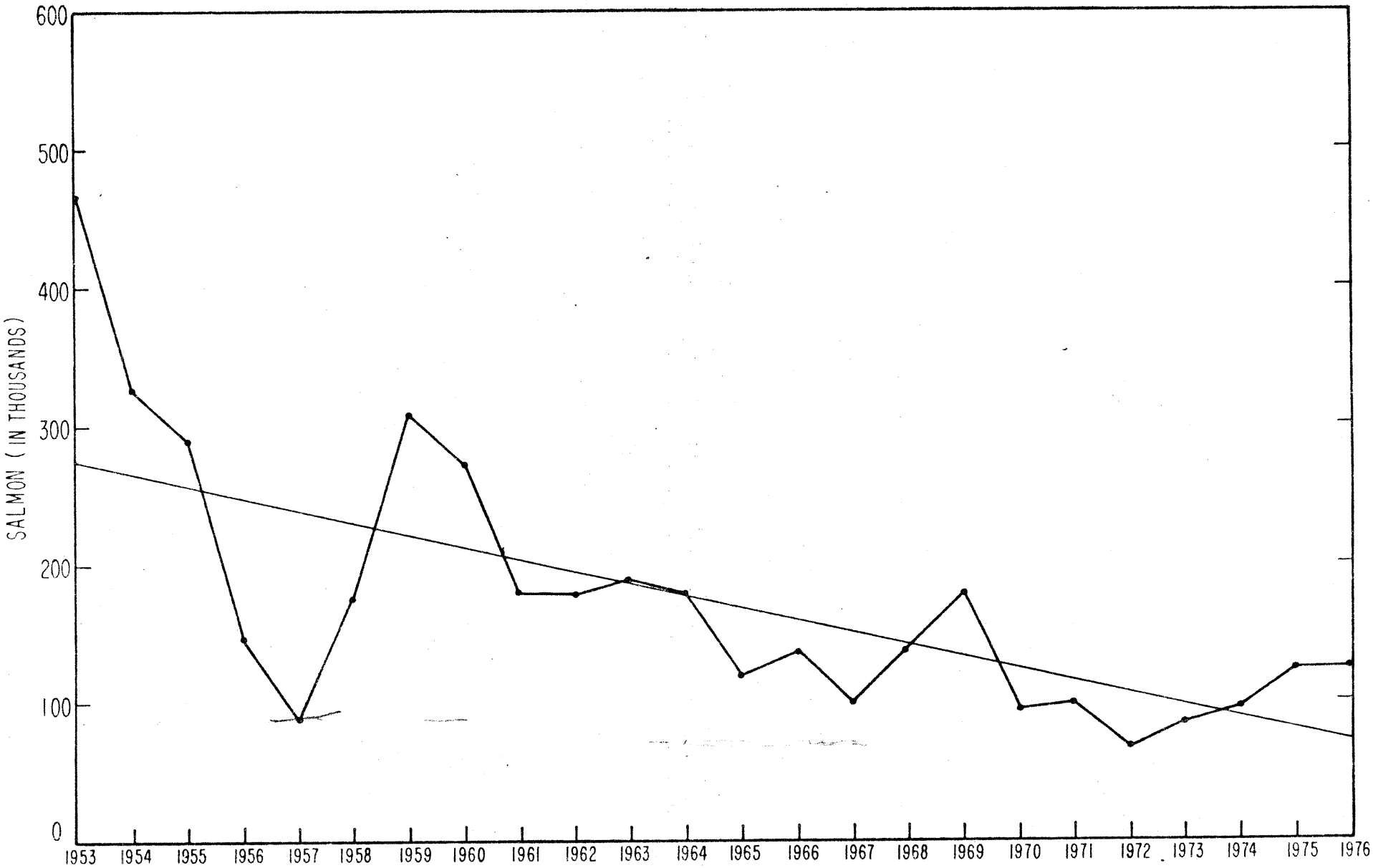


Figure 3. Sacramento River system above the Feather River, fall spawning king salmon populations, showing least-squares trend line, 1953-1976.

ing salmon using the upper Sacramento River system. During the 6 years from 1971 through 1976 the figures indicate a spawning escapement that fluctuated between 25,000 and 70,000 with an average of 50,000 fish. These figures are in most instances only partial counts since there were often periods, sometimes extended for 3-1/2 months or more during normal migration times, when no counts or only partial counts were made due to high water, murky water or to the dam being temporarily removed.

Average Spawning Escapement Goal

The average escapement goal is 65,000 spring spawners. This lesser number than for fall spawners, which includes 25,000 late fall- and 40,000 winter-run fish, is a result of the more limited redd area used by the spring spawners, i.e., primarily the main stem of the Sacramento above Red Bluff.

Feather River

The Feather River is the largest Sacramento River tributary available to salmon. With the completion of Oroville Dam on the Feather River in 1967, which is a total block to anadromous fish, part of the area available to spawning salmon in the main stem was eliminated as well as all of the habitat in the North Fork, Middle Fork, South Fork and West Branch. Feather River Salmon and Steelhead Hatchery and the associated salmon spawning channel since, converted to rearing ponds, was constructed to mitigate for damage to salmon and steelhead runs caused by construction of Oroville Dam Dam. Oroville Dam has especially limited the available spawning area for spring-run salmon. The remaining spring-run has been maintained

almost entirely by Feather River Fish Hatchery. A large fall-run and a small spring run now spawn in the Feather River below Oroville. Very few late fall salmon spawn there and although some probably enter the Feather River there are no estimates of their numbers, except for the 100 or so that have entered Feather River Fish Hatchery from January through March in recent years.

Spawning Populations Estimates

Practically all fall-spawning salmon in the Feather River are fall-run fish, as the spring run since 1967 has averaged only 400 fish at Feather River Hatchery. Feather River fall runs, from 1953 through 1976, have ranged from a high of 86,000 in 1955 to a low of 10,000 in 1957 (Figure 4). The average fall run during the past 10 years (1967-76) has totaled 49,000.

Average Spawning Escapement Goal

The average escapement goal for fall-spawning salmon in the Feather River is 41,000, including 40,000 fall-run and 1,000 spring-run fish.

Yuba River

Spawning Population Estimates

Salmon populations in the Yuba River fluctuated widely during the 24 years between 1953 and 1976, between a low of 1,000 in 1957 and a high of 37,000 in 1953 (Figure 5). Salmon spawning in the Yuba River are essentially all fall-run fish. The Yuba is historically known to have had a spring run but they have virtually disappeared.

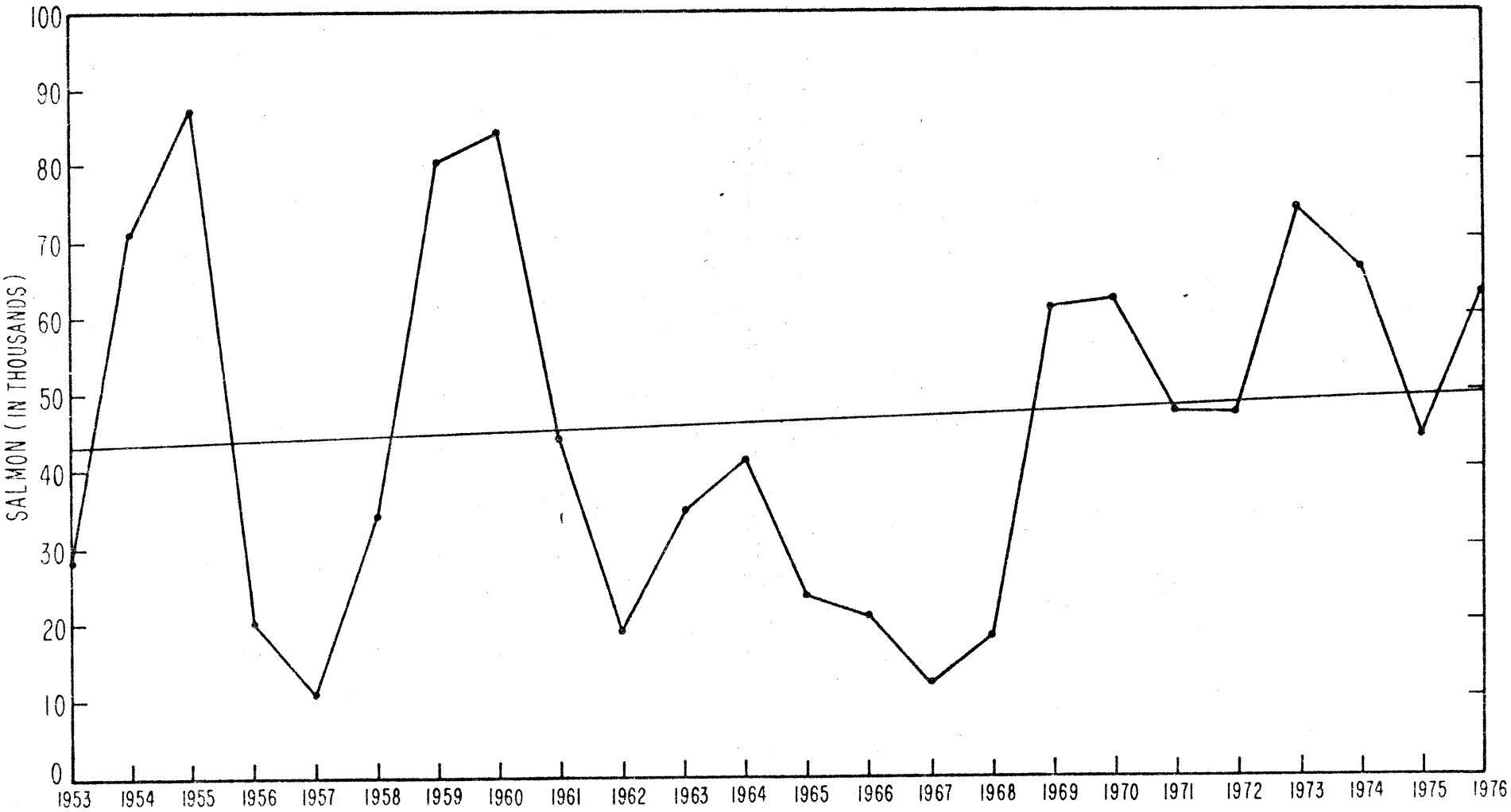


Figure 4. Feather River fall spawning king salmon populations, showing least-squares trend line, 1953-1976.

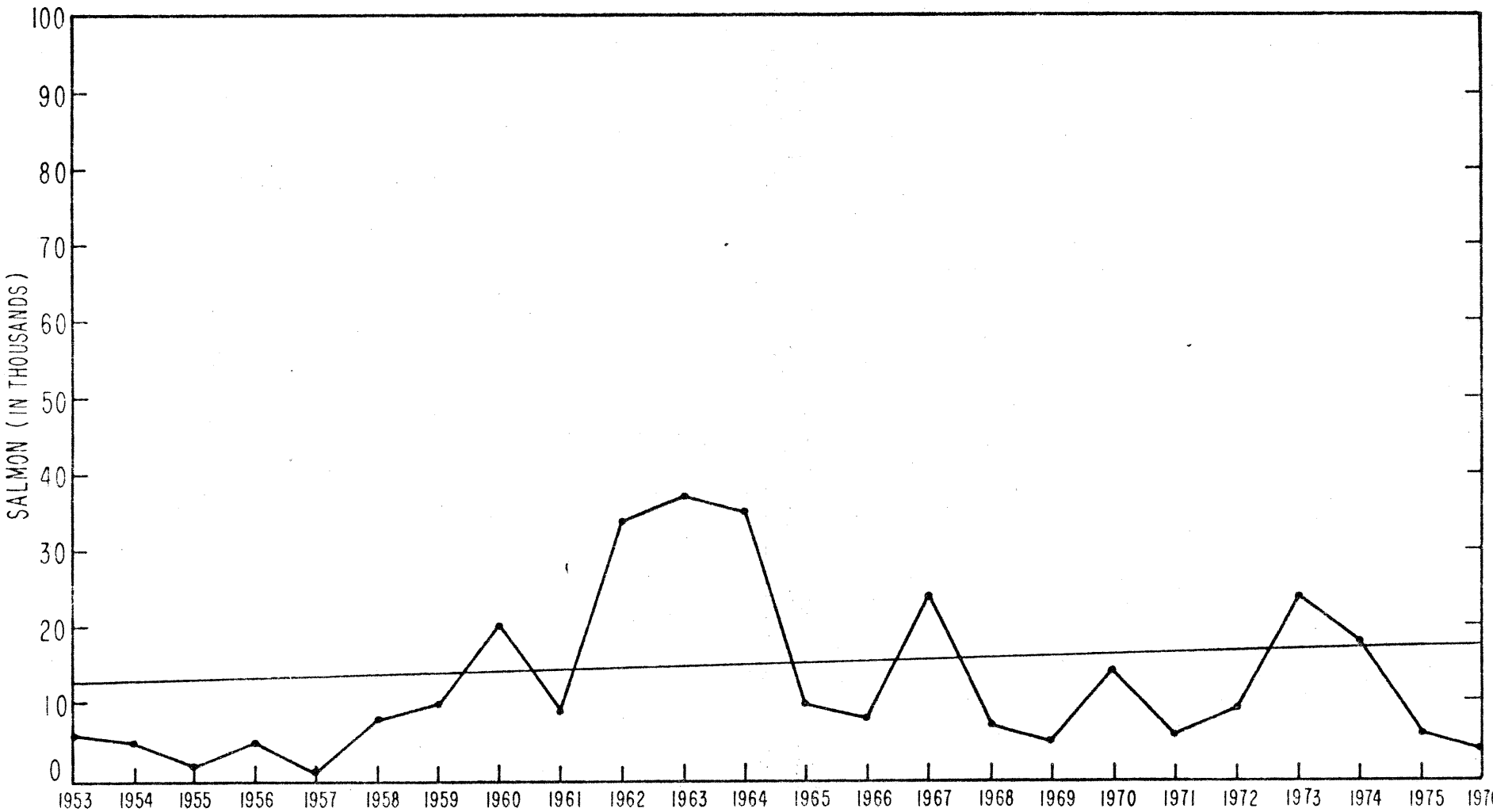


Figure 5. Yuba River fall spawning king salmon populations, showing least-squares trend line, 1953-1976.

The fall run averaged 13,000 during the 24 years from 1953-76, and 12,000 during the past 10 years (1967-76).

Average Spawning Escapement Goal

The average escapement goal in the Yuba River is 25,000. A combination of hatchery production and improvements to spawning and nursery habitat is planned as a part of water development on the Yuba. With such improvements, a goal of 25,000 is reasonable.

American River

Salmon populations in the American River are fall-run fish. In the late 1940's a small number of spring-run salmon still passed through the fishways at a dam near Folsom. After 1955 when Nimbus Hatchery went into operation the few remaining spring-run fish which entered the hatchery became so mixed with those of the much more numerous fall run that it was impossible to separate the two (Fry 1961). Aside from strays, no late fall- or winter-run salmon occur in the American River.

Since the early 1950's, American River salmon have been totally blocked by Nimbus Dam. This dam cut off spawning grounds which in the 1940's were used by over two-thirds of the fall-run fish.

Spawning Population Estimates

American River fall-run salmon spawning populations averaged 36,000 during the 24-year period (1953-76) and 44,000 during the last 10 years (1967-76). During the entire period they fluctuated from a low of 6,000 in 1956 to a high of 95,000 in 1973 (Figure 6).

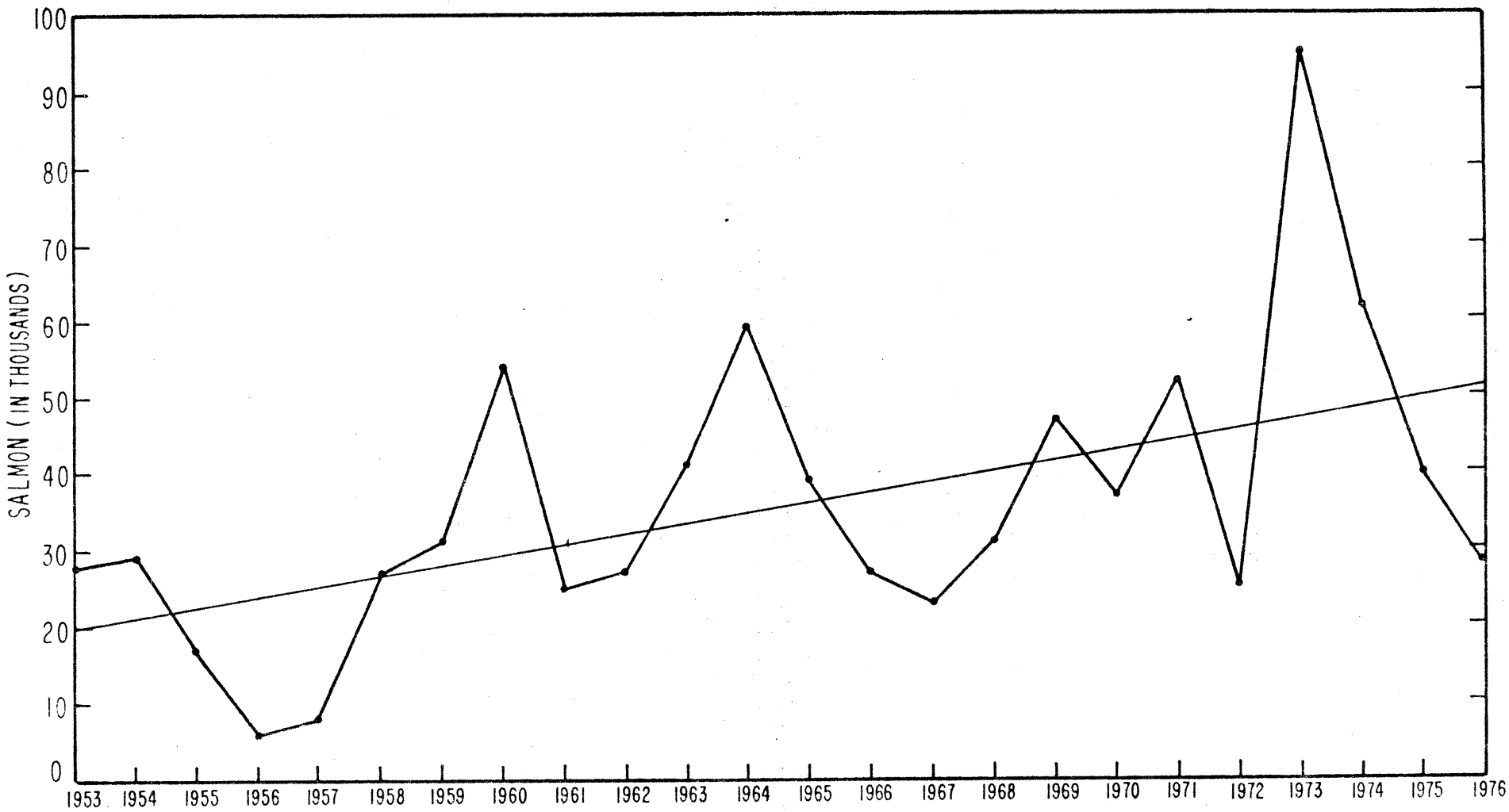


Figure 6. American River fall spawning king salmon populations, showing least-squares trend line, 1953-1976.

Average Spawning Escapement Goal

The average escapement goal in the American River is 30,000.

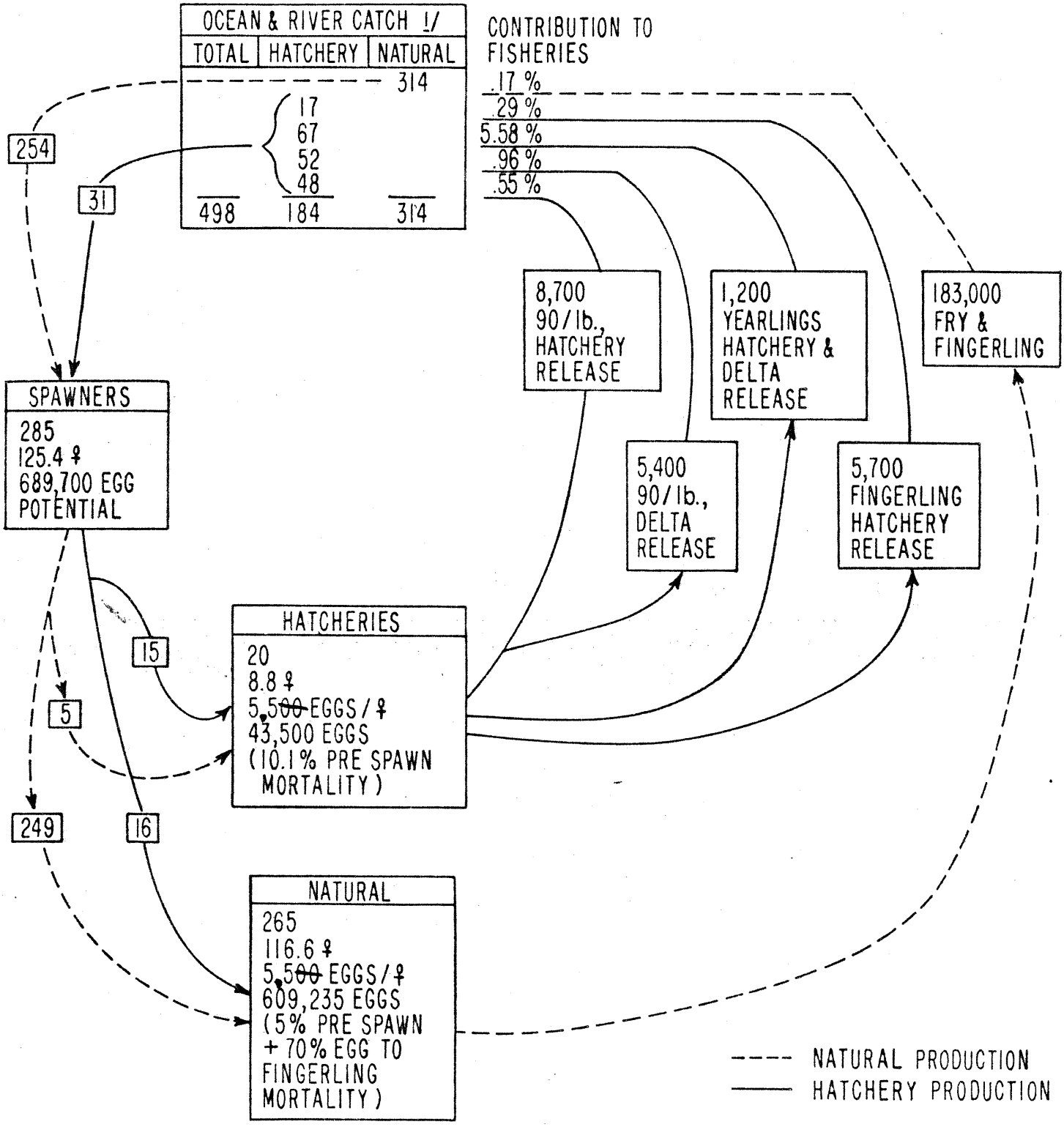
SACRAMENTO RIVER SYSTEM KING SALMON POPULATION MODELS

To get a better understanding of the factors which are presently influencing Sacramento River system salmon populations, relevant information was analyzed and a conceptual diagram or model of the population was constructed. The model represents the entire Sacramento River system's four salmon populations stabilized at an average for the 5 years from 1971 through 1975 (Figure 7).

The model is anchored by good estimates of the spawning populations, ocean commercial and sport catches, river sport catches and accurate records of adults handled and fish produced at Coleman, Feather River and Nimbus Fish Hatcheries as well as the Tehama-Colusa Fish Facility.

To estimate the average ocean catch of Sacramento River system salmon it is assumed that 95% are landed in California and that the California catch north of Point Arena consists of 40% Sacramento fish and the catch south of Point Arena 90%. That 5% are landed north of California is indicated by recent marking studies.

Percentages of males, females and grilse in the spawning populations are assumed to be 36, 44 and 20%, respectively. These figures are based upon Sacramento River system hatchery data and sampling of runs at Red Bluff Diversion Dam.



1/ INCLUDES RIVER SPORT CATCH OF 16.3

Figure 7. Sacramento River system king salmon; 1971-75 average (in thousands).

The ocean and INLAND fishery contribution rates for salmon released when weighing 90/lb (.55% for releases at the hatchery and .96% for downstream releases), when released as yearlings (5.58% for releases at the hatchery) and when released as fingerlings (.29% when released at hatcheries) are based upon Sacramento River system marking studies (Calif. Dep. Fish and Game unpublished data--Table 3).

Data on contribution to the fisheries of naturally-produced fry and fingerling is less reliable. The rate of contribution was arrived at by a process of elimination of known spawning escapement, catch, and marked hatchery contribution.

The model presented in Figure 7 is also based on counts of marked hatchery-produced adults returning to hatcheries and estimates of hatchery-produced adults which spawn naturally. The model indicates that the catch per spawner of hatchery-produced fish is around five times greater than the catch per spawner of naturally-produced fish.

There is no rational explanation for this anomaly. It seems more likely that our estimates of hatchery-produced natural spawners is in error and that hatchery- and naturally-produced adults are approximately equally vulnerable to ocean fisheries.

Another model was constructed (Figure 8) which forces the relative abundance of hatchery and wild fish in the spawning escapement to equal the relative abundance observed in ocean fishery landings.

Obviously, the second model demonstrates a much greater hatchery contribution to the naturally reproducing portion of the Sacramento River population. The real situation probably lies between the two models, closer to the second than the first.

Table 3

Estimated Average Returns
from Sacramento River System
Hatchery-reared Salmon Marking Experiments [1/]

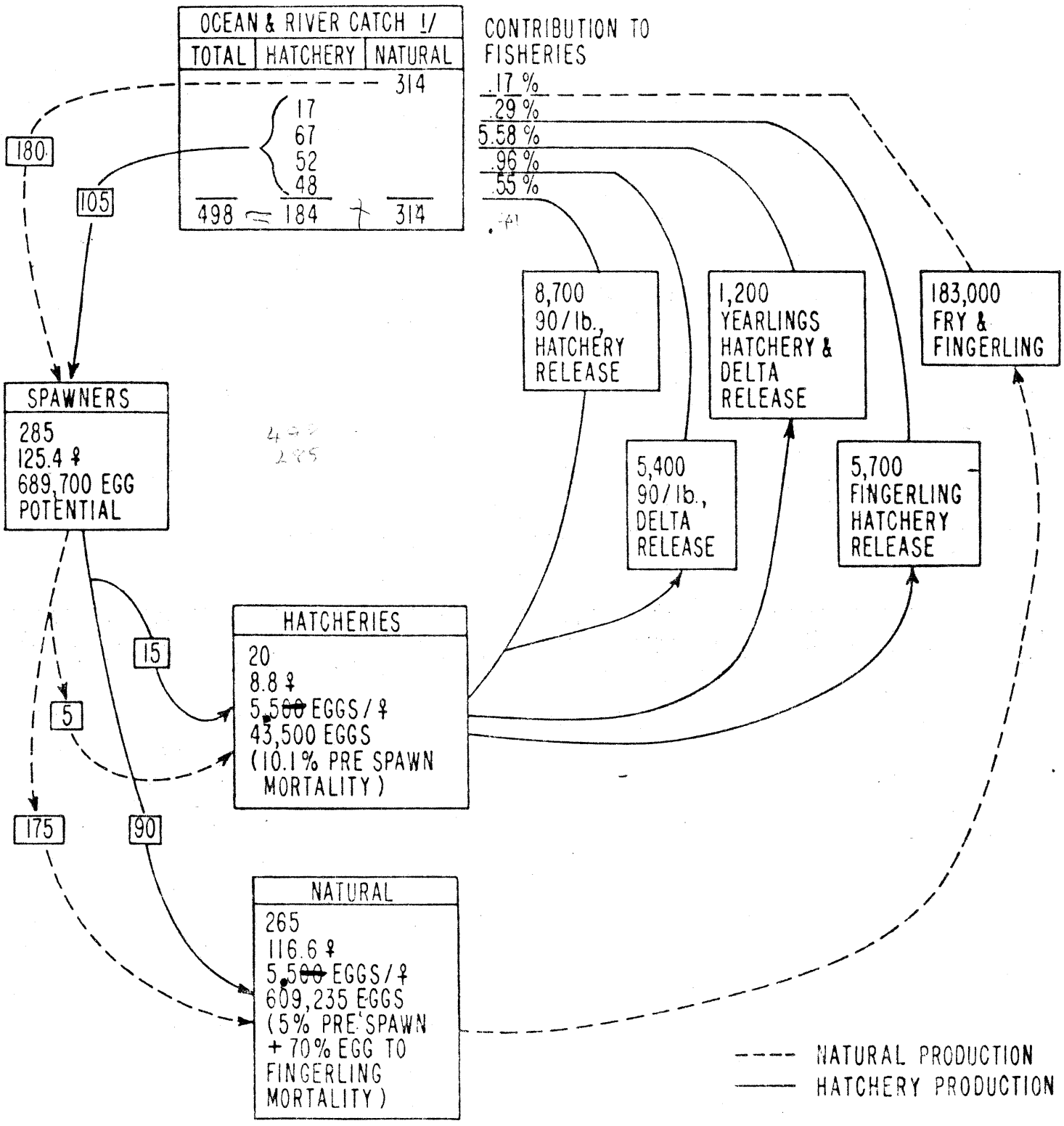
Size Released	Where Released	Percent Recovered		
		Ocean and Inland Fisheries	Hatcheries	Natural Spawners Based on Recovered Marks
Fingerling [2/]	Hatchery	0.29	0.037	0.027
90/lb [3/]	Hatchery	0.55	0.052	0.009
	Delta	0.96	0.068	0.015
Yearling [4/]	Hatchery	5.58	0.45	0.80
	Delta	4.15	0.16	1.20

[1/] California Department of Fish and Game, Unpublished data.

[2/] 1$\overline{M}$ Coleman Hatchery Marked fall-run salmon, released 1959-62.

[3/] 4$\overline{M}$ Coleman and Nimbus Hatchery Marked fall-run salmon, released 1969-71.

[4/] .267$\overline{M}$ Feather River Hatchery Marked fall-run salmon, released 1969-72.



1/ INCLUDES RIVER SPORT CATCH OF 16.3

Figure 8. Sacramento River system king salmon; 1971-75 average (in thousands), with the natural and hatchery cycles adjusted to show equal catch to escapement ratios.

Significance of Models

Regardless of which model is examined, there are several immediately apparent steps which can be taken to increase both fishery yield and escapement. Raising hatchery fish to larger release size and transporting juveniles to downstream release points dramatically increases survival. The Department of Fish and Game is contemplating an annual increase in yearling production of two million fish, which has the potential to increase fishery landings by 100,000 fish, and spawning escapement by at least 20,000.

The fact that upper Sacramento River escapements are apparently declining independently of other major segments of the Sacramento River system run has prompted ongoing investigations of potential mortality sources there, some of which are related to water development that has coincided with more recent declines in escapement.

The most significant inferences about the salmon populations that can be made from the models are; 1) hatcheries which now utilize 7% of the adult Sacramento River system salmon each year are producing 37% of the catch attributable to the Sacramento River system, 2) within the hatchery system there is a 52% loss between eggs taken and fish released, 3) a 41% loss occurs among 90/lb hatchery salmon during the downstream migration period; and is also assumed to occur among the young of naturally-produced fish as well, and 4) a 41% greater catch resulting from young salmon which were not exposed to downstream migration hazards (as compared with those that were) indicates that a positive relationship exists between the number of outmigrants reaching the sea and the catch.

Changes in the Hatchery Cycle and Their Anticipated Effects (Based on the Model in Figure 7)

The losses estimated to occur between stages in each of the natural- and hatchery-life cycles of the model are based upon percentage losses to the numbers appearing in the model under present environmental conditions. In the strictest sense, the percentage losses apply only to the actual numbers in the model. It is probable that if an extremely large increase were to be made in a life cycle stage, some of the percentage losses affecting the increased stage and the stages thereafter would change.

Some losses such as those due to predation could be affected by population density, while others such as losses in diversions are probably not. This means, for example, that if the entire loss between two of the early life cycle stages could be eliminated (which is highly improbable), resulting in a very large increase in the second of these two stages, it would be difficult to calculate directly from the model the effect of this change on the remaining stages and the fishery. However, it is assumed that a small or even a moderate increase in any one cycle stage would not significantly change the overall percentage losses affecting the increased stage or the stages thereafter, and that the effect upon the fisheries and spawning stocks resulting from a change of this type can be approximated from the model.

Changes which could have a great impact upon hatchery production without a great expansion of present facilities are, 1) elimination of SRCD and other diseases, 2) release of all fish at 90/lb and larger and 3) elimination of downstream migration losses by trucking more fish to the Delta, especially those smaller than yearlings.

Changes in the Natural Cycle and Their Anticipated Effects

There are many factors which control or limit natural salmon populations. The most significant known ones are those occurring 1) in fresh water between the time eggs are deposited and the young enter the ocean and 2) the numbers removed from the ocean either as catch or hooking mortality.

The ocean phase of Sacramento River system salmon is not covered in this report, but in passing, it should be noted that ocean hook scars among spawning salmon in the Sacramento River have increased from 10% in the 1950's to almost 40% in the 1970's. Although the ocean catch is apparently holding its own, it appears that in order to catch the same quantity of salmon it now takes about four times the effort.

Reversing the downward trend in the natural spawning populations by making changes in fresh water is much more difficult than in the hatchery cycle since the specific effects of the various hazards are unknown. For example, a 41% loss occurs among fingerlings during the downstream migration. This loss is attributed to predation, unscreened diversions, pollution, adverse stream flow, etc., but the effect of eliminating any one of these causes is not known. The effect of eliminating them all, by bypassing downstream migration, is known.

KNOWLEDGEABLE PERSONS FOR ADDITIONAL INFORMATION

Paul T. Jensen, Chief, Anadromous Fisheries Branch, Calif. Dep. Fish and Game, 1416 Ninth Street, Sacramento, Calif. 95814. Telephone (916) 445-8231.

SELECTED REFERENCES

Annual Central Valley king salmon spawning stock reports; contained in Calif. Dep. Fish and Game Anad. Fish. Admin. Reps.

Annual production reports; Coleman National Fish Hatchery, U. S. Fish and Wildlife Service.

Annual Feather River Salmon and Steelhead Hatchery reports; contained in Calif. Dep. Fish and Game Anad. Fish. Admin. Reps.

Annual Nimbus Salmon and Steelhead Hatchery reports; contained in Calif. Dep. Fish and Game Anad. Fish. Admin. Reps.

Annual Tehama-Colusa Fish Facilities spawning channel production reports; U. S. Fish and Wildlife Service.

Fry, Donald H., Jr. and Alexander Petrovich, Jr. 1970. King salmon (Oncorhynchus tschawytscha) spawning stocks of the California Central Valley, 1953-1969. Calif. Dep. Fish and Game Anad. Fish. Admin. Rep. 70-11. 21 p.