308

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FIVE SPECIES OF SALMON, *ONCORHYNCHUS*, IN THE SACRAMENTO RIVER, CALIFORNIA[1]

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King salmon (*O. tshawytscha*) are abundant in the Sacramento-San Joaquin river system of California, but other species of salmon are uncommon or rare. To determine the occurrence and abundance of the less common species, all such fish encountered during routine king salmon studies and hatchery operations were examined and recorded. From 1949 through 1958, a total of 130 chum, pink, sockeye, and silver salmon (*O. keta, O. gorbuscha, O. nerka, and O. kisutch*) was identified. All were from the Sacramento, its tributaries, or the Sacramento-San Joaquin Delta. No salmon other than kings were found in the southern tributaries of the Delta. These 130 fish do not include planted silver salmon, which began entering the rivers in 1956. After this planting was discontinued, silver salmon rapidly declined and have almost vanished from the Sacramento. Highly tentative estimates were made of the numbers of chum, pink, and sockeye salmon occurring in the Sacramento River system. It was concluded that these three species are present as very small spawning runs, but that silver salmon were so scarce that they should be regarded as strays.

INTRODUCTION

Five species of salmon, genus *Oncorhynchus*, are common to the Pacific Coast of North America (Davidson and Hutchinson, 1938). The question of what species other than king salmon, *O. tshawytscha*, enter California's Sacramento and San Joaquin River systems has been confusing to scientists and sportsmen alike for many decades. One reason for this confusion is the abundance of literature in which reference is made to kings being the only salmon in the Sacramento and San Joaquin River systems, or the only salmon commonly seen there, while at the same time there have also been sporadic published and unpublished reports of the presence of other species. Another reason is that to date no one has made a detailed report describing the occurrence and abundance of salmon other than kings in the Central Valley.

During the past 25 years the California Department of Fish and Game has kept records of the annual numbers of king salmon spawning in most of the principal streams in the Central Valley (Fry, 1961). During the 10-year period 1949 through 1958 the authors made a sustained effort to identify salmon other than kings, to encourage others who were handling large numbers of salmon to do the same, and to keep accurate records of those positively identified. In the 10-year study period, 130 salmon other than kings, including all of the other four species, were taken and identified in the Sacramento River system; 119 of them were taken above Sacramento. They included chum, pink, sockeye, and silver salmon (*O. keta, O. gorbuscha, O. nerka,* and *O.*

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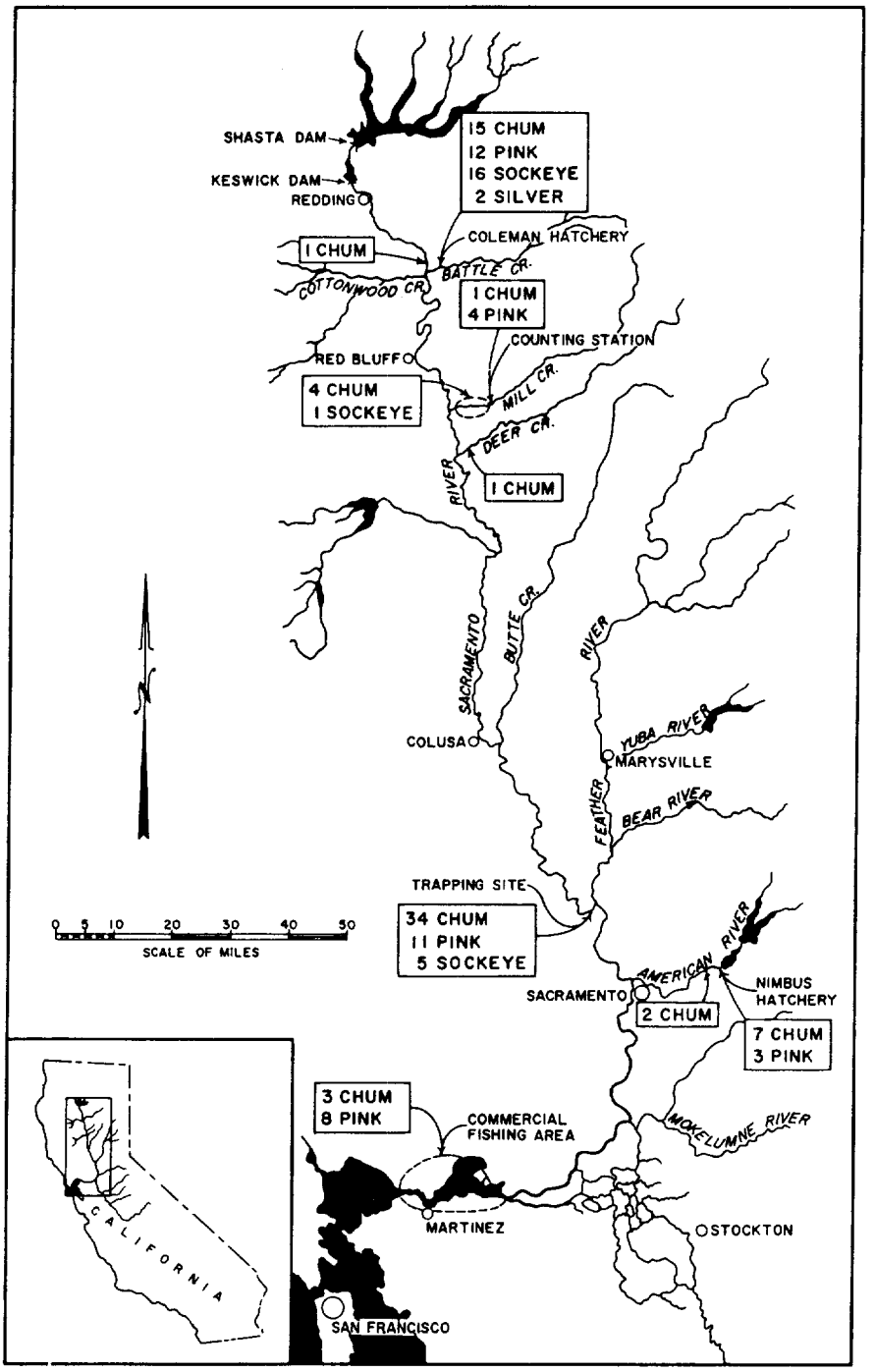

FIGURE 1—Sacramento River system, showing numbers and locations of chum, pink, and sockeye salmon taken from 1949–50 through 1958–59. Only those silver salmon taken before 1956 are shown. In that year planted silvers began returning to the river.

kisutch). In most instances they were noted among fall-run king salmon at counting stations, at fish hatchery traps, during salmon tagging studies, and while counting carcasses on spawning beds during annual population inventories. Eleven rare salmon (chums and pinks) were noted in commercial salmon landings from below the junction of the Sacramento and San Joaquin rivers during the same period. No unusual salmon were found in the San Joaquin River above the junction, in its tributaries, or in the Mokelumne River system. Thus, king salmon appear to be the only salmon reliably recorded from these other river systems in the Central Valley. Because of this, the chum and pink salmon recovered in the commercial fishery were considered to be Sacramento River fish.

The numbers of unusual salmon identified in the Sacramento River system do not give a true picture of their abundance, since they were found while sampling only a fraction of the total salmon present. Therefore, estimates were made of the total numbers of chums, pinks, and sockeyes which were present during the study period. Data were insufficient to permit a meaningful estimate of the numbers of silver salmon.

Data are also included on the estimated abundance of king salmon, which form over 99% of all salmon each year.

SPECIES OF SALMON

The species of salmon are listed in order of apparent abundance in the Sacramento River system, not in taxonomic order.

King Salmon, *Oncorhynchus tshawytscha* (Walbaum)

Distribution in North America and the Eastern Pacific

King salmon are found in the eastern Pacific Ocean from southern California to northwestern Alaska. Off the California coast, they are regularly caught in good numbers as far south as Monterey (lat. 36° 37′ N.), and in some years there is a fair fishery off San Luis Obispo County (to about lat. 35° N.). Kings are rare south of Point Conception (lat. 34° 27′ N.). In the early part of this century, the southernmost spawning in North America was by a small run in the Ventura River (lat. 34° 17′ N.), but at present the species spawns in suitable rivers from the Sacramento-San Joaquin river system to northwestern Alaska.

In California, kings are by far the most abundant species of salmon, but in North America as a whole they are the least abundant species.

Life History

King salmon are known to migrate farther into fresh water than any other salmon. They spawn over 2,000 miles from the sea in the Yukon River. In general, kings prefer the larger rivers but also enter some astonishingly small tributaries. A few relatively small coastal streams support runs of kings but as a rule these runs are small.

In California, most young king salmon migrate to the ocean during their first few months of life, but a few remain in fresh water until they are yearlings. In many California salmon rivers, summer temperatures are so high that in order to survive all young salmon must emigrate

before the water becomes too warm. Most king salmon mature at three or four years of age; two-year-old precocious males ("jacks") are also abundant. Five-year-old fish used to be common in California but now make up only a minor part of catches and spawning runs. Six-year-olds and yearling "jacks" are rare. North of California, five-year-olds are relatively more common and seven-year-olds are not unheard of. Kings are the largest of all Pacific salmon. Mature four-year-olds average a little over 20 pounds in weight, 40-pounders are not uncommon, and fish over 100 pounds have been recorded. Two-year-old "jacks" usually weigh about 3 pounds.

Occurrence in the Sacramento-San Joaquin River System

There are three basically different strains of king salmon in the Sacramento River system and two in the San Joaquin River system:

Fall-run fish are the most numerous. Most of these fish enter both rivers sometime between early September and early December, although many arrive either earlier or later than this. Fall-run fish reach peak spawning in November and December, and normally spawn relatively soon after they reach the appropriate part of the river. In general, fall-run fish enter the rivers after temperatures have begun to drop, and flows have started to increase. The timing of runs varies from stream to stream.

Spring-run salmon used to be abundant in the Central Valley but now relatively few streams support a spring run and most of the runs that still exist are quite small. The spring run enters a river in spring or early summer, during the time when the snowmelt usually supplies an adequate flow of cold water. The fish move upstream until they reach areas which normally remain cool in summer. Spawning takes place during early fall. On many Central Valley streams high dams have made it impossible for these fish to reach their ancestral spawning grounds, and below these dams low summer flows combined with high water temperatures have made it impossible for them to survive. Low stream temperatures below Shasta Dam have enabled a fair spring run to persist in the main Sacramento River, but they have become almost extinct in the San Joaquin River system.

Winter-run salmon are found only in the Sacramento River system, and about 98% spawn in the main stem of the Sacramento. The winter run usually reaches the upper river near Red Bluff in December and spends a relatively long period in the river before spawning. May and June are the principal spawning months. According to a theory advanced by Slater (1963), these fish are presumably descendants of a small run that formerly spawned in the McCloud River, a tributary of the Sacramento to which access has since been cut off by Shasta Dam. It is thought that a few fish survived the building of the dam, found temperatures and other conditions below the dam suited to their needs, and increased rapidly. The winter run is now considerably larger than the spring run.

Abundance in the Sacramento-San Joaquin River System

Detailed king salmon spawning escapement records presented in this paper cover only the period from 1953 through 1958. During this period, estimates of the size of the fall run for the entire Central Valley varied from a low of 117,000 in 1957 to a high of 597,000 in

1953 (Table 1). No satisfactory escapement records are available for winter- or spring-run salmon during these years. In a later period (1958 through 1963) Department of Fish and Game salmon spawning inventories show that the total fall run in the Central Valley averaged about 330,000 fish, the winter run perhaps 60,000, and the spring run about 28,000.

TABLE 1

Fall-Run King Salmon, Estimated Spawning Escapement
In Thousands of Fish
Sacramento-San Joaquin River System, 1953–54 Through 1958–59 Seasons *

	1953–54	1954–55	1955–56	1956–57	1957–58	1958–59
Grand total, all rivers	597	487	400	165	117	283
Total, Sacramento River and tributaries	513	412	369	153	102	237
Sacramento River Main Stem	408	276	231	94	68	128
Battle Creek†	16	12	26	21	5	29
Mill Creek	10	7	3	1	5	4
Deer Creek	4	3	—	—	2	1
Feather River	28	68	86	18	10	32
Yuba River	6	5	2	5	1	8
American River†	28	29	17	6	8	27
Other Sacramento River tributaries	13	12	4	8	3	8
Total, Mokelumne River and tributary	4	9	4	1	3	8
Cosumnes River	2	5	2	1	1	1
Mokelumne River	2	4	2	—	2	7
Total, San Joaquin River tributaries	80	66	27	11	12	38
Stanislaus River	35	22	7	5	4	6
Tuolumne River	45	40	20	6	8	32
Merced River	—	4	—	—	—	—

— Designates an escapement of 500 fish or less.
* From Fry (1961).
† Includes hatchery fish and natural spawners.

Chum Salmon, *Oncorhynchus keta* (Walbaum)

Distribution in North America and the Eastern Pacific

In the eastern Pacific Ocean, chum salmon have been found from near Del Mar in southern California (lat. 32° 57′ N., long. 117° 25′ W.) [2] to northwestern Alaska. There are recognized spawning runs in streams tributary to Tillamook Bay, Oregon, northward through Alaska and in the Arctic Ocean tributaries as far east as the McKenzie River, Yukon Territory, Canada. In California coastal streams, they have been reported from the San Lorenzo River (Scofield, 1916).

Chums do not form a measurable part of the California salmon catch, but in the entire North American salmon catch they usually rank third (behind pink and sockeye, and ahead of silver and king).

Life History

Most chum salmon spawn close to salt water, but some runs migrate considerable distances upstream. In the Sacramento River they have been found in spawning condition over 200 miles from the ocean. The

[2] Messersmith (1965).

TABLE 2

Chum, Pink, Sockeye, and Silver Salmon
Sacramento-San Joaquin River System, 1949–50 Through 1958–59 Seasons

	Earliest recorded date[1]	Latest recorded date[1]	Commercial fishing area[2]	Fyke traps—Sacramento R. ½ to 2 mi. above Feather R.	Sacramento River near Battle Creek	Coleman N.F. Hatchery[3]	Mill Creek spawning grounds[4]	Mill Creek Counting Station	Deer Creek spawning grounds	American River, Nimbus Hatchery	American River near Fair Oaks	TOTALS
Chum Salmon												
1949–50	"Fall"	"Fall"	—	—	—	1	—	—	—	—	—	1
1951–52	Sept. 8	Nov. 14	—	2	1	2	—	—	—	—	—	5
1952–53	Sept. 15	Nov. 5	1	3	—	1	—	—	—	—	—	5
1953–54	Oct. 27	Jan. 4	—	4	—	2	2	1	1	—	—	10
1954–55	Aug. 10	Dec. 23	2	17	—	3	1	—	—	—	2	25
1955–56	July 21	Nov. 20	—	4	—	2	—	—	—	—	—	6
1956–57	Aug. 27	Dec. 21	—	2	—	2	1	—	—	2	—	7
1957–58	Fall	Fall	—	—	—	1	—	—	—	—	—	1
1958–59	Aug. 6	Feb.	—	2	—	1	—	—	—	5	—	8
Total			3	34	1	15	4	1	1	7	2	68
Pink Salmon												
1949–50	Fall	Fall	—	—	—	1	—	—	—	—	—	1
1951–52	Sept. 20	Sept. 20	—	1	—	2	—	—	—	—	—	3
1952–53	Sept. 9	Sept. 21	—	2	—	1	—	—	—	—	—	3
1953–54	Sept. 3	Nov. 10	—	4	—	1	—	3	—	—	—	8
1954–55	Nov.	Nov.	—	—	—	1	—	—	—	—	—	1
1955–56	Aug. 30	Oct. 11	8	3	—	6	—	—	—	—	—	17
1956–57	Fall	Fall	—	—	—	—	—	—	—	1	—	1
1957–58	Fall	Fall	—	1	—	—	—	—	—	2	—	3
1958–59	Oct. 26	Oct. 26	—	—	—	—	—	1	—	—	—	1
Total			8	11	—	12	—	4	—	3	—	38
Sockeye Salmon												
1949–50	Fall	Fall	—	—	—	1	—	—	—	—	—	1
1950–51	Fall	Fall	—	—	—	2	—	—	—	—	—	2
1951–52	Fall	Fall	—	—	—	3	—	—	—	—	—	3
1952–53	Fall	Fall	—	—	—	2	—	—	—	—	—	2
1953–54	Fall	Fall	—	—	—	2	—	—	—	—	—	2
1954–55	Sept. 7	Nov.	—	2	—	3	—	—	—	—	—	5
1955–56	Sept. 20	Sept. 25	—	—	—	2	—	—	—	—	—	2
1956–57	July 24	July 24	—	1	—	1	—	—	—	—	—	2
1957–58	Oct. 1	Oct. 1	—	—	—	—	1	—	—	—	—	1
1958–59	Aug. 11	Aug. 20	—	2	—	—	—	—	—	—	—	2
Total			—	5	—	16	1	—	—	—	—	22
Silver Salmon[5]												
1949–50	Fall	Fall	—	—	—	1	—	—	—	—	—	1
1950–51	Fall	Fall	—	—	—	1	—	—	—	—	—	1
Total			—	—	—	2	—	—	—	—	—	2
Recap of totals												
Chum Salmon			3	34	1	15	4	1	1	7	2	68
Pink Salmon			8	11	—	12	—	4	—	3	—	38
Sockeye Salmon			—	5	—	16	1	—	—	—	—	22
Silver Salmon			—	—	—	2	—	—	—	—	—	2
Grand total			11	50	1	45	5	5	1	10	2	130

[1] Many fish entered hatchery ponds on an unknown date, were discovered later. These are referred to the appropriate month or season.
[2] In 1949, commercial salmon netting was permitted from Carquinez Strait to Rio Vista and in some of the lower San Joaquin Delta. Later, the area was reduced and in September 1957 was eliminated entirely.
[3] Coleman National Fish Hatchery received fish from Battle Creek and the Sacramento River. Except for king salmon, we could not determine which fish or how many came from each stream.
[4] Downstream from the counting station.
[5] Does not include planted silvers. Downstream migrating silver salmon yearlings were planted in Mill Creek in March 1956 and began returning that same fall.

young go to sea soon after emerging from the gravel, and maturity is usually reached in the fourth year of life. However, some may mature in the third or fifth year. At maturity, the average chum weighs about 10 pounds, with a maximum weight of about 30 pounds.

TABLE 3

Fork Lengths (mm) of Chum, Pink, Sockeye, and Silver Salmon Sacramento-San Joaquin River System, 1949–50 Through 1958–59 Seasons

M = Male F = Female	Chum			Pink			Sockeye			Silver		
	M	F	Sex not known	M	F	Sex not known	M	F	Sex not known	M	F	Sex not known
	625	470	470	455	530	335	595	270	580	840	--	--
	630	510	635	460	--	450	--	580	--	--	--	--
	720	620	710	605	--	560	--	--	--	--	--	--
	725	635	730	635	--	565	--	--	--	--	--	--
	740	660	760	--	--	590	--	--	--	--	--	--
	750	665	800	--	--	600	--	--	--	--	--	--
	785	665	--	--	--	--	--	--	--	--	--	--
	785	665	--	--	--	--	--	--	--	--	--	--
	795	675	--	--	--	--	--	--	--	--	--	--
	910	675	--	--	--	--	--	--	--	--	--	--
	--	675	--	--	--	--	--	--	--	--	--	--
	--	685	--	--	--	--	--	--	--	--	--	--
	--	700	--	--	--	--	--	--	--	--	--	--
	--	725	--	--	--	--	--	--	--	--	--	--
	--	740	--	--	--	--	--	--	--	--	--	--
Number of fish measured	10	15	6	4	1	6	1	2	1	1	0	0
Not measured	9	12	16	10	4	13	2	0	16	0	0	1
TOTALS	19	27	22	14	5	19	3	2	17	1	0	1
TOTALS	**Chums: 68**			**Pinks: 38**			**Sockeyes: 22**			**Silvers: 2**		

Occurrence in the Sacramento River

During the period of study, 68 chums were positively identified from the Sacramento River system. This includes catches made in the Delta (Tables 2 and 3). Of these fish, 34 were taken in the fyke traps which were operated in the Sacramento River near Fremont Weir, a short distance upstream from the mouth of the Feather River (Hallock, Fry, and LaFaunce, 1957), 15 were recovered at Coleman National Fish Hatchery on Battle Creek, 7 at Nimbus Salmon and Steelhead Hatchery on the American River, 3 from commercial salmon landings in the Delta, 1 at Mill Creek Counting Station in Tehama County, and 8 as spawned-out carcasses (4 in Mill Creek, 2 in the American River, and 1 each in Deer Creek and the Sacramento River).

Twenty-two of the chums taken in the fyke traps were tagged and released over a four-year period. Only two of these tagged fish were recovered. A male, 758 mm fork length, was tagged and released on November 3, 1953, and recaptured November 30, 1953, by department personnel on Mill Creek, a tributary some 140 miles upstream. The other was taken by a sportsman. Details could not be obtained.

Pink Salmon, *Oncorhynchus gorbuscha* (Walbaum)

Distribution in North America and the Eastern Pacific

Along the North American coast, pink salmon have been taken from La Jolla, California (Hubbs, 1946) to northwestern Alaska and eastward along the Arctic Coast to the McKenzie River, Yukon Territory. The southernmost American spawning runs of importance are in streams tributary to Puget Sound. Pinks are the most abundant North American salmon.

Off California, small catches of pinks are made in some years by salmon fishermen searching for king and silver salmon. Pink salmon have been recorded in several California coastal streams: Scofield (1916) reported that several had been taken in the San Lorenzo River in November 1915; Snyder (1931) reported them as present but rare in the Klamath River; Taft (1938) reported them as having entered Mad, Ten Mile, Garcia, and Russian rivers in 1937; Smedley (1952) recorded one in Prairie Creek, Humboldt County, in 1951; Roedel (1953) recorded pinks as spawning irregularly in some Mendocino County streams. On October 14, 1955, one of the present authors (Fry) watched pink salmon digging redds on one riffle in the lower part of the Russian River. At least six females were involved; there were males in the vicinity but not on the redds. Scofield (1916) reported several specimens from the San Lorenzo River. These records are in addition to those of the Sacramento River system, which will be discussed later.

Life History

On the average, pink salmon probably migrate shorter distances into rivers than any other Pacific salmon. Some pinks even spawn in tidal areas of streams at low tide, when the gravel is covered with fresh water. Although most pinks spawn within a few miles of salt water, there are some streams in which they travel considerable distances to reach spawning areas, such as those of Babine Lake on the Upper Skeena River in British Columbia. In the Sacramento River system, 12 pinks have been identified in Battle Creek, which is over 200 miles from the ocean.

Pink salmon are unique in that all individuals mature at the end of their second year. It follows that any stream which supports an annual run thus supports two independent populations. In many streams, there is a large spawning run one year followed by a small one the next, and sometimes one run or the other is nonexistent. In North America the southernmost pink salmon fisheries of importance land these fish in large quantities only in odd-numbered years. Most records of pinks in California have also been in odd-numbered years.

The pink salmon is sometimes known as the "humpback" because an exaggerated hump develops on the back of males between the head and the dorsal fin, as they near spawning condition. Pinks are the smallest of the Pacific salmon; they usually reach a weight of 3 to 6 pounds, and are occasionally as large as 11 pounds.

Occurrence in the Sacramento River

Jordan and Evermann (1896) reported that pinks were occasionally taken in the Sacramento River, where they were referred to as "Lost Salmon". Taft (1938) reported that a pink salmon was recovered in

Mill Creek (Tehama County) in 1933. Early records refer to an occasional pink being taken at hatcheries on the upper Sacramento River.

Many commercial gill-net fishermen who formerly fished for salmon in the Sacramento River have also fished for pink salmon in Alaska. These men recognize the species and some of them remember having taken an occasional pink in the Sacramento. Vincent Catania, a former Sacramento River gill-net fisherman now employed by the Department of Fish and Game, estimated that 30 years or so ago, in some seasons, the entire fishing fleet would take perhaps a dozen of these fish. Other fishermen recall the number as being higher than this.

In the period 1949 through 1958, 38 pink salmon were taken, identified, and recorded from the Sacramento River system. Twelve of these were from Coleman National Fish Hatchery, 11 were from fyke traps in the Sacramento River just above the mouth of the Feather River, 8 were taken by the commercial gill-net fishery (all in 1955), 4 were captured at the counting station on Mill Creek, and 3 were taken at Nimbus Salmon and Steelhead Hatchery on the American River (Tables 2 and 3).

Sockeye Salmon, *Oncorhynchus nerka* (Walbaum)

Distribution in North America and the Eastern Pacific

Sockeye salmon have been reported in the eastern Pacific Ocean from central California to northwestern Alaska. There are recognized spawning runs in suitable streams from the Columbia River northward to northwestern Alaska. Sockeye salmon are abundant off British Columbia and Alaska. In North America as a whole they are the second most abundant salmon.

Life History

Adult sockeye salmon usually ascend those rivers in which there are lakes. Some of them pass through the lakes and spawn in tributary streams, while others spawn along lake shores and in streams downstream from lakes. Relatively few sockeyes spawn in streams on which there are no lakes. A few young migrate to the ocean as fry immediately after emerging from the gravel, but the great majority spend between one and three years in a lake before descending to the sea. Those hatching upstream from a lake drop downstream into the lake, those which are hatched immediately below a lake move upstream into it, and those which hatch in a lake remain there. Sockeyes usually mature and return from the ocean to spawn at four or five years of age, but some mature at three, six, seven, or even eight years. The weight at maturity is usually 5 to 12 pounds, with a maximum of about 16 pounds.

Jordan and Evermann (1896) stated that sockeyes occurred in the Klamath River, and Scofield (1916) mentions that it was reported to him in 1916 that the commercial gill-net fishery at the mouth of the Klamath took 20 sockeyes. In contrast to these earlier reports, Snyder (1931) found nothing to substantiate the presence of even a stray sockeye in the Klamath in the 1920's. Before October 1917, salmon moving up the Klamath could continue as far as Klamath Lake and its tributary streams. On October 25, 1917, Copco Dam became a barrier that has since kept any salmon from reaching Klamath Lake. It is possible that the loss of this lake habitat was the final straw that led to the

extinction of sockeye salmon in the Klamath River. Taft (1937) reported a single sockeye taken in the Klamath River in 1936 and casts doubt on the identification of the fish reported to Scofield.

Occurrence in the Sacramento River

Twenty-two sockeye salmon were recovered and identified in the Sacramento River from 1949 through 1958 (Tables 2 and 3). There has been some speculation as to whether these were part of a remnant run, strays, or introduced kokanee salmon (the freshwater form of *Oncorhynchus nerka*) which had managed to migrate from lakes or reservoirs in the Sacramento-San Joaquin river system to the ocean, and were returning to spawn at maturity.

Kokanee were first introduced into California's inland waters in 1941 (Seeley and McCammon, 1963). By 1963, they had been stocked in 35 lakes. However, it was not until 1951 that they were stocked in lakes in the Sacramento River system. At that time, they were hatched and reared at Coleman National Fish Hatchery, from eggs taken in British Columbia, and released in Shasta Lake. Additional releases were made in Shasta Lake during 1952 and 1953. A large self-sustaining kokanee population developed rapidly in the lake.

It is probable that kokanee evolved from anadromous sockeye stocks where barriers to migration or other environmental changes caused conditions unfavorable to an anadromous existence. Apparently there are no structural differences between the two forms. The obvious differences of size and habit may be the result of environment rather than heredity.

It has been theorized that if kokanee were released where they had access to the ocean, some might migrate and return as sea-run adults. This phenomenon was actually demonstrated in Britsh Columbia, where sea-run sockeye were produced from kokanee reared and liberated as yearlings at Cultus Lake (Foerster, 1947). Fish passage studies by the U. S. Corps of Engineers at Shasta Dam showed that under favorable conditions fingerling salmonids passing through the turbines had a survival rate as high as 91% (Cramer and Oligher, 1964). The possibility that sockeye in the Sacramento River could develop from kokanee in Shasta Lake may account for some of the 22 sockeye recoveries made in the Sacramento River system, but it certainly does not account for all of them. Six of these 22 sockeye were recovered between 1949 and 1951; *i.e.,* before the first kokanee were planted in Shasta Lake.

Of the 22 sockeye recovered in the Sacramento River system, 16 were taken at Coleman National Fish Hatchery (Coleman spawns fish from Battle Creek and from the Sacramento River), 5 were taken in fyke traps in the main stem of the Sacramento, and 1 was recovered at Mill Creek Counting Station.

Silver Salmon, *Oncorhynchus kisutch* (Walbaum)

Distribution in North America and the Eastern Pacific

In the eastern Pacific Ocean, silver salmon have been found from about lat. 30° 50′ N., long. 116° 11′ W. (a few miles south of Cape Colnett, Baja California, Mexico) northward to northwestern Alaska (Messersmith, 1965). They are rare south of Monterey Bay. Silver salmon spawn in suitable streams from northern Monterey Bay, Cali-

fornia, northward to Alaska, but rarely enter the Sacramento-San Joaquin system, although there were and perhaps still are spawning runs in at least two small Marin County streams tributary to San Francisco Bay[3]. Silvers enter many small coastal streams that are not utilized by kings, but they are also found in many large rivers where kings do occur.

In California, silver salmon are of relatively minor importance—they constitute about 10% of the commercial catch and about 15% of the sport catch. In North America as a whole, silver salmon catches are exceeded by those of pinks, sockeyes, and chums.

Life History

Silver salmon may spawn a short distance from the ocean or they may proceed to the upper tributaries of the larger rivers.

Young silver salmon usually spend a little over a year in fresh water before migrating to the ocean; a few spend two years. This limits them to streams whose summer temperatures remain low enough for the young to survive. High summer temperature is probably an important factor preventing the establishment of silver salmon in streams of California's Central Valley (there may be other factors as well). Most silvers mature at the end of their third year. Under normal conditions, there are moderate numbers of two-year-old precocious males (grilse or "jacks"). Silver salmon older than three years are relatively rare. During their stay in fresh water, young silver salmon actively seek out stream areas which suit their needs and thus distribute themselves through the available watershed.

Mature silver salmon are normally between 6 and 12 pounds in weight and the maximum is about 30 pounds.

Occurrence in the Sacramento River

As previously mentioned, silver salmon (other than planted ones) have been the rarest of the five species of salmon in the Sacramento River system. From 1949 to 1956 (when they were introduced into the Sacramento) only two had been identified; both of these were taken at Coleman National Fish Hatchery. One was recovered in the fall of 1949 and the other in the fall of 1950 (Tables 2 and 3). One additional silver salmon was reported at Coleman before 1949 (John Pelnar, personal correspondence). It would seem safe to regard these three recoveries as strays rather than as remnants of a silver salmon run.

Introduction to the Sacramento River System

In March 1956 silver salmon were introduced into the Sacramento River system when 43,025 yearlings of Lewis River, Washington, stock were released in Mill Creek. These fish had been reared at the California Department of Fish and Game's Darrah Springs Hatchery on upper Battle Creek. The original plant was followed by 53,505 yearlings in February and March 1957, and 48,800 in April 1958; all were planted in Mill Creek.

Population estimates were made of returning silvers, using the Petersen method of tag and recapture. Calculated totals included a return

[3] These are Corte Madera Creek and Arroyo Corte Madera Del Presidio. The latter is often called Mill Valley Creek.

from the sea of 3,220 two-year-olds in the fall of 1956. This was followed by combined totals of 6,420 two- and three-year-old fish in 1957 and 11,600 in 1958. The introduced silvers scattered throughout the Sacramento River system when returning to spawn, but the greatest concentrations were in Battle Creek, the water in which they were reared until yearlings, and in Mill Creek, where they were planted. Returns were about equal in these two streams. No population estimates were attempted after 1958, but returns to Mill Creek and Coleman National Fish Hatchery, creel census studies, and examination of salmon carcasses on spawning beds indicate a rapid decline after the stocking ceased. By the fall of 1963, silvers were almost as scarce in the upper Sacramento River system as they had been before the introduction.

Apparently some of the introduced silver salmon strayed into the American River instead of returning to Battle Creek or Mill Creek. One ripe female appeared at Nimbus Hatchery in 1958 (a few introduced silver salmon "jacks" had been seen previously). There were no adult silvers at Nimbus Hatchery in 1959. Some silver salmon young were transferred from Coleman Hatchery to Nimbus and later planted as yearlings in the American River. Presumably, these were descendants of the introduced silvers which returned to Battle Creek. Ninety-nine adult silver salmon were reported as entering Nimbus Hatchery in 1960 and 87 in 1961. These fish were of small size and poor quality. Since that time, the American River has received no more silver salmon plants and the run has faded to practically nothing.

ESTIMATING THE NUMBERS OF CHUM, PINK, AND SOCKEYE SALMON IN THE SACRAMENTO RIVER SYSTEM

In the 10-year period during which data were collected, 130 salmon, other than kings, were identified in the Sacramento River or its tributaries. How many others entered the river? In an attempt to answer this question, two basically different methods were tried on chum, pink, and sockeye salmon and a third method on chums alone. Only two silver salmon were identified and no estimate of the total number of silvers appears in this paper.

Ratio of King Salmon Escapement to Kings Taken at Hatcheries and Counting Stations

Each year, thousands of salmon enter the two salmon hatcheries in the Sacramento River system. All of these fish are examined, and hatcherymen believe that there is little chance of unusual species of salmon being overlooked. If the total run of king salmon entering a spawning stream is X times the hatchery take from that stream, we might assume that the most probable number of salmon of each other species is also X times the hatchery take of that species. For this assumption to be valid, it is essential that the behavior of the various species be sufficiently similar to asure that the chance of an individual salmon entering a hatchery would be the same regardless of species. For example, a species that tended to spawn in the first suitable gravel might reach Coleman Hatchery in disproportionately small numbers. This or other differences in habits may affect the proportion of each species which reaches the hatcheries. Certainly, we cannot trust the method implic-

TABLE 4

Estimated Numbers of Chum, Pink, and Sockeye Salmon in the Sacramento River System Based on the Fraction of the Total King Salmon Runs Handled at Hatcheries and Counting Stations

	King			Chum		Pink		Sockeye	
	A	B	C	D	E	F	G	H	I
Location and year	Handled alive	Escapement (from Fry (1961))	1/Fraction handled (Col. "B"/ Col. "A")	Handled alive	Computed escapement (Col. "C" × Col. "D")	Handled alive	Computed escapement (Col. "C" × Col. "F")	Handled alive	Computed escapement (Col. "C" × Col. "H")
Sacramento River plus Battle Creek									
1950	6,084	115,000	18.9	0	0	0	0	2	38
1951	14,348	87,000	6.1	2	12	2	12	3	18
1952	16,130	282,000	17.5	1	18	1	18	2	35
1953	19,291	424,000	22.0	2	44	1	22	2	44
1954	13,641	288,000	21.1	3	63	1	21	3	63
1955	15,843	257,000	16.2	2	32	6	97	2	32
1956	10,099	115,000	11.4	2	23	0	0	1	11
1957	10,734	73,000	6.8	1	7	0	0	0	0
1958	22,496	157,000	7.0	1	7	0	0	0	0
Total					**206**		**170**		**241**
Mean					**22.9**		**18.9**		**26.8**
Mill Creek									
1953	3,765	10,000	2.7	1	3	3	8	0	0
1954	2,901	7,000	2.4	0	0	0	0	0	0
1955	1,722	3,000	1.7	0	0	0	0	0	0
1956	131	1,000	7.6	0	0	0	0	0	0
1957	1,341	5,000	3.7	0	0	0	0	1	4
1958	1,140	4,000	3.5	0	0	1	4	0	0
Total					**3**		**12**		**4**
Mean					**0.5**		**2.0**		**0.7**
American River									
1955	7,439	17,000	2.3	0	0	0	0	0	0
1956	1,537	6,000	3.9	2	8	1	4	0	0
1957	875	8,000	9.1	0	0	2	18	0	0
1958	9,571	27,000	2.8	5	14	0	0	0	0
Total					**22**		**22**		**0**
Mean					**5.5**		**5.5**		**0**
Sum of means (rounded to nearest whole number). Note that the means for each of the three areas covers a different time period.					**29**		**26**		**27**

itly, but it may give some indication of the population of the less common species.

Coleman Hatchery handles fish from Keswick Dam Fish Trap on the Sacramento River and from Battle Creek,[4] Nimbus Hatchery takes fish from the American River, and Mill Creek Counting Station (now dismantled) took fish that were moving up Mill Creek.[5] By using the approach given in the preceding paragraph, the average run in all streams combined was calculated to be 29 chums, 26 pinks, and 27 sockeyes. The time period involved was 1950 through 1958 for Coleman Hatchery and less for the other two stations (Table 4).

No Estimates Made From Carcass Counts

In theory, the carcasses of unusual salmon examined during the annual spawning stock surveys could be used to estimate the total escapement of each species in a manner similar to that just described. Unfortunately, this did not work out in practice. When the ratio of kings to other salmon examined at hatcheries was compared with the same ratio for spawned-out carcasses in the same streams it became evident that the carcass counters were either missing salmon of unusual species or misidentifying them as kings. When the data on all species are combined into a single 2x2 chi-square test, the difference is highly significant ($P=<0.001$). Part or all of this difference may be because it is not necessary to examine the carcasses as closely as it is the live fish, and because the carcasses may be fungus covered or badly decomposed.

Estimates From Fyke Trap Catches

Another method of estimating the total escapement of chums, pinks, and sockeyes involved the fraction of the total escapement taken by fyke traps in the Sacramento River. The purpose of these traps was to catch king salmon and steelhead trout *(Salmo gairdnerii gairdnerii)*, which were then tagged in the course of population estimates (Hallock, Van Woert, and Shapovalov, 1961). The gear also proved effective in the capture of the other species of salmon.

The first year for which we have satisfactory king salmon escapement figures for the entire Sacramento Valley is 1953. We also have steelhead escapements for the period 1953 through 1958. During this period, the traps took approximately 1 king salmon out of every 80 and 1 steelhead out of every 8 that went past the trapping site.

The traps proved to be highly size selective—most of the trapped king salmon were two-year-old "jacks". It seems probable that the high proportion of steelhead is due more to their smaller size than to species selection. Further verification of the size selectivity of this gear was provided by the hatchery-reared silver salmon which began migrating upstream past the trapping site for the first time in 1956. During the years 1956, 1957, and 1958, a total of 1,648 two-year-old silvers was taken in the traps. The total population of two-year-old silvers was computed to be 13,400—a ratio of 1 trapped out of every

[4] Unfortunately, we were not able to determine how many of the unusual salmon came from Battle Creek and how many from the Sacramento River. This introduces still another source of error, since the hatchery took the majority of the Battle Creek run but only a small fraction of the Sacramento River run.

[5] At the Mill Creek Counting Station, each fish was handled and it seems justifiable to assume that all unusual species were noted. Odd-appearing salmon which could not be readily identified were set aside for later study.

8.13 in the run. In 1957 and 1958, a total of 159 three-year-old silvers was taken out of a computed population of 7,840 three-year-olds—a ratio of 1 trapped out of every 49.3. The chums captured were about the size of three-year-old silvers; the pinks and sockeyes were smaller than three-year-old silvers but larger than two-year-olds.

Not only is there a problem of size selection by fyke traps but there is evidence which hints that there may be some difference in the fraction caught by species independent of size. From 1951–52 through 1958–59, the fyke traps took 34 chum salmon. Chums recovered farther upstream totaled only 22, a ratio of slightly over 1½ to 1 in favor of the traps. In the same period, the traps took 11 pink and 5 sockeye salmon, compared with 16 pinks and 16 sockeyes recovered upstream—ratios of roughly 1½ to 1 and 3 to 1 in favor of the upstream recoveries. By comparison with these upstream recoveries, the traps did much better with chums. This is the exact opposite of what one would expect if the selectivity of the traps favored small fish and depended on size alone. Obviously, this difference could be due to something besides species selectivity by the traps. For instance, there is much less chance of recovering fish which stay in the main stem of the Sacramento, compared with those which enter Battle Creek or Coleman Hatchery. The difference between species could be in preferred spawning areas and in the percentage recovered after spawning rather than in trap selectivity.

If we ignore the possibility of species selectivity and assume that the proportion of each species caught lies between that of two- and three-year-old silvers (*i.e.*, between 8 and 49 to 1), then for each species we can estimate a supposed maximum and minimum which we hope will bracket the true run size. For the period 1951–1959 the mean chum run calculated by this method is between 34 and 210, the mean pink run between 12 and 74, and the mean sockeye run between 5 and 31 (Table 5).

TABLE 5

Estimated Numbers of Chum, Pink, and Sockeye Salmon Sacramento River System Above the Feather River Based on Fyke Trap Catches

Year	Chum			Pink			Sockeye		
	Catch in fyke traps	Weighted fyke trap catch		Catch in fyke traps	Weighted fyke trap catch		Catch in fyke traps	Weighted fyke trap catch	
		catch × 8	catch × 49.3		catch × 8	catch × 49.3		catch × 8	catch × 49.3
1951–52	2	16	99	1	8	49	0	0	0
1952–53	3	24	148	2	16	99	0	0	0
1953–54	3	24	148	4	32	197	0	0	0
1954–55	18	144	887	0	0	0	2	16	99
1955–56	4	32	197	3	24	148	0	0	0
1956–57	2	16	99	1	8	49	1	8	49
1957–58	0	0	0	0	0	0	0	0	0
1958–59	2	16	99	1	8	49	2	16	99
Mean (of 8 years)		**34**	**210**		**12**	**74**		**5**	**31**
Mean 1953–56		**54**	**333**		**16**	**98**		**6**	**37**

Traps are more effective on small fish of a given species. From 1956–58, they caught approximately ⅛ of the two-year-old hatchery reared silver salmon which passed the trapping site. In 1957–58, they took only one three-year-old silver salmon out of every 49.3.

Estimation of Chum Population From a Single Tag Return

A method which could be used to estimate the number of chums involves use of the tagging data obtained while operating fyke traps in the lower Sacramento River. No pinks or sockeyes were tagged and no silvers were taken until introduced silvers started returning in 1956. Two chums were tagged in 1953, 16 in 1954, 4 in 1955 and 1 in 1956. Of these 23 fish, 1 was caught by a sportsman and thus became unavailable to be recovered by the hatcherymen or spawning survey crews. Of the remaining 22, 1 fish was recovered by the spawning survey crew in Mill Creek. During those same four years, 15 untagged chum salmon were recovered at Coleman Hatchery, or on the spawning grounds upstream from the trapping site.

The population was estimated by using a formula from Ricker (1958):

$$\text{Estimated population} = \frac{M\,(C+1)}{R+1}$$

$$= \frac{22\,(16+1)}{1+1}$$

$$= 187 \text{ for four years (1953–56) or an average annual run of 47 (rounded upward from 46.75).}$$

In the above equation:

M = Effective number of tagged fish (22)

C = Number of tagged and untagged fish in sample (1 tagged + 15 untagged)

R = Tagged fish recovered in sample (1)

Calculating the spawning escapement for a total of 4 years on the basis of a single tag return is very bad statistics, but the estimated annual run of 47 does lie within the range of estimates by the other methods.

SUMMARY AND CONCLUSIONS

King salmon are abundant in the Sacramento and San Joaquin river systems of California. To determine the occurrence and abundance of salmon other than kings in the Central Valley, a continuing effort was made to record all such salmon that were encountered by fisheries workers. This study lasted from 1949 until early 1959.

During the 10-year period, 130 unusual salmon, including chums, pinks, sockeyes, and silvers, were found among king salmon at counting stations, at fish hatchery traps, on spawning beds, in commercial fish landings, and during salmon tagging studies. All were taken in the Sacramento River system or below the junction of the Sacramento and San Joaquin rivers. No salmon other than kings were found in the San Joaquin system above its junction with the Sacramento, or in the Mokelumne River system.

Data on the distribution, life history, and occurrence of the five species of Pacific salmon, and on their abundance in the Sacramento River system, are included.

King salmon make up over 99% of all salmon in the Central Valley. From 1953 through 1958, the size of the fall run varied from a low of 117,000 in 1957 to a high of 597,000 in 1953.

During the study period, 68 chum, 38 pink, 22 sockeye, and 2 silver salmon were taken and identified in the Sacramento River system.

Order of magnitude estimates of the numbers of chums, pinks, and sockeyes in the Sacramento River system during the study period were made by two methods; a third method was used on chums alone. When we used the ratio of king salmon escapement to kings taken at hatcheries, as a basis for computing the abundance of the less common species, it was estimated that for the nine-year period 1950 through 1958 the average annual runs were: chums 29, pinks 26, and sockeyes 27. By computing their probable numbers from fyke trap catches it was estimated that for the eight-year period 1951 through 1958 the average annual number of chums was between 34 and 210, of pinks between 12 and 74, and of sockeyes between 5 and 31. Computing the chum salmon population from a single tag return gave an average annual run of 47 fish from 1953 through 1956. All of these methods have serious statistical weaknesses.

It was concluded that chum, pink, and sockeye salmon enter the Sacramento River regularly enough to be regarded as very small runs, but that silver salmon, before they were introduced in 1956, were so scarce and so irregular that they should be regarded as strays.

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