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A SURVEY OF ANADROMOUS FISH LOSSES IN IRRIGATION DIVERSIONS FROM THE SACRAMENTO AND SAN JOAQUIN RIVERS[1]

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INTRODUCTION

In spite of the encroachment of modern civilization, California's Central Valley continues to embrace one of the most important king salmon (*Oncorhynchus tshawytscha*) spawning areas in the world. A sizable steelhead rainbow trout (*Salmo gairdnerii gairdnerii*) population also spawns annually in the Sacramento River system.

There are now more than 900 irrigation, industrial, and municipal water supply diversions above the Sacramento-San Joaquin River Delta from stream sections utilized by salmon, steelhead, and other anadromous fishes as migration routes to and from the sea. Most of these diversions are for irrigation. In the Delta there are many additional diversions. Along the Sacramento and San Joaquin rivers water enters the numerous canals and ditches primarily through pumping stations, which vary in size from single two-inch diameter pumps to installations of 10 pumps ranging in size from 42 to 100 inches in diameter. Water is diverted by gravity as well as by pumps into many ditches leading from the tributary streams. In addition, there are a large number of siphons, up to 60 inches in diameter, in the Delta. Very few of these diversions are screened to prevent fish losses, although trash grids at the headworks of many canals and on pump intakes prevent losses of adult fish.

Over the years, considerable experimentation on the development of mechanical and electric fish screens to prevent anadromous fishes from being destroyed in diversions has been carried out in California. Perhaps even more study has been directed towards determining the time of year when juvenile king salmon migrate from Central Valley streams to the sea. As early as 1899, fyke nets were fished for this purpose in the lower Sacramento River at the head of Georgiana Slough (Rutter, 1903). A 40-year period lapsed after this early fyke netting, only to be followed—from 1939 until the present—by a series of systematic netting operations, both by the California Department of Fish and Game and the United States Fish and Wildlife Service, to study fingerling salmon migrations.

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[2] Both authors have transferred to Marine Resources Branch since this report was written.

Although considerable information has thus far been obtained on the migration times of juvenile Sacramento-San Joaquin River salmon and on how to prevent them from entering many types of ditches, particularly gravity diversions, only a comparatively moderate amount of study has been directed toward measuring actual fish losses at the various types of diversions, especially those utilizing pumps. Accordingly, in the spring of 1953 the California Department of Fish and Game initiated a survey of the multitude of unscreened diversions along the Sacramento and San Joaquin rivers and of the overall juvenile salmon and steelhead lossess occurring in them. While the task of measuring fish losses at each diversion would have been a monumental one and beyond the scope of the study, specific information was sought for typical diversions so that data obtained might be applied to other similar diversions. No attempt was made to study other than existing conditions, i.e., no experiments covering the effects of various theoretical diversion intake types on fish losses, etc., were conducted. Information on certain diversions for which an immediate evaluation of fish losses was essential, particularly on Butte Creek, a tributary to the Sacramento River, was also sought.

In 1953 and 1954 the diversion survey was centered along the Sacramento River between the cities of Redding and Sacramento. In 1955 the study was shifted to the San Joaquin River and into the Sacramento-San Joaquin River Delta. With an overall fish loss picture having been determined for the two principal rivers in the Central Valley,

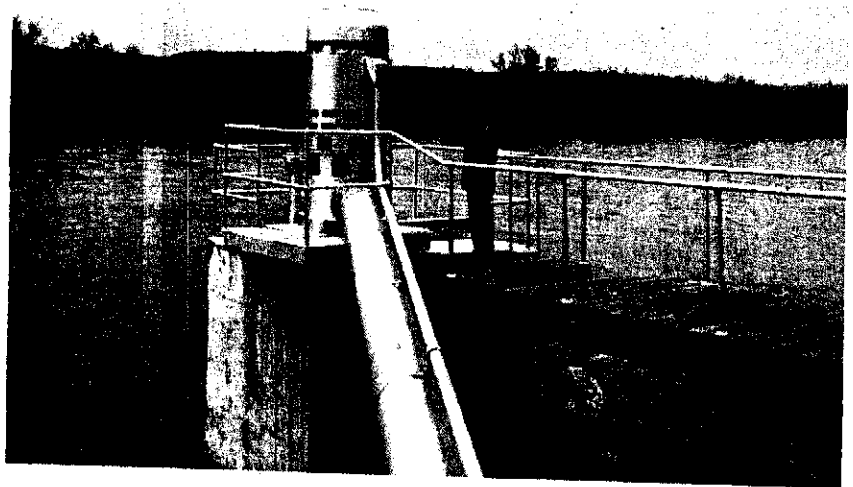

FIGURE 1. One of the Redding Municipal Water Supply pumps, a 14-inch diameter [illegible]

work in 1956 and 1957 was concentrated on Butte Creek. This report summarizes irrigation diversion fish loss data obtained during the five irrigation seasons from 1953 through 1957, with the major emphasis on fingerling king salmon.

ACKNOWLEDGMENTS

Many people contributed to the irrigation diversion survey. The authors are particularly indebted to Leo Shapovalov, Assistant Chief of the Inland Fisheries Branch, for guidance during the study and for invaluable assistance in the final preparation of the manuscript for publication. Several other members of the California Department of Fish and Game also contributed vitally to the success of the program. Harry A. Hanson instigated the study and, along with Elton D. Bailey and Don A. LaFaunce, did much of the work during the first two years. Mr. Bailey also reviewed the manuscript and offered many helpful suggestions. John E. Riggs was in charge of field work during the last three years of the study.

STUDY PLAN

The original plan called for a listing of pumps along the Sacramento and San Joaquin Rivers, grouped according to factors thought to influence fish losses, such as size, type, depth and position of intake, etc. Next, the total seasonal loss of juvenile salmon and steelhead was to be determined for pumps selected as representative of each group. Other pumps would then be evaluated on the basis of results from those tested. It was also thought losses at the selected pumps could be weighted by the number of similar pumps in each group, to provide an estimate of the total seasonal losses in all pump diversions in the study area. The selected pumps from each group were to be drawn only from those which were thought to operate continuously during the irrigation season and which the survey had indicated could be sampled with fyke nets. A similar study, time permitting, was planned for Butte Creek.

This plan, however, was not strictly followed because some of the selected pumps which had operated continuously during the irrigation season while the pump classification surveys were being made did not operate or operated only intermittently during the season when the diversion sampling took place. In addition, limitations in the availability of both men and equipment reduced the area in which the studies could be effectively carried out, and made it impractical to sample all of the selected diversions along the entire Sacramento and San Joaquin Rivers above the Delta.

The study plan then of necessity was altered to include only an overall survey and a general evaluation of fish losses in the diversions, with specific fish loss data to be obtained for certain diversions under consideration for screening in the near future.

To determine this general picture of the losses through pumps, the areas between Princeton and Meridian on the Sacramento River and between Stockton and Patterson on the San Joaquin River were selected.

The numbers of fish passing through pumps were obtained by operat-

determine net efficiencies. The sampling procedure consisted of setting one or more fyke nets in the canal as close to the discharge outlet of the pump as possible. The distance between the discharge outlet of the pump and the fyke net varied from a few feet to as much as one-half mile, but generally was less than 150 feet.

SAMPLING NETS

Riffle fyke nets of the type described by Hallock, Warner, and Fry (1952), and used by them to capture downstream migrant king salmon in the upper Sacramento River, were used to sample the discharge into

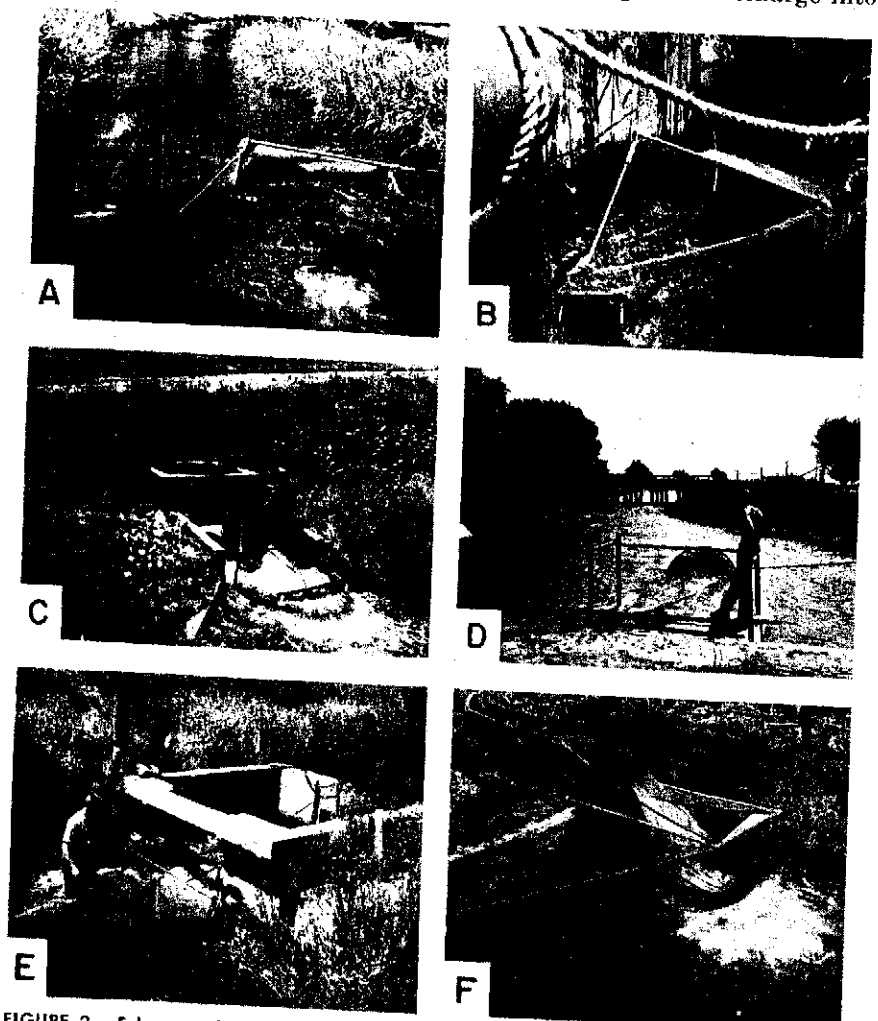

FIGURE 2. Fyke nets being fished in Sacramento River irrigation diversions during 1954, showing various methods of setting the nets. A, Hollis Sartain; B, Olive Percy Davis et al.; C, Wayne Hall; D, Sutter Mutual Water Company, Tisdale pumping plants No. 1 and No. 2; E, W. A. Larner; F, Tisdale Irrigation and Drainage Company. *Photographs A and B by Don A. LaFaunce; C, D, and F, by John E. Riggs; and E, by Elton D. Bailey.*

a number of the smaller ditches. These nets were made of one-half-inch stretched mesh cotton webbing hung on three rectangular metal frames. There was a 3-foot by 5-foot rectangular opening at the large end, and they were about nine feet long. A funnel of webbing tapered to a nine-inch square opening was installed inside the net at the second frame, 21 inches from the large open end. The pot of the net was formed by gathering together the webbing at the small open end and securing it with several turns of heavy twine.

Round fyke nets of slightly greater size were used to sample the discharge in the largest canals. These nets were also made of one-half-inch stretched mesh cotton webbing hung on three metal rings. They were 5 feet in diameter at the large open end and about 10 feet in length. A funnel of webbing, tapered to a round opening 11 inches in diameter, was installed inside the net at the second ring, 30 inches from the large open end. The pot of the net was formed in the manner described for the rectangular nets.

Simple bag nets of several shapes and sizes were used to sample the high velocity discharge from large pumps. These nets were made of one-half-inch stretched mesh cotton webbing, and had no funnels. One type was hung on a frame 4 feet square and had a bag 8 feet long. A second type was hung on a ring 3 feet in diameter, and also had a bag 8 feet long. The bag on the 3-foot circular net was later lengthened to about 10 feet, so that the pot could be moved to one side of the main discharge current to provide a resting place for the captured fish.

Near the end of the sampling period a round fyke net patterned after the one used by Schoeneman and Junge (1954) was made especially to sample the discharge from a 24-inch pump. This net consisted of a funnel of one-half-inch stretched mesh cotton webbing, a canvas pipe 8 feet long, and a live box of 2-inch cedar boards and hardware cloth (six meshes per inch). The funnel was 7 feet long. It tapered from 30 inches in diameter at the open end to 8 inches in diameter at the small end. The canvas pipe was eight inches in diameter. It had a metal ring sewn in at one end and a square metal frame at the other. The small end of the funnel and the round end of the pipe were sewn together. The live box was 18 inches wide, 24 inches high, and 36 inches long, with ends and framework of cedar, and was covered on the sides and bottom with hardware cloth. The box had a hinged lid, also covered with hardware cloth. One end of the live box had a rectangular opening at the top 7 inches wide by 7½ inches deep, to receive the square end of the canvas pipe which slipped into a slot just inside the live box opening. The canvas pipe and the live box were fastened together by slipping the square end of the canvas pipe into the slot provided for it, closing the lid, and securing it with a wing nut. A baffle board was placed in the bottom of the box to provide a resting place for the small fish captured. It was usually necessary to place a weight in the bottom of the box to keep it upright. With the live box placed in still water, the fish were kept in essentially the same condition as when they came through the pump. By opening the lid and detaching the canvas pipe, the live box was easily carried to shore and emptied.

Another net of this type was used in 1955. It included a funnel 9 feet long, tapering from a 2-foot by 4-foot rectangular opening at the large

FIGURE 3. *Typical pump types used in the Central Valley. A, Centrifugal pump, showing common installation method for single pumps; B, impeller from a centrifugal pump; C, screw-type pump; D, intake of a screw-type pump. Photographs A, by Elton D. Bailey; B, by William F. Van Woert; C, by Don A. LaFaunce; and D, by John E. Riggs.*

end to 9 inches square at the small end. The canvas pipe was omitted, and the small end of the funnel slipped directly into a slot in the live box. The live box was made of aluminum perforated plate with 5/32-inch round holes on 7/32-inch centers.

PUMP TYPES

Practically all irrigation water is diverted from the Sacramento and San Joaquin rivers by pumps of one type or another.

The high-speed rotative units are of two main types: One utilizes an impeller, or runner, similar in shape to a ship's propeller, and is called a screw-type pump. The impeller is simply an inclined plane which when rotated slices under the water and lifts it. This type of pump has the advantage of being able to deliver more water than the second or centrifugal type of impeller, for any given size.

The centrifugal impeller pump operates differently from the screw type in that water is thrown out of it, into the discharge outlet, by centrifugal force. One advantage of the centrifugal pump is that it will continue to give fair service even after the impeller parts are considerably worn (of course, with some loss of efficiency). The drive shaft of a centrifugal pump may be mounted either vertically or horizontally, although horizontal mounting is the more common.

A few of the horizontal centrifugal pumps and most of the vertical ones are called turbines because they have special cases or housings which differ materially from the simple volute or spiral-shaped case. In turbines the case, or impeller housing, contains stationary vanes which help direct the water to the discharge pipe, or to the next stage in the event it is a multiple stage pump. These vanes mark the pump as a turbine, whether the impeller be of the centrifugal or screw type. In some instances, the runners or impellers of turbines are designed so they will have some of the properties of both the screw-type and centrifugal-type pumps. These are called combination or mixed flow pump impellers. They combine the high discharge capacity of the screw impeller with other desirable features found only in the centrifugal pump.

SACRAMENTO RIVER

Salmon Migration

Adult king salmon migrate into the upper Sacramento River system during all months of the year, but there are three periods each year when the migration is greatly intensified. These peaks in the migration represent three distinct runs of fish, while most of those moving upstream between the peaks are apparently either early or late segments of one of the three main runs: winter, spring, and fall (Hallock, Fry, and LaFaunce, 1957).

The movement of winter- and spring-run salmon is fairly continuous in the lower river, between early November and the last of May, but with considerable overlap, and it is difficult to distinguish clear-cut peaks in their migration. However, even though they move up the river at about the same time, these two groups of fish separate in the upper river as dictated by their spawning characteristics. Most of the winter-run fish spawn during May and June, in the upper portion of the main stem of the Sacramento River, between Anderson and Keswick Dam;

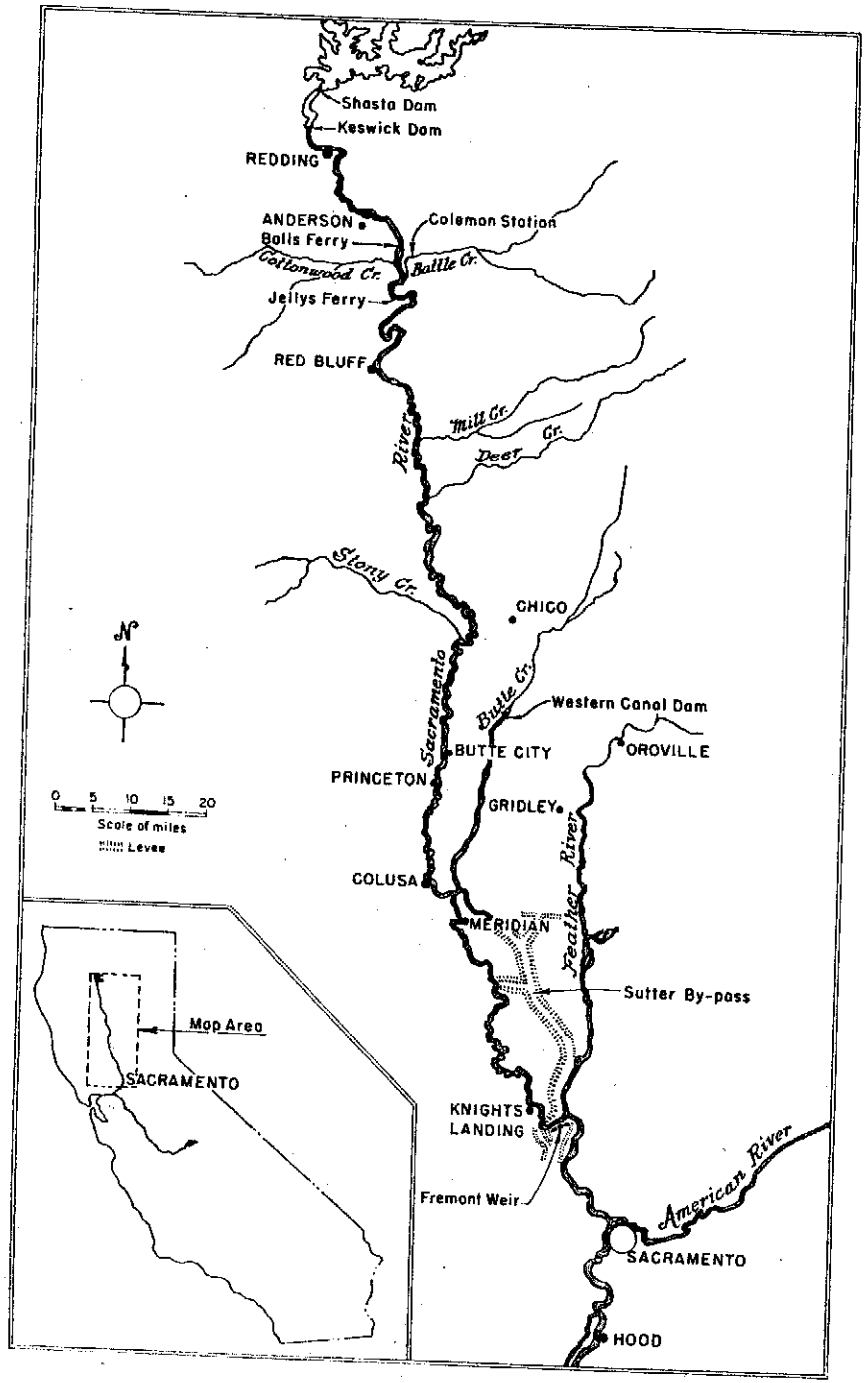

FIGURE 4. Map of the Sacramento River system, showing the areas where irrigation diversions were sampled.

however, in some years they also spawn in tributary streams. Spring-run fish spawn principally in late August, September, and early October. Spawning takes place primarily in the upper reaches of the Sacramento River above the City of Red Bluff, and in the higher reaches of the larger tributaries such as Butte, Deer, Mill, and Battle Creeks. The bulk of the fall run, which is larger in numbers than the other two combined, moves into the upper river between the middle of August and the early part of November. Most of the fall-run fish spawn between the middle of October and the latter part of December, with the greatest spawning activity taking place near the middle of November. Spawning takes place in the Sacramento River from a short distance below Chico to Keswick Dam, and also in the lower reaches of practically all suitable tributary streams.

The young of the Sacramento-San Joaquin king salmon either migrate to the ocean as soon as they reach the fingerling stage (when the yolk sac is absorbed and the fish can swim freely) or remain in the stream for about a year before going to sea. Between 80 and 90 percent of the young salmon go from fresh water to the ocean during their first year (Clark, 1929).

It is known that tremendous numbers of young salmon move down the Sacramento each winter and spring. Although there are no reliable estimates of the total numbers of migrants, partial figures are available for some years. For example, in the course of a marking experiment conducted by the California Department of Fish and Game in 1950, salmon were captured in the Sacramento River near Red Bluff, marked at the United States Fish and Wildlife Service's Coleman Fisheries Station on Battle Creek, and released in the Sacramento River at Jelly's Ferry. Marked fish were recaptured in sufficient quantity downstream at Red Bluff to provide a rough estimate of the total numbers passing the trapping site. According to figures based on recoveries following release of over 187,000 marked fish, close to 13,000,000 salmon moved downstream past Red Bluff between February 18 and March 10, 1950.

King salmon fry in the Sacramento River tend to move downstream at the time of seasonal increase in runoff. Salmon migration studies by the United States Fish and Wildlife Service in the Sacramento River at Balls Ferry, including 10 seasons of fyke netting between 1944 and 1953, show a measurable downstream movement between early October and the latter part of May in most years. The majority of the young salmon, however, migrate between early December and late April. The peak of the downstream movement varies from year to year; it may occur in late December, as in 1946, or even in late February, as in 1952. However, more often than not, two or even three peaks are evident between January and early March. Results of the 1944-1953 salmon migration studies at Balls Ferry are in agreement with the findings of studies made near the same location in 1899 (Rutter, 1903). Over 15,000 seaward migrants were handled between January 6 and April 25, 1899, and it was found that the height of the migration occurred between February 1st and 15th. Hanson, Smith, and Needham (1940) also noted a fall migration past Redding, finding a peak in mid-September of fish three to four inches long, thought to be salmon, which remained in the upper river (now blocked by Keswick and Shasta dams) over the summer.

Salmon migration studies also have been made in the lower Sacramento River. Fyke netting was carried out in the Sacramento River near Hood in 1899, 1940, 1941, 1947, and 1948. Findings were essentially the same in each of these years. Young king salmon were taken between mid-December and early June, with maximum numbers migrating during February and March, when as many as 80 percent of the total were taken.

Horizontal and Vertical Distribution of Downstream King Salmon Migrants

Between 1949 and 1953 tow net and push net operations by the United States Fish and Wildlife Service in the Sacramento River near Red Bluff revealed that during times of normal stream flows fingerling salmon migrate downstream at depths varying from the surface to four feet, moving in greatest numbers two to four feet under the surface. It was further demonstrated that the juvenile salmon migrate downstream fairly uniformly across the river but vary somewhat from midstream to the shores with changing water levels and velocities.

This is in accord with results of fyke netting operations carried on during the spring of 1950 by the California Department of Fish and Game in the Sacramento River just below Red Bluff. At that time 22 fyke nets were being fished side by side across the river over about half its width. Fingerlings were captured in all nets, with a few more fish usually being taken in the nets farthest from the shore.

During the 1954 netting operations in Sacramento River diversions it was discovered that during periods of high water and with flood conditions prevailing the fingerlings are spread throughout the river, and are to be found at considerable depths as well. In one instance near Colusa, fingerlings were being pumped in quantity into a canal when the pump intake was close to 20 feet under the river surface.

Irrigation Season

Records for the 10-year period, 1945-1954, show that the irrigation season along the Sacramento River between Sacramento and Redding extends from March to October (Figure 5). However, only 0.5 percent of the total seasonal volume used for irrigation is diverted in March and 8.4 percent in April. Seventy-six percent is diverted from May through August inclusive. An average of about 1,831,000 acre feet of water is diverted annually in this river section, which means that during the season an average of about 3,768 cubic feet of water per second leaves the river through the multitude of diversions during the entire eight-month season.

Fingerling Salmon Migration and the Irrigation Season

Individually the great majority of the pumping plants are small, and divert but a minor fraction of the Sacramento River flowing past their intakes. However, several of the larger ones do take enormous quantities of water, but usually late in the normal fingerling king salmon migration period. In 1954, the Glenn-Colusa Irrigation District diversion, which is the largest single diversion on the upper Sacramento, did not take water in February or March, but during April about 2.4 percent of the entire Sacramento River flowing past the intake was pumped onto the fields at this point. By May, 16 percent of the river's flow was

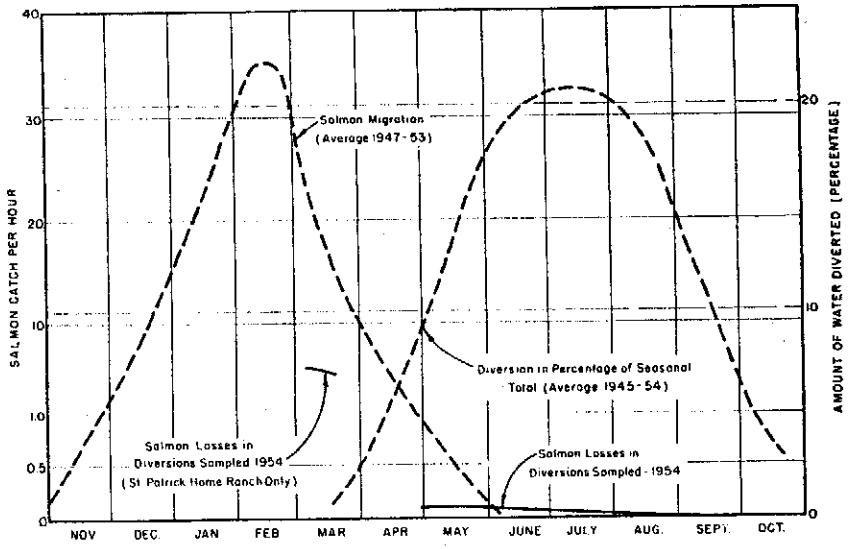

FIGURE 5. Comparison between times of the seaward migration of Sacramento River king salmon fingerlings, their losses in irrigation diversions, and the diversion of water for irrigation. The salmon migration was determined by fyke netting in the Sacramento River at Balls Ferry. Salmon losses were determined by fyke netting in irrigation diversions from the Sacramento River between Butte City and Knights Landing. The average diversion of irrigation water in percentage of the seasonal total includes data for the entire river between Sacramento and Redding.

being taken by this one diversion. Farther downstream near Meridian, the Sutter Mutual Water Company's large diversion took only 0.6 percent of the Sacramento River flowing past their pumps during April. However, during May, 10 percent of the river's flow was diverted.

A comparison between times of the annual seaward migration of juvenile salmon and the combined acre feet of water diverted by all pumps along the Sacramento River between Redding and Sacramento reveals that during most years the majority of the fingerlings have moved out of the upper river before the irrigation season gets into full swing (Figure 5). However, the migration tapers off through the spring and early summer, so some losses are to be expected each year during most of the summer months, particularly at the larger diversions. This is what occurred in 1954.

The one pump found to be operating in March, 1954, illustrated the potential danger of pumping, even during near-flood flows in the river, when fingerlings are migrating, since considerable losses of salmon occurred (Figure 5). Further reference to this pump, St. Patrick Home Ranch, appears in the section, "Diversions Sampled and Fish Losses."

The percentage of stream flow which is being diverted is perhaps of equal significance with the time when water is being diverted in determining salmon losses during the migration period. In 1954, less than 1 percent of the Sacramento River between Redding and Knights Landing was diverted in March, and less than 5 percent in April. However, by May, after most of the salmon had already migrated out of the upper river and into the Delta, about 25 percent of the river flow was diverted from this stream section.

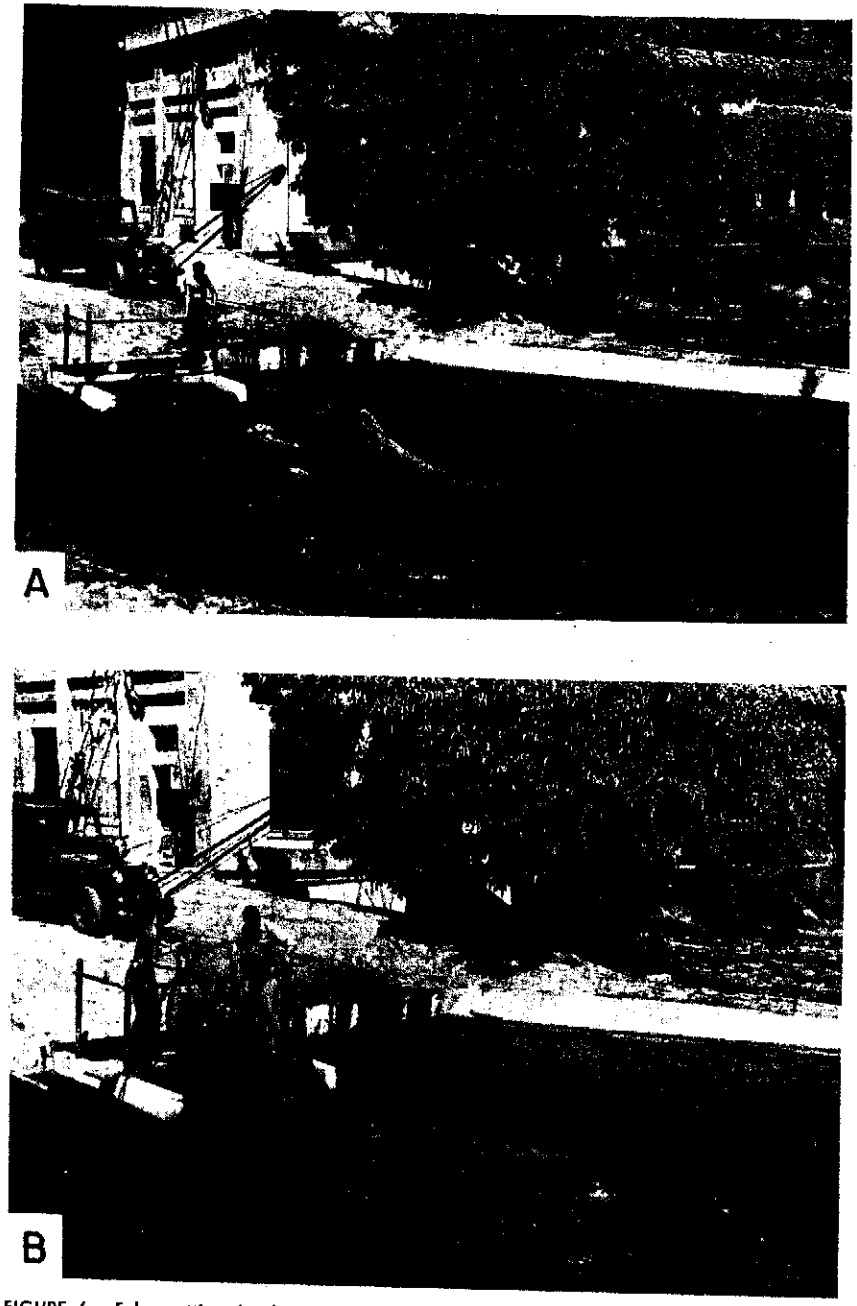

FIGURE 6. Fyke netting in the Sutter Mutual Water Company's Tisdale plants No. 1 and No. 2, Sacramento River, 1954. A, netting the discharge from two 48-inch diameter pumps; the discharge pipes from six 42-inch diameter pumps appear in the right background; B, putting net back in the canal after removing catch and cleaning; the jeep winch and hoist were used to remove the net from the water. *Photographs by John E. Riggs.*

Diversions Sampled and Fish Losses

In 1953 there were 335 separate diversions, utilizing a combined total of 448 pumps, along the Sacramento River between Redding and Sacramento, with the centrifugal-type pumps outnumbering the screw-type about 2 to 1. These pumps varied in size between 1¼ and 100 inches in diameter, with about 80 percent being from 6 to 24 inches in diameter. Eleven percent were larger than 24 inches in diameter. Preponderantly the diversions are single and double pump installations supplying water to limited acreages. However, along the river section between Knights Landing and Butte City, where the 1954 diversion sampling was conducted, there are also several larger pumping plants, including those of the Sutter Mutual Water Company (Tisdale plants No. 1 and No. 2), which utilize seven pumps ranging in size from 42 to 48 inches in diameter; Reclamation District No. 1,004, with three pumps from 30 to 50 inches in diameter; Provident Irrigation District, with five pumps from 24 to 42 inches in diameter; and the giant Glenn-Colusa Irrigation District diversion, with 10 pumps from 28 to 100 inches in diameter.

During 1953, initial surveys were made of 371 pumps, representing 294 separate diversions from the 246-mile section of the Sacramento River between Redding and Sacramento. At each pump site, information was obtained on factors believed to influence fish losses, such as size and type of pump, depth of intake, distance between intake and river bank, angle at which the intake pipe entered the water, velocity of flow past the intake, and size and type of intake screen if present. In each case, it was also determined whether or not the diversion could be adequately sampled for fish losses.

Pump intakes were located by probing with a three-quarter-inch by 12-foot aluminum pipe, with 6-inch graduations. This pipe was used to measure the depth of the intake and the distance between the intake and the river bank. The angle at which the intake pipe entered the water was estimated. Velocity of flow past the intake was measured with a Leitz current meter. Since the water was usually murky, information on the size and type of intake grids or screens was usually obtained from the owner or ranch foreman. This information applied only to the time that the intake was installed or last repaired, and therefore the condition of the screen at the time the survey was made was generally unknown. Data gathered on each pump were recorded on a "Unisort" edge-punched card to facilitate grouping and sample selection.

The Anderson-Cottonwood Irrigation District diversion at Redding was the only gravity flow diversion found along the upper Sacramento River; the remainder divert water by pumping.

A total of 23 diversions was sampled intermittently for fish losses during the 1953 irrigation season, with the greatest effort being expended during midseason. No diversion was found to be taking fingerling salmon or steelhead in serious quantities (Table 1).

In 1954, fyke nets were fished in nine selected diversions in the vicinity of Colusa, all with pumps from 14 to 50 inches in diameter, from late April through September. Fyke nets were also fished in other diversions for varying lengths of time (Table 2). Although some losses occurred during the entire irrigation season, particularly during the early part, the findings were essentially the same as in 1953, in that fish

TABLE 1

Diversions Sampled on the Sacramento River in 1953

Diversion	Location (mile and bank above Sacramento)	Number and size (diameter in inches) of pumps	Date	Hours of fyke netting	Number of juvenile salmon captured	Remarks
Anderson-Cottonwood Irrigation District	240.5 L	4–16	April 6–Aug. 20	134	136	All of the king salmon were captured during the period April 6-16, 1953. Combined catch of two nets.
Olive Percy Davis, et al.	78.8 R	1–24	July 27–Aug. 13	128	26	Pump broke down during night of July 27; time unknown.
Reclamation District No. 1004	112.1 L	2–30 1–50	June 3–18	94	1	
R. Pheiffer	155.7 R	1–2½	May 28–30	45		
V. G. Strain	150.8 R	1–12 1–16	June 16–17	26		
Provident Irrigation District	124.2 R	2–24 1–36 2–42	June 23–25	49		
Princeton-Codora Glenn Irrigation District	123.9 R	5–24	June 2–4	42		Combined catch of two nets.
Princeton-Codora Glenn Irrigation District	112.4 R	3–24	June 3–9	140		
Hollis Sartain	99.2 L	1–20	July 29–30	20		
Azro N. Lewis	95.6 L	1–12 1–20	Aug. 10–13	69		
Roger Wilbur	95.25 L	1–12 1–18	July 28–30	44		Not enough velocity to make a good set. Periodic water changing among ditches.
Roger Wilbur	87.4 R	1–10	July 27–28	8		Entire discharge sampled.
Wayne Hall	81.8 L	1–16	July 14–17	70		
Meridian Farms Water Company No. 1 and No. 2	80.0 L	1–10 1–20 1–24	July 15–17	48		
Olive Percy Davis, et al.	78.75 R	1–16 2–12	Aug. 10–13	64		
Robert Chesney	76.15 L	1–10	July 14–17	67		These pumps both discharge into the same basin; both pumps were operating during sampling.
J. H. Yates Estate	76.1 L	1–10				

TABLE 1

Diversions Sampled on the Sacramento River in 1953—Continued

Diversion	Location (mile and bank above Sacramento)	Number and size (diameter in inches) of pumps	Date	Hours of fyke netting	Number of juvenile salmon captured	Remarks
Meridian Farms Water Company No. 3	74.8 L	1–18	July 15–17	46		
Meridian Farms Water Company No. 4	71.1 L	1–24	Aug. 10–13	65		An estimated 60-70 dead salmonids (young and adults) observed in ditch August 10-12, 1953.
Faxon, Morton and P. Andreotti	69.2 R	1–10 2–16	July 27–30	34		
J. L. Browning	69.0 R	1–14 1–22	July 28	6		Only the 14-inch pump operated during sampling.
Newhall Land and Farming Company	67.5 L	1–12 2–24	July 14–17	64		
Natomas Central Mutual Water Company	16.0 L	1–24 2–32 2–38	Aug. 18–19	24		

losses at individual pumps were quite small. For example, the greatest seasonal loss encountered in 1954 consisted of 2,116 fingerling salmon and 110 yearling steelhead in the Olive Percy Davis diversion, with a 24-inch centrifugal pump. These are weighted figures, based on efficiency tests of the fyke nets fished in the canal behind the pumps, and represent the entire catch for the season. One pump was found to be operating unseasonally early, in March, 1954. This was a 20-inch centrifugal pump owned by the St. Patrick Home Ranch located between Princeton and Colusa. Fyke nets were fished in this diversion for eight days during the first half of March and over 1,200 fingerling salmon were captured. In addition, pieces of two adult salmon and one adult steelhead were recovered. This diversion was sampled again for three days during July, and no salmon or steelhead were taken.

There are indications that considerable damage could be done to the salmon and steelhead populations through losses of adults at pump intakes which do not have a trash grid or screen. A 24-inch centrifugal pump (Meridian Number 4) was sampled for three days in August, 1953. During this short period, 22 adult king salmon and 2 adult steelhead were captured in fyke nets. All were dead. In addition, between 60 and 70 dead adult salmon, which had either entered the canal before sampling began or were not captured in the fyke nets, were found floating in the ditch. Between the 1953 and 1954 irrigation seasons, a two-inch bar grill was placed over the pump intake by the irrigation company. In September, 1954, this diversion was examined again and no dead salmon were found in the canal.

TABLE 2

Diversions Sampled on the Sacramento River in 1954

Diversion	Location (mile and bank above Sacramento)	Number and size (diameter in inches) of pump	Date	Hours of fyke netting	Number of juvenile salmon captured	Fyke net efficiency (Percent)	Computed number of juvenile salmon captured, based on 100 percent fyke net efficiency and hours of fyke netting	Computed number of juvenile salmon captured, based on 100 percent fyke net efficiency and total possible hours of fyke netting during periods when salmon were captured
Olive Percy Davis, et al.	78.8 R	1-24	May 2-Sept. 11[1]	1,277	297	48.5	612	2,116
Meridian Farms Water Company No. 1 and No. 2	80.0 L	1-10 1-20 1-24	April 25-Sept. 18[2]	1,399	26	40.9	63	148
Reclamation District No. 1004	112.1 L	2-30 1-50	May 2-8	38	3			
Thousand Acre Ranch, H. W. Keller	106.0 R	1-14	April 25-May 29	290	4	Low velocity 95 percent of flow strained		
Charles W. Welch	103.7 R 103.8 R	1-16 1-14	April 25-May 8	115	2			
Nettie George and Ella Packer	102.8 R	2-12 1-20	May 9-29	167	1			
St. Patrick Home Ranch	101.1 R	1-20	Feb. 28-July 24	387	1,266	100.0 percent of flow strained		
Mayfair Packing Company	88.7 L	1-14	Oct. 3-9	8				
Howell Davis Wayne Hall	86.2 R 81.8 L	1-18 1-16	July 4-10 June 6-Sept. 25	44 1,242		66.0		
Olive Percy Davis, et al.	78.75 R	2-12 1-16	May 2-June 12	116	1			
J. H. Yates Estate	76.1 L	1-10	May 9-15	16				
Meridian Farms Water Company No. 3	74.8 L	1-18	April 25-Sept. 18	1,208	2	17.3		
Meridian Farms Water Company No. 4	71.1 L	1-24	April 25-May 22	209	2			
Hoffman, Beckley, Ritchie, Poundstone and Andreotti	70.4 R	1-16 1-20	April 18-Sept 4	811	3	70.0 percent of flow strained		
Faxon, Morton and P. Andreotti	69.2 R	2-16	June 13-Sept. 4	686		75.0 percent flow strained		
Newhall Land and Farming Company	67.5 L	1-12 2-24	April 25-May 8	156				
Tisdale Irrigation and Drainage Company	67.1 L	1-16 1-22	April 25-June 12	446		Medium velocity 50 percent of flow strained		
Tisdale Irrigation and Drainage Company	64.4 L	1-8 1-12	May 28-Sept. 18	113		100.0 percent of flow strained		
Sutter Mutual Water Company	63.75 L	2-48	May 23-Sept. 18	479	37			
W. A. Larner	60.4 L	1-14 1-16	May 16-Oct. 2	914	2	13.5		
Sacramento River Ranch	22.5 R	1-24	May 19-22	38	7			

[1] No estimate May 30-June 5.
[2] No estimate May 30-June 19 and June 27-September 18.

A summary of the individual diversions sampled with fyke nets during 1953 and 1954, together with the catches of all species, appears in the Appendix.

The only diversions in which fyke nets were fished along the upper Sacramento River during 1955 were the Meridian Farms Water Company Number 1 and Number 2 and the L. W. Seaver ditches. The pumping plant for the former is located near the City of Meridian and the one for the latter near Princeton. Nets were fished during the last week in March and the first week in April in the Meridian diversion and for one week only, in mid-March, in the Princeton diversion. Results, although meager, further substantiated findings from the 1954 work done on the Sacramento River in this same area.

FIGURE 7. Method used to clean the fyke nets. The net has been suspended from a hoist on the front of the jeep and the debris is being washed away with a 1½-inch diameter portable pump. The men beside the jeep are sorting the catch. Meridian Farms Water Company diversions No. 1 and No. 2, Sacramento River, 1954. *Photograph by Elton D. Bailey.*

Previous Diversion Sampling

In several instances, previous diversion sampling by the Department of Fish and Game along the upper Sacramento River and some of its tributaries resulted in similar experiences, since the young fish had migrated downstream before the irrigation season got under way. For example, between May 1 and June 9, 1943, fyke nets were fished in the Feather River near Oroville and in the Sutter Butte Canal Company and Western Canal Company diversions, which take water from the Feather River near Oroville. Results of the study were summarized by the statement that, "the movement of salmon was evidently early,

and most of them had moved out of the river by the time the ditches began taking water. Results obtained cannot therefore be considered significant."

However, fyke nets were also fished in the Feather River near Gridley from January 23 to May 31, 1944, and from January 13 to May 28, 1955, and it was found in each instance that the heaviest downstream movement of juvenile king salmon occurred during March and April. The Western Canal Company ditch opened in mid-April in 1944 and took very few salmon that year. The Sutter Butte Canal Company diversion opened early in April during 1944, and moderate numbers of salmon were taken in this canal between mid-April and the end of May.

Nets were also fished in the Sacramento River near Chico between May 1 and June 9, 1943, and in the Glenn-Colusa Canal, which diverts water from the Sacramento River at a nearby point. Practically no young salmon were taken, and it was concluded, as in the case of the Feather River, that most of the fish had migrated past this area before the netting was started. However, nets operated between April 18 and August 20, 1929, in the same diversion took large numbers of game fish, including salmon and steelhead. Substantial numbers of salmon were being lost in this canal even in late June, 1929.

Conclusions (Sacramento River)

On the basis of the 1953 and 1954 Sacramento River studies, appreciable losses of salmon in irrigation diversions now occur at few places on the river itself above Meridian. Individually, most of the small irrigation diversions do not destroy many young salmon and steelhead. Collectively, however, they do take considerable numbers. The largest diversion, that of the Glenn-Colusa Irrigation District, was not sampled adequately, nor was the large Anderson-Cottonwood Irrigation District gravity diversion at Redding. In view of the migration time of fingerling salmon, which results in the bulk of the fish moving out of the upper river and reaching the delta by late March, and an irrigation season which does not get into full swing until late April and early May, the small losses encountered in the diversions are not surprising. However, sampling has shown that the unscreened diversions do take fish at times when the pumps are in operation while fish are migrating, even under near flood conditions. A change in agricultural practices, resulting in an earlier irrigation season, or the installation of year-round diversion canals for the transportation of water to other areas of the State, could prove disastrous to the Sacramento River salmon resources unless adequate screens were provided.

Although losses at pumping plants along the upper Sacramento River were found to be very small during the spring of 1953 and 1954, it should not be concluded that losses of the same low magnitude occur in diversions from tributary streams. On the contrary, losses are known to be considerable in diversions from many tributaries. One of the leading factors contributing to this situation is a generally later spawning (and later downstream migration of young) of fall-run salmon in tributaries than in the Sacramento River. This situation results from low flows in tributary streams early in the fall, which make the spawning beds inaccessible until the first rains of winter arrive. Another factor contributing to large losses in some tributary stream diversions is the removal

of an increasing percentage of the stream flow as the season progresses, until the fish have no place to migrate except down the diversions.

SAN JOAQUIN RIVER

Salmon Migration

The annual migration of adult king salmon into the San Joaquin River system has consisted almost entirely of fall-run fish in recent years. Remnants of former large spring runs still persist in the Merced River, and to a much lesser degree in some of the other tributaries. Since the annihilation, by 1949, of salmon stocks which once spawned in the upper San Joaquin River, as a result of the lack of water releases from Friant Dam, the once important San Joaquin has served only as a passageway for salmon destined to spawn on riffles of tributary streams, including the Merced, Tuolumne, Stanislaus, Mokelumne, and Cosumnes Rivers.

The former San Joaquin River spring run, which included 56,000 salmon in 1945 and was valued at almost one million dollars annually, migrated past the mouth of the Merced between the middle of April and the middle of June, and usually peaked there in the first half of May. At Mendota, some 60 miles farther upstream, the adult run peaked during the early part of June. Spawning then took place in September and

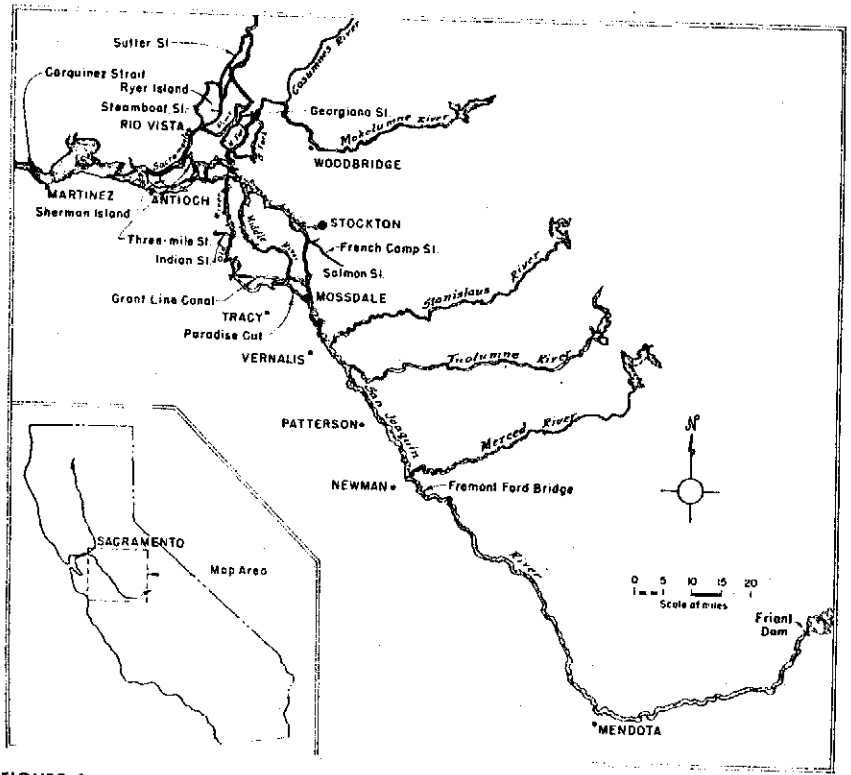

FIGURE 8. Map of the San Joaquin River system and the Sacramento-San Joaquin River Delta, showing the areas where irrigation diversions were sampled

early October in the San Joaquin River near Friant. In 1948 the Department of Fish and Game trapped 1,915 adult king salmon and hauled them to a canal through which they bypassed a dry section of the San Joaquin and reached the Friant Dam area safely. This was the last of this spring run.

The present fall run usually occurs a few weeks later than the Sacramento River fall run. There is also considerable variation in the time when these fish enter the tributaries. The Cosumnes and Merced Rivers have notoriously late runs, perhaps due in most years to low early flows, so that sometimes fish do not spawn in them until the middle of November. However, in the other tributaries the runs usually start in early October and continue through the middle of December, with a peak being reached some time in November.

The seaward migration of juvenile salmon in the San Joaquin River system occurs during the period of major seasonal runoff, as it does in the Sacramento. This was noted especially in studies made in 1940, prior to the storage of water at Friant Dam. However, while the storage of water behind Shasta Dam has had very little measurable effect upon the time pattern of juvenile salmon migrations in the Sacramento River, the storage of water at Friant Dam has brought about a considerable change in San Joaquin River fish migrations.

Fyke netting by the Department of Fish and Game in the San Joaquin River near Mendota between 1944 and 1949 showed that the majority of the fish then passed Mendota between late January and early June. In 1944 the migration of juvenile salmon was heavy at Mendota from January 27 through March and reached a peak in mid-February. Farther downstream, fyke netting at Mossdale in 1939 and 1940 demonstrated a measurable seaward movement of fingerling salmon between January and mid-June, with the greatest numbers descending during February and March. The highest percentage of the total number of migrants taken during any one month was 61 percent, during February, 1940.

The elimination of San Joaquin River flood flows as a result of water storage at Friant Dam considerably altered the juvenile salmon migration pattern. In 1948, at Mendota, there was a fairly steady downstream migration between February and June, but the peak was not reached until April. In 1949 the seaward migration was again measurable at Mendota between February and June, with peaks in early March and again in mid-May.

Juvenile salmon passing Mendota, at least in the decade prior to 1949, were for all practical purposes the progeny of spring-run adults only, since very few fall-run fish spawned in the upper San Joaquin. In 1948 and 1949 the last of the downstream migrants from the upper San Joaquin reached Mendota, only to be destroyed in irrigation diversions nearby. Only enough water was released from Friant Dam to fill the needs of agriculture, thus leaving a dry streambed, except for return irrigation water, from a few miles below Mendota to the mouth of the Merced, a distance of some 60 miles.

Fyke netting in the Delta in 1948 and 1949, then, for the first time did not include catches of fingerlings from the upper San Joaquin. All fingerlings were from spawning beds of tributary streams and were primarily the progeny of fall-run adults. This condition has existed

until the present time, i.e., the tributary streams from the Merced River to the Cosumnes now support the entire San Joaquin River salmon runs.

In 1948 and 1949 the San Joaquin River system seaward migrants did not reach the Delta near Stockton until the first week in April. This was six weeks after those from the Sacramento River drainage began entering the Delta waters near Hood. During 1949, salmon fingerlings moved seaward through the lower San Joaquin and into the Delta while the stream flow was actually receding, and it continued to recede during the migration period. In 1955 the peak of the downstream migration near Newman occurred between mid-March and mid-April. Thus, with the elimination of the early spawning spring run which formerly used the gravels above Mendota, and the storage of water at Friant, the juvenile salmon migration time pattern in the San Joaquin has changed considerably. During years of normal runoff, it formerly peaked near Stockton in February and it now peaks there around the last of March.

Irrigation Season

Records for the 10-year period (1946-55) show the irrigation season along the San Joaquin River between Stockton and the mouth of the Merced River to be principally between March and October, with some water diverted in February and November (Figure 9). Upstream, at Mendota, water is usually diverted during all months of the year. The monthly diversion of water in percentage of the seasonal total indicates that—between Stockton and the Merced River—5.8 percent is diverted in March, 14 percent in April, and 14 percent in May. About 67 percent is diverted from May through August, inclusive. On an average, about

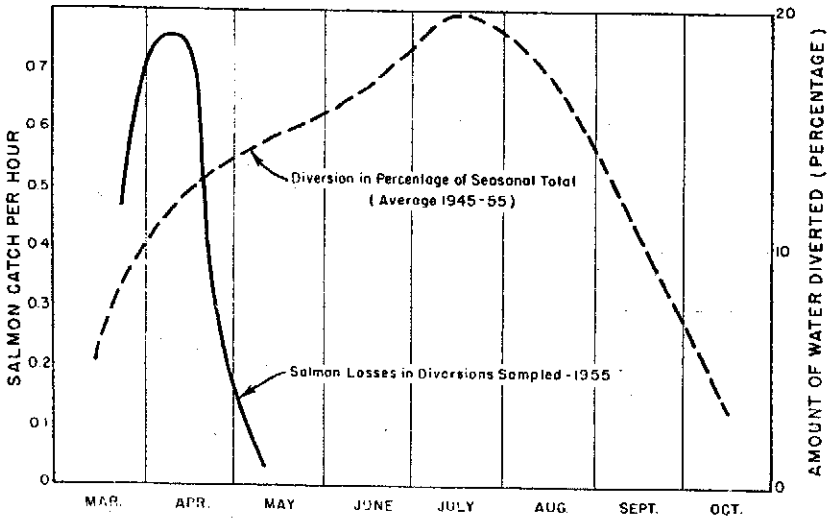

FIGURE 9. Comparison between times of San Joaquin River king salmon fingerling losses in irrigation diversions and the diversion of water for irrigation. Salmon losses were determined by fyke netting in irrigation diversions from the San Joaquin River between Patterson and Stockton (Old River). The average diversion of irrigation water in percentage of the seasonal total includes data for the entire river between Stockton and Newman (Fremont Ford.)

127,000 acre-feet of water are diverted annually in this river section, which means that during the eight principal months of the irrigation season an average of approximately 261 cubic feet of water per second leaves the river through the many diversions.

Fingerling Salmon Migration and the Irrigation Season

In comparison with Sacramento River diversions, those along the San Joaquin divert a much greater percentage of the river flow during the time when salmon fingerlings are migrating. For example, in 1955, Patterson Water Company diverted 17 percent of the entire flow of the San Joaquin River at its diversion intake during March, and by May was taking 20 percent of the flow. Farther downstream, at the Banta-Carbona Irrigation District intake, 4 percent of the river flow was diverted in March and 17 percent in April. A comparison between time of annual seaward migration of juvenile salmon, as determined by fyke net catches in irrigation diversions, and time of diversion of the combined volume of water diverted from the San Joaquin River in 1955 by all pumps between Stockton and the Merced River, shows that a much greater overall percentage of the seasonal irrigation water was pumped during the time fingerling salmon were migrating than on the upper Sacramento (Figure 9). Under these conditions, considerable fish losses were expected in the diversions sampled, and that is what happened during the 1955 irrigation season. The fish losses along the San Joaquin result not only because the irrigation season coincides with the juvenile salmon migration, but also because a large percentage of the entire San Joaquin flow is diverted early in the irrigation season, during the salmon migration period. In 1955 all pumps between Stockton and Patterson diverted about 20 percent of the entire San Joaquin flow in March and 40 percent in April.

Diversions Sampled and Fish Losses

In 1955 there were 113 separate diversions, utilizing 159 pumps, along the San Joaquin River between Stockton and the mouth of the Merced River. These diversions do not include those from French Camp Slough and Old River. The pumps varied in size from 2 to 36 inches in diameter, with about 85 percent being from 6 to 24 inches in diameter. As on the Sacramento River, the majority of the diversions are headed by single and double pump installations, with a few larger pumping plants which supply water to vast irrigation districts. The four largest water users include the Banta-Carbona Irrigation District, which utilizes 10 pumps ranging in size from 10 to 36 inches in diameter; West Stanislaus Irrigation District, with eight pumps from 12 to 26 inches (six of which are 26-inch pumps); Patterson Water Company, with seven pumps from 14 to 36 inches; and El Solyo Water Company, with a battery of four pumps from 10 to 18 inches in diameter.

Rather than to spend a season surveying the more than 100 diversions along the upper San Joaquin, as had been done in 1953 on the Sacramento, it was decided to forego this work on the San Joaquin and sample several of the larger typical pumping stations thoroughly during the entire 1955 season. This was done for the sake of expediency and to obtain a general picture of fish losses sooner. Previous work at several diversions in this area furnished some information and made this approach possible.

TABLE 3

Diversions Sampled on the San Joaquin River in 1955

Diversion	Location (mile and bank above mouth)	Number and size (diameter in inches) of pump	Date	Hours of fyke netting	Number of juvenile salmon captured	Fyke net efficiency (percent)	Computed number of juvenile salmon captured, based on 100 percent fyke net efficiency	Computed number of juvenile salmon captured, based on 100 percent fyke net efficiency and total possible hours of fyke netting during periods when salmon were captured
Banta-Carbona Irrigation District	67.5 L	2-10 2-16 2-20 3-24 1-36	Mar. 20-May 28[1]	504	386	6.4	6,024	19,748
El Solyo Water Company	82.0 L	1-10 3-18	Mar. 20-June 11[2]	428	105	4.7	2,234	9,494
Patterson Water Company	104.4 L	1-14 2-18 3-30 1-36	Mar. 20-May 28[3]	536	21	2.4	875	2,157

[1] No estimate May 15-28.
[2] No estimate April 24-June 11.
[3] No estimate March 20-26, April 17-23, and May 8-28.

In the spring of 1955, then, practically all of the diversion sampling was done on the San Joaquin River and in the Sacramento-San Joaquin River Delta. Pump diversions in which nets were fished along the San Joaquin included the Banta-Carbona Irrigation District and the El Solyo and Patterson Water Companies, located along a 43-mile section of the San Joaquin River between Stockton and Patterson. The large West Stanislaus Irrigation District diversion above Stockton was not sampled, but previous studies had shown this pumping plant to be an important salmon destroyer. All of the diversions sampled in 1955 on the San Joaquin River appear to be destroying more fingerling salmon than any of those sampled during the 1953, 1954, or 1955 seasons along the upper Sacramento River (Table 3). Of those diversions on the San Joaquin which were successfully studied, the Banta-Carbona Irrigation District pumping plant appears to be one of the greatest destroyers of young salmon. This irrigation district includes 17,000 acres of land. The diversion point is located on the west bank of the San Joaquin some 10 miles east of Tracy. The water flows by gravity about one mile to the headworks, where there are 10 pumps ranging in size from 10 to 36 inches in diameter. The average monthly flow through these pumps during April, May, and June for the five-year period 1948 through 1952 was slightly over 125 cubic feet per second. Juvenile salmon migrating down the San Joaquin River past the intake originate in the Merced, Tuolumne, and Stanislaus Rivers, all of which flow into the

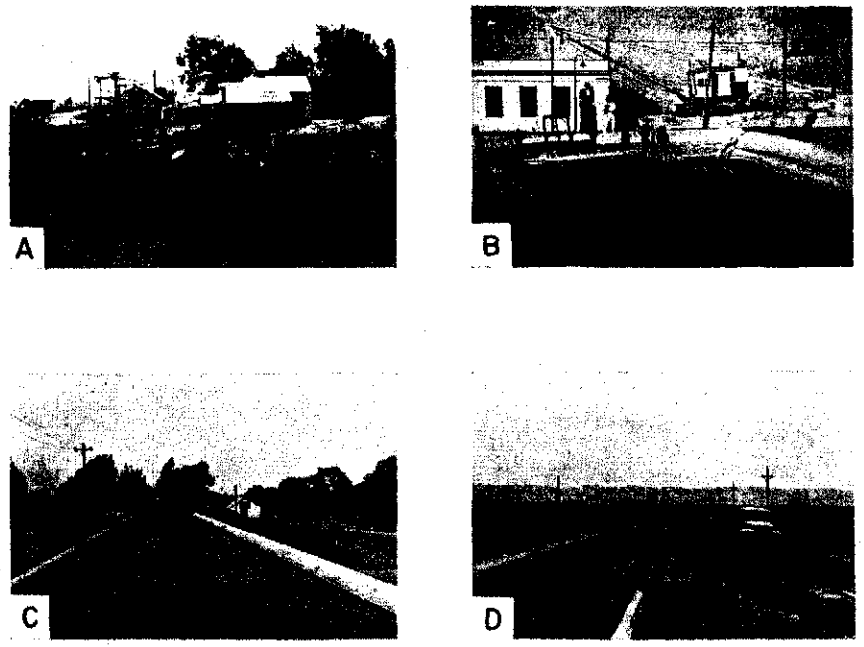

FIGURE 10. Two of the large irrigation diversions sampled along the San Joaquin River in 1955. A, Patterson Water Company pumping plant; B, Banta-Carbona Irrigation District pumping plant No. 1; C, Patterson Water Company canal, view toward the pumping plant; D, Banta-Carbona Irrigation District canal near pumping plant No. 2. *Photographs A, C, and D by John E. Riggs; and B, by William F. Van Woert.*

San Joaquin farther upstream. The studies showed that close to 20,000 juvenile salmon were destroyed in this one diversion during a two-month period between the middle of March and the middle of May, 1955.

During a one-month period of testing, between the middle of March and the middle of April, 1955, the El Solyo Water Company diversion, situated on the west bank of the San Joaquin River near Vernalis, took over 9,000 fingerling salmon. This diversion, which at the headworks includes four pumps ranging in size from 10 to 18 inches, has a normal average pumping rate of about 35 cubic feet per second during the salmon migration period. The intake is located above the mouth of the Stanislaus River, so that downstream migrants at that point originate in the Merced and Tuolumne rivers only. Percentage-wise, this diversion may be a greater destroyer of young salmon than the Banta-Carbona, since it draws from the migrants of one less river.

The same reasoning might also be applied to the results of studies made at the Patterson Water Company diversion. This company diverts water from the west bank of the San Joaquin River near Patterson, to provide for an irrigation district which includes 15,000 acres of land. At the headworks there are seven pumps, ranging in size from 14 to 36 inches in diameter. During the salmon migration period, flow through the pumps averages close to 110 cubic feet per second. Studies showed that between the middle of March and the early part of May more than 2,000 fingerling salmon were lost in this canal. However, although the number of fish destroyed was small, these fish were important, for this diversion draws on migrants only from the Merced River, and the run of adult salmon into the Merced the previous spring and fall was probably less than 1,000 fish.

A summary of the individual diversions sampled with fyke nets during 1955, along with catches of all species, appears in the Appendix.

Conclusions (San Joaquin River)

The 1955 studies on the San Joaquin River show that all of the large diversions sampled between Stockton and Patterson are destroying appreciable numbers of salmon fry. This is not surprising, since between 20 and 40 percent of the entire river flow is pumped into irrigation canals during the period when salmon are migrating downstream in this river section.

SACRAMENTO-SAN JOAQUIN RIVER DELTA

Originally it had not been planned to sample diversions in the Sacramento-San Joaquin River Delta as a part of this study. However, the need to obtain more data on fish losses in this area, particularly in some of the pump diversions with fish screens of questionable effectiveness, and in the large siphon diversions, had existed for some time. Accordingly, as time permitted, fyke nets were fished in several Delta diversions during March and April, 1955. Most of the San Joaquin River diversions ceased taking fingerling salmon early in May of 1955, and all work was shifted from the San Joaquin River above Stockton into the Delta.

Salmon Migration Time

Upon reaching the Delta, Sacramento River king salmon fingerlings migrate down the main stem of the river and the principal diverging channels, Sutter, Steamboat, and Georgiana sloughs, more or less in proportion to their respective flows (Erkkila et al., 1950). Studies in the Delta in 1948 and 1949 showed that although most Sacramento River migrants moved directly downstream, considerable numbers also traveled by way of Georgiana Slough, Three Mile Slough, and Sherman Lake.

In 1949 the bulk of the Sacramento River juvenile salmon had passed through the Delta by the end of March, but some fish continued to enter the Delta until mid-June.

Fingerling salmon entering the Delta from the San Joaquin River in 1949 traveled principally along Middle River to Salmon Slough and Grant Line Slough, then down Old River. They did not enter the Delta until early April, and then continued to do so through the latter part of June. The seaward movement of these fish from the Delta was measurable through July.

At Martinez, located at the lower end of the Delta on Carquinez Strait, fingerling salmon migration records are available for 1939 and 1940 (Hatton and Clark, 1942). During these two years the majority of the fish migrated seaward between the last of February and the middle of May, with more than 80 percent of them descending during March.

Diversions Sampled and Fish Losses

In 1955 the East Contra Costa Irrigation District and the United States Bureau of Reclamation's Contra Costa Canal, both of which divert water from the Delta near the City of Antioch, were sampled for fish losses. Two large siphons on Ryer Island, which is situated on the Sacramento River side of the Delta just upstream from Rio Vista, were also sampled. The siphons included one operated by Reclamation District 501 and another by the Passaglia Brothers. Woodbridge Irrigation District's gravity flow diversion on the Mokelumne River was also sampled early in the season, but work was discontinued because of low water velocities in the canal, which rendered the sampling gear ineffective. All of the sampled diversions were found to be taking young salmon (Table 4). However, with the exception of the East Contra Costa Irrigation District diversion, it was not possible to determine fyke net efficiencies so as to compute a total loss for any test period, because of scarcity of live fish for marking.

The East Contra Costa Irrigation District diversion was the only diversion in the Delta on which studies were carried out over a significant period of time. This diversion is located 36¼ miles upstream from the mouth of the San Joaquin River on Indian Slough. At the headworks of this diversion, located at the end of a 1½-mile-long canal leading from Indian Slough, there are six pumps, ranging in size from 18 to 30 inches in diameter. The average monthly flow through these pumps during April, May, and June for the five-year period 1948 through 1952 was slightly over 50 cubic feet per second. The studies indicated that over 6,000 fingerling salmon were destroyed between early April and mid-June in this canal.

TABLE 4

Diversions Sampled in the Sacramento-San Joaquin River Delta in 1955

Diversion	Location	Type, number, and size (diameter in inches) of diversion	Date	Hours of fyke netting	Number of juvenile salmon captured	Fyke net efficiency (percent)	Computed number of juvenile salmon captured, based on 100 percent fyke net efficiency	Computed number of juvenile salmon captured, based on 100 percent fyke net efficiency and total possible hours of fyke netting during periods when salmon were captured
East Contra Costa Irrigation District	San Joaquin River near Antioch	Pump 2-18 2-24 2-30	Apr. 3-June 18[1]	610	234	10.5	2,228	6,148
United States Bureau of Reclamation, Contra Costa Canal	San Joaquin River near Antioch	Pump 1-30 2-42	May 29-June 18	113	20			
Reclamation District 501	Sacramento River at Ryer Island	Siphon 1-30	May 29-June 18	183	48			
Passaglia Brothers	Sacramento River at Ryer Island	Siphon 1-20	May 29-June 18	162	19			
Woodbridge Irrigation District	Mokelumne River at Woodbridge	Gravity	Mar. 27-May 7	326	3			

[1] No estimate May 15-21.

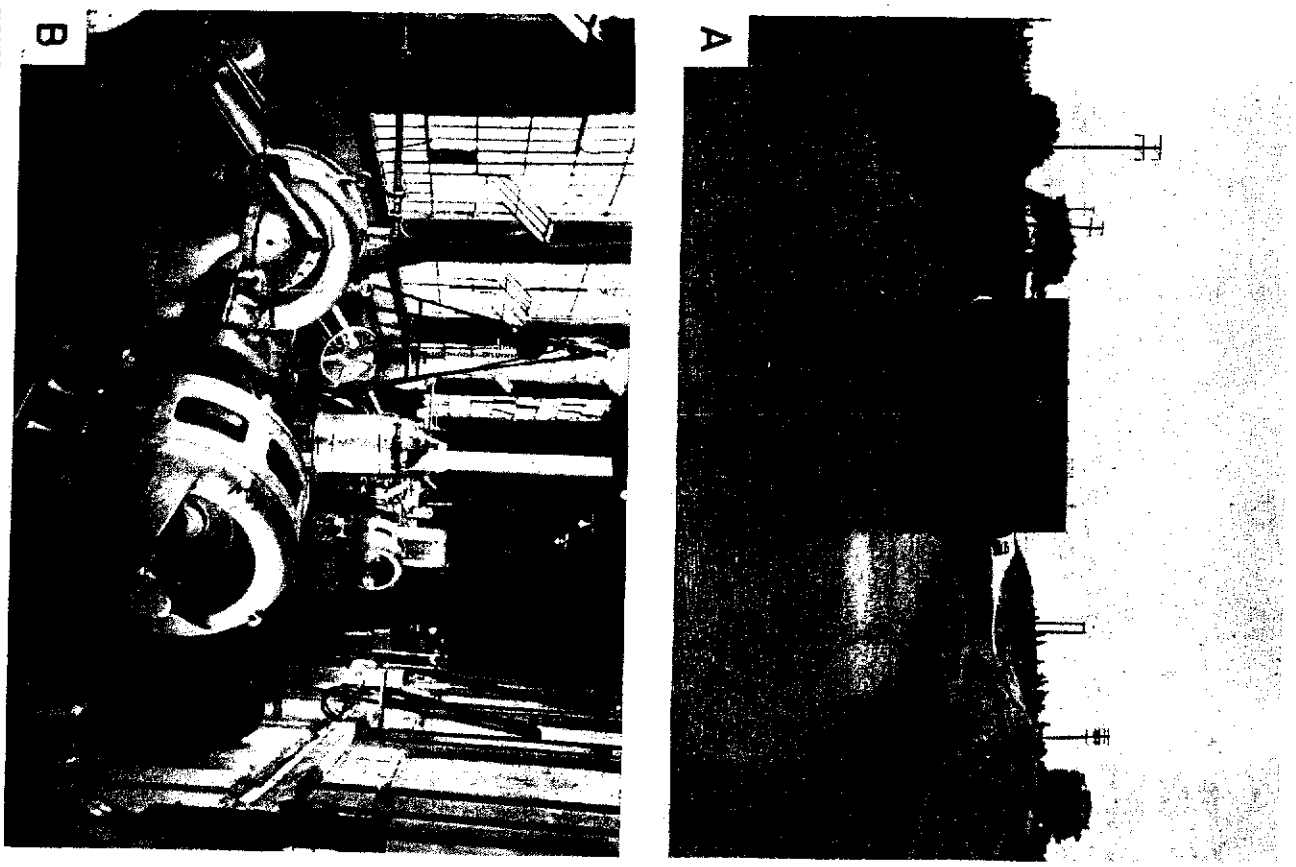

FIGURE 11. Two pumping plants in the Sacramento-San Joaquin River Delta at which fish losses were studied, 1955. A, The United States Bureau of Reclamation's Contra Costa Canal pumping plant; B, interior view of the East Contra Costa Irrigation District pumping plant. *Photographs by John E. Riggs.*

A summary of the individual diversions in the Delta sampled with fyke nets during 1955, along with the catches of all species, appears in the Appendix.

Conclusions (Sacramento-San Joaquin Delta)

Although the test periods were short, it was demonstrated that fish screens are needed at the East Contra Costa and Contra Costa canals, since considerable losses occur in these diversions. Further, the large siphons in the Delta are also destroying salmonids and other kinds of fishes. Additional study should be directed toward determining the extent of the siphon problems in the Delta, and the fish losses at the Woodbridge Irrigation District diversion.

SALMON MORTALITY

Since an efficient and economical fish screen for pump intakes has not been developed, the possibility of installing screens in canals to save juvenile salmon and steelhead after they have passed through the pumps was considered. Screens placed in canals below the pumps would be practical only if a large percentage of the young fish passed through the pumps alive and uninjured.

Studies showed that injuries received by fingerling salmon in passing through irrigation pumps in the Central Valley were similar to those listed by Schoeneman and Junge (1954) for downstream migrant salmon at dams on the Elwha River in Washington. Injuries which they commonly observed included: bulging or missing eyes, loss of scales, torn fins, ruptured abdomen, and "bisection." Although the causes of observed fish injuries were not determined in the present study, the injuries probably resulted in the ways suggested by Schoeneman and Junge, i.e., from pressure changes and mechanical causes, or a combination of the two. It was also found in the present study that some of the observed injuries, including missing eyes, loss of scales, torn fins, and ruptured abdomens, could result from use of a certain type of net in a high velocity discharge.

Since the causes of fish injuries were not definitely determined, and since in many cases pump injuries could not be distinguished from fyke net injuries, only the condition of salmon trapped in pump diversions at which fishing conditions were close to optimum for the available gear is covered in this report. The number of deaths resulting from latent injuries received in passing through the pumps was not determined, since live fish were returned to the river immediately or used to determine fyke net efficiencies.

Riffle fyke nets have been used successfully to live trap fingerling king salmon by Hallock, Warner, and Fry (1952) in velocities of 1 to 1½ feet per second. On the Sacramento River at the St. Patrick Home Ranch, where two of these nets were used to sample the discharge from an 18-inch centrifugal pump, 87.4 percent of the juvenile salmon taken were alive and apparently uninjured (Table 5). At the other Sacramento River diversions sampled, either velocities in the canals were unsuitable for efficient live trapping, or the numbers of salmon captured were too small to permit a reliable estimate of mortality.

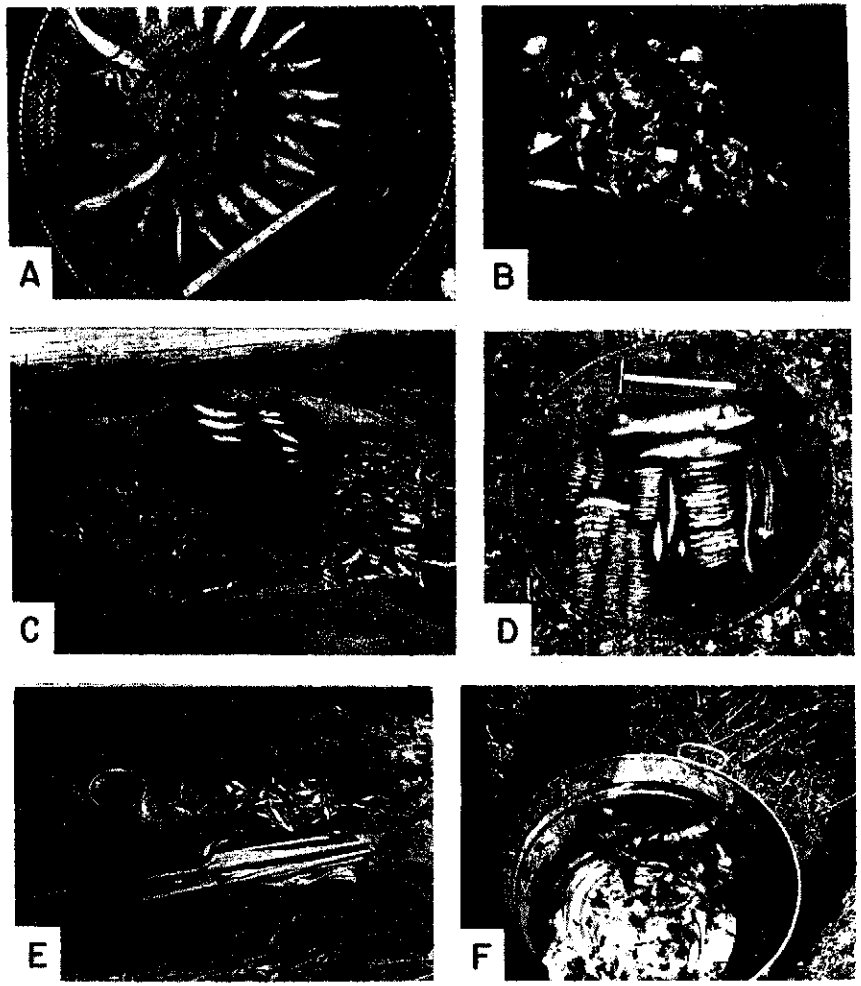

FIGURE 12. Typical daily fyke net catches (except E), showing the scarcity of salmonids, and the differences between fish which have passed, respectively, through centrifugal and screw-type pumps. A and F, Meridian Farms Water Company No. 1 and No. 2, showing catfish, lampreys, sunfish, and salmon (A, right portion of circle); these fish passed through large centrifugal pumps; note whole fish up to 7 and 8 inches in length; B, Faxon, Morton, and P. Andreotti irrigation diversion, showing fish after passing through a screw-type pump; most of the fish have been cut into small pieces; C, D, and E, Olive Percy Davis et al irrigation diversion, showing catches of lampreys, carp, sunfish and some salmon; the fish up to 18 inches in length were passed "whole" through a 24-inch diameter centrifugal pump; after this canal was drained at the end of the irrigation season, all that remained were small cyprinids, sunfish, and catfish (E). *Photographs A, B, D, and F, by William F. Van Woert; and C, by Dalan R. Drane.*

Two rectangular fyke nets with aluminum perforated plate live boxes attached were used for diversion sampling along the San Joaquin River and in the Delta. Limited use of this type of net at a Sacramento River diversion had indicated that the live boxes would provide more reliable information on pump mortality.

TABLE 5

Survival of Juvenile Salmon Passing Through Irrigation Pumps

Water user	Salmon captured				
	Number			Percentage	
	Live	Dead	Total	Live	Dead
Sacramento River					
St. Patrick Home Ranch	898	129	1,027	87.4	12.6
San Joaquin River					
El Solyo Water Company	32	11	43	74.4	25.6
Banta-Carbona Irrigation District	36	136	172	20.9	79.1
Sacramento-San Joaquin River Delta					
Reclamation District No. 501	14	2	16	87.5	12.5
Passaglia Brothers	16	2	18	88.9	11.1
Contra Costa Canal (Bureau of Reclamation	18	1	19	94.7	5.3

As previously stated, the El Soyo Water Company and Banta-Carbona Irrigation District diversions on the San Joaquin River and the United States Bureau of Reclamation's Contra Costa Canal in the Delta were large, multiple pump plants. With a fyke net set in the canal near the discharge outlets of several pumps, it was often impossible to tell through which pump the fish had passed. Therefore, no information is available on the mortality caused by individual pumps.

Reclamation District 501 and Passaglia Brothers diversions in the Delta were both siphons, through which fingerling salmon should be able to pass without injury. The small numbers of dead salmon observed at these locations probably resulted from net injuries.

From the limited data obtained, it is evident that many juvenile salmon pass through some pumps alive (Table 5). In general, there appeared to be a tendency for fish to pass through some of the older centrifugal pumps alive and apparently uninjured, while passage through some of the newer screw-type pumps usually resulted in death and often "bisection."

BUTTE CREEK

King Salmon Migration

Butte Creek presents a rather unique problem to those managing its salmon populations, since it is theoretically possible for Feather River salmon, both young and adults, to use the lower end of Butte Creek as a migration route to and from the Sacramento River. This could be accomplished through the unscreened Western Canal Company diversion, leading from the Feather River near Oroville to Butte Creek near Durham. To further complicate the picture, adult salmon may also enter Butte Creek from the Sacramento River via Sacramento Slough and the Sutter Bypass without passing through the flap gates at the mouth of Butte Creek, which lead through a levee to the Sacramento River at Ward's Landing. Fingerling salmon are also free to use the latter route but, of course, they would be moving in the opposite direc-

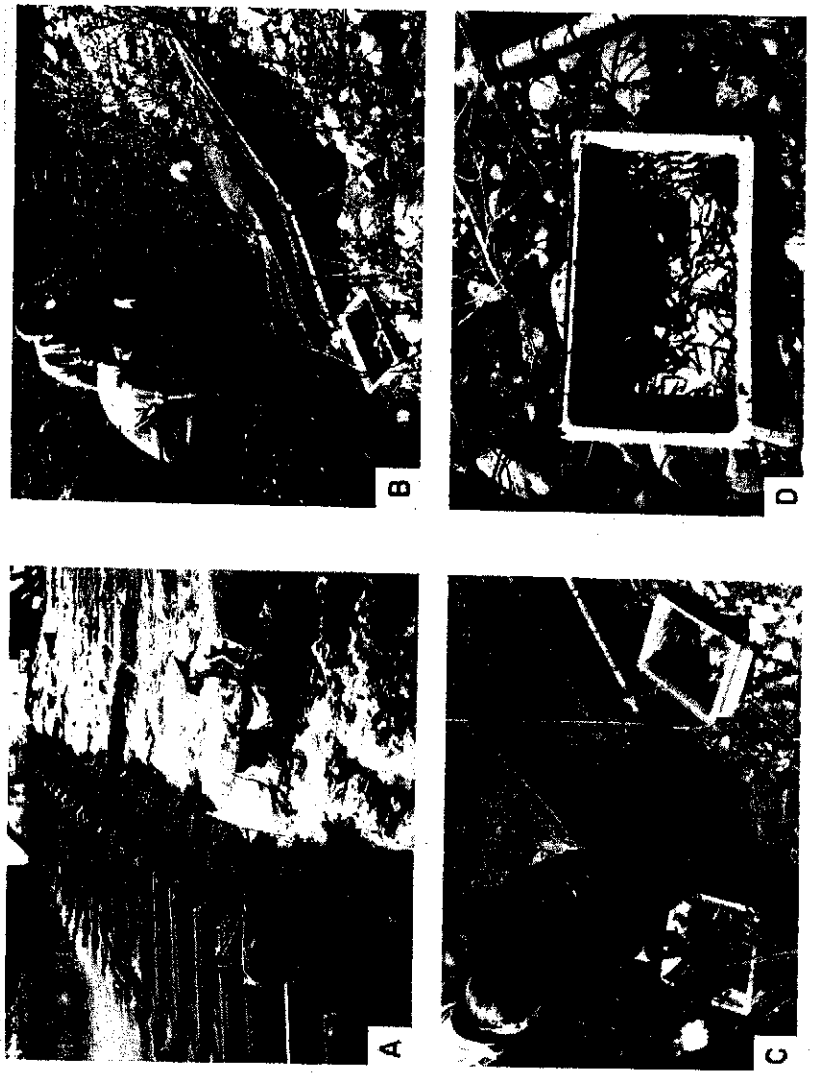

FIGURE 13. Determining the juvenile salmon migration time in Butte Creek. A, setting a fyke net below the apron of the Western Canal Company dam; this dam is a demountable structure, and the flashboards are not installed; B, examining the fyke net on shore, before removing the catch; C, sorting out the trash and examining captured salmon for marked fish; D, typical daily fyke net catch of salmon during the migration period. *Photographs by John E. Riggs.*

tion. There is evidence that salmon use these so-called secondary routes; however, the numbers involved are unknown.

Butte Creek supports an early spring run of adult king salmon, the bulk of which spawn in the 10-mile section below the Centerville Powerhouse in late September and early October. The remnants of a late fall run still persists, and occasionally considerable numbers of fish are able to find their way through the maze of commercial gun club and irrigation diversions from the lower stream to reach the spawning beds. Fall-run salmon were observed spawning in Butte Creek as far downstream as the Western Canal Company dam in 1956.

In March, April, and May, 1956, fyke nets were fished in Butte Creek below Gorrill Dam and the Western Canal Company dam, to determine the time of seaward salmon migration. However, only one juvenile salmon was captured during the entire three months, so it was apparent that there was either a poor hatch or the migration had taken place prior to the netting. Since flood conditions prevailed prior to the netting operation, it is probable that the scarcity of fish was due to both a poor hatch and an early but complete migration of fish from the eggs that did hatch.

In 1957, fyke netting was begun during December to determine the time of downstream migration. Fingerling salmon were found moving seaward in measurable quantities during the latter part of December, and the migration continued through the early part of March. The bulk of the fish moved out of the stream, or at least out of the area above the Western Canal Company diversion dam, in February.

Irrigation Season

The normal irrigation season on Butte Creek coincides with that of the Sacramento River above Sacramento, i.e., it does not get into full swing until late April and continues through September. However, some water is usually diverted from the lower section of Butte Creek through December by commercial gun clubs.

Diversions Sampled and Fish Losses

There are eight large unscreened irrigation diversions from Butte Creek, along a 25-mile section near Chico. Water enters six of them by gravity and is pumped into the other two. Lower Butte Creek also supports a host of diversions which supply water to commercial gun clubs and agricultural land. During part of each summer, water in the lower end of Butte Creek is supplemented and eventually replaced entirely by Feather River water, which is transported via the Western Canal Company ditch. The last of the Butte Creek water is usually diverted above the Western Canal Company dam.

In the spring of 1956, even though no juvenile salmon were being captured in fyke nets fished in Butte Creek, during April nets were also operated in irrigation diversions, including those of the Phelan-Parrott Irrigation System (often referred to as Parrott-Phelan) and Durham Mutual Water Company, Ltd., to further verify the scarcity of fingerlings. No salmon were captured. Since no fingerlings to study losses in the diversions were available, work was shifted toward the determination of the extent of adult spring-run salmon losses in these same diversions. It was soon found that many of these fish strayed into the unscreened gravity-flow diversions and were unable to find their way back to the stream. For example, on April 25 about 40 adult salmon were visible at one time in the Western Canal Company diversion. These fish had passed from the creek into the canal through the headgates and were then concentrated in the canal near the headgates in an attempt to re-enter the creek. Reduction of the velocity of water entering the canal failed to induce any salmon to return to the creek. Later, observations revealed that these fish did not re-enter the creek and perished in the canal.

In May, 1956, adult salmon were again observed in the Western Canal Company diversion, as well as in the diversions leading from Adam's Dam and the Phelan-Parrott Dam. Adult salmon were also reported by sportsmen to be present in the Durham-Mutual Water Company canal.

Adult salmon were also observed in the Western Canal Company diversion during May, 1957, but estimates of the numbers involved were not obtained. Simple trash grids installed at irrigation diversion headworks would save many adult salmon each spring in Butte Creek.

In 1957, two diversions, Phelan-Parrott and Durham Mutual, were found to be operating unseasonally early. Each diverted water off and on during January and February, then shut down again. Fyke nets were fished in the canals during these periods, and again it was demonstrated that losses of salmon occur in unscreened diversions if water is being diverted when the salmon are migrating (Table 6).

In only one instance were sufficient tests conducted to determine the percentage of the fish migrating down Butte Creek taken by a particular diversion. These studies were made at the Phelan-Parrott Irrigation System's gravity flow diversion during a five-day period in the middle of January, 1957. As previously stated, this diversion was operated during the early part of the juvenile salmon migration, prior to the normal irrigation season. During the five days of testing, close to one-sixth of the juvenile salmon moving seaward past the intake were drawn into the canal, with only about 20 cubic feet of water per second being diverted.

Results of the limited tests on Butte Creek were not surprising in view of the findings of other workers. Wales and Coots (1955) found that salmon losses were approximately proportionate to the amount of water being diverted into a specially constructed test diversion from Fall Creek, Siskiyou County, California. For example, when 10 percent of the water was diverted, 10 percent of the migrating fish entered the gravity flow diversion. Studies by the Department of Fish and Game in the Los Molinos Mutual Water Company's lower diversion from Mill Creek during 1951 revealed that between February 20 and March 27, with a water flow into the ditch of between 16 and 35 cubic feet per second, about 10,000 fingerling salmon or one-seventh of the total downstream migrants which passed the intake were destroyed. At this same site, during a three-day period in the early part of April, 1951, when between 40 and 65 cubic feet of water per second was being diverted, close to one-fourth of the downstream migrants were drawn into the diversion.

A summary of the individual diversions sampled with fyke nets during 1957, along with the catches of all species, appears in the appendix.

TABLE 6

Diversions Sampled on Butte Creek, 1956 and 1957

Diversion	Location	Type of diversion	Date	Hours of fyke netting	Number of juvenile salmon captured	Fyke net efficiency (percent)	Computed number of juvenile salmon captured, based on 100 percent fyke net efficiency	Computed number of juvenile salmon captured, based on 100 percent fyke net efficiency and total possible hours of fyke netting during periods when salmon were captured
Phelan-Parrott Irrigation System*	Butte Creek near Chico	Gravity	Apr. 10-12, 1956 May 2-4, 1956	120				
Durham-Mutual Water Company, Ltd.; R. Bank	Butte Creek near Chico	Gravity	Apr. 10-12, 1956	48				
Phelan-Parrott Irrigation System*	Butte Creek near Chico	Gravity	Jan. 6-Feb. 9, 1957	256	118	13.2	776	2,545
Durham-Mutual Water Company, Ltd.; R. Bank	Butte Creek near Chico	Gravity	Feb. 3-Feb. 23, 1957	192	205	18.0	1,139	2,995

* Often referred to as Parrott-Phelan.

Conclusions (Butte Creek)

One might conclude from results of the 1956 and 1957 studies on Butte Creek that losses of fingerling salmon are so small that fish screens would be hard to justify economically under present agricultural practices. However, findings of the 1956 and 1957 work conflict with the results of tests made by the Department of Fish and Game at many of the same diversions in 1955. Whereas no fingerlings were present in Butte Creek in the spring of 1956 and none after mid-March in 1957, they were recovered in fair numbers in six of the eight diversions during the middle of April in 1955.

Variance in the test results points up the need for further work on this stream before a screening program for juvenile salmonids is adopted or abandoned. The loss of adult salmon in the diversions was amply demonstrated in 1956 and 1957, and the need for screens to protect them is obvious.

SUMMARY

There are more than 900 irrigation, industrial, and municipal water supply diversions above the Sacramento-San Joaquin River Delta from stream sections utilized by salmon, steelhead, and other anadromous fishes as migration routes to and from the sea. Most of these diversions are for irrigation. Practically all irrigation water diverted from the Sacramento and San Joaquin rivers is pumped.

In 1953 the California Department of Fish and Game initiated a survey of the Central Valley diversions and of the over-all salmon and steelhead losses occurring in them. Specific fish loss data were also sought for particular diversions under consideration for screening in the near future. The study was especially aimed at determining king salmon losses.

The method of diversion sampling consisted of fishing fyke nets of various types in the canals and releasing marked fish to determine net efficiencies.

Adult king salmon migrate into the upper Sacramento River system during all months of the year. There are three main runs: winter, spring, and fall.

There is a measurable seaward migration of fingerling salmon in the Sacramento River near Balls Ferry between early October and the latter part of May in most years. However, the majority of the fish migrate out of the upper river between early December and late April. In the upper river, during periods of normal flow, fingerlings migrate downstream fairly uniformly across the river and principally at depths varying from the surface to four feet. They move in greatest numbers between two and four feet. In the lower Sacramento River near Hood, the seaward migration occurs between mid-December and early June, with maximum numbers migrating in February and March.

The irrigation season along the Sacramento River between Sacramento and Redding extends from March to October. However, only 0.5 percent of the total seasonal volume used for irrigation is diverted in March and 8.4 percent in April.

In 1953 there were 335 separate diversions, utilizing a combined total of 448 pumps, along the Sacramento River between Redding and Sacramento. In 1953, 294 diversions, including 371 pumps, were sur-

veyed. Factors which might influence the take of fish were listed. Twenty-three diversions were sampled intermittently for fish losses. In 1954, nine diversions near Colusa were sampled during the entire irrigation season.

Although some losses occurred during the entire irrigation seasons, the numbers of juvenile salmon and steelhead destroyed at individual diversions were quite small in 1953 and 1954. The greatest seasonal loss at one diversion consisted of about 2,000 young salmon and 110 yearling steelhead.

The small juvenile salmon losses encountered are not surprising, since fyke netting has shown that during years of normal runoff most of the fish migrate out of the upper river before the start of the main irrigation season. Evidence that considerable losses of adult salmon and steelhead occur at pump intakes which do not have trash grids or screens was gathered.

The adult king salmon migrations in the San Joaquin River system during recent years have consisted almost entirely of fall-run fish which spawn in the tributaries from the Merced to the Cosumnes rivers. The once large upper San Joaquin spring run was destroyed by 1949 as a result of the lack of flow releases from Friant Dam. The present fall run usually takes place a few weeks later than the Sacramento River fall run.

The seaward migration of San Joaquin River juvenile salmon usually peaks in the Stockton area some time in March.

The irrigation season along the San Joaquin River between the mouth of the Merced River and Stockton usually runs from early March through October, with some water diverted in February and November. On the average, about 5.8 percent of the water used for irrigation is diverted in March and 14.1 percent in April.

In 1955 there were 113 separate diversions, utilizing 159 pumps, along the San Joaquin River between Stockton and Newman (Fremont Ford). Three diversions were sampled during the time of the salmon fingerling seaward migration. All were found to be destroying more fingerling salmon than any of those sampled during the previous two years along the upper Sacramento. The expectancy of fish losses in diversions along the San Joaquin is illustrated not only by the coincidence of the irrigation season with the salmon migration, but also by the large proportion of San Joaquin flows which is diverted early in the irrigation season, during the salmon migration period.

A limited amount of diversion sampling was done in the Sacramento-San Joaquin River Delta in April, May and June, 1955, at pumps as well as siphons. All sampled diversions were found to be taking fingerling salmon.

By the end of June the last salmon fingerlings from the two river systems have usually entered the Delta. The seaward movement from the Delta is measurable through July. Close to 80 percent of the migrants pass through the Delta during March.

Many juvenile salmon pass through the pumps alive. In general, the centrifugal type pump appears to pass more fish alive than the screw type.

In 1956 and 1957, diversion sampling was also done on Butte Creek. Butte Creek supports an early spring run of adult king salmon. The fall run is small.

The seaward migration of fingerling salmon in Butte Creek occurred from the latter part of December through the early part of March in 1957, with practically all of the fish having moved out of the upper reaches by the end of February.

The normal irrigation season along Butte Creek extends from late April to late September.

There are eight large unscreened diversions on Butte Creek near Chico. Fyke nets were fished in two of these diversions, as well as at two points in the stream. The study showed that practically all of the fingerling salmon migrated out of the stream before the irrigation seasons started in 1956 and 1957. These results are in conflict with the findings of studies made in 1955, which showed that fingerling salmon losses in these same diversions occurred as late as mid-April.

The loss of adult salmon in Butte Creek diversions, particularly the Western Canal Company ditch, was demonstrated in 1956 and 1957. It is concluded that screens are necessary to protect them.

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APPENDIX

TABLE A-1

List of Common and Scientific Names of Fishes Captured in Fyke Nets During the Irrigation Diversion Survey

Common name	Scientific name
Family Petromyzontidae. The Lamprey Family.	
1. Pacific lamprey	*Entosphenus tridentatus* (Gairdner)
2. Brook lamprey	*Lampetra planeri* (Bloch)
Family Acipenseridae. The Sturgeon Family.	
3. White sturgeon	*Acipenser transmontanus* Richardson
Family Clupeidae. The Herring Family.	
4. American shad	*Alosa sapidissima* (Wilson)
Family Osmeridae. The Smelt Family.	
5.	Unknown
Family Salmonidae. The Salmon and Trout Family.	
6. King salmon	*Oncorhynchus tshawytscha* (Walbaum)
7. Steelhead rainbow trout	*Salmo gairdnerii gairdnerii* Richardson
Family Catostomidae. The Sucker Family.	
8. Sacramento western sucker	*Catostomus occidentalis occidentalis* Ayres
Family Cyprinidae. The Carp or Minnow Family.	
9. Carp	*Cyprinus carpio* Linnaeus
10. Sacramento blackfish	*Orthodon microlepidotus* (Ayres)
11. Sacramento hitch	*Lavinia exilicauda exilicauda* Baird and Girard
12. Sacramento squawfish	*Ptychocheilus grandis* (Ayres)
13. Splittail	*Pogonichthys macrolepidotus* (Ayres)
Family Ictaluridae. The Catfish Family.	
14. Channel catfish	*Ictalurus punctatus* (Rafinesque)
15. White catfish	*Ictalurus catus* (Linnaeus)
16. Brown bullhead	*Ictalurus nebulosus* (LeSueur)
Family Poeciliidae. The Topminnow Family.	
17. Mosquitofish	*Gambusia affinis* (Baird and Girar
Family Pleuronectidae. The Righteyed Flounder Family.	
18. Starry flounder	*Platichthys stellatus* (Pallas)
Family Serranidae. The Sea Bass Family.	
19. Striped bass	*Roccus saxatilis* (Walbaum)
Family Centrarchidae. The Sunfish Family.	
20. Largemouth bass	*Micropterus salmoides* (Lacé pè de)
21. Warmouth bass	*Chaenobryttus gulosus* (Cuvier)
22. Green sunfish	*Lepomis cyanellus* Rafinesque
23. Bluegill	*Lepomis macrochirus* Rafinesque
24. Black crappie	*Pomoxis nigromaculatus* (LeSueur)
Family Embiotocidae. The Viviparous Perch Family.	
25. Tule perch	*Hysterocarpus traskii* Gibbons
Family Cottidae. The Sculpin Family.	
26. Sculpin	*Cottus* sp.
Family Gasterosteidae. The Stickleback Family.	
27. Threespine stickleback	*Gasterosteus aculeatus* Linnaeus

TABLE A-2

Sacramento River Irrigation Pump Survey, 1953

Size of Pump (diameter in inches)	Number of pumps surveyed*				Number of pumps listed†		
	Turbine	Centrifugal	Screw type	Total	Diverting water	Not diverting water	Total
1¼	1	--	--	1	1	--	1
1½	--	2	--	2	2	--	2
2	--	1	--	1	3	1	4
2½	--	4	--	4	5	--	5
3	--	6	--	6	4	2	6
4	--	8	--	8	9	2	11
5	--	7	--	7	11	1	12
6	1	28	--	29	25	11	36
7	--	3	--	3	2	2	4
8	4	28	2	34	35	5	40
10	10	36	1	47	45	8	53
12	16	37	8	61	56	8	64
14	14	12	7	33	31	5	36
15	--	5	--	5	5	1	6
16	27	8	1	36	37	4	41
18	3	11	1	15	16	2	18
20	10	8	1	19	23	1	24
22	4	1	--	5	5	--	5
24	10	16	--	26	35	--	35
28	--	--	--	--	1	--	1
30	2	1	--	3	3	--	3
32	2	--	--	2	2	--	2
36	1	6	--	7	8	--	8
38	--	--	--	--	2	--	2
42	5	7	--	12	12	--	12
48	2	--	--	2	4	--	4
50	--	3	--	3	4	--	4
54	--	--	--	--	1	--	1
66	--	--	--	--	4	--	4
72	--	--	--	--	3	--	3
100	--	--	--	--	1	--	1
Totals	112	238	21	371	395	53	448

* It was not determined whether the turbines had centrifugal or screw-type runners because only external examination of the pump was possible. The screw-type pumps may also have been turbines but this was not determined for the same reason.

† Report of Sacramento-San Joaquin Water Supervision for 1953.

TABLE A-3

Sacramento River, Diversion Sampling: Number of Fish Trapped in the Canal During the 1953 Irrigation Season

Species of fish captured (common name)	Anderson-Cottonwood Irrigation District[1]	Olive Percy Davis et al. 78.8 R[2]	Reclamation District No. 1004	R. Pheiffer
	Apr. 6-Aug. 20	July 27-Aug. 13	June 3-18	May 28-30
King salmon (Fork length in inches)				
1.0-1.4	17			
1.5-1.9	34			
2.0-2.4				
2.5-2.9				
3.0-3.4		1		
3.5-3.9		1	1	
4.0-4.4		3		
4.5-4.9		11		
5.0-5.4		7		
5.5-5.9		2		
6.0-6.4		1		
Not measured	85			
Totals	136	26	1	
Adult king salmon				
Steelhead rainbow trout				
Pacific lamprey		1	1	
Brook lamprey				
Ammocoete (species?)	2	1		
American shad				
Sacramento western sucker		382		
Carp		146		
Sacramento squawfish				
Splittail		2		
Unidentified minnows		362		
White catfish	6	22	1	
Mosquitofish		3		
Largemouth bass		7		
Green sunfish		1,785	1	
Warmouth				
Tule perch		2		
Sculpin (species?)		130	5	
Threespine stickleback	23			
Tadpole				
Crayfish		1	9	

No fish captured

[1] All of the king salmon were captured during the period April 6-16, 1953. Combined catch of two nets.

[2] Pump broke down during night of July 27; time unkown. An estimated 2,500 sunfish, minnows and suckers trapped on July 29 are not included in these totals.

TABLE A-3—Continued

Sacramento River, Diversion Sampling: Number of Fish Trapped in the Canal During the 1953 Irrigation Season

Species of fish captured (common name)	V. G. Strain	Provident Irrigation District	Princeton-Codora Glenn Irrigation District 123.9 R[3]	Princeton-Codora Glenn Irrigation District 112.4 R
	June 16-17	June 23-25	June 2-4	June 3-9
King salmon (Fork length in inches)				
1.0-1.4				
1.5-1.9				
2.0-2.4				
2.5-2.9				
3.0-3.4				
3.5-3.9				
4.0-4.4				
4.5-4.9				
5.0-5.4				
5.5-5.9				
6.0-6.4				
Not measured				
Totals				
Adult king salmon				
Steelhead rainbow trout				
Pacific lamprey	No fish captured			
Brook lamprey				
Ammocoete (species?)			1	5
American shad				
Sacramento western sucker				
Carp				
Sacramento squawfish		1		
Splittail				
Unidentified minnows		4		1
White catfish				2
Mosquitofish				
Largemouth bass				
Green sunfish				
Warmouth				
Tule perch			1	
Sculpin (species?)		1		4
Threespine stickleback		14		
Tadpole		2		16
Crayfish		1		1

[3] Combined catch of two nets.

TABLE A-3—Continued

Sacramento River, Diversion Sampling: Number of Fish Trapped in the Canal During the 1953 Irrigation Season

Species of fish captured (common name)	Hollis Sartain	Azro N. Lewis	Roger Wilbur 95.25 L[4]	Roger Wilbur 87.4 R[5]
	July 29-30	Aug. 10-13	July 28-30	July 27-28
King salmon (Fork length in inches)				
1.0-1.4				
1.5-1.9				
2.0-2.4				
2.5-2.9				
3.0-3.4				
3.5-3.9				
4.0-4.4				
4.5-4.9				
5.0-5.4				
5.5-5.9				
6.0-6.4				
Not measured				
Totals				
Adult king salmon				
Steelhead rainbow trout				
Pacific lamprey	No fish captured		No fish captured	
Brook lamprey				
Ammocoete (species?)				
American shad				
Sacramento western sucker		1		
Carp		43		1
Sacramento squawfish				
Splittail				
Unidentified minnows				
White catfish				
Mosquitofish				
Largemouth bass				
Green sunfish		4		
Warmouth				
Tule perch				
Sculpin (species?)				1
Threespine stickleback				
Tadpole				
Crayfish				

[4] Not enough velocity to make a good set; periodic water changing among ditches.
[5] Entire discharge sampled.

TABLE A-3—Continued

Sacramento River, Diversion Sampling: Number of Fish Trapped in the Canal During the 1953 Irrigation Season

Species of fish captured (common name)	Wayne Hall	Meridian Farms Water Company No. 1 and No. 2	Olive Percy Davis et al. 78.75 R	Robert Chesney J. H. Yates Estate[6]
	July 14-17	July 15-17	Aug. 10-13	July 14-17
King salmon (Fork length in inches)				
1.0-1.4				
1.5-1.9				
2.0-2.4				
2.5-2.9				
3.0-3.4				
3.5-3.9				
4.0-4.4				
4.5-4.9				
5.0-5.4				
5.5-5.9				
6.0-6.4				
Not measured				
Totals				
Adult king salmon				
Steelhead rainbow trout				
Pacific lamprey		1		
Brook lamprey		1		
Ammocoete (species?)		1		
American shad				
Sacramento western sucker	5	1	2	1
Carp	7	4		23
Sacramento squawfish	2	1		1
Splittail			1	
Unidentified minnows		1	2	
White catfish	3	1		120
Mosquitofish				
Largemouth bass				
Green sunfish	2	1	34	2
Warmouth				
Tule perch			2	
Sculpin (species?)			2	1
Threespine stickleback				
Tadpole				
Crayfish	27	25		10

[6] These pumps discharge into the same basin, both pumps were operating during sampling.

TABLE A-3—Continued

Sacramento River, Diversion Sampling: Number of Fish Trapped in the Canal During the 1953 Irrigation Season

Species of fish captured (common name)	Meridian Farms Water Company No. 3	Meridian Farms Water Company No. 4[7]	Faxon, Morton and P. Andreotti	J. L. Browning[8]
	July 15-17	Aug. 10-13	July 27-30	July 28
King salmon (Fork length in inches)				
1.0-1.4				
1.5-1.9				
2.0-2.4				
2.5-2.9				
3.0-3.4				
3.5-3.9				
4.0-4.4				
4.5-4.9				
5.0-5.4				
5.5-5.9				
6.0-6.4				
Not measured				
Totals				
Adult king salmon		22		
Steelhead rainbow trout		1		
Pacific lamprey				
Brook lamprey				
Ammocoete (species?)				
American shad				
Sacramento western sucker			1	
Carp			1	
Sacramento squawfish				
Splittail				
Unidentified minnows			1	
White catfish				
Mosquitofish				
Largemouth bass				
Green sunfish				
Warmouth				
Tule perch	1	2	1	
Sculpin (species?)				
Threespine stickleback				
Tadpole				
Crayfish			1	

No fish captured

[7] An estimated 60-70 dead salmonids (6-24 inches in length) observed in ditch August 10-12, 1953.
[8] Only the 14-inch pump operated during sampling.

TABLE A-3—Continued

Sacramento River, Diversion Sampling: Number of Fish Trapped in the Canal During the 1953 Irrigation Season

Species of fish captured (common name)	Newhall Land and Farming Company	Natomas Central Mutual Water Company
	July 14-17	Aug. 18-19
King salmon (fork length in inches)		
1.0-1.4		
1.5-1.9		
2.0-2.4		
2.5-2.9		
3.0-3.4		
3.5-3.9		
4.0-4.4		
4.5-4.9		
5.0-5.4		
5.5-5.9		
6.0-6.4		
Not measured		
Totals		
Adult king salmon		
Steelhead rainbow trout		
Pacific lamprey		
Brook lamprey		
Ammocoete (species ?)	2	
American shad		1
Sacramento western sucker		
Carp		
Sacramento squawfish	16	1
Splittail		
Unidentified minnows	39	
White catfish	2	2
Mosquitofish		
Largemouth bass		
Green sunfish	1	
Warmouth		1
Tule perch		
Sculpin (species?)	1	
Threespine stickleback		
Tadpole	1	
Crayfish	1	

TABLE A-4

Sacramento River; Olive Percy Davis et al. Diversion, 78.8 R *: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9	2												2
2.0-2.4	3	17	1										21
2.5-2.9	6	18	6					1					31
3.0-3.4	3	25	11	3	15	1	1						59
3.5-3.9		8	16	14	36	12	4	1					91
4.0-4.4		2	4	8	9	9	12	1					45
4.5-4.9				2	1	2	1	1	1				8
5.0-5.4		1	1				1						3
Not measured	1	17	3	9	7	3			3				43
Totals	15	88	42	36	68	27	19	4	4				303
Adult king salmon										1			1
Steelhead rainbow trout	3	11	1		4				1				20
Pacific lamprey	7	8	1	9	80	21	6	8	2				145
Brook lamprey	58	150	41	3	7								259
Ammocoete (species?)	5	1					1						7
White sturgeon		2			1								3
American shad													
Sacramento western sucker	1	4	7	1	6		17	4	17	14			71
Carp	30	164	2	46	234	198	127	80	34	18			933
Sacramento blackfish													
Sacramento hitch					1								1
Sacramento squawfish	1	7											8
Splittail													
Unidentified minnows	8	152	3	17	330	392	36	17	13	3			971
Channel catfish						2	1	3					6
White catfish	7	24	8	14	68	42	24	11	3	10			211
Brown bullhead		1				11		1					13
Mosquitofish					1								1
Striped bass		1						1					2
Largemouth bass	3	97		1	45		2	3	2	6			159
Green sunfish	1	8	2	2	3	973	112	15	48	6			1,170
Bluegill													
Black crappie					9		1						10
Tule perch		2		1	4				1				8
Sculpin (species?)			1		22	50	35	4	3				115
Tadpole		7			3	1			1				12
Crayfish		11	6		4	2	2	1	1				27

* Mile and bank above Sacramento.

TABLE A-5

Sacramento River; Meridian Farms Water Company No. 1 and No. 2 Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 28–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9	1												1
2.0-2.4	11												11
2.5-2.9	8	1			1								10
3.0-3.4		2	1		2								5
3.5-3.9													
4.0-4.4													
4.5-4.9													
5.0-5.4													
Not measured	1				3								4
Totals	21	3	1		6								31
Adult king salmon		1			1	1	1	2	1	2	1		10
Steelhead rainbow trout	4					3		1	1				9
Pacific lamprey	10	1	1	1	16	7	7	3					46
Brook lamprey	185	28	13	5	5	1							237
Ammocoete (species?)	4	5	2	6	9	1	3	6	1	2			42
White sturgeon													
American shad													
Sacramento western sucker	3		1	1	1	2	1	1	9	3			22
Carp	13	10	3	506	127	68	15	10	15	9	2		817
Sacramento blackfish	1	1		8	5	3							18
Sacramento hitch							1		2	1	11		15
Sacramento squawfish	1			1									
Splittail						1							5
Unidentified minnows	5	1	1		2	2	6	2		1	1		1
Channel catfish		2	1	1	1	2		3					21
White catfish	35	27	11	19	128	69	90	59	23	29	19		10
Brown bullhead	3	1			10	188	7			4	2		509
Mosquitofish													245
Striped bass		52		2	1				1				56
Largemouth bass	7	50			4						1		71
Green sunfish	7	1		2	2	2	2	2		2			20
Bluegill	1												1
Black crappie			1	1									2
Tule perch	6	2		3	8	1	3	4	3	5			35
Sculpin (species?)	6	1	2	5	11	3	4	2	2	2			38
Tadpole	1	9	2	1	2						1		16
Crayfish	62	99	70	158	290	91	64	92	91	47	11		1,075

TABLE A-6

Sacramento River; St. Patrick Home Ranch Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	Mar. 1–13	Mar. 14–27	Mar. 28–Apr. 10	Apr. 11–24	Apr. 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4	202	24			21								247
1.5-1.9	438	126			32								596
2.0-2.4	9	7											16
2.5-2.9	1	1				2							4
3.0-3.4													
3.5-3.9													
4.0-4.4	2												2
4.5-4.9													
5.0-5.4													
Not measured	389	11			1								401
Totals	1,041	169			51	2							1,266
Adult king salmon	1												1
Steelhead rainbow trout	1				1								2
Pacific lamprey	10	15			2								27
Brook lamprey	5												5
Ammocoete (species?)	32	4			4	11							51
White sturgeon													
American shad													
Sacramento western sucker	11				2	8				1			22
Carp						4				3			7
Sacramento blackfish													
Sacramento hitch	1												1
Sacramento squawfish	2												2
Splittail													
Unidentified minnows													
Channel catfish													
White catfish	1					21				11	1		34
Brown bullhead	1												1
Mosquitofish													
Striped bass										2			2
Largemouth bass													
Green sunfish		1											1
Bluegill													
Black crappie													
Tule perch	3					7				1			11
Sculpin (species?)	8	1			1	3				2	1		16
Tadpole													
Crayfish	2					8				5	3		18

TABLE A-7

Sacramento River; Wayne Hall Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9													
2.0-2.4													
2.5-2.9													
3.0-3.4													
3.5-3.9													
4.0-4.4													
4.5-4.9													
5.0-5.4													
Not measured				1									1
Totals				1									1
Adult king salmon													
Steelhead rainbow trout													
Pacific lamprey													
Brook lamprey													
Ammocoete (species?)					1		2		1	3	2		9
White sturgeon													
American shad													
Sacramento western sucker				1	45	113	23	4	4	16	1		207
Carp				49	11	9	2	39	12	14	110	9	255
Sacramento blackfish								1		10	1		12
Sacramento hitch								2					2
Sacramento squawfish								1					1
Splittail													
Unidentified minnows				60	32	87	2	19	8		4		212
Channel catfish													
White catfish				13	19	21	3	7	2	1	5	2	73
Brown bullhead					7	8	1		1		1		18
Mosquitofish													
Striped bass													
Largemouth bass				4	1			13	11	5	3		37
Green sunfish											1	5	6
Bluegill													
Black crappie									1				1
Tule perch				3	4	1		4					12
Sculpin (species?)				3	2		1	3	2	3			14
Tadpole							1						1
Crayfish				62	81	50	19	31	46	43	58	16	406

TABLE A-8

Sacramento River; Olive Percy Davis et al. Diversion, 78.75 R *: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9													
2.0-2.4													
2.5-2.9													
3.0-3.4				2									2
3.5-3.9				11									11
4.0-4.4				4									4
4.5-4.9													
5.0-5.4													
Not measured		1											1
Totals		1		17									18
Adult king salmon													
Steelhead rainbow trout													
Pacific lamprey		4											4
Brook lamprey	9	37		1									47
Ammocoete (species?)		1											1
White sturgeon													
American shad													
Sacramento western sucker		1		1									2
Carp		31											31
Sacramento blackfish													
Sacramento hitch													
Sacramento squawfish													
Splittail													
Unidentified minnows	3			1									4
Channel catfish													
White catfish		2		3									5
Brown bullhead													
Mosquitofish													
Striped bass		61											61
Largemouth bass		23											23
Green sunfish		4											4
Bluegill													
Black crappie													
Tule perch		2											2
Sculpin (species?)													
Tadpole		3											3
Crayfish		3		3									6

* Mile and bank above Sacramento.

TABLE A-9

Sacramento River; Meridian Farms Water Company No. 3 Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9		1											1
2.0-2.4													
2.5-2.9													
3.0-3.4													
3.5-3.9													
4.0-4.4													
4.5-4.9													
5.0-5.4													
Not measured	1												1
Totals	1	1											2
Adult king salmon													
Steelhead rainbow trout													
Pacific lamprey													
Brook lamprey	1												1
Ammocoete (species?)	3	3	1			2	3	1					13
White sturgeon													
American shad													
Sacramento western sucker								2	2	1			5
Carp	1	7	8	13	8	1	1						39
Sacramento blackfish													
Sacramento hitch													
Sacramento squawfish													
Splittail													
Unidentified minnows		4	6	6	4	1							21
Channel catfish													
White catfish		1		1	4	9	1	3	1				20
Brown bullhead							6	1	3				10
Mosquitofish							1						1
Striped bass		65											65
Largemouth bass	6	11	1	1	4			1					54
Green sunfish	1	22	18		1	1							43
Bluegill	1												1
Black crappie		36	21	17	3			1					78
Tule perch		1	2	12	3		1	1	1				21
Sculpin (species?)	3	2	1	3	2		1	2	1		1		16
Tadpole	4	19	12	9	3								47
Crayfish	4	15	9	20	18	2	4	5	1	1			79

TABLE A-10

Sacramento River; Meridian Farms Water Company No. 4 Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9													
2.0-2.4													
2.5-2.9		1											1
3.0-3.4													
3.5-3.9													
4.0-4.4													
4.5-4.9													
5.0-5.4													
Not measured		1											1
Totals		2											2
Adult king salmon													
Steelhead rainbow trout													
Pacific lamprey	1	1											2
Brook lamprey	31	6											40
Ammocoete (species?)	3	1											4
White sturgeon													
American shad													
Sacramento western sucker		1											1
Carp		5											5
Sacramento blackfish													
Sacramento hitch													
Sacramento squawfish		1											1
Splittail													
Unidentified minnows		6											6
Channel catfish													
White catfish	11	4											15
Brown bullhead		2											2
Mosquitofish													
Striped bass		3											3
Largemouth bass		24											24
Green sunfish		2											2
Bluegill													
Black crappie													
Tule perch	4	1											5
Sculpin (species?)	6												6
Tadpole		3											3
Crayfish	9	11											20

TABLE A-11

Sacramento River; Hoffman, Beckley, Ritchie, Poundstone, and Andreotti Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	Mar. 28–April 10	April 11-24	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9													
2.0-2.4													
2.5-2.9													
3.0-3.4							1						1
3.5-3.9													
4.0-4.4									1				1
4.5-4.9													
5.0-5.4									1				1
Not measured													
Totals							1		2				3
Adult king salmon													
Steelhead rainbow trout								1		1			2
Pacific lamprey													
Brook lamprey		2											2
Ammocoete (species?)							1						1
White sturgeon													
American shad													
Sacramento western sucker						5	5			2	5	6	33
Carp						5	9	5	2	3	2	2	28
Sacramento blackfish											2		2
Sacramento hitch											39	17	56
Sacramento squawfish													
Splittail											1		1
Unidentified minnows						5	303	9	24	47	22		410
Channel catfish								2		1		1	4
White catfish						14	24	19	25	41	15	5	143
Brown bullhead						1	1			2	1	2	7
Mosquitofish											1		1
Striped bass													
Largemouth bass							3		1			1	5
Green sunfish													
Bluegill													
Black crappie						1							1
Tule perch						1	2	2		1	8	1	15
Sculpin (species?)							9			1	2	1	13
Tadpole							3						3
Crayfish		1				16	31	8	23	22	19		120

TABLE A-12

Sacramento River; Faxon, Morton, and P. Andreotti Diversion: Number of Fished Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9													
2.0-2.4													
2.5-2.9													
3.0-3.4													
3.5-3.9													
4.0-4.4													
4.5-4.9													
5.0-5.4													
Not measured													
Totals													
Adult king salmon													
Steelhead rainbow trout									1				1
Pacific lamprey													
Brook lamprey													
Ammocoete (species?)				5	7	2	5	4	3				26
White sturgeon													
American shad					2								2
Sacramento western sucker							2	2	27	1			32
Carp				25	57	12	9	5	3				111
Sacramento blackfish					2								2
Sacramento hitch										1			1
Sacramento squawfish													
Splittail													
Unidentified minnows				1	1		3		1	1			7
Channel catfish													
White catfish				1	15	7	9	3	2				37
Brown bullhead													
Mosquitofish													
Striped bass					4		1						5
Largemouth bass					1								1
Green sunfish				1	1	1							3
Bluegill													
Black crappie													
Tule perch				2	10		8	3	13				36
Sculpin (species?)					3	2	1	1	1	2			10
Tadpole				1									1
Crayfish				1	42	18	23	31	22	6			143

TABLE A-13

Sacramento River; Tisdale Irrigation and Drainage Company Diversion, 67.1 L*: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9													
2.0-2.4													
2.5-2.9													
3.0-3.4													
3.5-3.9													
4.0-4.4													
4.5-4.9													
5.0-5.4													
Not measured													
Totals													
Adult king salmon													
Steelhead rainbow trout	2												2
Pacific lamprey													
Brook lamprey	1		1										2
Ammocoete (species?)	4	1											5
White sturgeon													
American shad													
Sacramento western sucker													
Carp	1	18	14	10									43
Sacramento blackfish													
Sacramento hitch													
Sacramento squawfish													
Splittail													
Unidentified minnows	39	2		1									42
Channel catfish													
White catfish	2	1											3
Brown bullhead													
Mosquitofish													
Striped bass		62											62
Largemouth bass	4	11											15
Green sunfish				1									1
Bluegill		8											8
Black crappie		3	10										13
Tule perch			1										1
Sculpin (species?)		1											1
Tadpole			1	1									2
Crayfish			1										1

* Mile and bank above Sacramento.

TABLE A-14

Sacramento River; Sutter Mutual Water Company Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9													
2.0-2.4					1								1
2.5-2.9			9	1									10
3.0-3.4			12	2	1	1							16
3.5-3.9			3	2		1							6
4.0-4.4							1						1
4.5-4.9									1				1
5.0-5.4													
Not measured			3	1		3	1	1					9
Totals			27	6	2	5	2	1	1				44
Adult king salmon													
Steelhead rainbow trout													
Pacific lamprey													
Brook lamprey			13	1									14
Ammocoete (species?)			6	1			4		2				13
White sturgeon													
American shad													
Sacramento western sucker							1		6				7
Carp			1	58	27	30	41	19	17		1		194
Sacramento blackfish				3					1		1		5
Sacramento hitch													
Sacramento squawfish					1								1
Splittail													
Unidentified minnows			2	8	1	1	5						17
Channel catfish													
White catfish			4	1	1	2	7	2	1				18
Brown bullhead													
Mosquitofish													
Striped bass													
Largemouth bass			1		1	3			1		1		7
Green sunfish				8	5	3	10	1	3				30
Bluegill				1		1							2
Black crappie				2				1			1		4
Tule perch			1	15	11	2	4	3	1		1		38
Sculpin (species?)			1				2						3
Tadpole			5	1			2						8
Crayfish			2	27	122	63	65	46	17				342

TABLE A-15

Sacramento River; W. A. Larner Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9													
2.0-2.4													
2.5-2.9			1										1
3.0-3.4													
3.5-3.9													
4.0-4.4													
4.5-4.9													
5.0-5.4													
Not measured				1									1
Totals			1	1									2
Adult king salmon													
Steelhead rainbow trout													
Pacific lamprey		1											
Brook lamprey			1	5					1				2
Ammocoete (species?)			3	2	6		1						6
White sturgeon													12
American shad													
Sacramento western sucker											1		1
Carp		3	3	28	3	3					14	2	56
Sacramento blackfish					1								1
Sacramento hitch													
Sacramento squawfish													
Splittail													
Unidentified minnows				4	3								7
Channel catfish											1		1
White catfish		4	6	22	10	10	7	25	3		1		88
Brown bullhead							1						1
Mosquitofish													
Striped bass					1	1	1						3
Largemouth bass		32	1		2								35
Green sunfish		2	2	1	5		1	2	1		1	2	17
Bluegill				1									1
Black crappie													
Tule perch			10	23	14	4	2	2	1	1	2		59
Sculpin (species?)					1								1
Tadpole			1	1									2
Crayfish		18	28	54	65	24	32	34	20	10	20	4	309

TABLE A-16

Sacramento River; Thousand Acre Ranch (H. W. Keller) Diversion: Number of Fish Trapped in the Canal During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 25–May 8	May 9–22	May 23–June 5	June 6–19	June 20–July 3	July 4–17	July 18–31	Aug. 1–14	Aug. 15–28	Aug. 29–Sept. 11	Sept. 12–25	Sept. 26–Oct. 9	Seasonal total
King salmon (Fork length in inches)													
1.0-1.4													
1.5-1.9	3												3
2.0-2.4													
2.5-2.9	1												1
3.0-3.4													
3.5-3.9													
4.0-4.4													
4.5-4.9													
5.0-5.4													
Not measured													
Totals	4												4
Adult king salmon													
Steelhead rainbow trout													
Pacific lamprey	5												5
Brook lamprey	4												4
Ammocoete (species?)													
White sturgeon													
American shad													
Sacramento western sucker													
Carp			15										15
Sacramento blackfish													
Sacramento hitch			1										1
Sacramento squawfish													
Splittail													
Unidentified minnows	3	4	1										8
Channel catfish													
White catfish	2												2
Brown bullhead													
Mosquitofish													
Striped bass		1											1
Largemouth bass													
Green sunfish		1											1
Bluegill	1												1
Black crappie													
Tule perch													
Sculpin (species?)	1												1
Tadpole													
Crayfish													

TABLE A-17

Sacramento River; Diversion Sampling: Number of Fish Trapped in the Canals During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	Reclamation District No. 1004	Charles W. Welch	Nettie, George and Ella Packer		Mayfair Packing Company	Howell Davis
	Apr. 25-May 8	Apr. 25-May 8	May 9-22	May 23-June 5	Sept. 26-Oct. 9	July 4-17
King salmon (Fork length in inches)						
1.0-1.4						
1.5-1.9	2					
2.0-2.4	1					
2.5-2.9	1			1		
3.0-3.4						
3.5-3.9						
4.0-4.4						
4.5-4.9						
5.0-5.4						
Not measured	1	2				
Totals	5	2		1		
Adult king salmon						
Steelhead rainbow trout						
Pacific lamprey	1					
Brook lamprey	1					
Ammocoete (species?)	2	1	25	7		
White sturgeon						
American shad						
Sacramento western sucker	1					
Carp	1	7		1		
Sacramento blackfish						
Sacramento hitch						
Sacramento squawfish		1				
Splittail						
Unidentified minnows		2				
Channel catfish						
White catfish	2		3			
Brown bullhead		2				
Mosquitofish						
Striped bass						
Largemouth bass			1			
Green sunfish		5	1			
Bluegill		1	1			
Black crappie						
Tule perch	1				1	1
Sculpin (species?)	3	1	2	1		
Tadpole	4	2	5	1		
Crayfish	2		2		1	1

TABLE A-17—Continued

Sacramento River; Diversion Sampling: Number of Fish Trapped in the Canals During the 1954 Irrigation Season by Two-week Periods

Species of fish captured (common name)	J. H. Yates Estate	Newhall Land and Farming Company	Tisdale Irrigation and Drainage Company 64.4 L*			Sacramento River Ranch
	May 9-22	Apr. 25-May 8	May 23-June 5	Aug. 15-28	Sept. 12-25	May 9-22
King salmon (Fork length in inches)						
1.0-1.4						
1.5-1.9						
2.0-2.4						
2.5-2.9						3
3.0-3.4						1
3.5-3.9						1
4.0-4.4						
4.5-4.9						
5.0-5.4						
Not measured						2
Totals						7
Adult king salmon		1				
Steelhead rainbow trout						2
Pacific lamprey		3				1
Brook lamprey		39				
Ammocoete (species?)			2			
White sturgeon						
American shad						2
Sacramento western sucker						
Carp		10				9
Sacramento blackfish						
Sacramento hitch						
Sacramento squawfish						
Splittail						
Unidentified minnows		6				
Channel catfish						
White catfish	1	7	1		1	2
Brown bullhead		3				
Mosquitofish						
Striped bass	1	1				
Largemouth bass		5				1
Green sunfish						
Bluegill						
Black crappie						
Tule perch	1					
Sculpin (species?)		3				
Tadpole						
Crayfish		14	10	3	10	

* Mile and bank above Sacramento.

TABLE A-18

Sacramento River; Diversion Sampling: Number of Fish Trapped in Canals During the 1955 Irrigation Season by Two-week Periods

Species of fish captured (common name)	L. W. Seaver 99.3 R*	Meridian Farms Water Company No. 1 and No. 2, 80.0 L*	
	Mar. 6-19	Mar. 20-Apr. 2	Apr. 3-16
King salmon (Fork length in inches)			
1.0-1.4	2	1	
1.5-1.9		2	
2.0-2.4		1	
2.5-2.9		2	
3.0-3.4			
3.5-3.9		1	
4.0-4.4			
4.5-4.9			
5.0-5.4			
Not measured			
Totals	2	7	
Adult king salmon			
Steelhead rainbow trout	1		
Pacific lamprey			
Brook lamprey			
Ammocoete (species?)			
White sturgeon			
American shad			
Sacramento western sucker			
Carp		3	5
Sacramento blackfish			
Sacramento hitch			
Sacramento squawfish			
Splittail			
Unidentified minnows			
Channel catfish			
White catfish			
Brown bullhead			
Mosquitofish			
Striped bass			
Largemouth bass			
Green sunfish			
Bluegill			
Black crappie			
Tule perch			
Sculpin (species?)			
Tadpole		7	
Crayfish	3	2	19

* Mile and bank above Sacramento.

TABLE A-19

San Joaquin River; Banta-Carbona Irrigation District: Number of Fish Trapped in the Canal During the 1955 Irrigation Season by Two-week Periods

Species of fish captured (common name)	Mar. 20-April 2	April 3-16	April 17-30	May 1-14	May 15-28	Seasonal total
King salmon (Fork length in inches)						
1.0-1.4	13	1				14
1.5-1.9	58	22				80
2.0-2.4	19	80	18	7		124
2.5-2.9	6	95	24	13		138
3.0-3.4		27	6	2		35
3.5-3.9		1		1		2
4.0-4.4						
4.5-4.9						
5.0-5.4						
5.5-5.9						
6.0-6.4						
Not measured		1				1
Totals	96	227	48	23		394
Steelhead rainbow trout						
Pacific lamprey						
Brook lamprey						
Ammocoete (species?)		10	12			22
American shad		2				2
Smelt (species?)						
Carp				1		1
Splittail						
Unidentified minnows	7	3	2		1	13
Channel catfish						
White catfish	4	8	4	1	4	21
Brown bullhead		2				2
Mosquitofish	1		1			2
Starry flounder						
Striped bass	2	4	1	1		8
Largemouth bass						
Green sunfish	6	8				14
Warmouth						
Bluegill						
Black crappie		5	1	3		9
Tule perch						
Sculpin (species?)						
Threespine stickleback						
Tadpole	2					2
Crayfish						

TABLE A-20

San Joaquin River; El Solyo Water Company: Number of Fish Trapped in the Canal During the 1955 Irrigation Season by Two-week Periods

Species of fish captured (common name)	Mar. 20-April 2	April 3-16	April 17-30	May 1-14	May 15-28	May 29-June 11	Seasonal total
King salmon (Fork length in inches)							
1.0-1.4	14	1					15
1.5-1.9	22	15	4				21
2.0-2.4		8	27				35
2.5-2.9		1	10				11
3.0-3.4			1				1
3.5-3.9			1				1
4.0-4.4							
4.5-4.9							
5.0-5.4							
5.5-5.9							
6.0-6.4							
Not measured		1					1
Totals	36	26	43				105
Steelhead rainbow trout							
Pacific lamprey							
Brook lamprey							
Ammocoete (species?)							
American shad							
Smelt (species?)							
Carp		2	2	4	8		16
Splittail							
Unidentified minnows			2		1		3
Channel catfish							
White catfish	2	1	3		1		7
Brown bullhead							
Mosquitofish	2	5	12				19
Starry flounder							
Striped bass						1	1
Largemouth bass	1						1
Green sunfish	5	2	2		4		13
Warmouth							
Bluegill							
Black crappie			1				1
Tule perch							
Sculpin (species?)		1					1
Threespine stickleback							
Tadpole		2	1				3
Crayfish	2	2	2	1			7

TABLE A-21

San Joaquin River; Patterson Water Company: Number of Fish Trapped in the Canal During the 1955 Irrigation Season by Two-week Periods

Species of fish captured (common name)	Mar. 20-April 2	April 3-16	April 17-30	May 1-14	May 15-28	Seasonal total
King salmon (Fork length in inches)						
1.0-1.4			1			1
1.5-1.9						
2.0-2.4						
2.5-2.9	2	1		1		4
3.0-3.4	10	4				14
3.5-3.9	2					2
4.0-4.4						
4.5-4.9						
5.0-5.4						
5.5-5.9						
6.0-6.4						
Not measured						
Totals	14	5	1	1		21
Steelhead rainbow trout						
Pacific lamprey						
Brook lamprey						
Ammocoete (species?)			1			1
American shad						
Smelt (species?)						
Carp	3				1	4
Splittail	1				1	2
Unidentified minnows	9	2	1		1	13
Channel catfish						
White catfish	9	1	2	6	4	22
Brown bullhead						
Mosquitofish	1					1
Starry flounder						
Striped bass						
Largemouth bass						
Green sunfish	9				2	11
Warmouth						
Bluegill						
Black crappie		1			1	2
Tule perch						
Sculpin (species?)						
Threespine stickleback						
Tadpole		7	3	2	1	13
Crayfish	1		2	2	1	6

TABLE A-22

Sacramento-San Joaquin River Delta; East Contra Costa Irrigation District: Number of Fish Trapped in the Canal During the 1955 Irrigation Season by Two-week Periods

Species of fish captured (common name)	April 3-16	April 17-30	May 1-14	May 15-28	May 29-June 11	June 12-25	Seasonal total
King salmon (Fork length in inches)							
1.0-1.4							
1.5-1.9					2		2
2.0-2.4	1			2	2	2	7
2.5-2.9	4	4	9	24	16	10	67
3.0-3.4	2	16	16	30	23	5	92
3.5-3.9		13	2	3	3		21
4.0-4.4	1	6	1				8
4.5-4.9	2	2					4
5.0-5.4	2	3	1				6
5.5-5.9							
6.0-6.4		1					1
Not measured	2	1	12	4	3	1	23
Totals	14	46	41	63	49	18	231
Steelhead rainbow trout		1	1				2
Pacific lamprey			5				5
Brook lamprey							
Ammocoete (species?)		6		4	3		13
American shad							
Smelt (species?)	5	1			500		506
Carp		2	1	4	10		17
Splittail							
Unidentified minnows	6	1		2	3		12
Channel catfish							
White catfish	15	1	1	2	6		25
Brown bullhead							
Mosquitofish							
Starry flounder		2	2	7	8		19
Striped bass	3	1	1		2		7
Largemouth bass							
Green sunfish	10	7	4	3	10		34
Warmouth							
Bluegill							
Black crappie			1				1
Tule perch							
Sculpin (species?)	3		1	1	4		9
Threespine stickleback	1	1	1	2	2		7
Tadpole							
Crayfish	1						1

TABLE A-23

Sacramento-San Joaquin River Delta; Diversion Sampling: Number of Fish Trapped in Canals During the 1955 Irrigation Season

Species of fish captured (common name)	Contra Costa Canal Bureau of Reclamation		Reclamation District No. 501		Passaglia Brothers		Woodbridge Irrigation District			
	May 29-June 11	June 12-25	May 29-June 11	June 12-25	May 29-June 11	June 12-25	Mar. 20-Apr. 2	Apr. 3-16	Apr. 17-30	May 1-14
King salmon (Fork length in inches)										
1.0-1.4							1			
1.5-1.9										
2.0-2.4		1	4			2		2		
2.5-2.9	5	8	21	5		3				
3.0-3.4		4	12	5		3				
3.5-3.9			1		3	8				
4.0-4.4	1									
4.5-4.9										
5.0-5.4										
5.5-5.9										
6.0-6.4										
Not measured		1								
Totals	6	14	38	10	3	16	1	2		
Steelhead rainbow trout										
Pacific lamprey										
Brook lamprey					8	3				
Ammocoete (species?)							1	7	18	
American shad										
Smelt (species?)	30		10	1	6					
Carp			13		1					
Splittail										
Unidentified minnows			5	2		2				
Channel catfish					1					
White catfish		3	74	18	45	28				
Brown bullhead			5		2	1				
Mosquitofish										
Starry flounder	5									
Striped bass		4	1							
Largemouth bass										
Green sunfish		1	150	2	5	1	6	12	1	1
Warmouth						1				
Bluegill			1							
Black crappie					6					
Tule perch				1						
Sculpin (species?)	2			1						
Threespine stickleback	1									
Tadpole	2						8	1		
Crayfish			11							

TABLE A-24

Butte Creek; Diversion Sampling: Number of Fish Trapped in Canals During the 1957 Irrigation Season

Species of fish captured (common name)	Phelan-Parrott* Irrigation system					Durham Mutual Water Company, Ltd.				
	Jan. 6-19	Jan. 20-Feb. 2	Feb. 3-4	Feb. 17-Mar. 2	Seasonal total	Jan. 6-19	Jan. 20-Feb. 2	Feb. 3-16	Feb. 17-Mar. 2	Seasonal total
King salmon										
1.5-2.0 inches (fork length)		66	21		87			45	160	205
Not measured	31				31					
Totals	31	66	21		118			45	160	205
Pacific lamprey								1		1
Sacramento western sucker	1	3	1		5					
Unidentified minnows	4	45	14		63			2		2
Riffle sculpin			1		1					

* Often referred to as Parrott-Phelan.