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INFLUENCES OF FRESHWATER INFLOW ON CHINOOK SALMON (ONCORHYNCHUS TSHAWYTSCHA) IN THE SACRAMENTO-SAN JOAQUIN ESTUARY

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ABSTRACT

This paper describes present knowledge regarding the influence of freshwater inflow on the survival, abundance, migration and rearing of chinook salmon in the upstream (Delta) portion of the Sacramento-San Joaquin Estuary. Preliminary results indicate that additional inflow at the appropriate time will increase the numbers of fry and juvenile salmon using the estuary and the survival of juveniles in the estuary. Results are based on seine and trawl surveys, salmon collections at water diversion fish screens, and mark-recapture techniques. Flow related concerns for salmon in the estuary stem from 1) water development activities that have altered the distribution of flow resulting in impacts on young and adult migration, and 2) the lack of comprehensive flow standards with which to protect salmon.

Future efforts to better quantify salmon flow needs include long term seine and trawl surveys in both the upper and lower portions of the estuary, as well as intensive, replicated marking experiments done under varied flow conditions and supported by estuarine, ocean and inland recovery programs.

INTRODUCTION

Freshwater inflow is a dominant factor that influences the character of estuaries and in turn their ability to provide for the life history needs of anadromous salmonids that use these systems for migration and rearing.

Chinook salmon and steelhead trout (Salmo gairdneri) are the principal salmonids utilizing the Sacramento-San Joaquin Estuary. On a price-per-pound basis, chinook are the most valuable of the Pacific salmon, and only the Columbia River system produces more than California's Central Valley rivers (California Department of Fish and Game, 1976). These California rivers supply about 75% of the State's ocean commercial catch of over 500,000 chinook and probably contribute a similar fraction to both the ocean and inland sport fishery harvest of more than 125,000 fish annually (Ganssle, 1962; California Department of Fish and Game, 1976).

Specific information documenting the importance of freshwater inflow to chinook salmon while inhabiting the estuary has been limited. Recent studies, designed to define the impacts of water development on the estuary's fish and wildlife resources, have provided new information regarding the importance of freshwater flows to salmon. More information, however, is needed to develop a sound management program that best meets salmon life history needs. These studies have concentrated on the upper (Sacramento-San Joaquin Delta) portion of the estuary (Figure 1). Only recently, (1980), has data, specific to salmon, been collected from the lower (San Francisco-San Pablo Bays) portion of the system.

The purpose of this paper is 1) to summarize our present knowledge of the influences of freshwater inflow to chinook salmon in the Sacramento-San Joaquin Estuary, 2) to describe the methods utilized to obtain this knowledge and 3) to summarize our present estuarine research activities with chinook salmon.

Most of the information discussed within this paper is based upon studies completed, and planned, as part of the co-operative, (Four Agency) Ecological Study Program for the Sacramento-San Joaquin Estuary between the California Department of Fish and Game (CFG), California Department of Water Resources, United States Fish and Wildlife Service and the United States Water and Power Resources Service. While our paper is specific to chinook salmon/flow relationships, a more general review of fishery resources in the Sacramento-San Joaquin System is provided by Herrgesell, et al (1980) in the proceedings of this symposium.

LIFE HISTORY OF CHINOOK SALMON

Chinook salmon are anadromous fish, spawning in fresh water and spending much of their life in saltwater. Eggs are buried in stream gravel associated with rapid current. Depending on water temperature, eggs hatch after approximately 50 to 60 days incubation and the fry move up through and emerge from the gravel in about 30 days. There is considerable variation as to the time of downstream movement with some fish initiating migration as soon as they emerge while others remain upstream for more than a year.

Residence time in the estuary prior to their movement to sea also is variable with some fish using it for rearing while others pass through quickly. Chinock generally remain in the ocean from one to four years. Accompanying maturation, salmon move upstream through the estuary and spawn, usually in the same drainage system from which they hatched as young. Chinook adults die following spawning (for further review see Heubach, 1968; Jensen, 1972, and California Fish and Game, 1976).

Over 90% of the Central Valley's chinook are produced in the Sacramento River system (California Department of Fish and Game, 1976). Four major runs (fall, late fall, winter and spring) identified by the season in which upmigration and spawning occurs, spawn in the Sacramento system (Hallock and Fry, 1967). Figure 2 provides a description of the timing of migration for the fall, winter and spring run. While less well understood, the late fall run appears to follow a similar pattern to that of the fall run, but is approximately a month later. The Sacramento fall run is largest in numbers (140,000 to 300,000 between 1964 and 1977). The San Joaquin River system supports only a fall run. Numbers since 1973 were less than 10,000 fish (Hoopaugh and Knutson, 1979). The assemblage of runs result in salmon inhabiting both the estuary and river habitats in the Central Valley throughout the year.

STUDY AREA

The Sacramento-San Joaquin Estuary is formed by the Sacramento and San Joaquin Rivers joining and flowing through a series of embayments to the Pacific Ocean. These rivers comprise the two major drainage systems of California's Central Valley. The large lowland area formed by the junction of these two rivers is known as the Sacramento-San Joaquin Delta. The Delta is triangular in shape and is bounded by Sacramento on the north, Pittsburg on the west and the easternmost point on the San Joaquin River as shown in Figure 1.

The Delta is composed of 298,660 hectares (738,000 acres) of land and water. There are 1130 kilometers (700 miles) of navigable channels and 30 large, leveed below-sea-level islands. Tidal action occurs to the upstream limit of the Delta. Some Delta channels are edged by narrow stretches of intertidal marsh but most of them have steep banks of mud or riprap. Delta levees are covered by riparian vegetation. Detailed descriptions of both the upper (Delta) and lower (Bays) portions of the estuary are provided by Kelley (1966), Skinner (1962) and Conomos (1979) as well as by Herrgesell, et al (1980) and other authors in the proceedings of this symposium.

WATER DEVELOPMENT

Water development projects in California have caused major changes in the flow patterns within the estuary and the amount of flow entering the ocean. One result of upstream development is that the average annual freshwater flow to the ocean from the Sacramento-San Joaquin system has been halved since the 1800's. Most of the water in the San Joaquin system is captured and utilized in upstream areas, while development on the Sacramento has been designed for both upstream use and the transport of water through the Delta to more southern parts of California. Ninety percent of the freshwater inflow to the estuary is from the Sacramento River.

Presently, water is exported to the south by pumping plants in the southern Delta (Figure 1) operated by the Central Valley Project (CVP) of the Federal Water and Power Resources Service and the State Water Project (SWP) of the California Department of Water Resources. Typical export rates substantially exceed the flow of the San Joaquin River, hence most of the San Joaquin flow goes to the pumps. Remaining export needs are met by diversions from the Sacramento River. A part of the flow from the Sacramento crosses the Delta through channels upstream from the mouth of the San Joaquin. The dimensions of these channels are too small to carry larger flows, so at higher export rates water is drawn up the San Joaquin from its junction with the Sacramento. Such net upstream flows (reverse flows) in the San Joaquin are typical in the spring, except in wet years, and in the summer and fall of all years (Chadwick, et al 1977).

Future water development plans, as authorized under recent state legislation (Senate Bill 200, signed July, 1980), include construction of additional upstream storage reservoirs and a peripheral canal. The Peripheral Canal project is designed to divert water at a maximum of approximately 650 m^3/s (23,000 ft^3/s) from the Sacramento River at Hood and transport it around the eastern edge of the Delta to the pumps in the southern Delta (Figure 1). More detailed discussion of water development in the estuary is provided in Bulletin 76 by the California Department of Water Resources (1978).

Such water development has altered and will continue to alter the character of freshwater inflow to the Sacramento-San Joaquin Estuary. These alterations have the potential to change the survival of chinook salmon and may affect the adult population size. Water development impacts on salmon in more upstream waters have been more obvious, particularly those relating to dam construction where large amounts of spawning and rearing habitat have simply been lost. The operations of Delta water development facilities influence estuarine migrations of young and adults as well as estuarine rearing by juveniles.

RESULTS AND FUTURE STUDIES

Our knowledge concerning the influence of freshwater inflow on chinook salmon populations in the Central Valley has been obtained through observations of the annual and seasonal variation in salmon abundance, migration and survival as the magnitude, distribution and quality of river flow has fluctuated. Changes in the character of freshwater inflow is the result of both variation in natural weather patterns and operations of water development projects in upstream and estuarine waters. Annual and spring variation in the quantity of freshwater inflow to the estuary is primarily influenced by annual weather patterns. Summer inflow is influenced most by project reservoir releases. However, a peripheral canal and additional upstream storage reservoirs would temper both the annual and seasonal inflow variation considerably. The distribution of flow in the various channels of the Delta is presently altered by the design and operation of the state and federal water projects. The quality of inflow is influenced by natural weather patterns and water project operations through their impact on flow magnitude which affects dilution of municipal, agricultural and industrial discharges, particularly in the San Joaquin drainage.

The major goals of our salmon studies are: 1) to define the impacts of water development upon estuarine salmon populations, and 2) to document the water quality requirements (including flow standards) that salmon need to both sustain and enhance their populations. Past experience with striped bass has emphasized that only through long-term efforts can we expect to achieve such goals (Chadwick, 1977). Present Delta water quality standards, set by the State Water Resources Control Board (see Johns, 1980 in the proceedings of this symposium) provide some protection for salmon, but are limited by our incomplete knowledge.

VARIATION IN THE QUANTITY OF FLOW

Fry Migration to the Estuary

Spring seine surveys in the Delta and the resulting weekly abundance index based on the mean number of fish per haul, indicate that peak catches of salmon fry often follow flow increases associated with storm runoff (Figure 3). This information suggests that flow surges influence the numbers of fry that migrate from upper river spawning grounds into the estuary. Hence, increased flow velocities associated with high runoff apparently increase the rate of migration for fry.

Regression analysis indicated that there was a significant relation between the mean monthly index of fry abundance and mean monthly inflow to the Delta, however flow only accounted for 30% of the variation in the abundance index. Data from 1980 appears biased downward since, although it was an extremely high flow year, salmon were observed in San Francisco and San Pablo Bays but these numbers are not reflected in the index. Hence, the number of salmon in the estuary might be more closely related to flow than indicated by the regression. Nevertheless, the total number of fry that potentially migrate to the estuary and rear there prior to their entrance to the sea appears to be influenced by a variety of factors.

Many of these factors appear to be associated with the rivers above the estuary. The number of fry available for estuarine rearing may be influenced by the number of fall spawners (Painter, et al 1977), spawning and incubation flows (Stevens and Miller, CFG, unpublished MS), and the numbers of fish already using upper river rearing habitat as new fry emerge (Reimers, 1968). The low numbers of fry in the Delta during the drought of 1977 and moderate numbers in 1978 (Figure 3) may be primarily due to the poor spawning and incubation flows that existed in the fall of 1976 and 1977, respectively.

Our present and future mark-recapture studies, and seining and trawling surveys emphasize study of the effects of freshwater inflow on fry migrations and comparisons between the survival of estuarine and river reared fry. The latter will help establish the importance of estuarine rearing to adult stock abundance. Fish are marked with adipose fin clips and implanted with coded wire nose tags (CWT), (Jefferts, et al 1963; Opdycke and Zajac, 1980) which have been successfully used with fry as small as 45 mm. Clipping the adipose fin allows for identification later. Releases are being made in the upper river and estuary. Marked juveniles are recovered during our routine seine and trawl surveys in the estuary, and adults by sampling in the ocean fishery and at hatcheries.

Additional studies have been initiated in San Pablo and San Francisco Bays to document the freshwater requirements in the lower estuary. We know that salmon use the bays as a migration route, but the extent of rearing there is unknown. As noted earlier, salmon fry were observed in the central part of San Francisco Bay following large river flows during January and February 1980. Salinities were up to 26 $^{o}/oo$. A release of 50,000 fry, marked with CWT's, was made in the Central Bay during this period. Four of these fish were recovered in the Bay several weeks later. Survival estimates of these fish will be made from data on ocean recoveries beginning in 1981. A portion of the future field work in 1981 by the Four Agency's San Francisco Bay Study Program (see Herrgesell, et al 1980, this symposium for details) is designed to document the distribution and relative abundance of salmon in the Bay via surface trawl and beach seine surveys on a year round basis.

Juvenile Abundance in the Delta

Flows in the upper Sacramento and San Joaquin Rivers during spawning and nursery periods apparently influence the numbers of juvenile chinook surviving to migrate to the Delta. This conclusion is based first on correlations between annual abundance indices for chinook and inflow to the Delta (Stevens and Miller, CFG, unpublished MS). December and January appeared to be the most important months. The abundance indices are based upon catches at the State/Federal fish screens in the south Delta from April to June and from an annual Delta midwater trawl survey (September to December).

Secondly, observations made in the San Joaquin system between 1957 and 1973 indicate that numbers of chinook spawners are influenced by the amount of river flow during the nursery and downstream migration period (March to June) 2½ years earlier (Figure 4). Thus, it appears that flow affects juvenile survival which in turn affects adult abundance. Several factors may cause this relation between abundance and flow. Dams and diversions have reduced flows to near minimum levels in most years in the San Joaquin drainage and the high water temperatures that occur concurrently kill many juvenile salmon (California Department of Fish and Game, 1976). Hence, the earlier these downstream migrants leave the spawning grounds the better their chance of reaching the estuary. Juveniles entering the estuary early in their development may also require additional growth before migrating to salt water which suggests that conditions in the estuary may be important for at least part of the San Joaquin downstream migrants. One major factor in the Delta may be pumping by the State and Federal water projects. Probably a high fraction of the San Joaquin downstream migrants are exposed to the pumping plant screening systems (see later section entitled Juvenile Migration) as most of the San Joaquin flow is diverted during peak outmigration in most years. Poor water quality due to agricultural return flows in the San Joaquin in the fall also may influence the survival of returning adults which may contribute to variation in the numbers of downstream migrants (Figure 4).

Juvenile Survival in the Delta

A regression of estimated juvenile survival rate against river flow suggests that river flow influences chinook survival during downstream migration through the Delta (Figure 5). Survival was estimated during 1969, 1970 and 1971 by comparing ocean return rates from fish marked and released as juveniles in the upper and lower Delta (California Department of Fish and Game, 1976). Estimates for the other years are based on recoveries of juveniles released above the Delta and recaptured by trawling at stations in both the upper and lower Delta. Some of these fish were marked with spray dye (1976-1977), while others by the CWT technique (1978-1980).

Verification of our initial estimates of survival based on trawling recoveries from 1978 to 1980 will be made by comparing ocean catches of fish from the same releases and another "control" release downstream from the Delta in Suisun Bay (Figure 1). Preliminary ocean recoveries obtained from the sport and commercial fisheries in 1979 and 1980 confirmed our initial estimate of survival, close to 0%, in 1978 (Figure 5). Interestingly the 1979 and 1980 ocean CWT recoveries indicate survival of the control group released in Suisun Bay in 1978 was at least 100 times that of the fish released just above the Delta (R. Menchen, CFG, personal communication). Hence, conditions in the Delta, probably were more limiting to juvenile survival than conditions in the lower estuary. We plan to continue to estimate juvenile survival rates using the CWT technique.

ALTERATIONS IN THE DISTRIBUTION OF FRESHWATER FLOW

Juvenile Migration

The most direct evidence of alterations in Delta flow patterns adversely impacting chinook salmon is the occurrence of young salmon at the State/Federal pumping plant fish screens. Records of salmon observed at the screens and respective spring export rates indicate that as exports increase more downstream migrating salmon are drawn to the screens. Before the State project began exporting water, mean monthly exports by the Federal project (CVP) (1959 to 1967) for April through June were 81 m^3/s (2870 ft^3/s) with the mean total catch of salmon for the three months combined, about 113,000 fish. From 1968 to 1979 when both projects (CVP and SWP) were diverting, water exports and salmon collections increased to 132 m^3/s (4670 ft^3/s) and 194,000 fish respectively. The number of salmon observed at the fish screen probably represents less than 5% of the total downstream migration in the system (California Department of Fish and Game, 1976), but a much larger fraction probably is drawn out of their normal migration path as will be discussed below. While many salmon are observed and counted at the fish screen collection facility, an additional 10 to 35% (dependent on size) are lost through the screens (Skinner, 1974). Based on four yearly mark-recapture experiments, an average of 58% also are lost due to handling during the screen salvage process that returns fish to the lower Delta out of the influence of the pumps (R. Menchen, CFG, personal communication). In addition, mark-recapture studies indicated that approximately 96% of the juvenile salmon released in the forebay located just in front of the State project screen (Figure 1) are lost to predation (Hall, 1980).

Additional, but poorly quantified, losses exist in the numerous agricultural, industrial and municipal diversions in the Delta and upstream. Most of these are unscreened and together cause appreciable losses of salmon (Hallock and Van Woert, 1959).

Fish screen studies in the Four Agency program include continued assessment of fish salvaged at the pumping plants in the south Delta and a major effort to develop biological and engineering information required to plan, design, construct, operate and evaluate the Peripheral Canal intake diversion structure and associated fish screen facilities at Hood so as to result in the protection of fisheries exposed to that new diversion.

The alterations in flow distribution caused by drafting increased volumes of water across the Delta to the pumps apparently increases mortality of salmon that do not ever reach the fish screens. In 1976, marked juvenile salmon were released in three areas in the northern Delta to determine how survival of juveniles would be affected by the cross Delta flow pattern. Recoveries were made by trawling in the western Delta near Pittsburg. Results indicate that the highest survival (based on % recovery) occurred for fish released in the Sacramento River and Steamboat Slough system (Figure 6). These two channels represent the most direct route through the Delta and those fish would be least affected by the cross Delta pumping. Fish released in the South Fork of the Mokelumne River (the eastern most route) had the lowest survival and least direct route through the Delta and, along with those released in the North Fork of the Mokelumne River and Georgianna Slough, were on a direct path to the pumping plants. Recoveries were greater for the larger fish of a given release group suggesting that survival rate increases as the migrant size increases regardless of the path of migration.

Adult Migration

Adult migration through the estuary also has been affected by alteration of the Delta flow patterns due to south Delta pumping operations. Adult salmon are guided to their spawning grounds by olfactory perception of "homestream" water (Hasler, 1960). Impacts on San Joaquin stocks were quantified by sonic tagging studies from 1964 to 1967 (Hallock, et al 1970). This work indicated that San Joaquin River spawners were prevented from using some channels normally used for migration due to flow reversals caused by water project pumping in the south Delta.

ALTERATIONS IN THE QUALITY OF FRESHWATER FLOW

Limited information is available in the Sacramento-San Joaquin Estuary to document water quality related impacts on salmon that are associated with freshwater flow. High water temperature and low dissolved oxygen have been shown to adversely influence adult migrations in the San Joaquin near Stockton in the fall (Hallock, et al 1970). Salmon were reluctant to ascend the San Joaquin River near Stockton (Figure 1) when temperature exceeds 19°C (66°F) and are virtually stopped when dissolved oxygen drops below 5 mg/l. Generally the problem is relieved when inflow to the Delta increases in late October or November. The low dissolved oxygen is due to high biological oxygen demand (BOD) most likely caused by high levels of organic materials from suspended organics in the river, sewage treatment plants, effluent discharges and agriculture return flows.

SUMMARY

This paper has provided a review of our current understanding of the influence of river inflow on chinook salmon in the Sacramento-San Joaquin River Estuary. As part of our discussion, we have described the methods used to gain this knowledge and developed hypotheses that link inflow to the survival, abundance, migration and rearing of salmon. We have presented evidence that the quantity, quality, distribution and timing of freshwater inflow in this estuary are potential factors that determine the survival of chinook in the Sacramento-San Joaquin River system.

Many of the present and potential flow related problems for salmon are largely attributed to water development operations both upstream and within the estuary. Management plans have been designed to correct some of these problems.

One plan, the Peripheral Canal with associated fish screen facility, would potentially overcome present problems for salmon resulting from alterations in the distribution of flow. Conversely, there are unknown risks associated with the Peripheral Canal and related upstream storage reservoirs that may impact salmon adversely. Future management actions will attempt to understand these risks and take appropriate measures to lessen the impact on salmon.

Another management plan is to develop and utilize well documented and comprehensive flow standards that protect salmon while in the estuary. While present information indicates that by increasing fresh inflow to the estuary at appropriate times we will see an increase in fry and juvenile abundance and juvenile survival, we do not know what this means for adult stocks. Unfortunately, the demand for water exceeds the supply. Hence, flow standards for salmon compete with other water management goals and they must be well documented.

Our approach to increase knowledge of salmon flow needs in the estuary includes 1) the use of mark-recapture studies using coded wire nose tags to document effects of varied conditions on salmon survival, and to define the relative importance of estuarine rearing, and 2) plans for long-term monitoring throughout the estuary since flow standards need to be based on replicate data sets collected over varied flow conditions. Continuous monitoring also is needed to verify present knowledge and to develop new information so that flow standards can be improved as environmental conditions and salmon populations change.

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FIGURE LEGENDS

FIGURE 1. The Sacramento-San Joaquin Estuary, California.

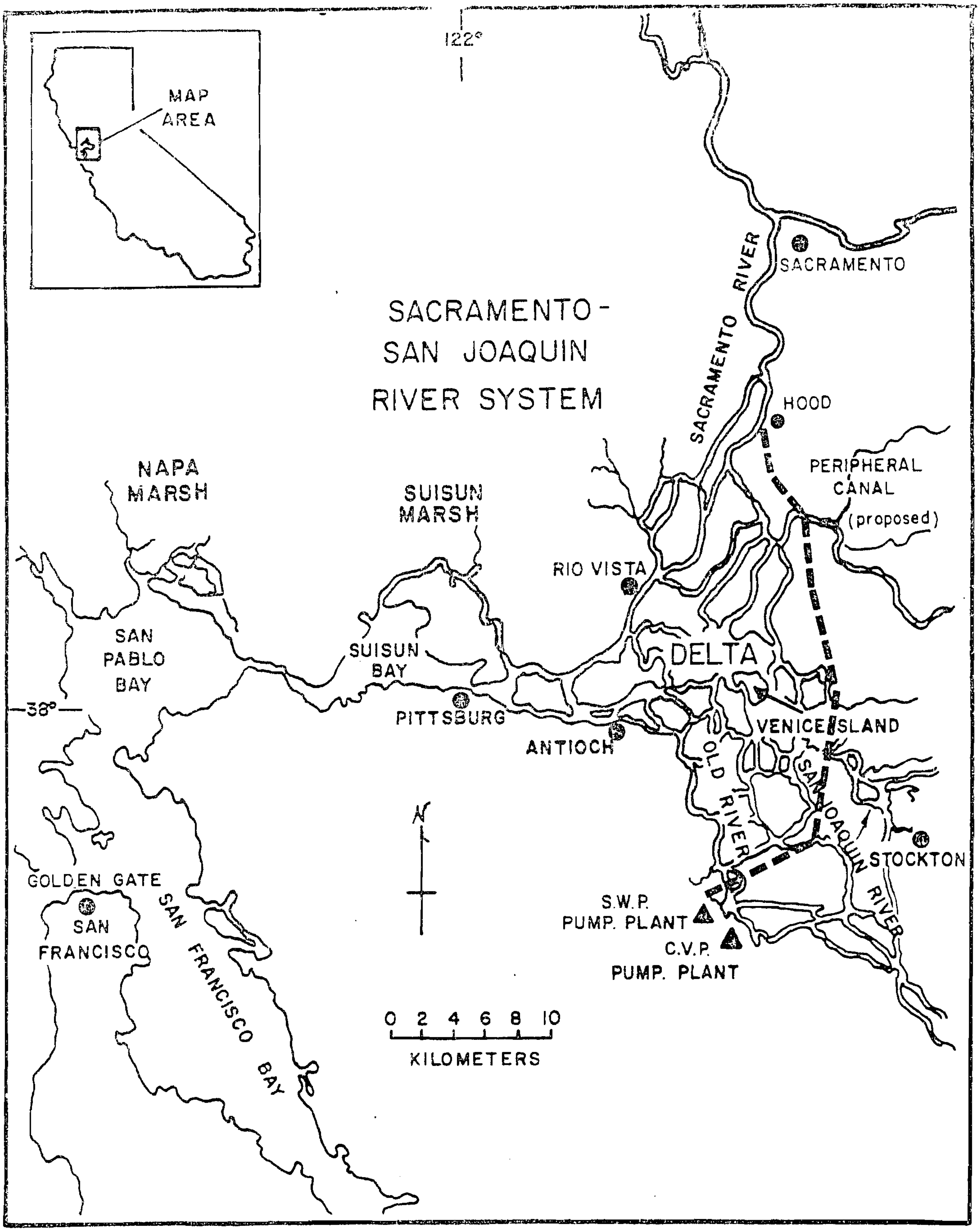
FIGURE 2. Seasonal migrations and spawning periods of three major runs of Sacramento River chinook salmon in the Sacramento-San Joaquin Estuary.

FIGURE 3. Sacramento River inflow to the Sacramento-San Joaquin Delta at Sacramento and chinook salmon seine indices for the years 1974 and 1977 through 1980. The abundance indices for salmon fry were determined by weekly seine surveys throughout the Delta. 1 cfs = 0.03 m^3.

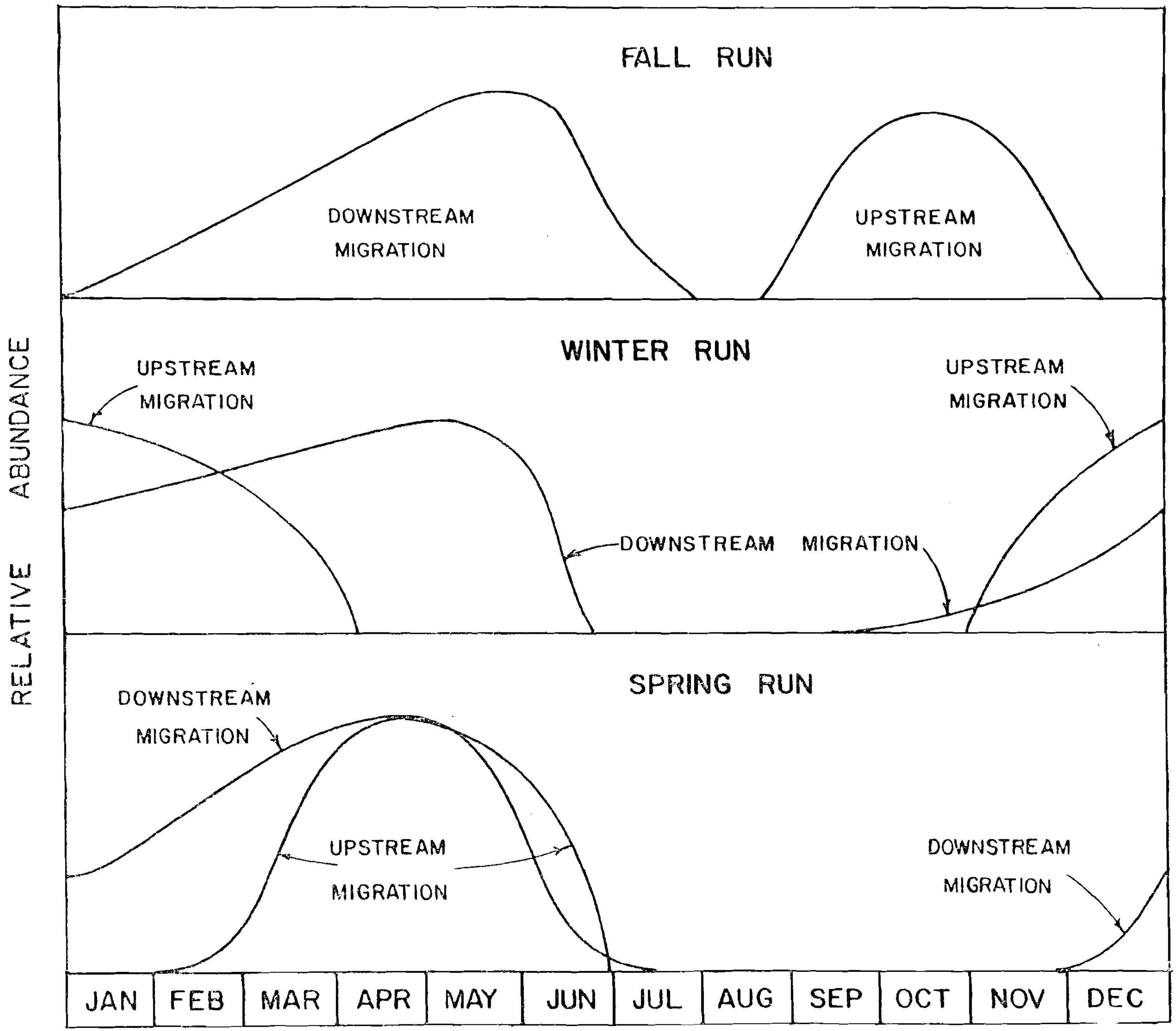
FIGURE 4. Relationship between the total March to June inflow of the San Joaquin River to the Sacramento-San Joaquin Delta (X) and the number of female chinook salmon spawning 2½ years later (Y). Data is from the years 1957 to 1973. The regression equation is $Y = 2.10 + 0.004\ X$; $r^2 = 0.689$. 1 acre foot = 1.233×10^{-3} hectometers^3.

FIGURE 5. Relationship between spring (May or June) inflow to the Sacramento-San Joaquin River Delta at Sacramento (X) and estimated percent survival of marked juvenile chinook salmon as they migrate through the Delta (Y). Numbers adjacent to points indicate the years from 1969-1980. The regression equation is $Y = -0.137 + 0.000036\ X$; $r^2 = 0.762$. 1 cfs = 0.03 m^3.

FIGURE 6. Relationship between percent survival index (Y) and size of marked juvenile chinook salmon released (X) at Sacramento River-Steamboat Slough (Sac. R.); North Fork Mokelumne River-Georgianna Slough (N.F. Mokel. R); and South Fork Mokelumne River (S.F. Mokel. R.) in the Sacramento-San Joaquin Delta. Survival indices are based on recovery of marked fish with a midwater trawl near Pittsburg during November, 1976. The regression equations for the Sacramento River-Steamboat Slough, North Fork Mokelumne River-Georgianna Slough and South Fork Mokelumne River locations are $Y = -0.447 + 0.0049\ X$, $r^2 = 0.64$; $Y = -0.443 + 0.0045\ X$, $r^2 = 0.71$; $Y = -0.246 + 0.0027\ X$, $r^2 = 0.77$, respectively.



SACRAMENTO-
SAN JOAQUIN
RIVER SYSTEM
MAP AREA
122°
38°
SACRAMENTO
SACRAMENTO RIVER
HOOD
PERIPHERAL CANAL (proposed)
NAPA MARSH
SUISUN MARSH
RIO VISTA
SAN PABLO BAY
SUISUN BAY
PITTSBURG
ANTIOCH
DELTA
VENICE ISLAND
OLD RIVER
SAN JOAQUIN RIVER
STOCKTON
S.W.P. PUMP. PLANT
C.V.P. PUMP. PLANT
GOLDEN GATE
SAN FRANCISCO
SAN FRANCISCO BAY
N
0 2 4 6 8 10
KILOMETERS



FALL RUN
DOWNSTREAM MIGRATION
UPSTREAM MIGRATION
WINTER RUN
UPSTREAM MIGRATION
UPSTREAM MIGRATION
DOWNSTREAM MIGRATION
SPRING RUN
DOWNSTREAM MIGRATION
UPSTREAM MIGRATION
DOWNSTREAM MIGRATION
RELATIVE ABUNDANCE
JAN
FEB
MAR
APR
MAY
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JUL
AUG
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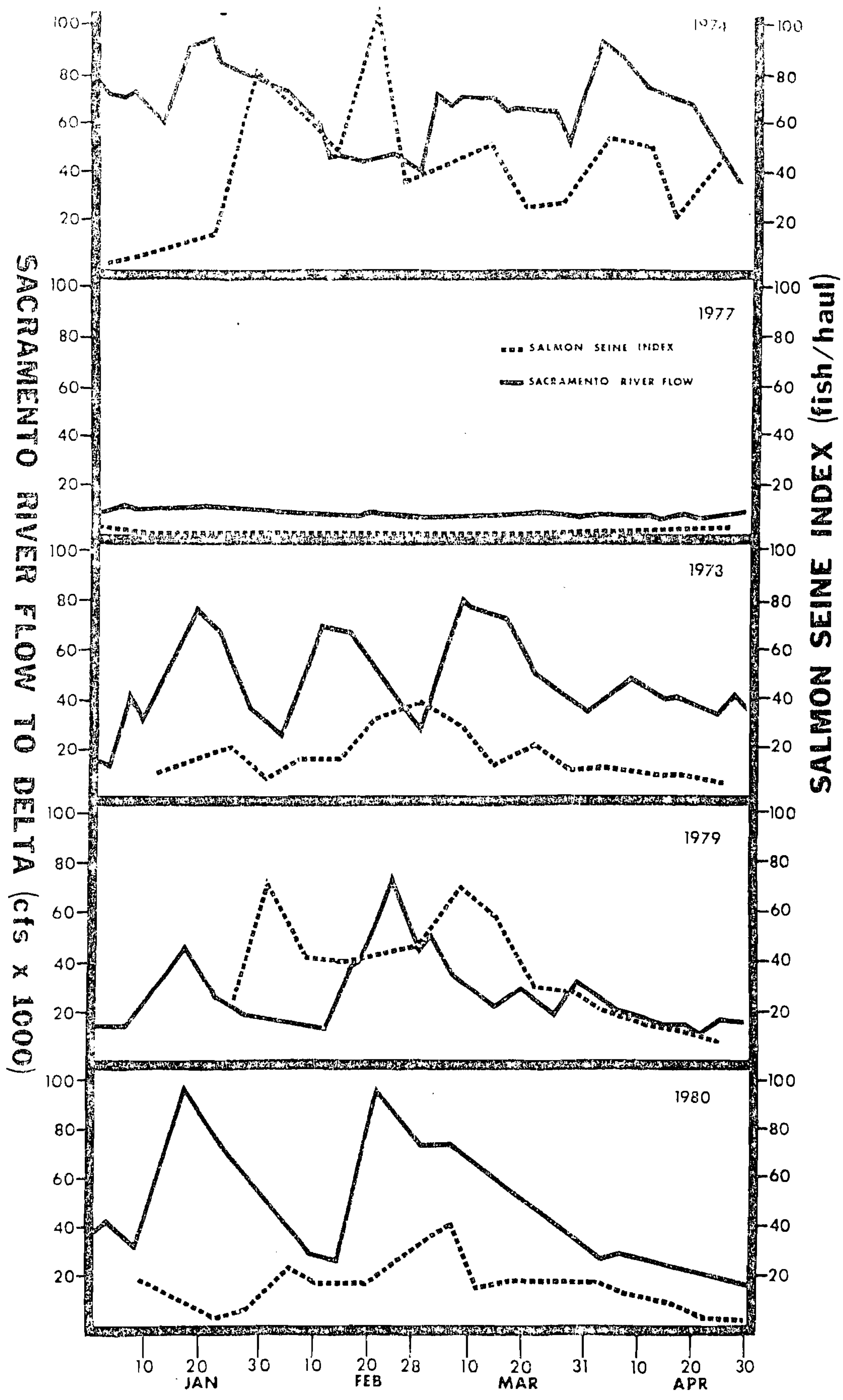
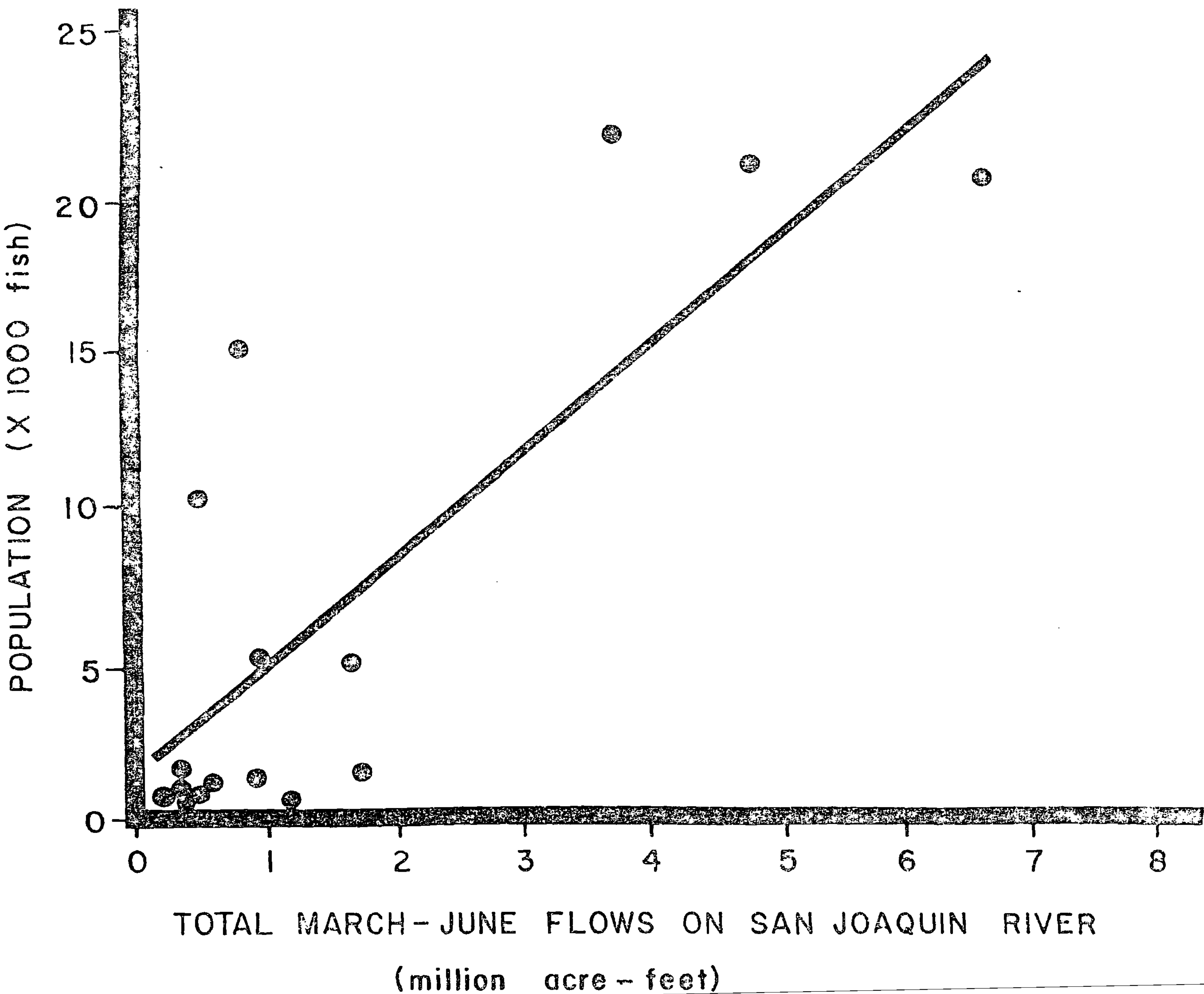
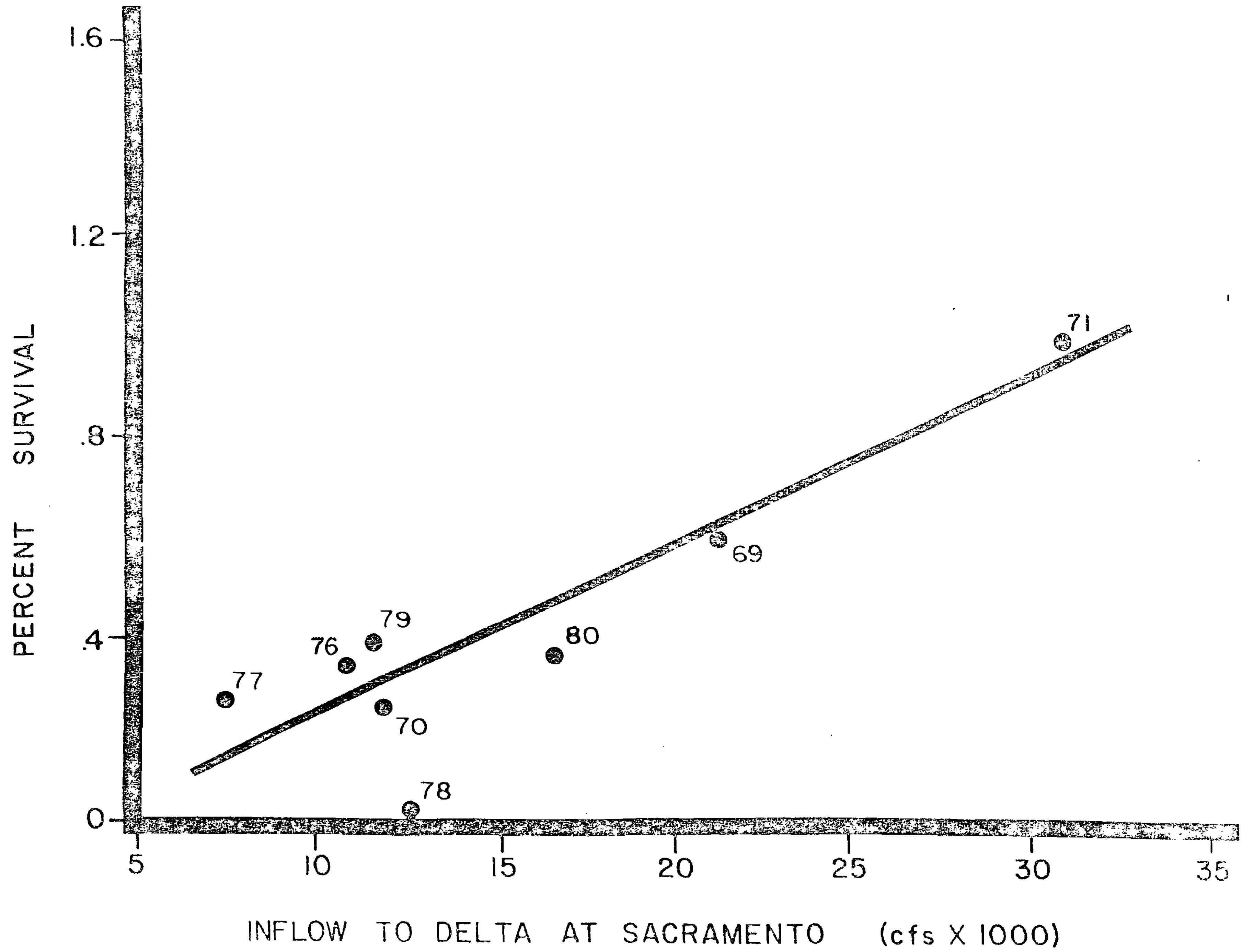
NOV
DEC



SACRAMENTO RIVER FLOW TO DELTA (cfs x 1000)
SALMON SEINE INDEX (fish/haul)
1974
1977
SALMON SEINE INDEX
SACRAMENTO RIVER FLOW
1973
1979
1980
10
20
JAN
30
10
20
FEB
28
10
20
MAR
31
10
20
APR
30



POPULATION (X 1000 fish)
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
TOTAL MARCH-JUNE FLOWS ON SAN JOAQUIN RIVER
(million acre-feet)


1.6
1.2
.8
.4
0
PERCENT SURVIVAL
77
76
79
70
78
80
69
71
5
10
15
20
25
30
35
INFLOW TO DELTA AT SACRAMENTO (cfs X 1000)