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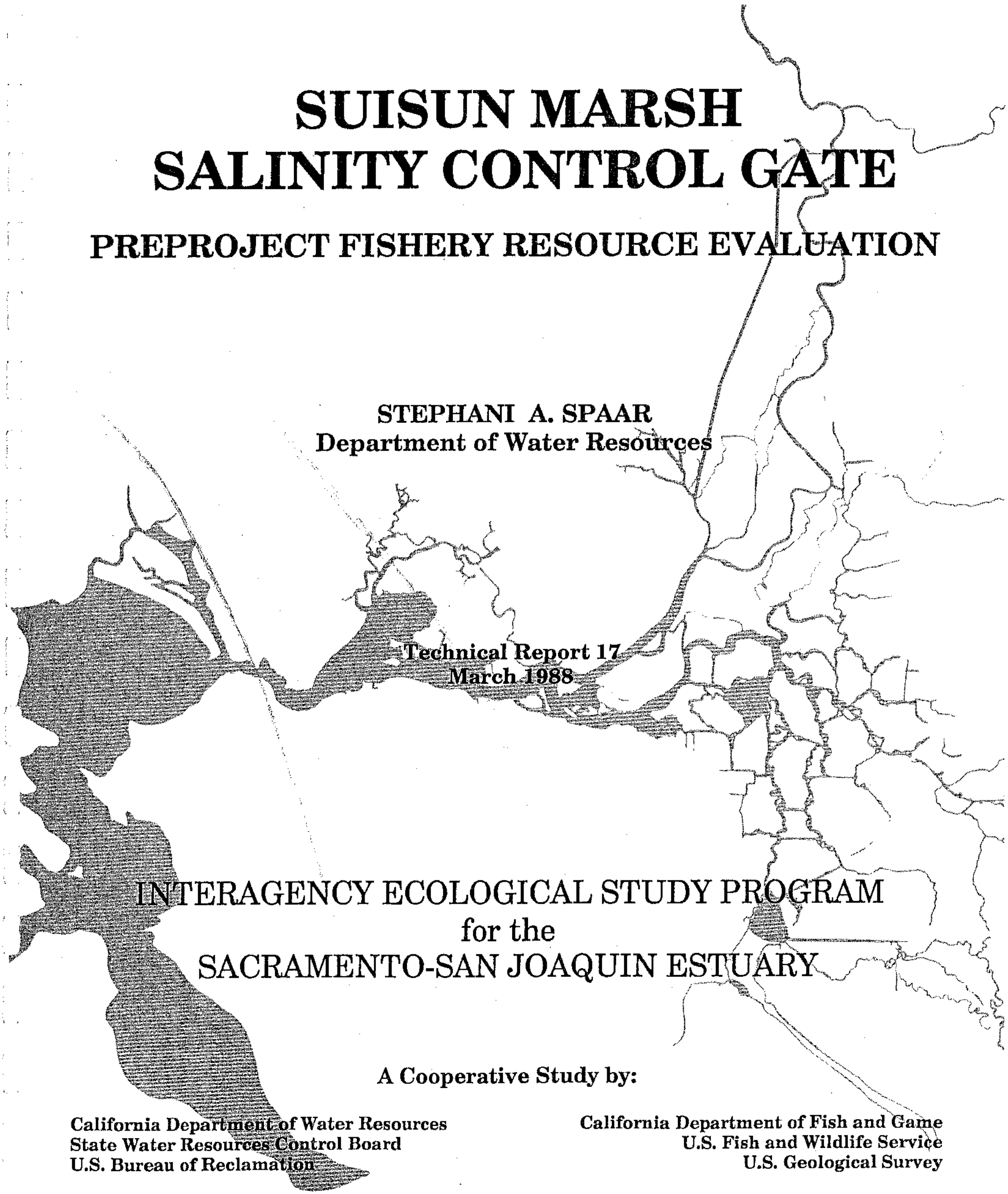
SUISUN MARSH SALINITY CONTROL GATE

PREPROJECT FISHERY RESOURCE EVALUATION

STEPHANI A. SPAAR
Department of Water Resources



Technical Report 17
March 1988

INTERAGENCY ECOLOGICAL STUDY PROGRAM
for the
SACRAMENTO-SAN JOAQUIN ESTUARY

A Cooperative Study by:

California Department of Water Resources
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ORGANIZATION

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Chapter 1. INTRODUCTION

Located west of the confluence of the Sacramento and San Joaquin rivers in the San Francisco Bay estuary, Suisun Marsh is one of the largest estuarine marshes in the United States. It has 57,000 acres of managed marshland and 28,000 acres of intertidal bays and sloughs (California Department of Water Resources 1978) (Figure 1). The marsh is a major wintering area for waterfowl of the Pacific Flyway. Not only does the marsh provide valuable habitat for waterfowl, but it also supports a wide variety of mammals, fish, reptiles, invertebrates, and birds. Its intertidal bays and sloughs are being increasingly recognized as important nursery areas and migration routes for striped bass (*Morone saxatilis*), chinook salmon (*Oncorhynchus tshawytscha*), and other fish species (Baracco 1980). Resident and seasonal populations of various freshwater, estuarine, and marine species utilize this diverse habitat.

Waterfowl are attracted to the marsh by its abundance of water areas and waterfowl food plants such as alkali bulrush, fat hen, and brass buttons. Proper water management to maintain an abundance of food plants relies on the seasonal flooding and draining of marshlands and on adequate water quality to provide proper soil salinities (California Department of Water Resources 1978). Soil salinities of 7,000 to 14,000 mg/L TDS are required in the root zone during spring to assure germination of the desired plant mixture. Maximum seed production occurs at 9,000 mg/L TDS (California Department of Water Resources 1978). As upstream diversions reduce the supply of fresh water available to the marsh, the frequency of less than adequate water quality in the tidal sloughs increases, resulting in less than optimum soil salinities and waterfowl food production.

In recognition of the possible adverse effects of water project operations on the marsh, the State Water Resources Control Board, in Decision 1485, established water quality criteria for the marsh and required development of the Suisun Marsh Plan of Protection (State Water Resources Control Board 1978). Working through the Suisun Marsh Technical Committee of the Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary, the California Department of Water Resources (DWR) documented the plan with an EIR published in 1984 (California Department of Water Resources 1984). The Suisun Marsh Salinity Control Gates on Montezuma Slough near Collinsville were the main feature of the plan (Figure 2).

The purpose of the salinity control gates is to tidally pump water from the Sacramento River through Montezuma Slough to provide water of suitable quality to the marsh during periods of moderate to low Delta outflow. The projected schedule of operations would have the gates operated from September through May when normal circulation would not provide water of adequate quality (Table 1). In all "normal" years, the gates would be closed during portions of the tidal cycle in all Septembers, probably 12.5 out of 25 hours. In all normal and wet years, the gates would always be open in April and May. The structure would never be operated in June, July, or August. Based on the period of record, the historical frequency of occurrence for the three water year types is 38 percent for dry and critical; 28 percent for normal; and 34 percent for wet years. "Normal" year operation was obtained by combining above normal and below normal water years.

In 1985, DWR applied to the U.S. Army Corps of Engineers to construct and operate the Suisun Marsh Salinity Control Gates in Montezuma Slough. The U.S. Environmental Protection Agency, National Marine Fisheries Service, and U.S. Fish and Wildlife Service expressed concerns to the Corps of Engineers regarding potential impacts of the structure on anadromous fish (chinook salmon and striped bass) and fish food organisms (*Neomysis* shrimp) that use the slough. The major concerns were that the gates would increase predation losses to migrating salmon, delay migrating salmon, and reduce the abundance of *Neomysis* shrimp and juvenile striped bass in Suisun Marsh.

The Corps of Engineers signed the construction permit on May 7, 1986. The permit contains a provision for approval of a fish monitoring agreement by January 1, 1987. The agreement provides for a fish monitoring program to determine impacts of the salinity control gates on the aquatic environment, criteria to be applied to the monitoring data to determine if significant degradation has occurred, and a mitigation plan to be implemented should excessive adverse impacts occur.

The salinity control structure was fabricated on barges in Stockton and towed to Rio Vista in May 1987 for completion. In August 1987, the gates were towed to Montezuma Slough for installation. They are scheduled to be used for the first time in the fall of 1988.

The purpose of this report is to provide baseline, background information on Suisun Marsh, and Montezuma Slough in particular, for the fish monitoring plan submitted in January 1987 to the Corps of Engineers. The plan includes elements for monitoring striped bass eggs, larvae, and juveniles; chinook salmon fry and smolts; *Neomysis;* and general fish abundance. Predator populations and possible fish losses at the structure due to predation will also be examined. A more detailed layout of the plan is provided in Chapter 4.

Table 1

PERCENT OF TIME SUISUN MARSH SALINITY CONTROL GATES ARE PROJECTED TO BE OPERATED (By Month and Water Year Type)

	Water Year Type		
Month	**Critical**	**Normal**	**Wet**
September	100	100	0
October	70	90	30
November	80	80	20
December	90	20	10
January	90	60	0
February	90	40	10
March	100	30	10
April	70	0	0
May	60	0	0
June	0	0	0
July	0	0	0
August	0	0	0

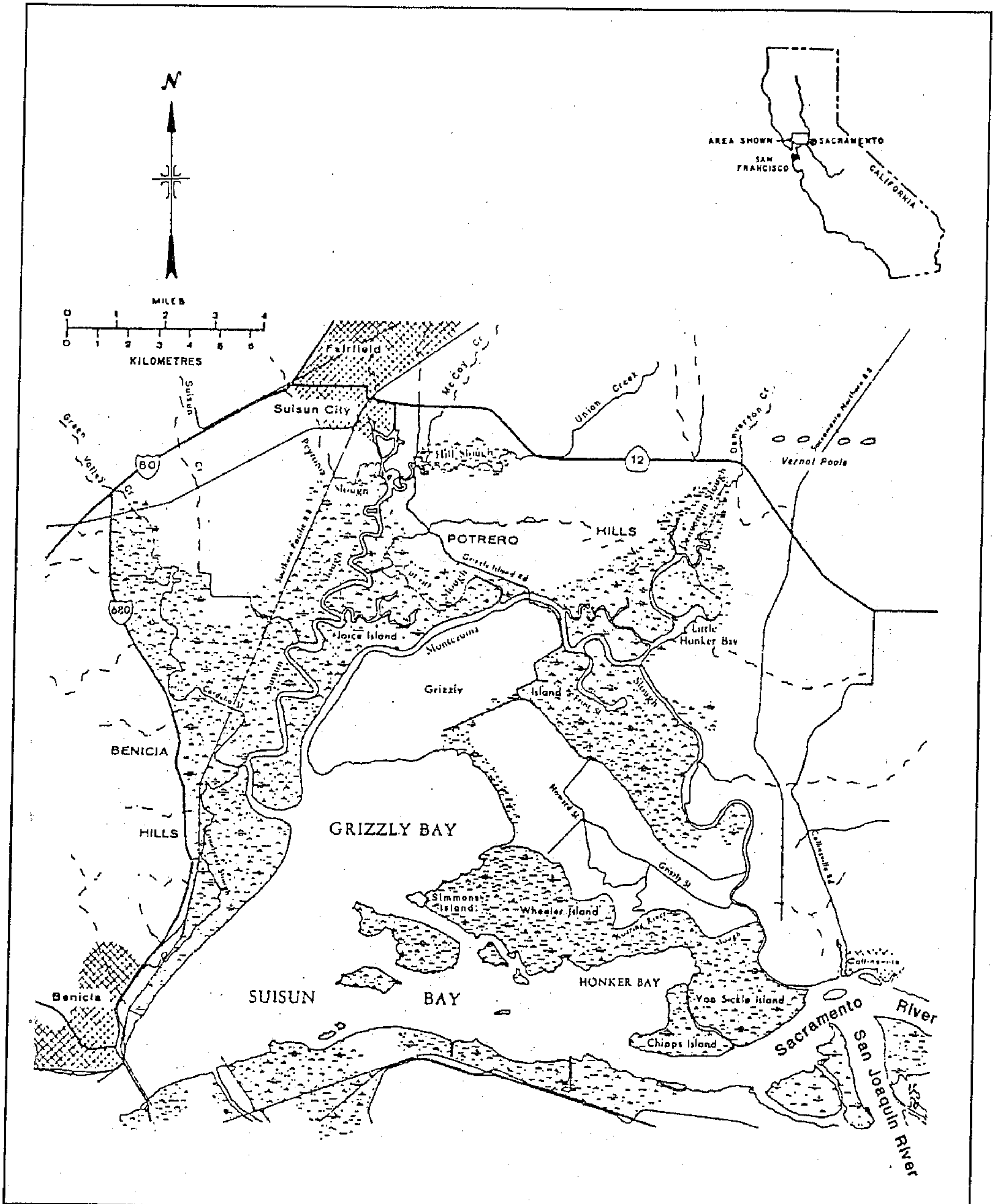


Figure 1

LOCATION MAP, SUISUN MARSH, CALIFORNIA

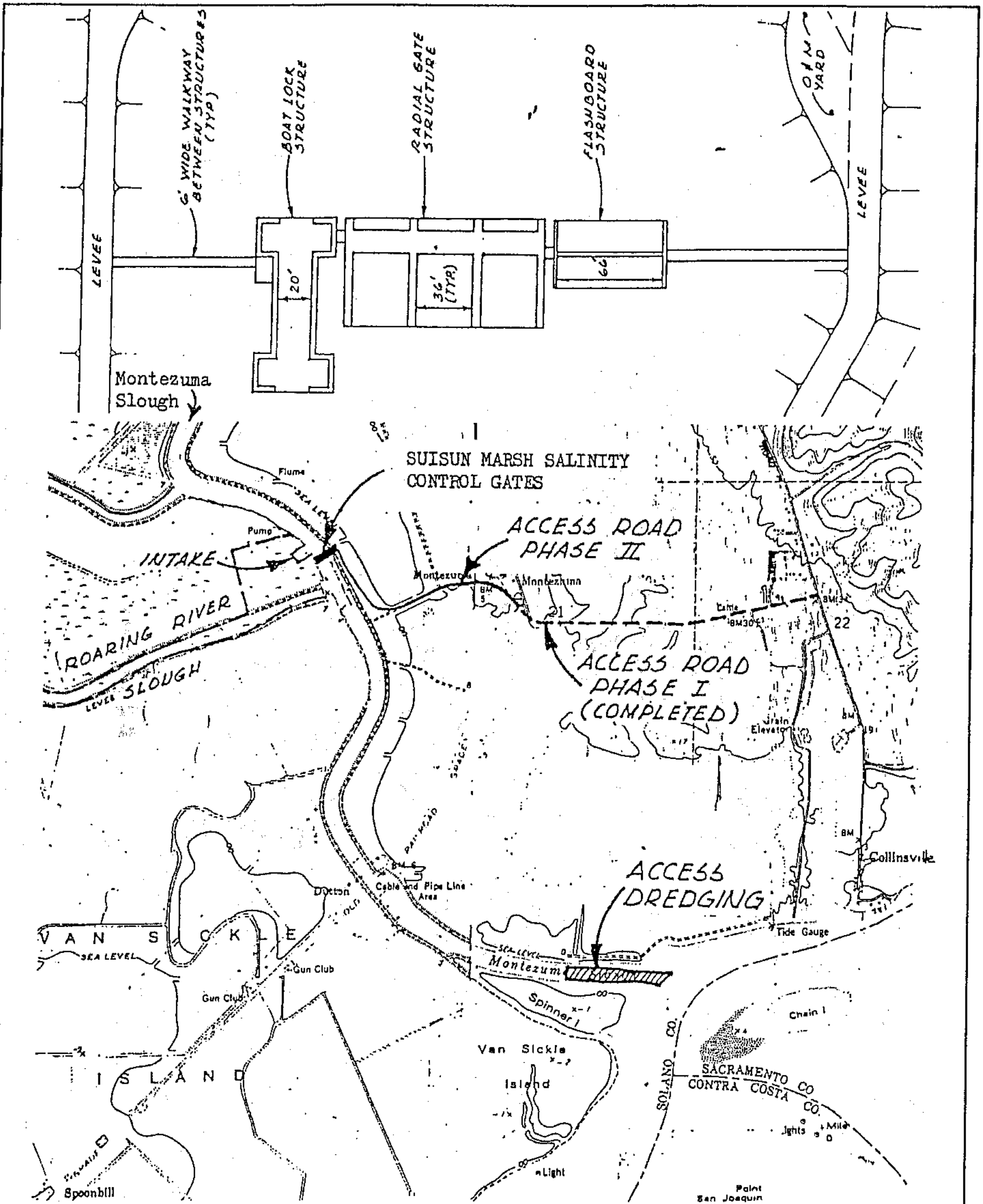


Figure 2

SUISUN MARSH SALINITY CONTROL GATES AND ROARING RIVER SLOUGH INTAKE ON MONTEZUMA SLOUGH, SUISUN MARSH

Chapter 2. METHODS USED IN THIS AND RELATED STUDIES

Several studies have been designed to provide data regarding distribution and abundance of fish in Suisun Marsh and Montezuma Slough. In general, support for these studies has been provided by the Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary, although the University of California, Davis (Dr. Peter Moyle), has provided some funding. The following summarizes methodology used in studies of fish ecology and related aquatic organisms in Suisun Marsh and Montezuma Slough.

Striped Bass Egg and Larva Survey

As part of the Interagency Striped Bass Study Program, the Department of Fish and Game (DFG) has conducted a spring and summer survey of striped bass eggs and larvae from 1961 through 1977 (except 1974) and 1984 through 1986. The survey is designed to measure the abundance of eggs as well as the abundance, growth, distribution, and survival of larvae in the major striped bass spawning areas of the estuary. In addition, the 1984-1986 surveys were designed to measure the food supply of larval bass in relation to stomach contents, growth, and survival rates in an attempt to estimate effects of environmental factors on bass survival (Fusfeld-Low 1986a). Montezuma Slough stations were included in the survey in 1975 (stations 67-68), 1984 (station 68), 1985 (stations 606-609, 67-68), and 1986 (station 68) (Figure 3).

Sampling was conducted by towing fine mesh nets for a standardized time at specific locations in and downstream of the spawning areas. Details of the sampling program and methods are described by Fusfeld-Low and Miller (1986). The preserved samples were returned to the laboratory, where fish eggs and larvae were washed, sorted from debris, identified, counted, and measured. Survey results provide abundance indices for eggs and larvae, mortality rates over time, growth rates, feeding habits, and indications of periods of major spawning. In addition, chlorophyll *a* and zooplankton were sampled at each station beginning in 1984.

Problems with the survey are accurately judging the spawning period and clogging of nets due to algal blooms and detritus (Brown 1986). Missing the early

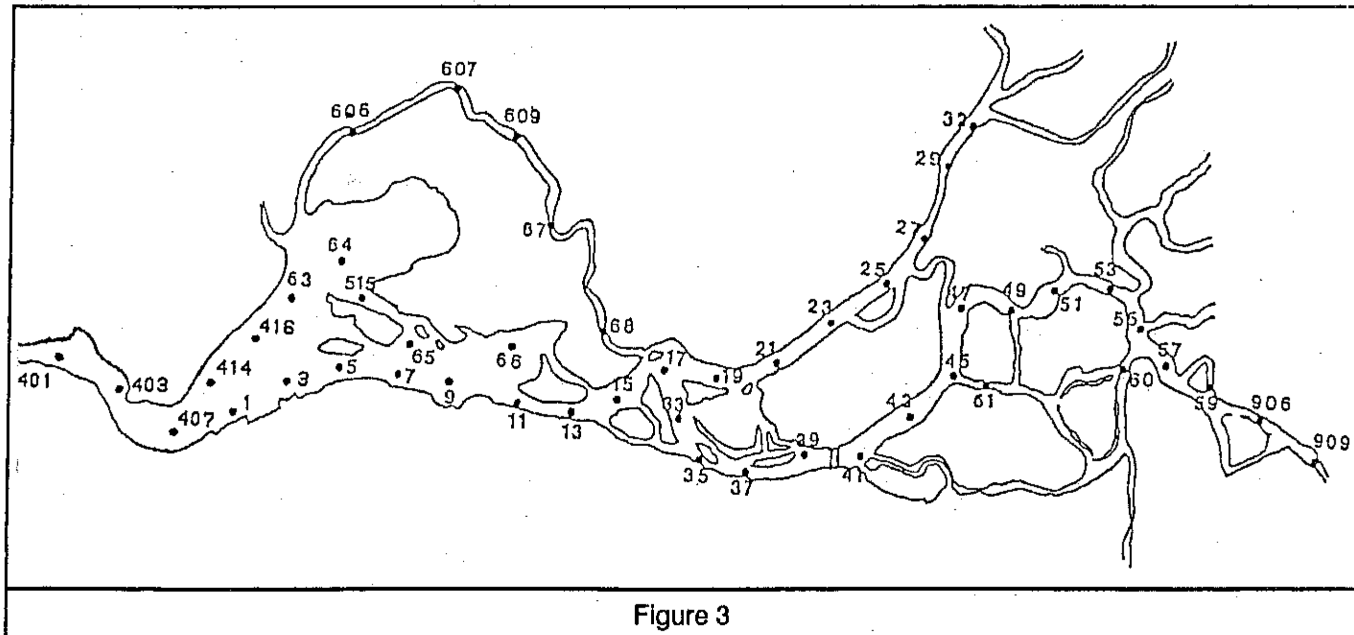


Figure 3

LOCATIONS OF ESTUARINE SAMPLING STATIONS, STRIPED BASS EGG AND LARVA SURVEY SACRAMENTO-SAN JOAQUIN ESTUARY, CALIFORNIA or late contribution to the spawn may bias the results. Net clogging can decrease sampling efficiency, increase sorting time, and in extreme cases make reliability of the results questionable.

Striped Bass Summer Townet Survey

The DFG striped bass townet survey is another major component of the Interagency Striped Bass Study Program. The townet survey was designed to provide a measure of the initial year class strength based on the abundance index of juvenile striped bass when their average fork length (FL) is 1.5 inches (38 mm). The survey has been conducted since 1953, but only since 1959 have field methods been standardized to facilitate evaluation of the annual changes in abundance (Brown 1986).

Standardized diagonal (bottom to top) tows with a townet mounted on skis were made every two weeks at about 30 sites in the major nursery areas of the estuary. Methods are described by Chadwick (1964) and Turner and Chadwick (1972). The survey includes several stations in Montezuma Slough (Figure 4).

Samples were collected from the time young bass became vulnerable to the sampling gear at about 0.7 inch until the mean length was > 1.5 inches. Preserved samples were then returned to the laboratory to be sorted, identified, counted, and measured. Survey timing varies annually due to changing environmental conditions. However, the index is usually set during the period from mid-July to early August.

A shortcoming of the summer townet survey is that sampling sites selected may not provide

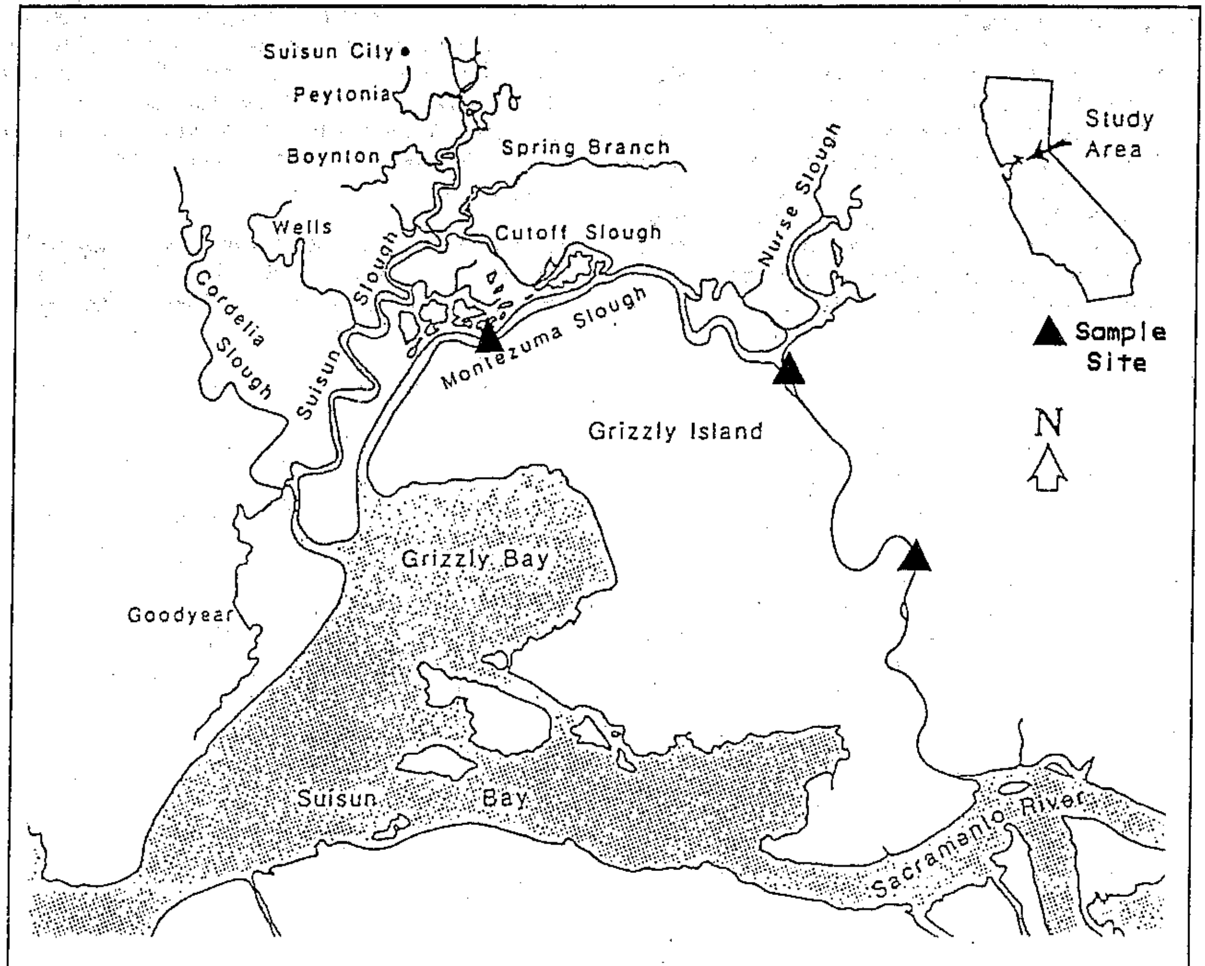


Figure 4

SAMPLING SITES FOR STRIPED BASS TOWNET SURVEY IN MONTEZUMA SLOUGH, SUISUN MARSH, CALIFORNIA

representative coverage in all water years (Brown 1986). During high flow years, many young bass are transported downstream, out of major sampling areas and into San Pablo Bay. Underestimates of bass abundance are likely, since only one San Pablo Bay station is sampled routinely. Annual differences in length frequency distribution and growth rate may also bias the index to some extent (Turner and Chadwick 1972).

Interagency Salmon Study

The U.S. Fish and Wildlife Service has conducted a 2-part sampling program for chinook salmon in the estuary since 1978. Objectives of the program are to measure the abundance of juvenile salmon, both fry and smolt, and determine the impacts of water development on these populations (Brown 1986). The study consists of a beach seine program and a trawling program. Standardized sampling is conducted each year from San Francisco Bay through the Delta and up the Sacramento River to Red Bluff. The program develops annual juvenile salmon abundance indices for fry and smolts, which are related to actual abundance and are comparable from year to year.

Two types of sampling gear were used to sample the two life stages. Salmon fry tend to congregate near shore and were sampled with a 50-foot by 4-foot 1/4-inch mesh bag seine. One haul was made at each site per sampling day, covering about 50 to 100 feet of shoreline. In 1980 and 1981, four stations in Montezuma Slough were included in the beach seine survey (Figure 5). The sampling season usually runs from January 1 to April 30, but collections have been made in other months as well.

In open water, salmon smolts are generally in the upper water column, and were sampled with a 30- by 10- by 82-foot midwater trawl at Chipps Island (Figure 5). The smolt abundance index is the average number of salmon per 20-minute tow at a standardized speed and depth. The sampling season usually runs from April through June.

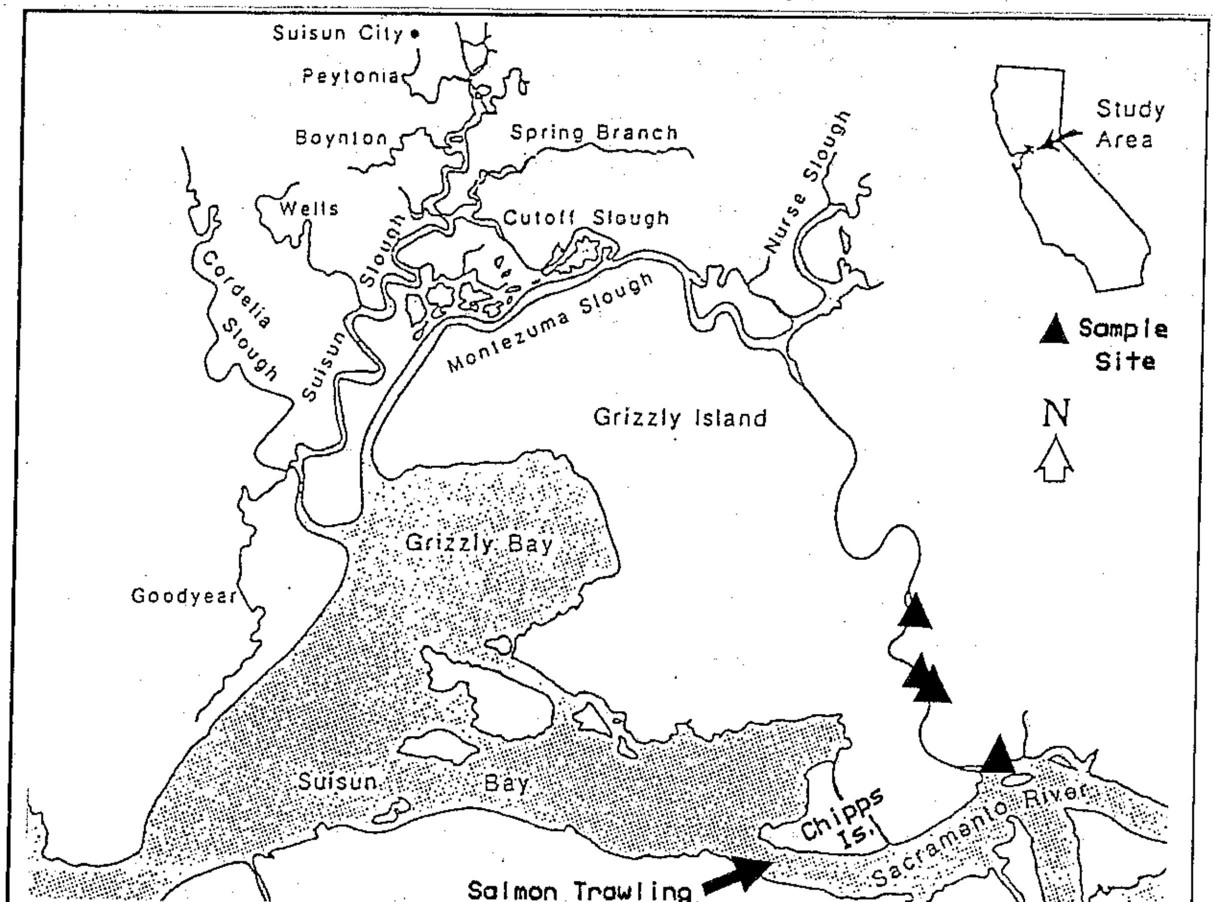


Figure 5

SAMPLING SITES FOR USFWS SALMON TRAWLING AND SALMON SEINING SURVEY IN MONTEZUMA SLOUGH, SUISUN MARSH

Suisun Marsh General Fish Monitoring

DFG conducted general fish monitoring from 1974 through 1979 at six sites in Suisun Marsh (Figure 6). Although no sampling was done in Montezuma Slough, there was a sampling site in Denverton Slough, which feeds Montezuma Slough via Nurse Slough. Fish were sampled every four months (February, June, September) with gill nets and an otter trawl in the small, dead-end sloughs of the marsh. Two sizes of gill nets were fished for 24 hours. The larger net was 250 by 12 feet, with equally sized panels of 2.5-, 3-, 3.5-, and 4-inch stretched mesh (SM) netting. The smaller net was 75 by 6 feet, with 1-inch SM netting. Two 10-minute tows were made on the bottom with an otter trawl of 1.5-inch SM netting in the body and 0.5-inch SM at the cod end.

Some sampling biases were associated with these gear types. The gear were inefficient for juvenile chinook salmon. Salmon smolts, which generally prefer open water, are able to avoid otter trawls. Visual avoidance of fish on the net, especially by large fish, may affect reliability of the data. Salmon fry and other species that tend to congregate near shore and in emergent vegetation were under-sampled by the otter trawl, as were smolts in the upper water column (Kjelson and Colby 1977). Gill net mesh sizes were too large to capture small fish. The nets were most efficient for 3.5- to 4.5-inch and 10- to 20-inch fish. The narrowness and shallowness of the sloughs probably minimize these problems, as did standardized sampling to ensure consistency of biases throughout the sampling.

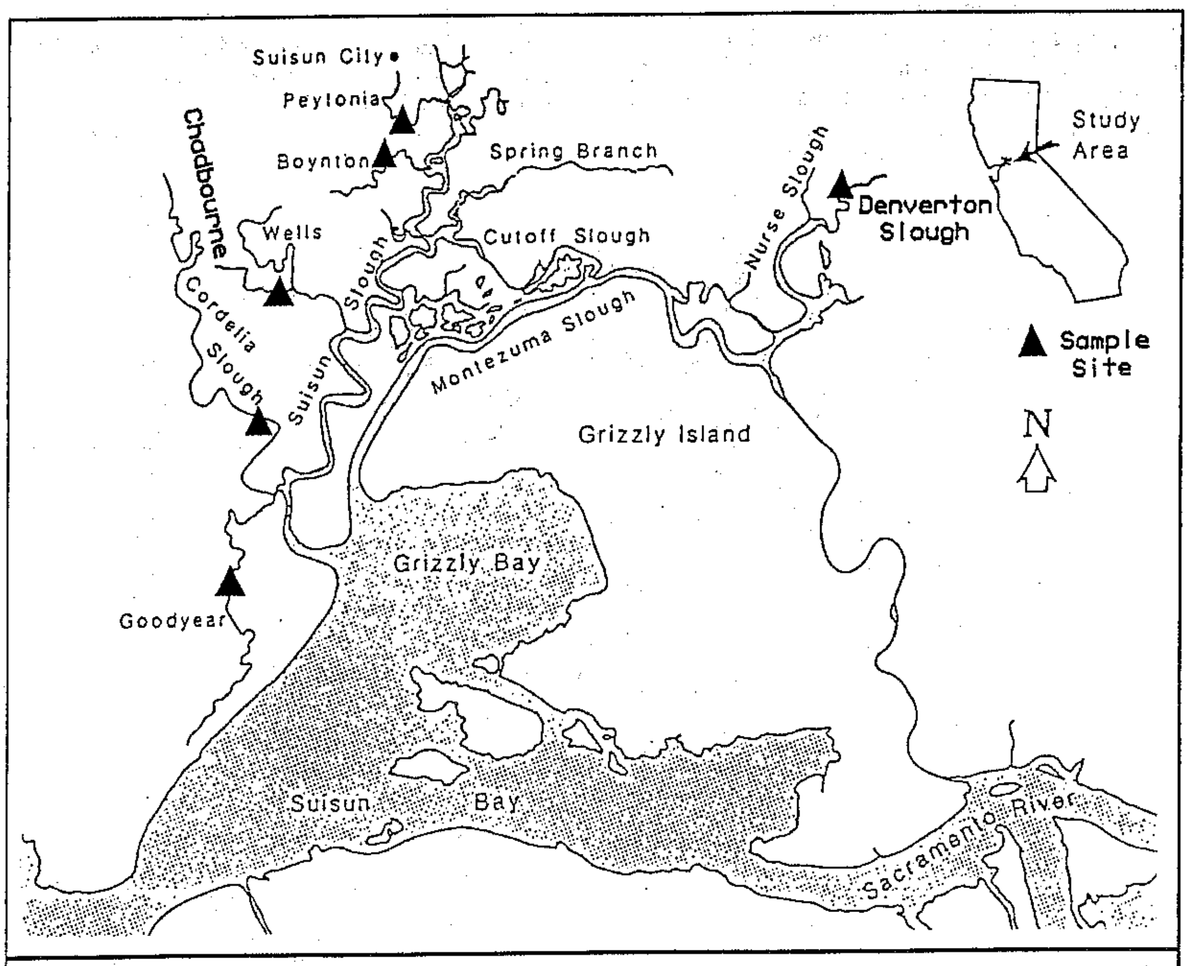


Figure 6

SAMPLING SITES FOR DFG GENERAL FISH MONITORING IN SUISUN MARSH

Suisun Marsh Fish Monitoring Program

Students and staff of the Department of Wildlife and Fisheries Biology, U.C. Davis, under the direction of Dr. Peter Moyle, began systematically monitoring fish in the interior marsh channels in 1979. In 1980, DWR began funding this effort to help in documenting overall effects of Suisun Marsh facilities on the environment before, during, and after a series of major alterations to the flow patterns (Brown 1987). Within this context, the main purposes of the program have been to determine abundance patterns of fish species through time and to evaluate the importance of various habitats to each species.

Monthly samples were taken throughout the marsh, including two sites in Montezuma Slough (Figure 7). The principal sampling gear was a 4-seam otter trawl used for standardized tows twice a month. A beach seine was also used monthly at two locations when possible, but extreme high or low tides often made this impossible. A description of sampling procedures is given by Moyle et al. (1986). Sampling biases were again associated with the otter trawl, and chinook salmon smolts were not sampled efficiently. However, beach seining was more efficient for salmon fry due to their tendency to stay close to banks and vegetation.

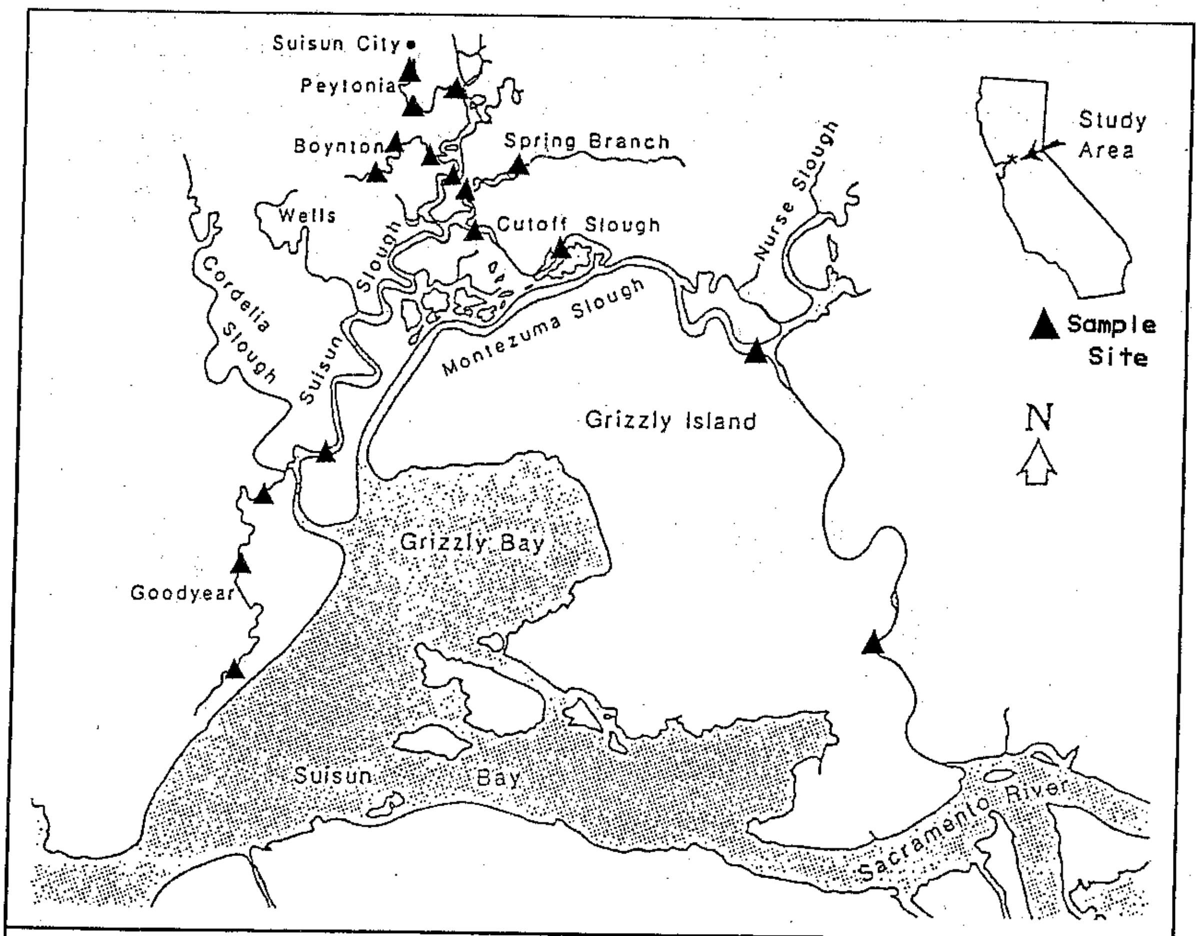


Figure 7

SAMPLING SITES FOR U.C. DAVIS FISH MONITORING PROGRAM IN SUISUN MARSH

Roaring River Fish Screen Evaluation

As part of the initial facilities of the Suisun Marsh Plan of Protection, the Roaring River Slough Distribution System was constructed in 1981 just downstream of the then-proposed site of the salinity control gates (Figure 2, California Department of Water Resources 1986). In 1983, DWR completed the project with the construction of the Roaring River fish screens. To evaluate screen effectiveness, DFG conducted a study to determine the numbers, sizes, and species of fish at the intake during its normal period of operation (October-May) (Pickard et al. 1982). A 65.5-foot fyke net of 1/8-inch mesh was cinched around the downstream end of an unscreened culvert connecting Montezuma Sough and Roaring River Slough. Collections were made during the 1980-81 and 1981-82 diversion seasons at the highest tide(s) of a 14-day tidal cycle, usually over a 24-hour period. Details of the evaluation program can be found in Pickard et al. (1982).

Neomysis/Zooplankton Survey

The mysid shrimp, *Neomysis mercedis*, is important in the diets of many marsh fishes, including striped bass. Since the early 1960s, DFG has sampled *Neomysis* (and zooplankton) in the estuary, including several stations in Montezuma Slough (Figure 8). *Neomysis* are monitored to determine population trends and to identify possible environmental factors affecting its distribution and abundance.

Neomysis were collected by a 10-minute oblique (bottom to top) net tow using a 0.505 mm mesh conical plankton net attached to a wide-mouth towing frame. Surveys were made twice each month from March through October and once in other months if feasible. Knutson and Orsi (1983) describe the sampling in detail. *Neomysis* abundance indices were calculated from sampling densities. Although the densities are not actual population sizes, they are comparable between years and are, therefore, able to detect population fluctuations. Surface temperature, specific conductance, and algal pigment chlorophyll *a* were also measured at each site.

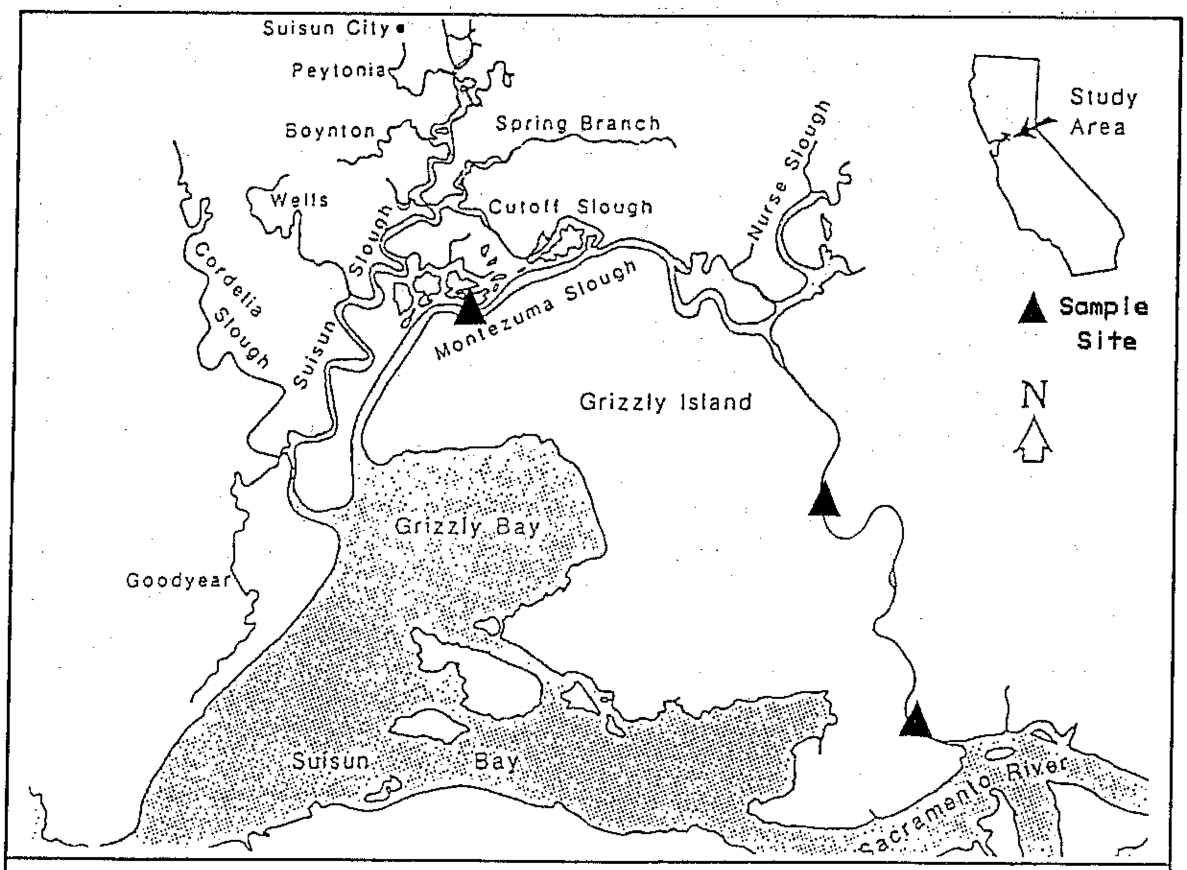


Figure 8
SAMPLING SITES FOR *NEOMYSIS*/ZOOPLANKTON SURVEY IN MONTEZUMA SLOUGH

Chapter 3. RESULTS OF FISHERY RESOURCE EVALUATION AND RELATED STUDIES

Results of the monitoring programs are organized by aquatic species or group: striped bass, chinook salmon, resident fish and seasonal species, *Neomysis*, and primary productivity. Within each section, results are described for each study program.

Striped Bass

Striped bass were introduced into the Bay-Delta estuary in 1879. Suisun Marsh, and in particular Montezuma Slough, have been increasingly recognized as major nursery areas for striped bass, and as an important migratory pathway (Baracco 1980). Two studies in the marsh have been geared specifically for striped bass -- the Striped Bass Egg and Larva Survey and the Summer Townet Survey. Three other monitoring programs collected striped bass data incidental to information on other fish species. These were the DFG Suisun Marsh General Fish Monitoring Program, U.C. Davis Suisun Marsh Fish Monitoring Program, and Roaring River Slough Fish Screen Evaluation.

The egg and larva survey produced abundance indices of larvae for various parts of the Delta, including Suisun Bay and Montezuma Slough. The indices for 6-14 mm striped bass larvae comparing Montezuma Slough stations to the total Delta-Suisun index indicate that a minor, but relatively constant proportion of 6-14 mm striped bass larvae were captured in Montezuma Slough from 1984-1986 (Table 2). However, in 1975 the index was much higher, perhaps because the overall abundance was higher in 1975, than in any other year. The relative percentage of total 6-14 mm larvae in the slough is surprisingly similar between 1975 and 1984 but declines in 1985 and 1986. Tables 2 to 6 give comparable indices for other areas and years in the estuary.

The overall Delta-Suisun index and Montezuma Slough indices were low in 1984 compared to other years (Table 2). The low spring outflow in 1984 concentrated the larvae more in the Delta than Suisun Bay, but significant numbers of larvae were collected in upper Suisun, Grizzly, and Honker Bays (Table 3). Few larvae were collected in Carquinez Strait. Data for 1985 followed a somewhat similar distribution (Table 4). Again the larvae were concentrated in the Delta, but fewer were found in upper Suisun, Grizzly, and Honker bays. Overall larvae abundance in 1985 and 1986 were comparable and higher than 1984, but much lower than 1975 (Table 6). In 1975 the 6-14 mm index was high overall, being influenced by the high 6-8 mm index. These indices represent catches for all stations except those in Montezuma Slough and Carquinez Strait, and adjustments were made to the 1968 to 1977 data to make them comparable to 1984 and later years (Fusfeld-Low and Miller 1986). Due to high flows in early spring 1986, a relatively high proportion of larvae was in Suisun Bay and upper Suisun, Grizzly, and Honker bays (Table 5). Conversely, a low proportion was found in Carquinez Strait and Montezuma Slough.

Table 2

STRIPED BASS LARVAE ABUNDANCE INDICES FOR MONTEZUMA SLOUGH AND THE DELTA FOR 1975 AND 1984-1986 (ABUNDANCE x 10^4)

Year	8mm	9-11mm	12-14mm	6-14mm	Delta* 6-14mm	% in** Slough
1975	10,211	1,988	1,533	13,733	5,959,806	0.23
1984	1,237	114	57	1,408	639,329	0.22
1985	1,338	285	217	1,839	1,445,45	0.13
1986	1,674	201	113,	1,998	1,910,292	0.11

* Suisun, Grizzly, and Honker Bays; Lower Sacramento River; San Joaquin River.
**Abundance of Montezuma Slough 6-14mm larvae as a percentage of Delta 6-14mm larvae.

DATA FROM : DFG; Fusfeld-Low 1986a, 1986b; Fusfeld-Low and Miller 1986.

Table 3

ABUNDANCE INDICES (SUM OF WEIGHTED CATCH) OF STRIPED BASS LARVAE FOR SIX AREAS, 1984 (Abundance x 10^4)

Area (Stations)	6-8mm	9-11mm	12-14mm	6-14mm
Suisun Bay Channel 1-15)	58,160	8,045	1,434	67,639
Lower Sacramento River (17-32)	104,726	5,157	985	110,868
Upper Suisun, Grizzly, Honker Bays(414,416,515,63-66)	32,839	4,588	870	38,297
San Joaquin River (33-61)				
4/16-5/18	72,647	1,304	0	73,951
5/22-7/13	62,159	3,168	558	65,885
Montezuma Slough (68)	1,237	114	57	1,408
Carquinez Strait (401,403,407)	90	83	0	173

SOURCE: Fusfeld-Low and Miller 1986.

Table 4

ABUNDANCE INDICES (SUM OF WEIGHTED CATCH) OF STRIPED BASS LARVAE FOR FIVE AREAS, 1985
(Abundance x 10^4)

Area (Stations)	6-8mm	9-11mm	12-14mm	6-14mm
Suisun Bay Channel (5-15)	31,179	2,869	74	34,789
Lower SacramentoRiver (17-32)	224,856	5,459	333	230,648
Upper Suisun, Grizzly, Honker Bays (515,63-66)	7,553	51	24	7,628
San Joaquin River (33-61,906,909)				
4/12-5/22	574,429	1,864	0	576,293
5/26-7/13	158,842	2,342	330	161,513
Montezuma Slough (67, 68, 606-609)	1,338	285	217	1,839

SOURCE: Fusfeld-Low 1986a

Table 5

ABUNDANCE INDICES (SUM OF WEIGHTED CATCH) OF STRIPED BASS LARVAE FOR SIX AREAS, 1986
(Abundance x 10^4)

Area (Stations)	6-8mm	9-11mm	12-14mm	6-14mm
Suisun Bay Channel (1-15)	198,897	19,680	3,464	222,041
Lower Sacramento River (17-32)	294,334	4,817	1,483	300,634
Upper Suisun, Grizzly, Honker Bays(414,416,515,63-66)	129,898	19,966	5,247	155,111
San Joaquin River (33-61)				
4/18-5/26	270,762	5,326	305	276,393
5/30-7/13	130,846	6,606	1,713	139,165
Montezuma Slough (68)	1,674	201	113	1,998
Carquinez Strait (401,403,407)	1,732	63	0	1,795

SOURCE: Fusfeld-Low 1986b.

Table 6

ABUNDANCE INDICES (SUM OF WEIGHTED CATCH) OF STRIPED BASS LARVAE FOR 1968-1986 FOR SUISUN, GRIZZLY, AND HONKER BAYS, LOWER SACRAMENTO RIVER, AND SAN JOAQUIN RIVER

(Abundance x 10^4)

Year[1]	6-8mm	9-11mm	12-14mm	6-14mm
1968	872,828	132,177	28,535	1,033,540
1970	2,292,883	197,831	55,254	2,545,968
1971	[2]5,008,934	136,983	28,234	5,174,151
1972	2,381,722	219,189	50,350	2,651,261
1973	----	148,436	40,988	----
1975	5,815,994	113,847	29,965	5,959,806
1977	320,658	11,884	365	332,907
1984	588,415	43,220	7,694	639,329
1985	1,419,289	23,306	2,856	1,445,451
1986	1,778,712	107,462	24,118	1,910,292

[1]Data for 1968-77 include extrapolations for time period and upper Suisun Bay stations. Data for 1968-73 corrected for differences in net efficiency.
[2]Actual weighted catch sums, no time period extrapolations.

SOURCE: Fusfeld-Low and Miller 1986b.

The abundance of striped bass larvae varies seasonally from year to year. Striped bass larvae were collected in Montezuma Slough from April through July in 1984 and 1986, with peak abundances occurring in May and early June (Figure 9). The catch declined through June and into July as the larvae grew out of the 6-14 mm index size. A breakdown of the 1985 catch data by size group shows the seasonal variability of striped bass larvae and the effect of growth on size group abundance (Figure 10). The 6-8 mm larvae were the most abundant group, appearing in April and disappearing by mid-June. In early May, the 9-11 mm group was first seen, and remained at a much lower level of abundance than the 6-8 mm larvae, finally waning in early July. The 12-14 mm larvae followed a similar pattern and first appeared in mid-May.

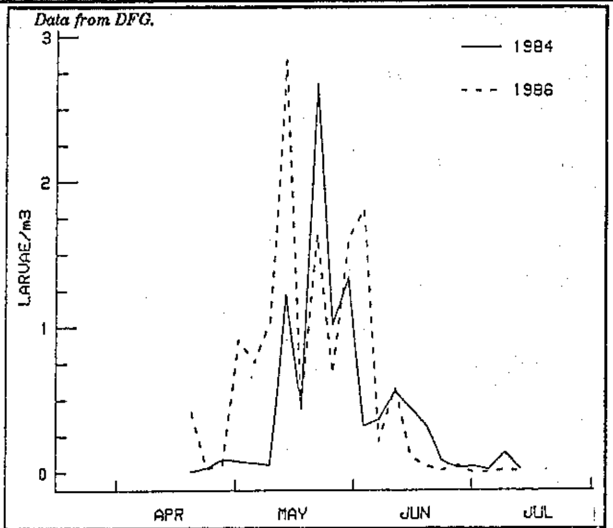


Figure 9

DENSITY OF STRIPED BASS (6-14 mm) IN MONTEZUMA SLOUGH, 1984 AND 1986

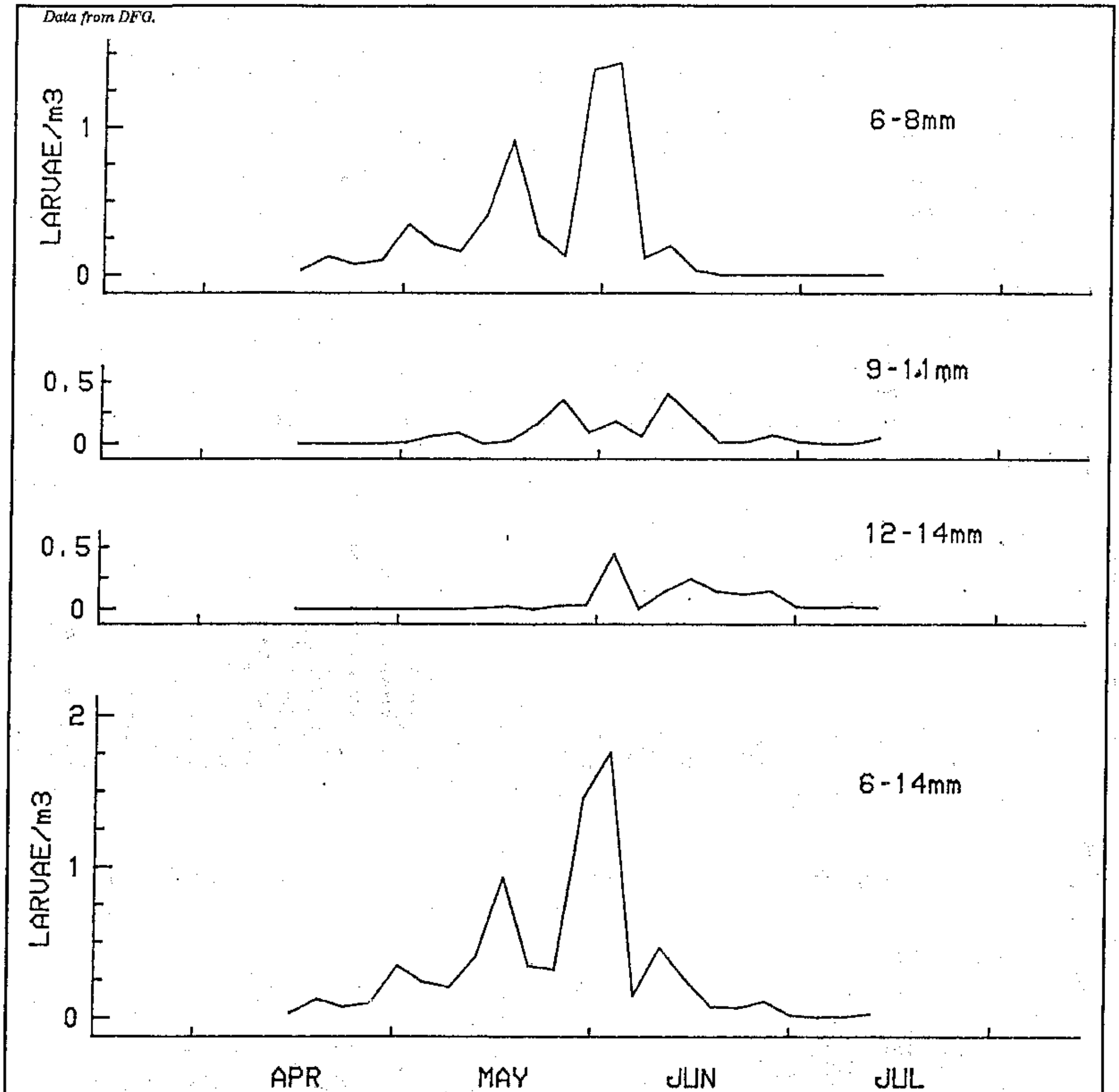


Figure 10

SEASONAL VARIABILITY IN DENSITY OF STRIPED BASS, BY SIZE, IN MONTEZUMA SLOUGH, 1985

The summer townet survey is designed to provide an abundance index of juvenile striped bass when their average length is 38 mm. A comparison of the striped bass index for six areas in the estuary, including Montezuma Slough, is shown in Figure 11. These areas are used by DFG to describe townet results from stations that apparently are similar geographically and environmentally. Historically, four of these areas, Montezuma Slough, Suisun Bay, lower Sacramento River, and lower San Joaquin River, have apparently been the most important rearing areas for juvenile striped bass. In the mid-1960s an unsteady, but persistent downward trend began in the abundance of young striped bass in these areas. Abundance indices reached a low in 1977, with some recovery since that time. Overall the indices have remained lower than the levels of abundance before 1977. Of these areas, Montezuma Slough appears to have experienced the least fluctuations and has almost recovered to the pre-drought abundance levels. Since 1970, the index in Montezuma Slough has ranged from less than 1 to about 12. Most of the indices have been about 5. What appeared to be a return of the index to "normal" levels in 1986 (4.8 index) may have been an anomalous event rather than a return to conditions producing abundances comparable to the 1959-1976 period. The 1987 striped bass index for Montezuma Slough was again low, at 1.9.

Data from DFG, Turner 1986.

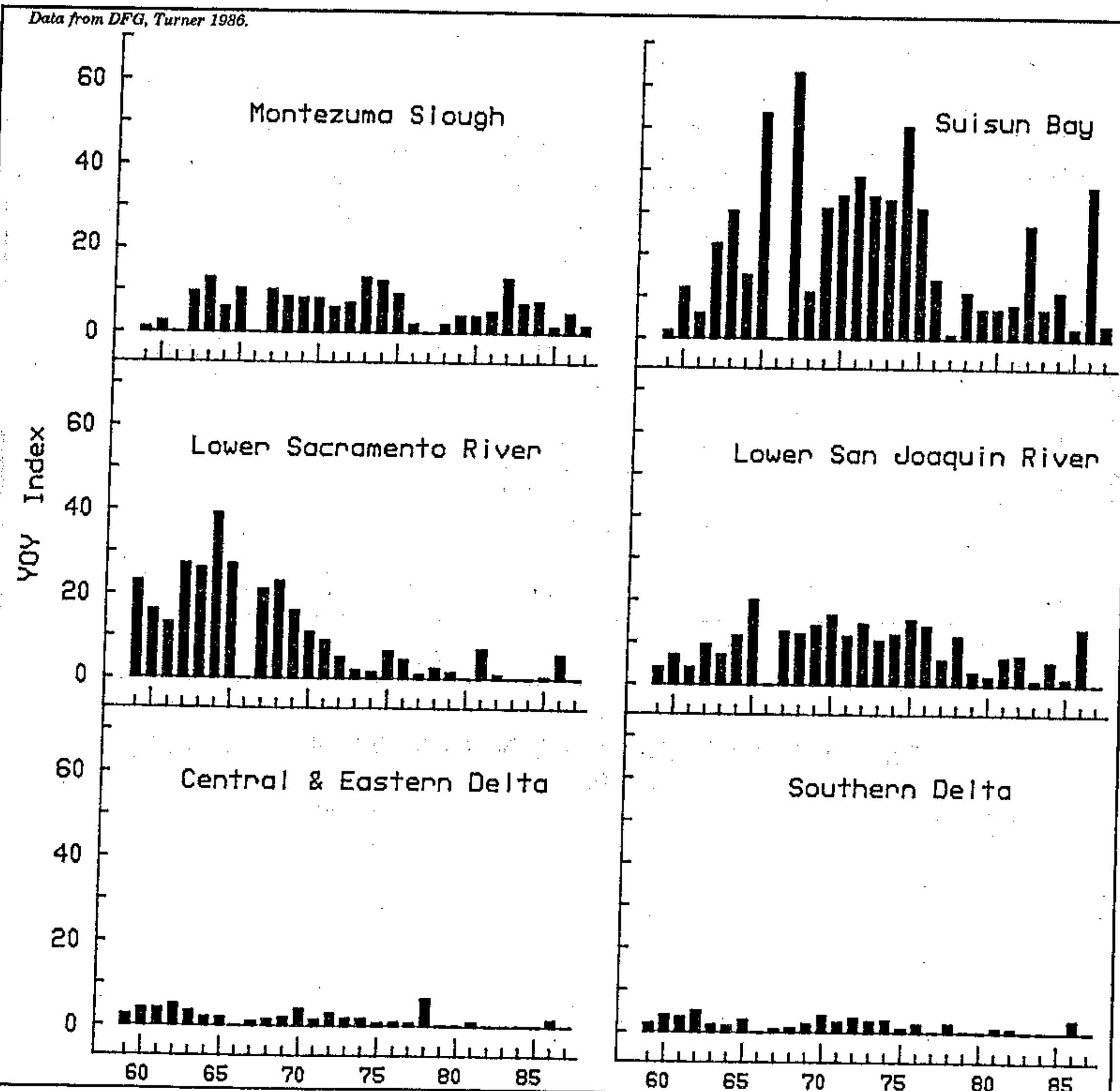


Figure 11

YOUNG STRIPED BASS INDEX IN VARIOUS REGIONS OF THE SACRAMENTO-SAN JOAQUIN ESTUARY FROM 1959-1986 (EXCEPT 1966)

Although the DFG General Fish Monitoring Program in Suisun Marsh was not designed specifically for striped bass, this species was the most abundant collected (about 27,000 fish) from 1974 to 1979. Of 26,929 striped bass ages 0 to 3+ captured, 23,115 were June age 0 fish. The bulk of the striped bass population appears to have been young-of-the-year (YOY) fish.

Striped bass age 0 through 3+ were seasonally abundant at the interior marsh stations (Figure 12). Peak abundance occurred during early summer in most years when the catch was primarily made up of YOY fish. In 1976 and 1977 (dry/drought years), very few YOY were caught in June. Two age 0 fish were collected in 1976 and none in 1977. All age classes of striped bass were present throughout the year, but in general the populations tended to peak during summer (Figure 13).

The individual sloughs varied in their contribution to the total striped bass catch over the study period (Figure 14). The contribution to all age classes combined was greatest from Denverton Slough, the slough closest to the salinity control gates (35 percent), followed by Peytonia Slough (24 percent). Goodyear Slough had the lowest contribution (6 percent) and does not appear to be as important for YOY fish as are the other sloughs. The percent contribution to total catch minus the June catch of age 0 fish shows a different pattern. Areas that appear to support a striped bass population older than June YOY are Goodyear Slough (25 percent) and Denverton Slough (22 percent). Young-of-the-year were present at some level in all sloughs. Denverton Slough had the highest abundances of striped bass for all age classes. Goodyear Slough seemed to support an age class of fish slightly older than YOY.

Data from DFG.

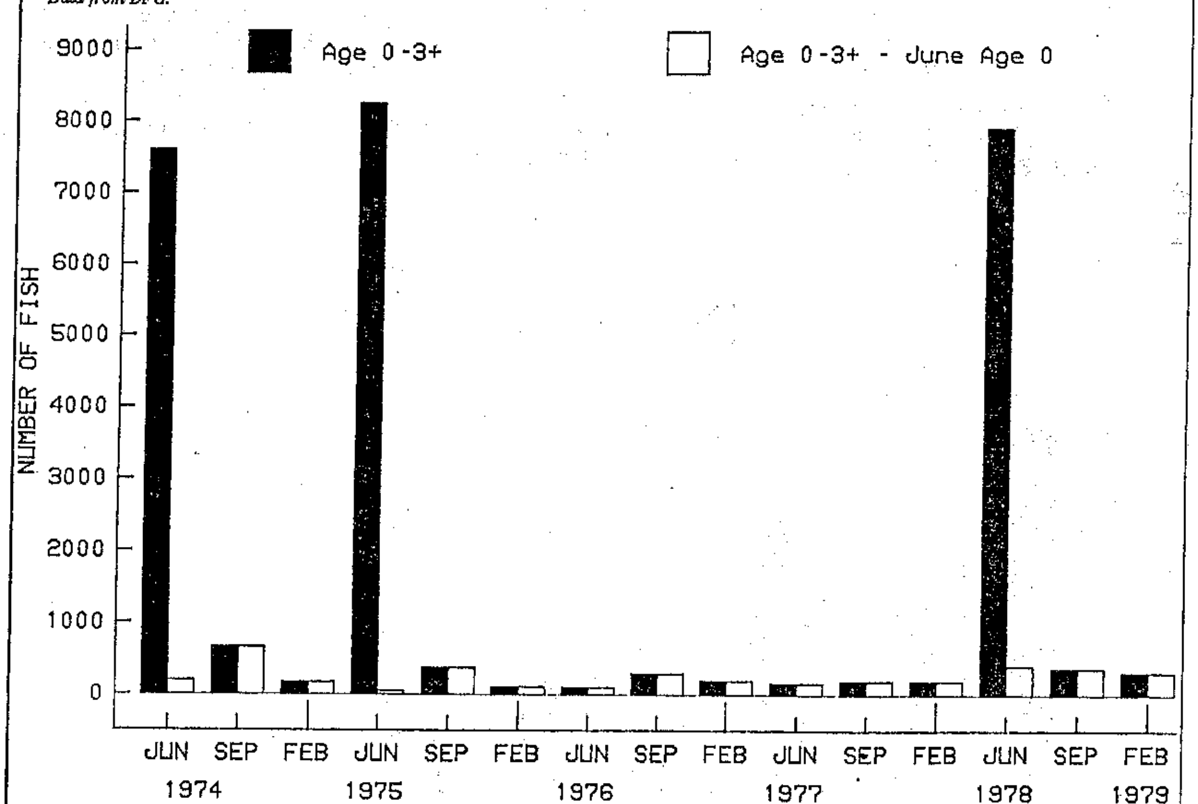


Figure 12

CATCHES OF TWO GROUPS OF STRIPED BASS IN SUISUN MARSH, 1974-1979

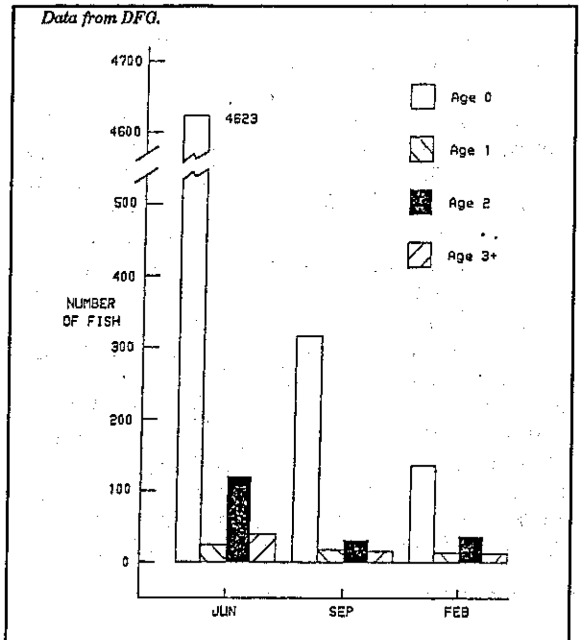


Figure 13

MEAN CATCH OF STRIPED BASS (BY AGE GROUP) IN SUISUN MARSH, 1974-1979

Striped bass were also the most abundant (about 24,000) fish collected by the U.C. Davis monitoring program from 1979 to 1983. As a fairly stable part of the marsh ecosystem, striped bass were captured throughout the year. Abundances increased through summer, with a consistent influx of YOY in June, and peaked later than other species in August (Figure 15). The lowest abundance levels were in February and March. This seasonal variability follows the general pattern found in the DFG General Fish Monitoring Survey. Both adults and juveniles were well dispersed throughout the marsh, but were most often collected in the main sloughs.

One of the main sloughs, Montezuma Slough, is particularly important to young striped bass. A comparison of Montezuma Slough with all other samples sites shows that on the average a larger number of young were consistently captured in Montezuma Slough than at all other sites combined (Figure 16). Again the general pattern of abundance of striped bass was followed. Numbers peaked in early to mid-summer (May-July) and were lowest during the winter months.

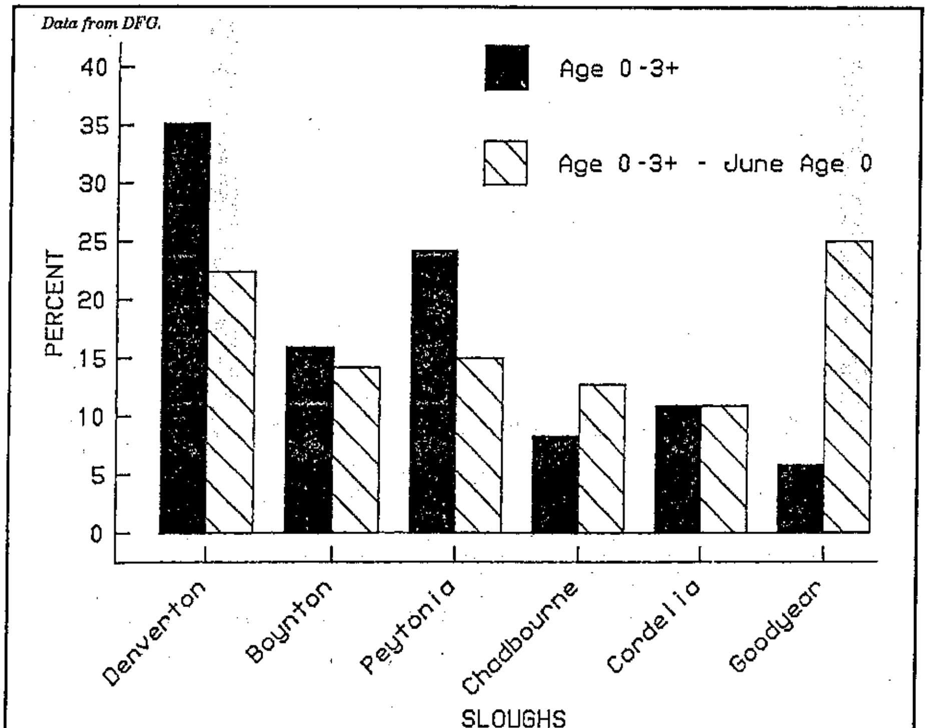


Figure 14

PERCENT CONTRIBUTION, BY SLOUGH, TO TOTAL CATCH OF STRIPED BASS IN SUISUN MARSH, 1975-1979

The growth rate of striped bass also exhibits a seasonal pattern (Figure 17). The annual year class appears to show up in mid-May to early June, with fairly rapid growth and recruitment to the marsh population during summer months. During winter, growth appears to virtually cease.

Daily catches of striped bass at unscreened culverts at Roaring River Slough also confirm the usage of Montezuma Slough by the species. Striped bass were captured throughout the 1980-81 and 1981-82 diversion seasons (Table 7, Figure 18). The abundance of bass varied seasonally, with the largest catches from September through November. During both seasons, fish captured ranged from YOY to a few older individuals.

These striped bass studies and surveys in Suisun Marsh provide valuable information on the abundance and utilization of Montezuma Slough and the marsh by this species. Striped bass are found in Montezuma Slough and Suisun Marsh at all life stages and appear to be the most abundant fish species present. Peak abundance usually occurs in May and June, and lowest abundance is usually in February and March. Adults and juveniles are well dispersed through the marsh, but most often are collected in the main sloughs. Montezuma Slough is particularly important to age 0 fish. Of the small, dead-end sloughs, Denverton Slough, a tributary of Montezuma Slough, also seems to be important to age 0 fish. The marsh appears to be used as a migratory pathway and nursery area for striped bass.

FROM: Moyle et al. 1986.

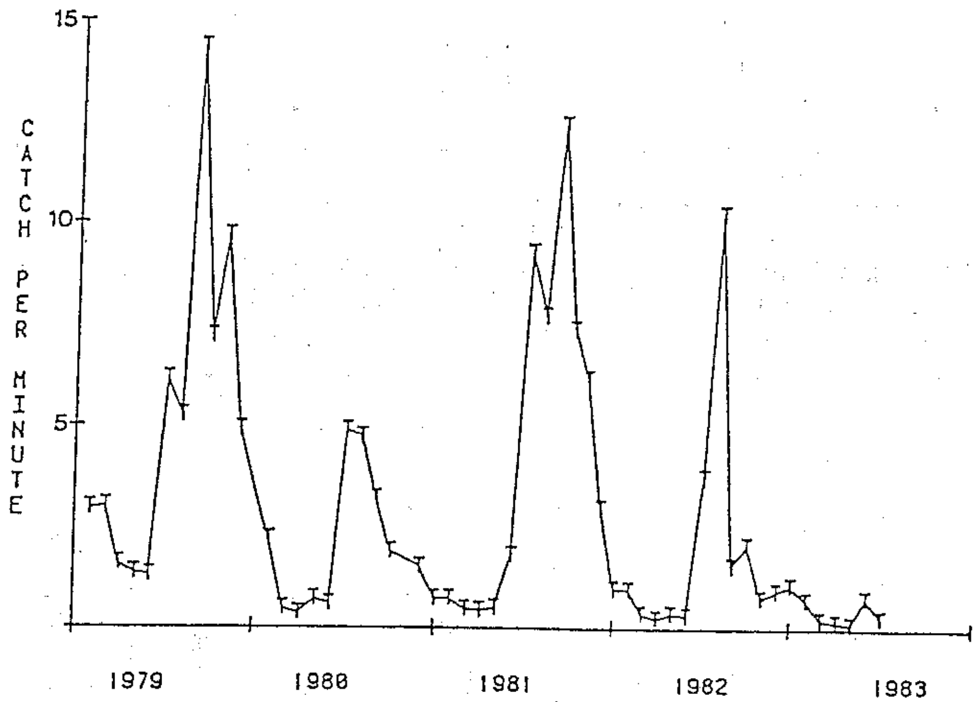


Figure 15

CAPTURE RATES OF STRIPED BASS IN SUISUN MARSH, 1979-1983

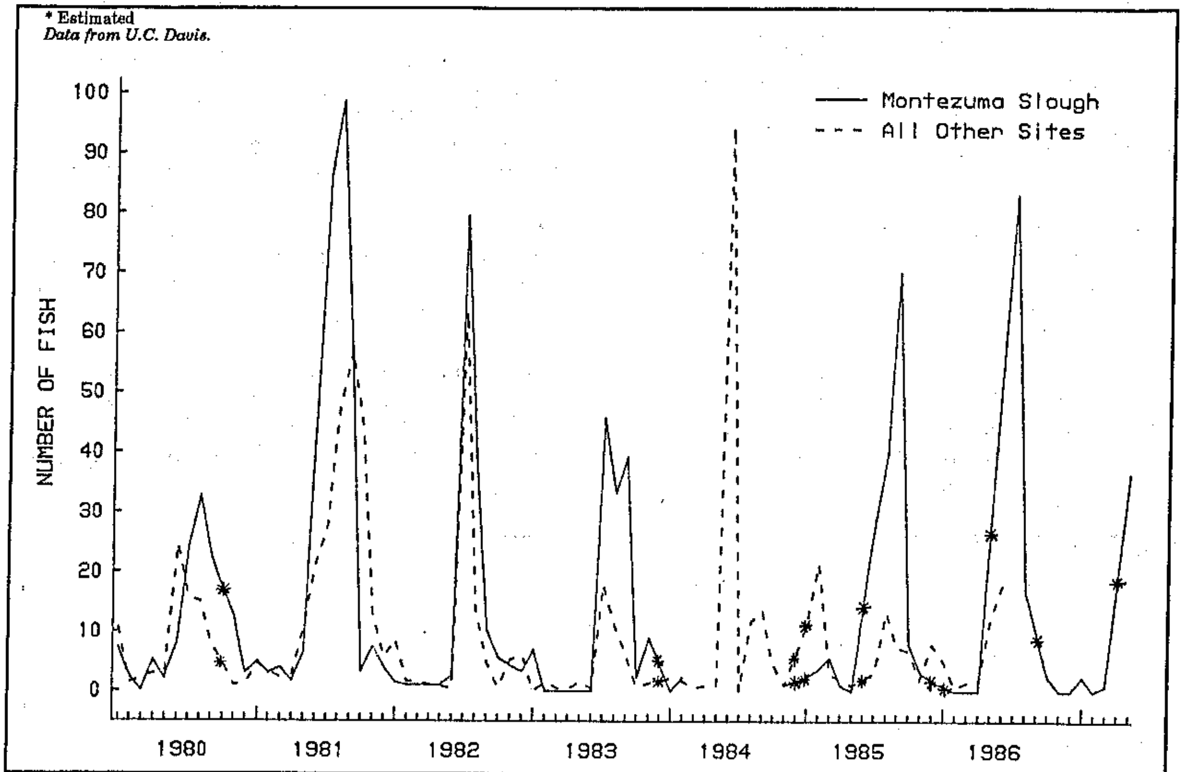


Figure 16

MEAN CATCH OF STRIPED BASS YOUNG IN MONTEZUMA SLOUGH (EXCEPT 1984) AND ALL OTHER SAMPLE SITES COMBINED IN SUISUN MARSH, 1980-1987

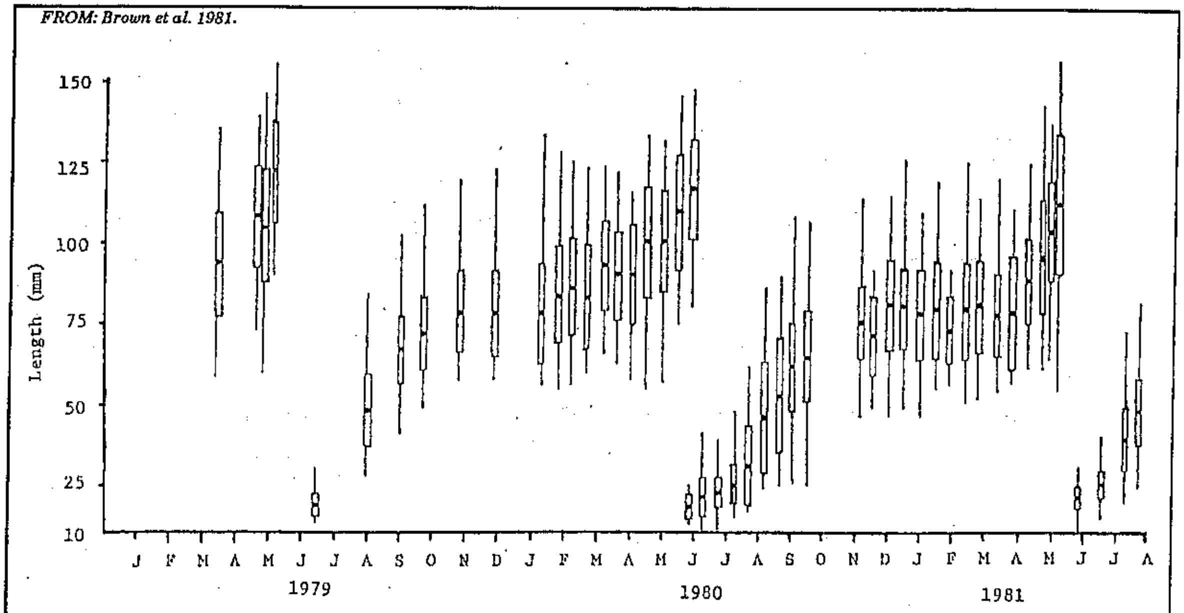


Figure 17

MEAN LENGTH (± 1 S.D.) AND RANGE IN LENGTH FOR STRIPED BASS FOR ALL SAMPLE DATES

Table 7

DAILY CATCHES AND SIZES OF STRIPED BASS AT ROARING RIVER SLOUGH INTAKE (UNSCREENED CULVERT), 1980-1982

Date	Catch	Mean Length(mm)	Range	Sample Size
		1980-81 Diversion Season		
11-06	1	102.00	---	1
11-21	11	83.00	61-117	11
12-02	15	90.33	71-120	15
12-18	30	89.77	68-120	30
01-02	2	84.50	72-92	2
01-16	1	253.00	---	1
02-03	8	85.75	64-110	8
02-17	5	100.60	95-105	5
03-03	25	89.16	56-113	25
03-16	1	83.00	---	1
04-30	9	100.11	80-115	9
05-14	9	109.78	89-128	9
Total	117			
		1981-82 Diversion Season		
09-29	209	70.44	49-180	27
10-26	26	70.35	51-102	26
11-23	227	84.60	57-195	50
12-21	10	84.50	56-116	10
01-26	9	76.89	70-94	9
02-08	3	108.00	93-122	3
02-22	1	105.00	---	1
03-08	0	---	---	---
Total	456			

DATA FROM: DFG, Pickard et al. 1982

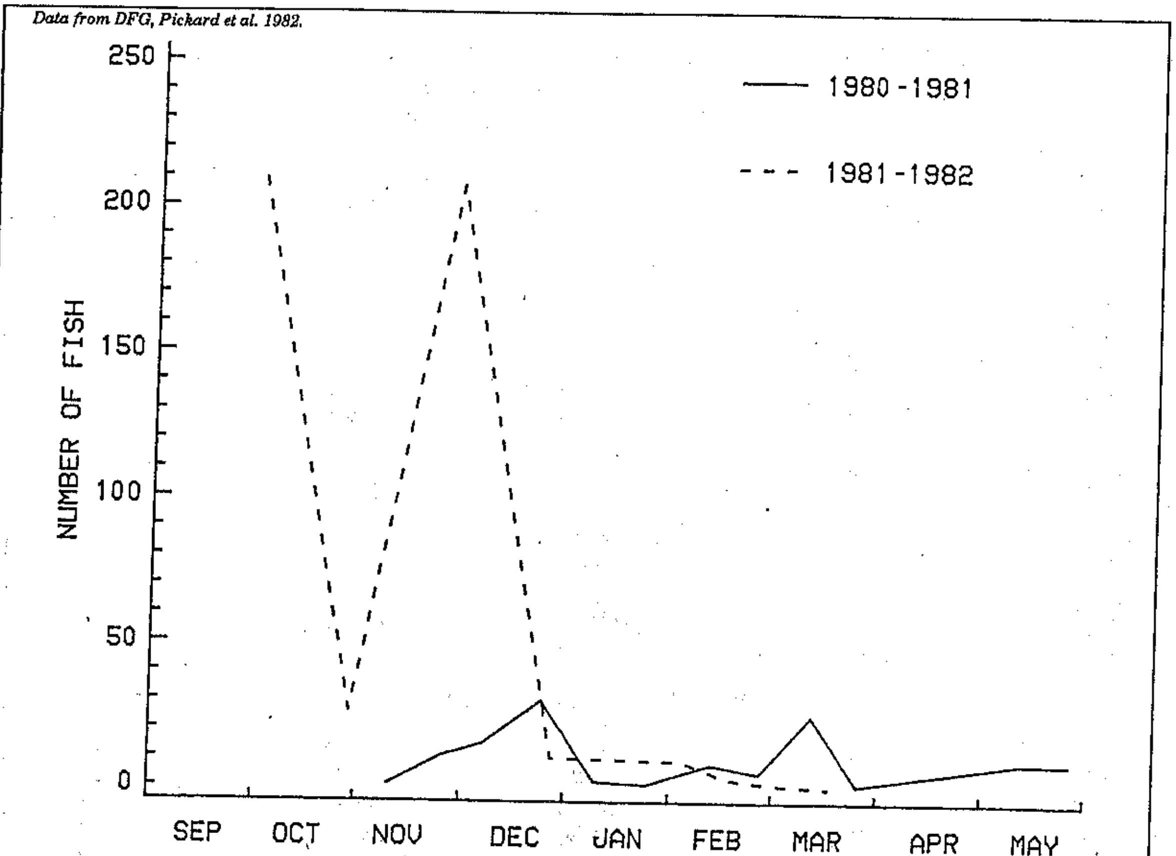


Figure 18

DAILY CATCH OF STRIPED BASS OVER TWO DIVERSION SEASONS AT ROARING RIVER SLOUGH INTAKE (UNSCREENED CULVERT), 1980-1982 (No Night Sampling Prior to March 1981)

Chinook Salmon

Although the waterways of Suisun Marsh, especially Montezuma Slough, have been recognized as nursery areas and migration routes for chinook salmon, data on this species in the marsh are sparse. Studies within the marsh with potential for generating salmon data are the USFWS Beach Seine Survey, DFG Suisun Marsh General Fish Monitoring Program, U.C. Davis Suisun Marsh Fish Monitoring Program, and the Roaring River Slough Fish Screen Evaluation. The USFWS Salmon Trawling Program at Chipps Island also provides information on salmon entering the Suisun Bay area from the Sacramento and San Joaquin Rivers.

The beach seine survey captured chinook salmon fry in Montezuma Slough in 1980 and 1981 from January through April (Figure 19). Peak abundance occurred in February, and no fry were collected past the end of April in either year, probably due to the fry smolting. High flows during this period moved the fry down into the estuary and Montezuma Slough. In 1981, it appears the peak migratory period between January and February was slightly earlier than in 1980, and only the tail end of the peak was included in sampling. A total of 76 fry were captured in 1980 (mean 1.31 fish/haul) and 29 fry in 1981 (mean 1.32 fish/haul). The fry abundance indices (catch/haul) are shown in Table 8 for other areas in the estuary (Figure 20). The Montezuma Slough indices were similar to those in the central Delta and San Francisco Bay. The lower Sacramento River area had the highest index for 1981 with 23 fish/haul, followed by the northern Delta at 12 fish/haul.

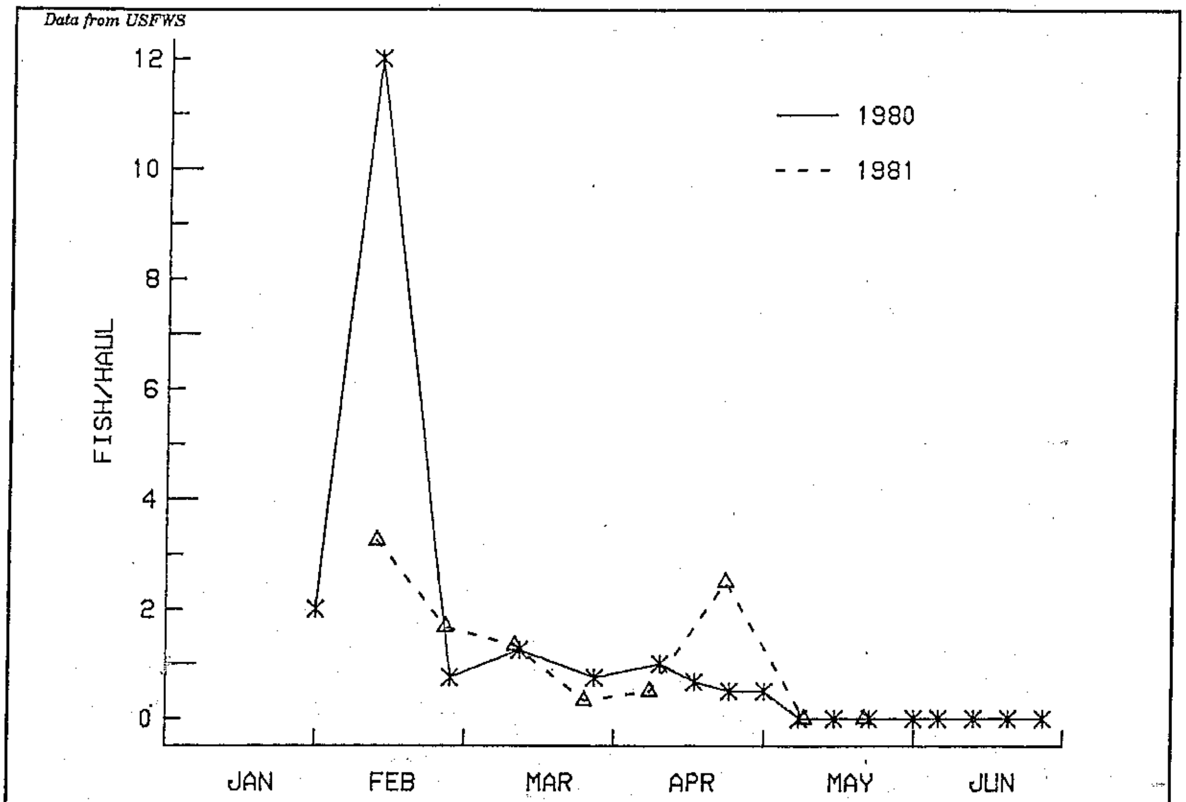


Figure 19

CHINOOK SALMON FRY ABUNDANCE INDEX FOR MONTEZUMA SLOUGH, 1980 AND 1981

Table 8

AVERAGE CATCH PER SEINE HAUL OF CHINOOK SALMON FRY IN THE BAY-DELTA ESTUARY AND LOWER SACRAMENTO RIVER, JANUARY THROUGH APRIL 1977-1986

Year	Northern Delta	Central Delta	San Francisco Bay	Lower Sacramento	Montezuma Slough
1986	30	10	2	27	NS
1985	10	3	0	2	NS
1984	11	4	0	9	NS
1983	39	9	2	30	NS
1982	21	4	1	23	NS
1981	12	2	0.5	23	1
1980	17	2	4	NS	1
1979	33	6	NS	NS	NS
1978	16	NS	NS	NS	NS
1977	0.37	NS	NS	NS	NS
n =	12	9	*8	7	2

* These 8 stations are circled on Figure 20.
n = The number of seining stations in sample area
NS = Not sampled.

DATA FROM: USFWS, USFWS 1987a

Stations circled are those used to estimate the average catch per seine haul of fry in San Francisco Bay from 1977 to 1986.
FROM: USFWS 1987a

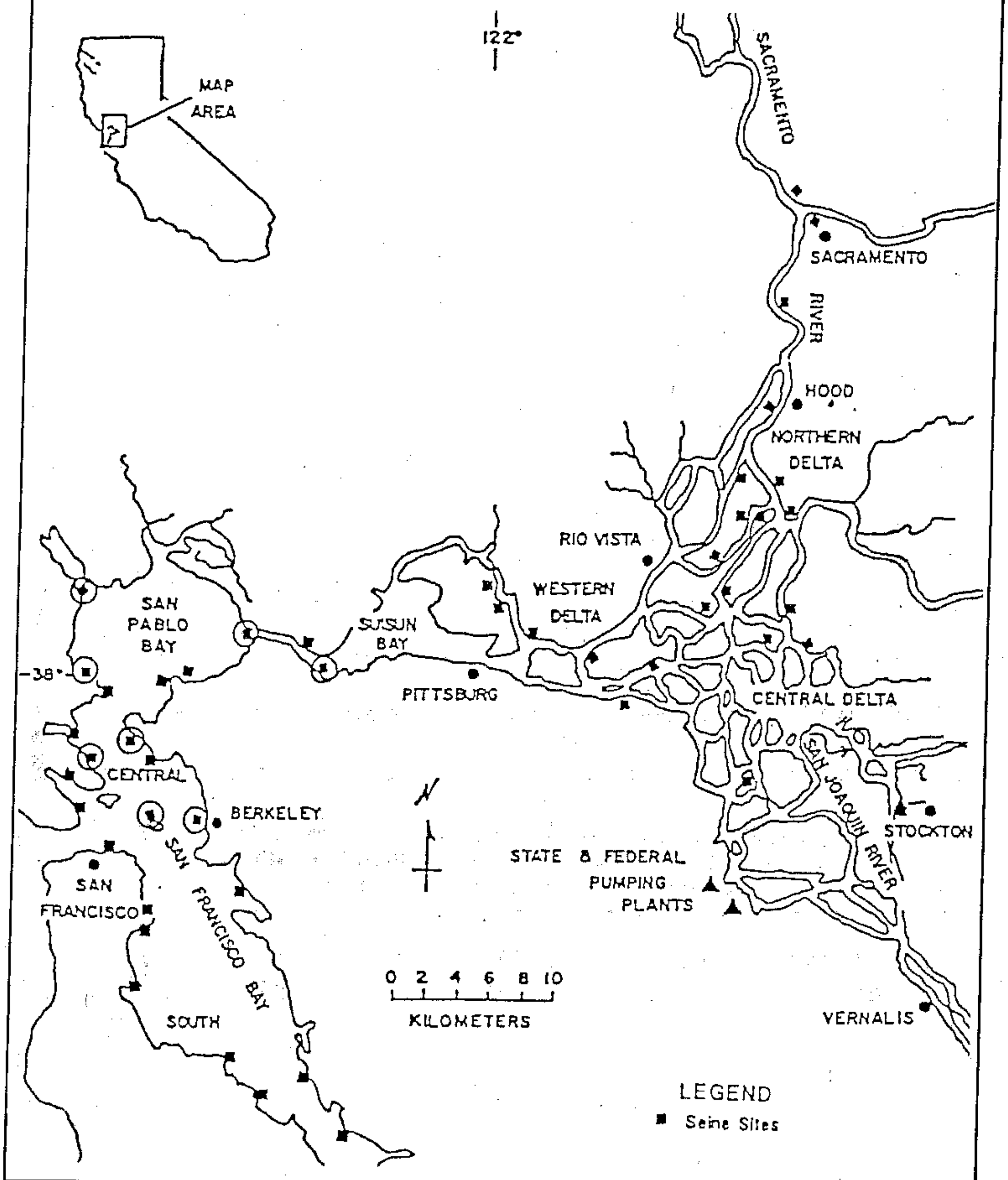


Figure 20

BEACH SEINE RECOVERY SITES FOR SALMON FRY STUDIES

No chinook salmon were captured by DFG's general fish monitoring in Suisun Marsh, This undoubtably reflects sampling gear efficiency and location rather than salmon abundance. Fry tend to congregate near shore and, therefore, were not sampled efficiently by the gear, which does not fish near shore. Also, the gill net mesh sizes were too large to capture these small fish. Salmon smolts are generally found in the upper water column in open water, and probably did not encounter the otter trawl, which fishes on or near the bottom. Smolts are also able to avoid otter trawls.

The Suisun Marsh Fish Monitoring Program of U.C. Davis was somewhat more successful in capturing juvenile salmon. Chinook salmon did not appear to be as abundant as other species collected, which again probably reflects sampling gear efficiency rather than actual salmon abundance. About 60 salmon of fry and smolt size were captured by the otter trawl between 1979 and 1986 (Table 9). Beach seining was more efficient than otter trawls, and about 100 small chinook were captured. Of these, about twice as many fry were collected in marsh areas outside Montezuma Slough (66 fry) by beach seine as were in the slough (31 fry), and even fewer were caught by trawling.

It appears that Montezuma Slough is used as a migratory pathway and perhaps nursery area for fry washed out of upstream areas by high outflows. Salmon fry appeared in numbers in February and March of most years (periods of high flows) and stayed no longer than April, when they had most likely smolted (Table 10). The spring period of high flows moves fry downstream into the estuary and marsh areas. Abundance during this time is affected by Delta outflow, and higher abundances would be expected in years of higher outflow. During the short period salmon are present in the marsh, an increase in standard length is apparent (Table 10). It is difficult to determine whether this growth is occurring within the marsh population or is due to the immigration of later, larger migrants. During April 1983, four of the juveniles captured were 70 mm or longer, indicating that smolt size salmon do find their way into marsh waterways. Two smolts were also captured in December 1981 in Montezuma Slough. These could be from the late fall or winter run of salmon.

Daily catches of salmon at unscreened culverts at Roaring River Slough also confirm the usage of Montezuma Slough by both fry and smolts. Chinook salmon were captured seasonally, with peak abundances in February during the 1980-81 and 1981-82 diversion seasons (Figure 21). They appeared to be mainly fry washed out of the upper river by freshets, although a few fry showed up early in the 1981-82 season. The early group in November 1981 was made up of fry and smolts (70 mm or larger), indicating it is possible that late fall, winter, and spring run chinook salmon also use Montezuma Slough as a migratory pathway (Table 11). A few smolts were also caught in April and May 1981.

Table 9

CHINOOK SALMON FRY COLLECTED BY BEACH SEINE AND OTTER TRAWL IN MONTEZUMA SLOUGH AND ALL OTHER SAMPLE SITES COMBINED IN SUISUN MARSH, 1979-1986

	Montezuma Slough		All Other Sites	
Year	Beach Seine	Otter Trawl	Beach Seine	Otter Trawl
1979	0	0	0	0
1980	28	5	4	9
1981	0	0	2	18
1982	3	0	27	0
1983	0	2	25	8
1984	0	0	2	1
1985	0	0	0	0
1986	0	6	6	8
Total	31	13	66	44

DATA FROM: U.C. Davis

Table 10

MEAN STANDARD LENGTH AND RANGE FOR ALL CHINOOK SALMON CAPTURED IN SUISUN MARSH, 1980-1987

Date	Sample Size	Range (mm)	Mean Length (mm)
01-80	2	30-35	32.5
02-80	18	31-54	42.1
03-80	23	31-62	43.3
02-81	2	7-50	48.5
03-81	16	45-61	53.1
12-81	2	69-101	85.0
03-82	30	30-47	37.7
04-82	2	32-45	38.5
02-83	9	44-57	48.3
03-83	9	39-65	50.0
04-83	17	42-81	58.4
02-84	3	39-50	43.0
02-86	15	31-44	35.3
03-86	2	39-44	41.5
03-87	1	---	36.0

DATA FROM: U.C. Davis

Data from DFG, Pickard et al. 1982.

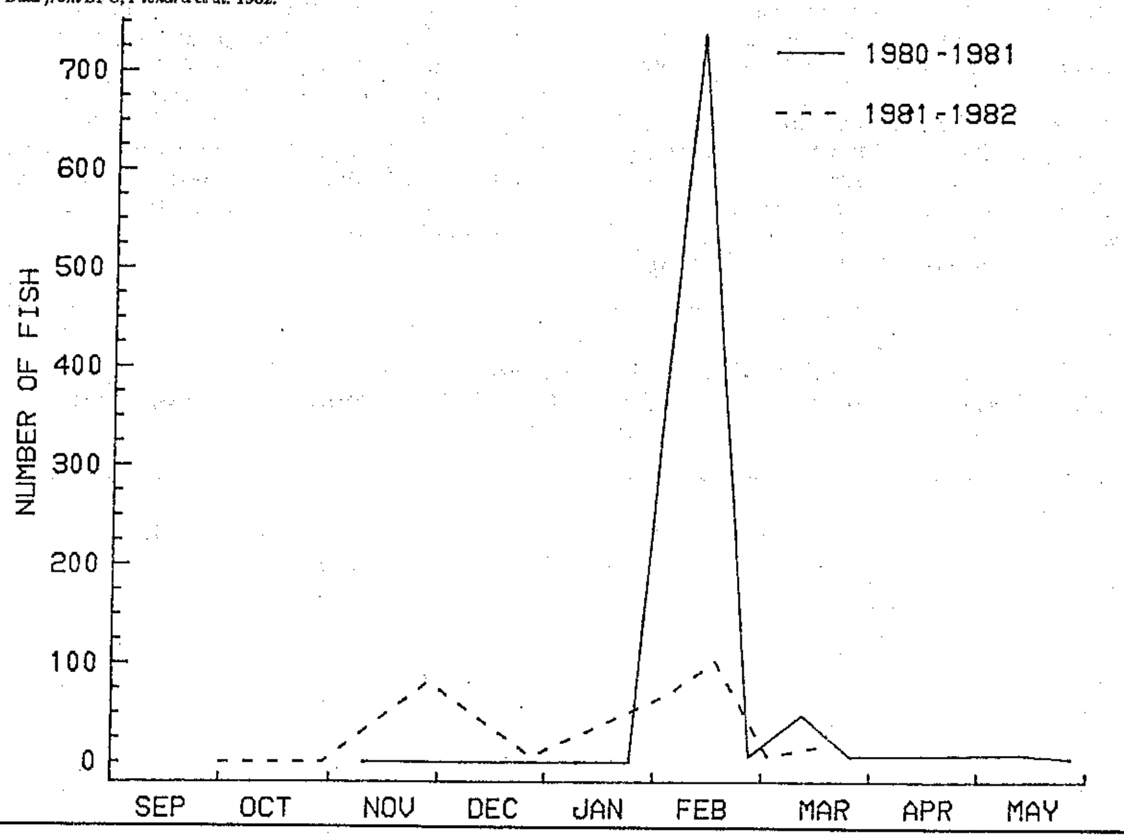


Figure 21

DAILY CATCH OF CHINOOK SALMON OVER TWO DIVERSION SEASONS, ROARING RIVER SLOUGH INTAKE (UNSCREENED CULVERT) 1980-1982 (No Night Sampling Prior to March 1981)

Table 11

DAILY CATCHES AND SIZES OF CHINOOK SALMON AT ROARING RIVER SLOUGH INTAKE (UNSCREENED CULVERT), 1980-1982

Date	Catch	Mean Length (mm)	Range	Sample Size
		1980-81 Diversion Season		
11-06	0	---	---	---
11-21	0	---	---	---
12-02	0	---	---	---
12-18	0	---	---	---
01-02	0	---	---	---
01-16	0	---	---	---
02-03	738	35.96	30-51	50
02-17	6	44.00	42-47	6
03-03	48	40.92	33-55	48
03-16	6	40.67	36-46	6
04-30	8	69.25	53-92	8
05-14	4	69.00	65-73	4
Total	810			
		1981-82 Diversion Season		
09-29	0	---	---	--
10-26	0	---	---	---
11-23	81	48.50	32-77	50
12-21	6	36.33	31-41	6
01-26	68	34.63	30-41	43
02-08	102	36.02	30-46	50
02-22	6	38.33	35-41	6
03-08	16	40.36	33-53	14
Total	279			

DATA FROM: DFG, Pickard et al. 1982

Information on salmon smolts in Montezuma Slough is even more scarce than abundance and migratory information on fry. Since smolts survive to adults at a much greater rate than do fry, there is a need to quantify the use of the slough by migrating smolts. Since part of the Sacramento River flow enters Montezuma Slough, theoretically some smolts migrating down the river could also enter the slough. According to a mathematical model, an estimated Delta outflow of about 19,000 cfs would result in a maximum flow in the slough of about 4,000 cfs. A few smolts migrating downstream have been caught in the studies.

Since most of the Delta outflow passes Chipps Island and into Suisun Bay, the salmon trawling program at Chipps Island provides some information on salmon smolts in Suisun Marsh and Montezuma Slough. The yearly smolt abundance index (smolts/tow) has ranged from 10 in 1984 to 48 in 1983 (Table 12). Smolts were primarily present at Chipps Island from April through June, and were largely fall run salmon (Figure 22). The peak in migration varied slightly from year to year, occurring from late April (1985) to early June (1980). The peak is probably dependent on the type of water year and perhaps on releases from the Coleman National Fish Hatchery. Mid- to late May was the most common time of peak activity (1981-1983), and May usually had the largest percentage of the yearly catch (Table 13). Sampling in 1980 showed that a smaller migration peak also occurs in the fall and appears to be fall-run yearlings

(Figure 23). Larger fish present from January through March were probably winter or spring run smolts.

These studies on chinook salmon in Montezuma Slough and Suisun Marsh provide valuable information on abundance for use in assessing the usage of the marsh by salmon. In general, it appears that these areas are used as a migratory pathway for fry washed out of upstream areas during periods of high outflow, usually January through April. The fry may also use the marsh as a nursery area until they smolt and move out to sea. Based on the limited information available, Montezuma Slough appears to be a migratory pathway for chinook salmon smolts, but the extent is not known. Some chinook salmon fry and smolts have been found during November and December, indicating the marsh is utilized by races other than the fall run, but on a limited basis. While winter run and spring run chinook salmon are not candidates for the list of endangered and threatened species, they are species of concern in the Sacramento-San Joaquin estuary.

Table 12

MEAN CATCH OF SALMON SMOLTS PER 20-MINUTE TOW BY MIDWATER TRAWL AT CHIPPS ISLAND DURING APRIL, MAY, AND JUNE 1978 TO 1987

Year	April	May	June	Annual[1] Mean	Mean[2] Temp(°F)	Percent[3] Diverted
1978	23.1	34.0	27.6	28	63	45
1979	14.9	41.6	23.2	25	63	55
1980	5.6	14.0	21.1	17	62	38
1981	17.3	25.3	8.3	15	67	55
1982	18.9	51.7	34.6	38	60	27
1983	24.8	65.0	42.8	48	57	23
1984	3.2	20.0	7.0	10	64	50
1985	10.3	24.7	4.1	20	66	61
1986	22.5	32.9	4.7	24	65	44
1987	15.4	19.3	0.8	16	NA	NA

[1] Total catch divided by total number of tows for April through June.
[2] Sacramento River at Freeport (mean April through June).
[3] Percent of Sacramento River diverted at Walnut Grove (mean April through June).

SOURCE: USFWS 1987a

SOURCE: USFWS 1987a

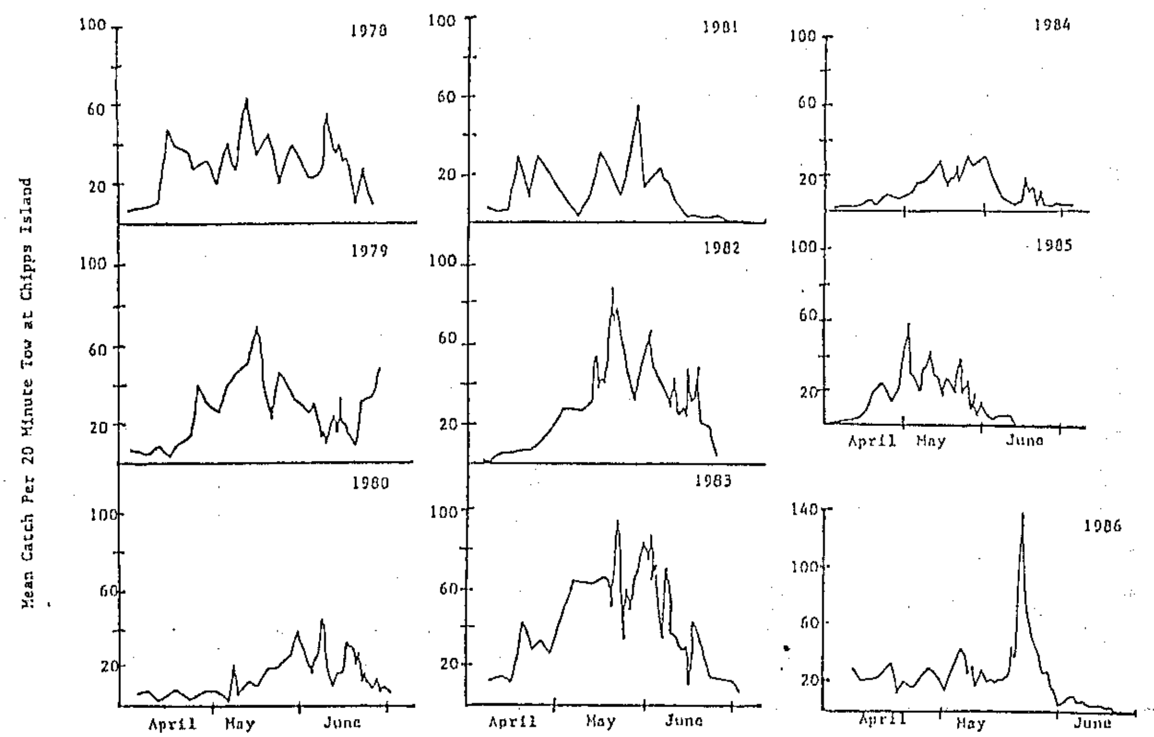


Figure 22

MEAN MIDWATER TRAWL CATCH PER 20-MINUTE TOW AT CHIPPS ISLAND DURING SPRING (APRIL THROUGH JUNE), 1978-1986

Table 13

DISTRIBUTION, BY MONTH, OF TOTAL MIDWATER TRAWL CATCH OF SMOLTS AT CHIPPS ISLAND, 1978-1987

	Percent Of Catch		
Year	**April**	**May**	**June**
1978	27	40	33
1979	19	52	29
1980	14	34	52
1981	34	50	16
1982	18	49	33
1983	19	49	32
1984	11	66	23
1985	26	63	11
1986	37	55	8
Mean (1978-1986)	22	51	27
1987	44	54	2

SOURCE: USFWS 1987a

SOURCE: USFWS 1987a

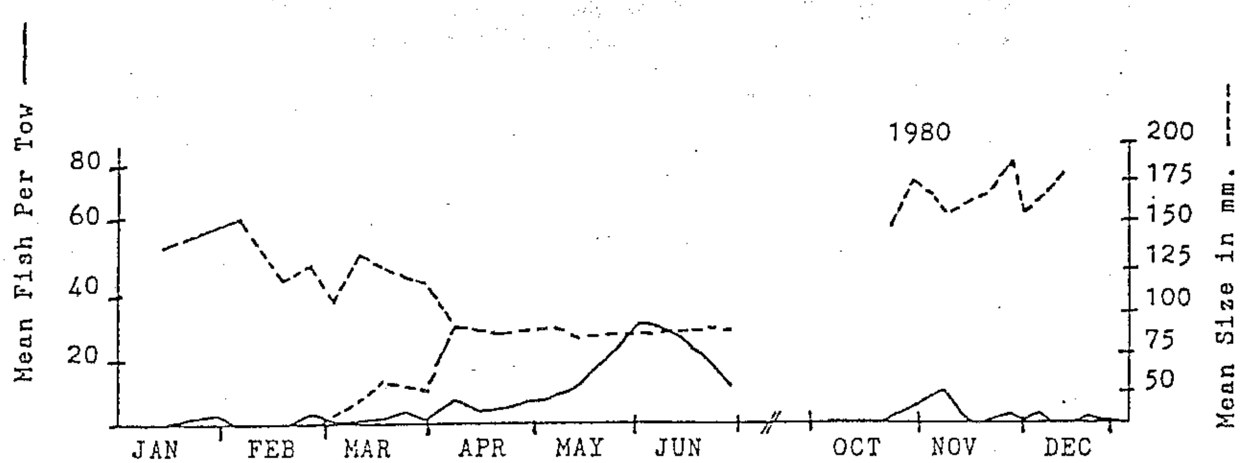


Figure 23

MEAN MIDWATER TRAWL CATCH PER 20-MINUTE TOW AT CHIPPS ISLAND AND MEAN SIZE OF CATCH OVER TIME IN 1980
(Two size groups were observed in March and early April)

Resident Fish and Seasonal Species

Many species of fish other than striped bass and chinook salmon use the aquatic habitat in Suisun Marsh. Resident and seasonal populations of a variety of freshwater, estuarine, and marine fishes are found in the marsh. The DFG Suisun Marsh General Fish Monitoring Program, the University of California, Davis, Suisun Marsh Monitoring Program, and the Roaring River Slough Fish Screen Evaluation have each contributed information on the abundance and distribution of this group of fish.

The DFG monitoring in Suisun Marsh collected 32 species (Table 14). Estuarine (euryhaline and anadromous) species dominated abundance, followed by freshwater species. Striped bass (27,000 fish), threespine stickleback (1,200 fish), splittail (800 fish), and yellowfin goby (800 fish) were the most abundant species from 1974 to1979. A few marine species, such as Pacific staghorn sculpin, surf smelt, and northern anchovy, were captured in low numbers. Delta smelt were collected in the western part of the marsh, and several Sacramento perch were collected in the upper reaches of some of the dead-end sloughs.

Steelhead and American shad were also present in limited numbers. Similar to chinook salmon, steelhead and American shad utilize the marsh, particularly Montezuma Slough, for juvenile and adult migration and nursery habitat (Baracco 1980). Steelhead were captured during February and October (43 fish each), but not during June, indicating this area is used mainly for migration and feeding during fall and winter, and not as year-round nursery habitat. American shad are abundant in the fall and scarce by December or January, migrating to the ocean as temperatures fall (Baracco 1980, Table 15). A similar movement was seen at Carquinez Strait in 1961-62 (Messersmith 1966).

Table 14

FISHES COLLECTED IN SUISUN MARSH BY DFG SUISUN MARSH GENERAL FISH MONITORING PROGRAM, 1974-1979 (In Decreasing Order of Abundance)

Species	Type*	Total
Striped bass		
Age 0-3+	E	26,929
All Ages-June Age 0		3,814
Threespine stickleback	F-E	1,247
Splittail	E	792
Yellowfin goby	E-M	787
Common carp	F	592
Sacramento sucker	F	516
Tule perch	F-E	320
Threadfin shad	E	279
White catfish	F	233
Black crappie	F	179
Sacramento squawfish	F	140
Sacramento blackfish	F	108
Pacific staghorn sculpin	M	104
Steelhead	A	86
American shad	A	83
Brown bullhead	F	82
Delta smelt	E	75
Prickly sculpin	F-E	60
Starry flounder	M	44
Goldfish	F	43
Surf smelt	M	21
Northern anchovy	M	13
Black bullhead	F	11
Hitch	F	9
Sacramento perch	F	5
Bluegill	F	4
White sturgeon	E	3
Pacific tomcod	M	2
Channel catfish	F	2
Largemouth bass	F	1
Longfin smelt	E	1
Mosquitofish	F	1

* A=Anadromous
E=Estuarine
F=Freshwater
M=Marine

Data from DFG

Table 15

MONTHLY TOTAL OF JUVENILE AMERICAN SHAD CAPTURED BY MIDWATER TRAWL IN MONTEZUMA SLOUGH, 1967-1978 (EXCEPT 1974)

Year	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1967	--14	18	33	1	5	2	0	
1968	8	15	16	8	4	1	0	0
1969	10	0	13	--	4	0	--	0
1970	3	7	0	0	0	0	1	2
1971	--	2	2	0	0	0	0	0
1972	--	0	0	6	3	0	0	0
1973	--	6	2	4	0	0	--	--
1975	--	16	4	5	7	--	--	--
1976	--	--	0	4	--	1	--	--
1977	--	0	0	6	1	2	--	0
1978	--	42	6	9	5	--	1	--
AVERAGE	7.0	10.2	5.5	7.5	2.5	1.0	0.7	0.3

Baracco 1980

The species composition of fish in the sloughs fluctuated with salinity and flow (Herrgesell et al. 1981) (Figure 24). In 1977, the salinity increased dramatically due to drought conditions. This increase was accompanied by a decrease in freshwater fish abundance and a slight increase in that of marine species. Abundance of euryhaline species, such as striped bass, remained fairly stable and increased markedly into 1978 with a drop in salinity.

Through 1983, the U.C. Davis fish monitoring program has collected 42 species in Suisun Marsh (Table 16). Similar to DFG's study, striped bass (24,000 fish), splittail (11,000 fish), and threespine stickleback (10,000 fish) were the most abundant fish species in the marsh. Fewer than 25 fish were collected for half of the species represented, and these were usually present only during periods of extremely high or low outflow (Brown 1987). The remaining species were abundant enough to be classified as residents (native or introduced species) or regularly invading seasonals.

The patterns of occurrence of the more abundant species produced three seasonal groups (Moyle et al. 1986). Abundance of the resident fish (species 1-8, Table 16), including striped bass, splittail, and tule perch, increased and peaked with influxes of young-of-the-year as summer progressed. Winter seasonals (Delta smelt, longfin smelt, threadfin shad) tended to be most abundant from November to January, during periods of high outflow and low salinity. Spring/summer seasonals (staghorn sculpin and starry flounder) were represented mainly by YOY and peaked between March and September under more saline conditions. Resident species with little seasonal variation in abundance were carp, Sacramento sucker, and yellowfin goby. With no seasonal influx of YOY, these species showed little evidence of reproduction in the marsh.

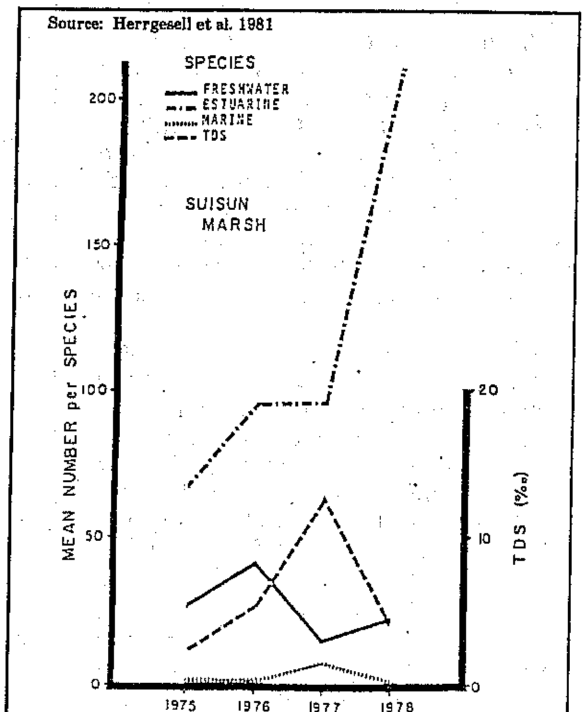


Figure 24

CHANGES IN ABUNDANCE OF FISHES, GROUPED BY SALINITY TOLERANCE, IN SUISUN MARSH, 1975-1978

Table 16

FISHES COLLECTED IN SUISUN MARSH IN U.C. DAVIS FISH MONITORING PROGRAM (In Decreasing Order of Abundance)

Species	Numbers	Origin
Striped bass, *Morone saxatilis*	24,154	E. North America (E)
Splittail, *Pogonichthys macrolepidotus*	11,250	Native (E)
Threespine stickleback, *Gasterosteus aculeatus*	9,956	Native (F-E)
Tule perch, *Hysterocarpus traski*	7,693	Native (F-E)
Prickly sculpin, *Cottus asper*	4,639	Native (F-E)
Yellowfin goby, *Acanthogobius flavimanus*	1,786	Japan (E-M)
Sacramento sucker, *Catostomus occidentalis*	1,703	Native (F)
Common carp, *Cyprinus carpio*	1,573	Asia (F)
Threadfin shad, *Dorosoma petenense*	1,088	E. North America (E)
Staghorn sculpin, *Leptocottus armatus*	985	Native (M)
Starry flounder, *Platichthys stellatus*	849	Native (M)
Longfin smelt, *Spirinchus thaleichthys*	650	Native (E)
Delta smelt, *Hypomesus transpacificus*	450	Native (E)
American shad, *Alosa spadissima*	218	E. North America (A)
Sacramento squawfish, *Ptychocheilus grandis*	140	Native (F)
Chinook salmon, *Oncorhynchus tshawytscha*	96	Native (A)
Hitch, *Lavinia exilicauda*	56	Native (F)
Inland silverside, *Menidia beryllina*	50	E. North America (F-E)
Goldfish, *Carassius auratus*	45	Asia (F)
Northern anchovy, *Engraulis mordax*	34	Native (M)
Sacramento blackfish, *Orthodon microlepidotus*	25	Native (F)
Pacific herring, *Clupea harengeus*	24	Native (M)
White catfish, *Ictalurus catus*	23	E. North America (F)
Bluegill, *Lepomis macrochirus*	16	E. North America (F)
Mosquitofish, *Gambusia affinis*	15	E. North America (F)
Black crappie, *Pomoxis nigromaculatus*	14	E. North America (F)
Bigscale logperch, *Percina macrolepida*	10	Texas (F)
White sturgeon, *Acipenser transmontanus*	10	Native (E)
Fathead minnow, *Pimephales promelas*	9	E. North America (F)
Brown bullhead, *Ictalurus nebulosus*	6	E. North America (F)
Rainwater killifish, *Lucania parva*	5	E. North America (E)
Green sunfish, *Lepomis cyanellus*	4	E. North America (F)
Pacific sanddab, *Citharichthys sordidus*	4	Native (M)
Pacific lamprey, *Lampetra tridentata*	4	Native (A)
Surf smelt, *Hypomesus pretiosus*	3	Native (M)
Channel catfish, *Ictalurus punctatus*	3	E. North America (F)
Black bullhead, *Ictalurus melas*	3	E. North America (F)
Shiner perch, *Cymatogaster aggregata*	3	Native (M)
Golden shiner, *Notemigonus crysoleucus*	3	E. North America (F)
Warmouth, *Lepomis gulosus*	1	E. North America (F)
Rainbow trout, *Salmo gairdneri*	1	Native (A)
Longjaw mudsucker, *Gillichthys mirabilis*	1	Native (M)

A=Anadromous, E-Estuarine, F=Freshwater, M=Marine

FROM: Moyle et al. 1986.

Patterns of occurrence of fish in the marsh varied spatially as well as seasonally (Brown 1987). Beach seining collected a different group of species than did trawling, and emphasized species that tend to congregate near shore, such as inland silversides, chinook salmon, and threespine stickleback. The upper reaches of dead-end sloughs yielded mainly native resident species, while introduced residents were captured throughout the marsh.

Throughout the study, measures of overall fish abundance showed a general decline (Moyle et al. 1986) (Figure 25). The mean number of fish per trawl showed short periods of high abundance in late summer due to YOY contributions. However, these peaks declined with successive years, and a smooth decline in biomass was also apparent. Species diversity (Shannon-Weiner diversity function) has also declined over time and is significantly correlated ($r=0.64$; $p>0.05$) with the number of months since the sampling program began.

FROM: Moyle et al. 1986.

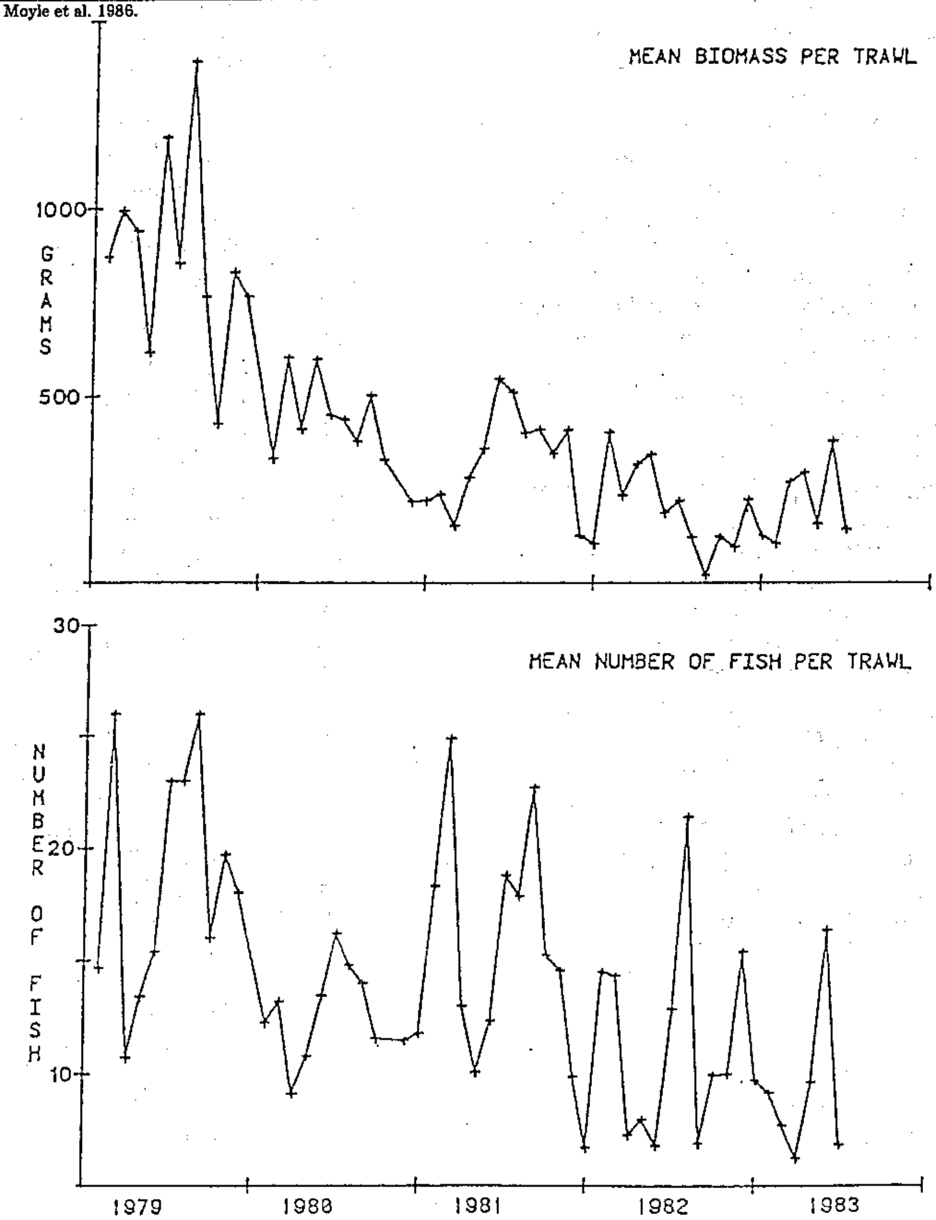


Figure 25

TRENDS IN OVERALL FISH ABUNDANCE IN SUISUN MARSH, 1979-1983

Patterns of occurrence in Montezuma Slough were somewhat different than in other marsh sites. On the whole, Montezuma Slough had a lower percentage of resident fish species than did other sites (Figure 26). The difference was most pronounced during the period from October through March. At this time of year, trawls consisted more of seasonal species than resident species, particularly smelts. The Delta smelt tended to be most abundant from November to January and was found in abundance with longfin smelt and threadfin shad. However, since 1985, no Delta smelt have been caught in this study. Abundances have also been low in other areas of the estuary since 1983. The percentage of resident fish was higher during summer due to the decrease of winter seasonals and the influx of young-of-the-year residents, especially striped bass.

The resident fish population in Montezuma Slough was made up of introduced and native species. The introduced species (striped bass, carp, yellowfin goby) were much more abundant in the trawls than the native fish (splittail, prickly sculpin, tule perch, sucker, Figure 27). However, striped bass contributed most to the abundance of introduced residents (Figure 28). Without this species, the abundance of introduced and native residents were comparable, with some variation between winter and summer. Splittails, a native species of concern due to recent significant population declines, were usually low in abundance, with occasional large catches in January and February.

During the 1980-1982 evaluation of the Roaring River Fish Screen, 33 species of fish were captured. Threespine stickleback and Delta smelt were the most common species caught during both diversion seasons (Table 17). Longfin smelt, chinook salmon, and striped bass were also numerous. Splittails were present in low abundance. Most fish collected were either juveniles or from species that are not large as adults (Pickard et al. 1982). Some of the fish were seasonally abundant (chinook salmon, tule perch, American shad, and Sacramento squawfish). Other species were collected throughout the diversion seasons (Delta smelt, longfin smelt, striped bass, and threespine stickleback). Catches were usually higher for samples taken at night.

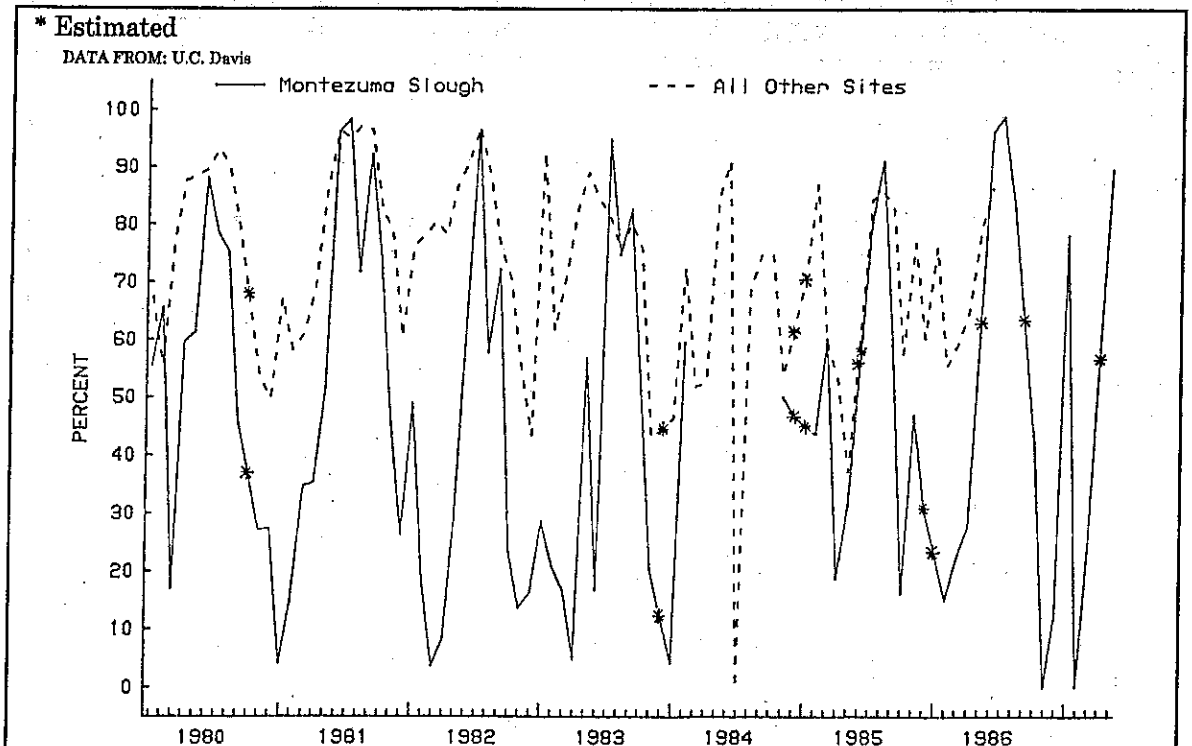


Figure 26

PERCENTAGE OF RESIDENT FISH IN CATCH FOR MONTEZUMA SLOUGH (EXCEPT 1984) AND ALL OTHER SAMPLE SITES COMBINED IN SUISUN MARSH, 1980-1987

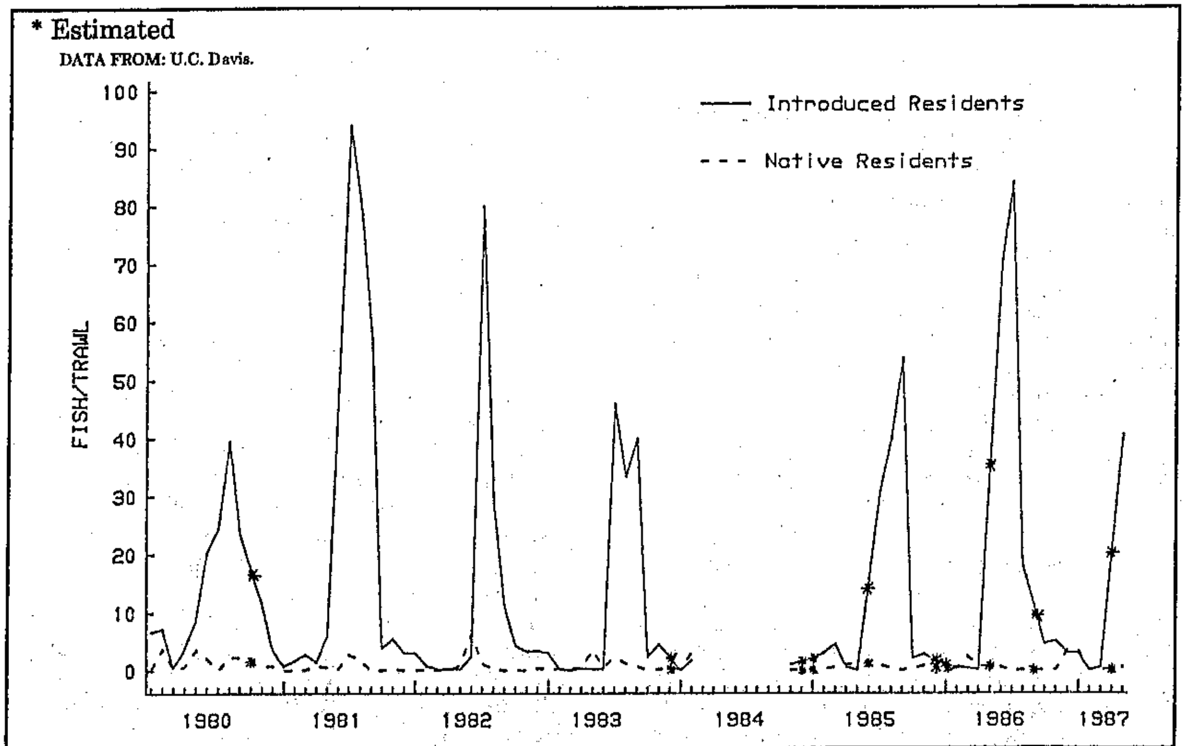


Figure 27

MEAN CATCH OF RESIDENT FISH IN MONTEZUMA SLOUGH AND ALL OTHER SAMPLE SITES COMBINED IN SUISUN MARSH, 1980-1987 (EXCEPT 1984)

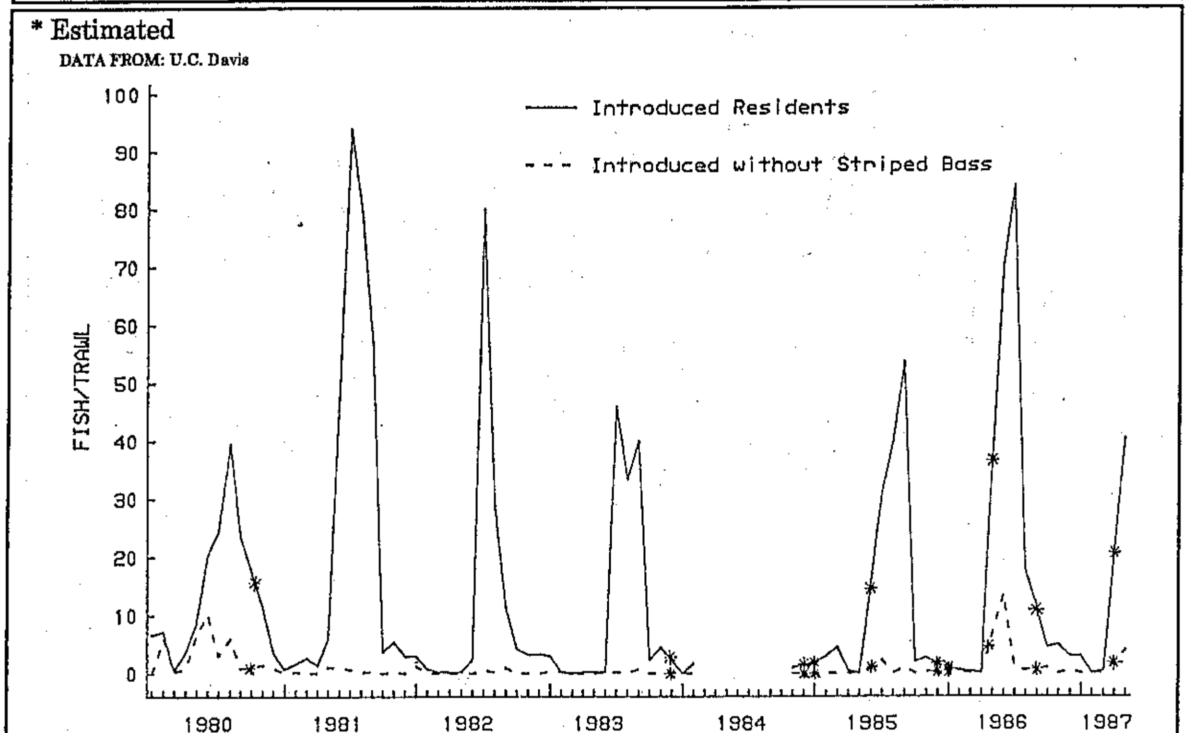


Figure 28

MEAN CATCH OF INTRODUCED RESIDENT FISH WITH AND WITHOUT STRIPED BASS IN MONTEZUMA SLOUGH AND ALL OTHER SAMPLE SITES COMBINED IN SUISUN MARSH, 1980-1987 (EXCEPT 1984)

These studies provide insight into abundance and distribution of fish species within Suisun Marsh. Salinity is probably one of the main factors controlling the types of species present, as it appears that estuarine species dominate in this habitat. Typically, striped bass was the most abundant fish, with threespine stickleback, splittail, and yellowfin goby also consistently abundant. Tule perch, threadfin shad, and Delta smelt, which are forage for striped bass, were moderately abundant. Delta smelt and splittail have declined significantly and are being studied to determine if they can be added to the List of Endangered and Threatened Wildlife (USFWS 1987b). Sacramento perch are also a species of concern, but appear to be limited to freshwater, upper reaches of dead-end sloughs.

Table 17

FISHES COLLECTED AT ROARING RIVER SLOUGH INTAKE (UNSCREENED CULVERT), 1980-1982

Species	Type	Total
Delta smelt	E	5,841
Threespine stickleback	F-E	3,586
Longfin smelt	E	1,133
Chinook salmon	A	1,089
Striped bass	E	582
Threadfin shad	E	230
Inland silverside	F-E	218
Yellowfin goby	E-M	137
Prickly sculpin	F-E	111
Bluegill	F	57
Tule perch	F-E	47
Sacramento squawfish	F	44
Bigscale logperch	F	25
Splittail	E	23
Black crappie	F	16
Pacific lamprey	A	15
Rainwater killifish	E	11
American shad	A	9
Common carp	F	9
Redear sunfish	F	7
White catfish	F	6
Northern anchovy	M	6
Warmouth	F	6
Pacific herring	M	3
Brown bullhead	F	3
Pacific staghorn sculpin	M	2
Green sunfish	F	2
Rainbow trout	A	1
Largemouth bass	F	1
California roach	F	1
Golden shiner	F	1
Hardhead	F	1
Mosquitofish	F	1

* A = Anadromous
E = Estuarine
F = Freshwater
M = Marine

Data from: Pickard et al. 1982

Neomysis

Due to its size, large concentration, and simultaneous occurrence with young fish, the mysid shrimp, *Neomysis mercedis*, is an important dietary component for many marsh fishes, including striped bass (Heubach 1972). Many fish species would be affected by any substantial change to the *Neomysis* population due to alterations of the environment. The DFG *Neomysis*/zooplankton survey and U.C. Davis Suisun Marsh Fish Monitoring Program have included *Neomysis* monitoring to examine distribution and abundance of this organism.

In general, DFG's survey data demonstrate that substantial numbers of mysid shrimp are commonly found in Suisun Marsh. In Montezuma Slough, *Neomysis* are abundant and vary annually and seasonally (Figure 29). Prior to 1977, annual variation in mysid density was pronounced, with several years of high densities (1973, 1974, 1976) and two years of much lower densities. Under 1977 drought conditions, densities dropped dramatically, and *Neomysis* were practically nonexistent in Montezuma Slough. *Neomysis* populations did return after 1977, but did not reach the previous high density until 1985.

The seasonal variability of *Neomysis* in Montezuma Slough followed a consistent pattern from year to year (Figures 29 and 30). Two peaks in density were common during the year. Densities usually increased in April and May and peaked in May or June, the period of highest abundance throughout the year. Numbers dropped in July and August, often followed by a second, smaller peak in September or October. Lowest densities were usually in November through March.

Suisun Bay *Neomysis* populations followed a similar pattern of abundance (1970, 1973, 1974, Figure 31). Densities were higher from May to July and tended to peak at about the same time as in Montezuma Slough. In comparison, two areas of the western Delta exhibit similar seasonal variations, with very low densities in 1977 to 1979 (Figures 32 and 33). The decline in the Sacramento River appears to have begun prior to 1976.

Broken line indicates period of no sampling.
Data from DFG.

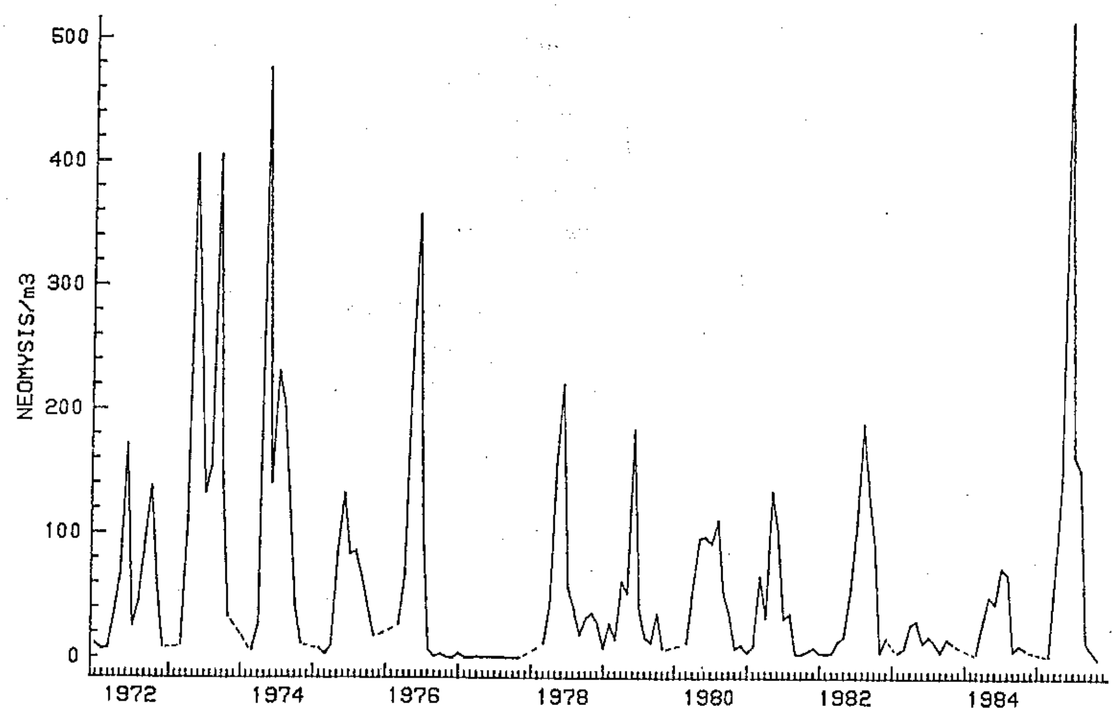


Figure 29

MEAN DENSITIES OF *NEOMYSIS* 4 MM OR LONGER, MONTEZUMA SLOUGH, 1972-1985

Data from DFG.

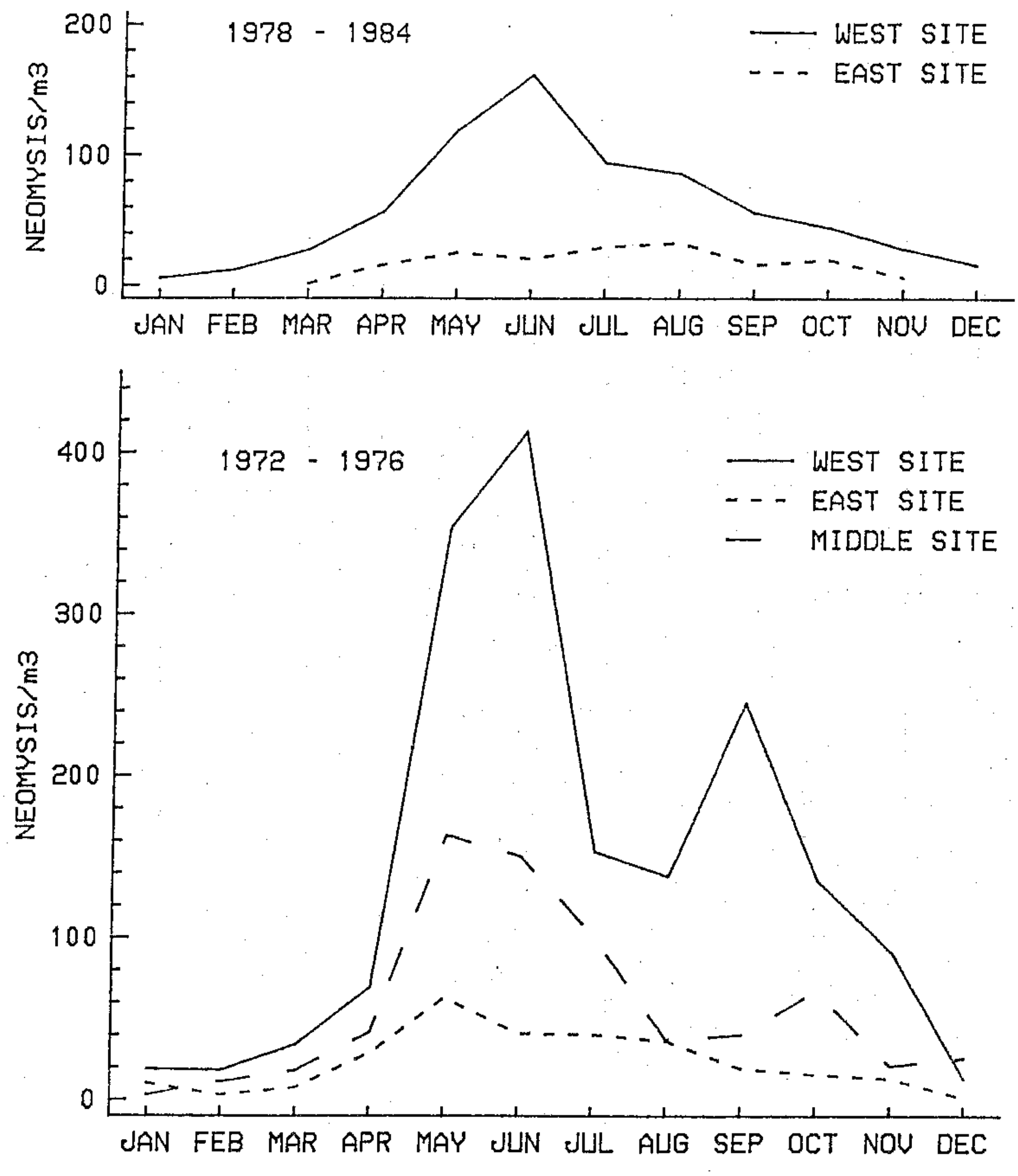
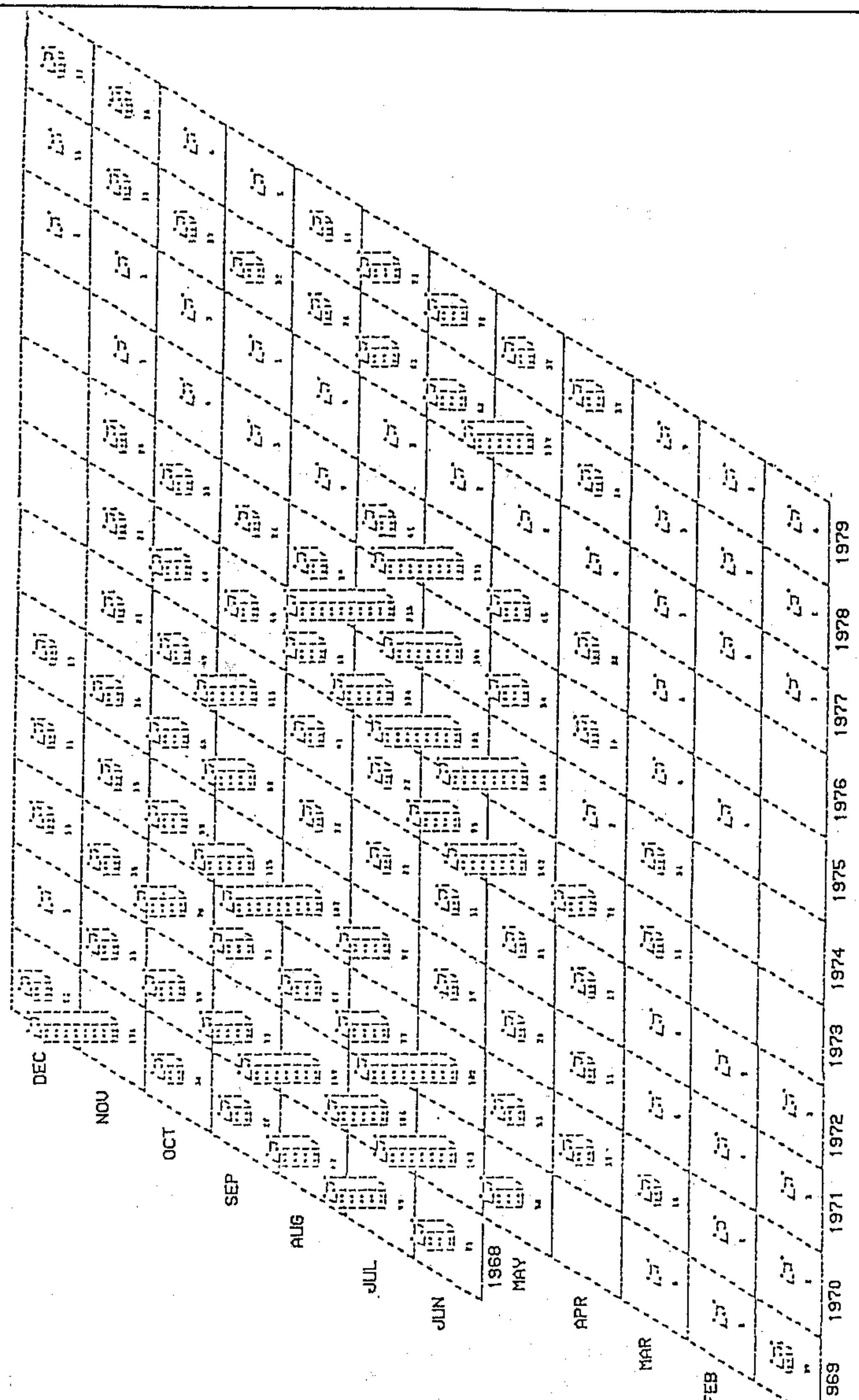


Figure 30

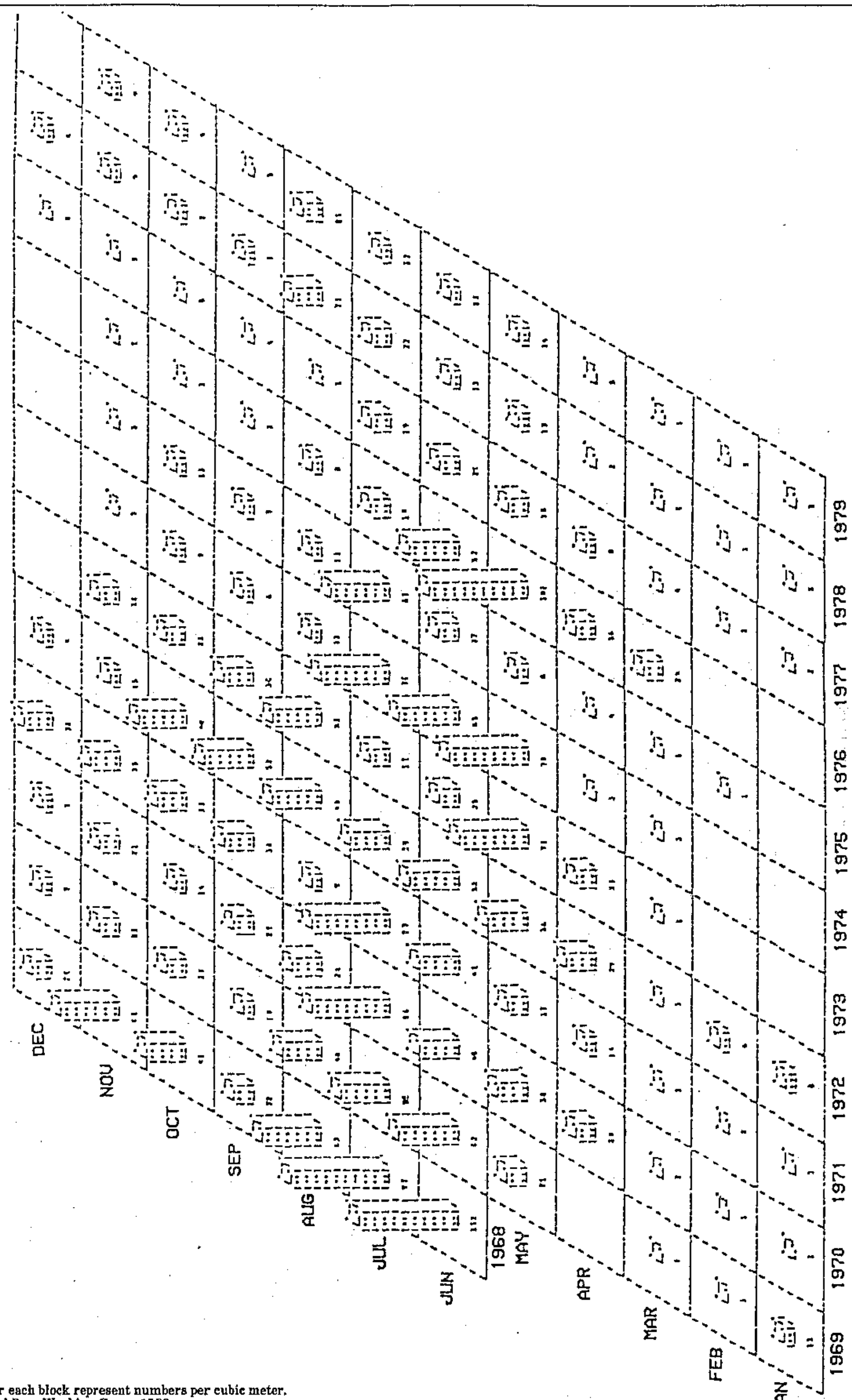
MEAN DENSITIES OF *NEOMYSIS* 4 MM OR LONGER FOR SAMPLE SITES IN MONTEZUMA SLOUGH, 1978-1984 AND 1972-1976



Numbers under each block represent numbers per cubic meter.
FROM: Striped Bass Working Group 1982.

Figure 31

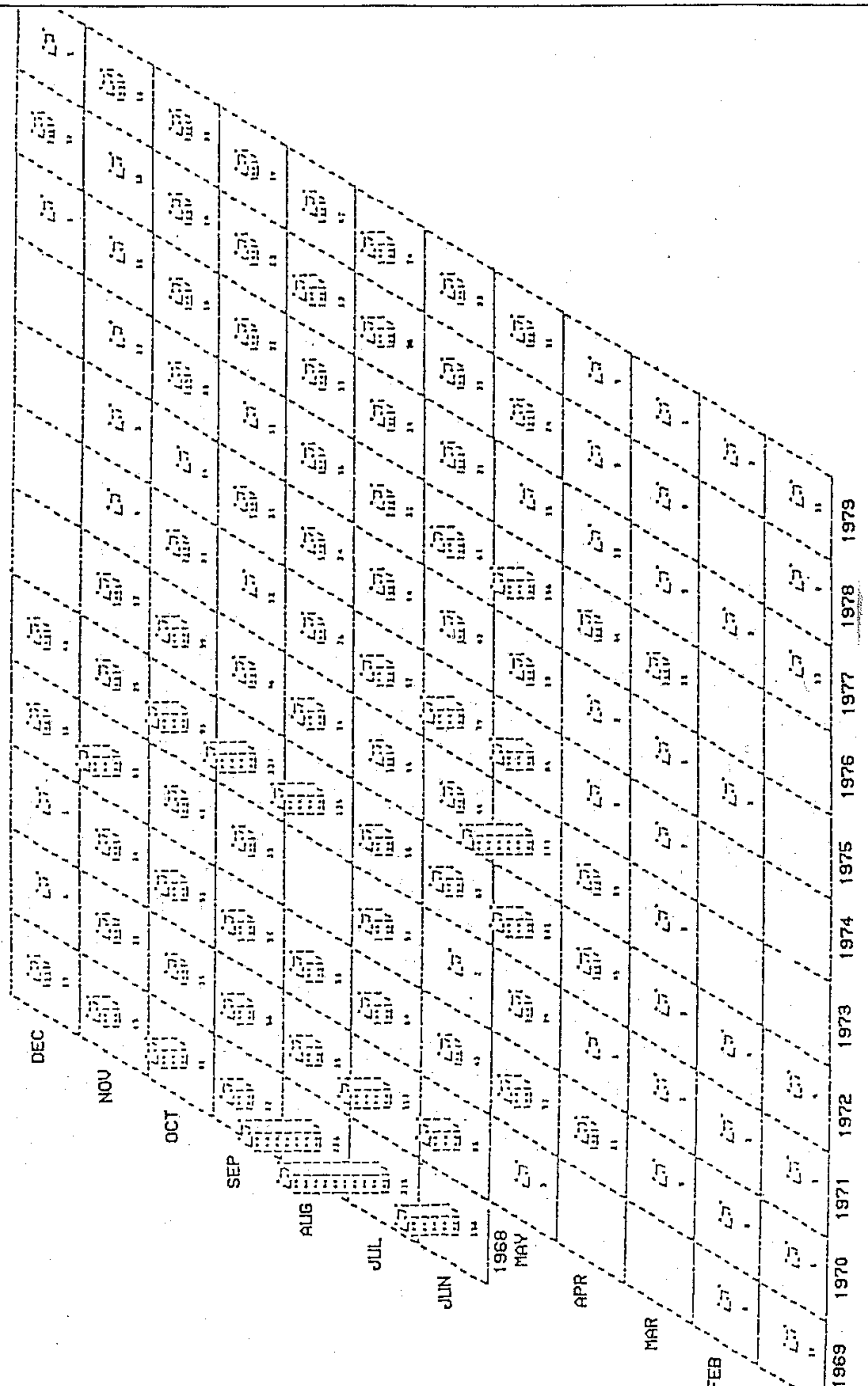
CONCENTRATIONS OF *NEOMYSIS* OVER TIME, MAIN CHANNEL OF SUISUN BAY, 1968-1979



Numbers under each block represent numbers per cubic meter.
FROM: Striped Bass Working Group 1982.

Figure 32

CONCENTRATIONS OF *NEOMYSIS* OVER TIME, LOWER SAN JOAQUIN RIVER, 1968-1979



Numbers under each block represent numbers per cubic meter.
FROM: Striped Bass Working Group 1982.

Figure 33

CONCENTRATIONS OF *NEOMYSIS* OVER TIME, LOWER SACRAMENTO RIVER, 1968-1979

Dr. Moyle's study of marsh fish populations included a qualitative *Neomysis* component. The otter trawl used was reasonably efficient for the shrimp, and a numerical rating was assigned to each catch to describe abundance of the shrimp (Moyle et al. 1986):

1 Less than 3 shrimp
2 3 to 50 shrimp
3 50 to 200 shrimp
4 200 to 500 shrimp
5 More than 500 shrimp

The average monthly index values of *Neomysis* in Suisun Marsh (all stations) for 1979 through 1983 exhibited extreme seasonal fluctuations (Figure 34). Shrimp were very abundant from April to June, and numbers declined rapidly through the summer to a low level in winter months. The results of this qualitative survey appear to support the DFG data showing that populations tend to peak in late spring and early summer.

Substantial numbers of *Neomysis* are generally found in Suisun Marsh. In the vicinity of Suisun Bay, conditions are favorable to high standing crops of *Neomysis* in the entrapment zone during summer (Arthur and Ball 1978). In this area, the mixing of saline and fresh water results in aggregation or "entrapment" of suspended materials, such as zooplankton and phytoplankton. *Neomysis* feed on phytoplankton and, therefore, find favorable conditions to produce high density populations. In all but the driest years, an estimated 60 percent of the summer *Neomysis* population can be found in Suisun Bay, while 8 percent resides in Montezuma Slough (California Department of Fish and Game 1976). Years of low Delta outflow can cause the entrapment zone to move from Suisun Bay upstream into the Delta, reducing habitat and phytoplankton productivity. The low *Neomysis* densities after 1976 appear to be related to this movement.

Primary Productivity

Phytoplankton are the base of the aquatic food chain in Suisun Marsh and are mainly utilized by zooplankton and some fish. These microscopic plants respond quickly to major alterations in their environment. Chlorophyll *a* is a measure of phytoplankton production and has been measured as a part of the Striped Bass Egg and Larva Survey and the *Neomysis*/ Zooplankton Survey.

FROM: Moyle et al. 1986.

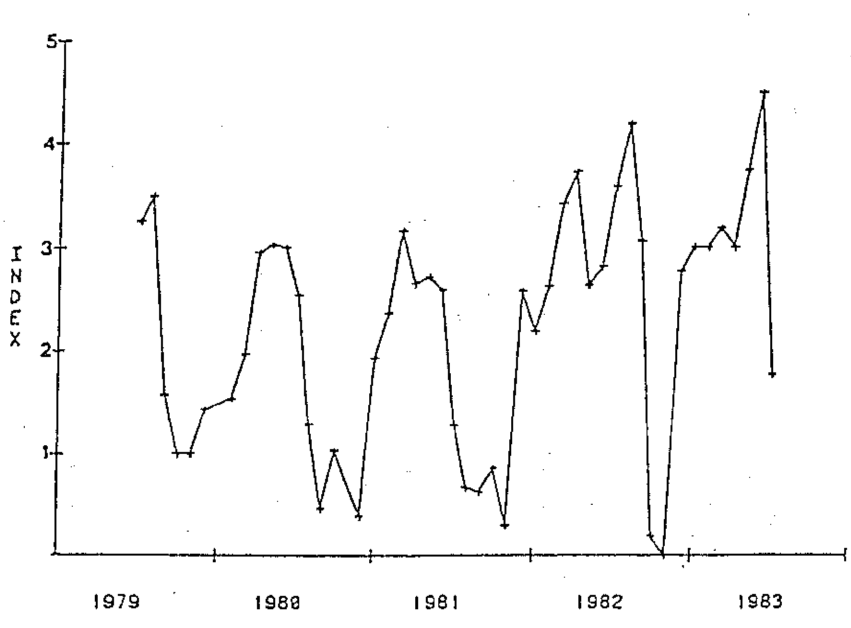


Figure 34

VARIATION IN INDEX OF *NEOMYSIS* CATCH, ALL SUISUN MARSH STATIONS, 1979-1983

General trends in basic productivity from 1969 through 1982 were examined for the western Delta and Suisun Bay, which are important nursery areas for young fish, from (Striped Bass Working Group 1982). In the western Delta (Figure 35), a spring bloom of phytoplankton occurred during most years, usually in April and May (1970-1976, 1981) but sometimes as late as June or July (1982, 1969). No spring bloom occurred from 1977 to 1980.

Solid line represents monthly mean for all years; dashed line is mean for that year.
FROM: Striped Bass Working Group 1982.

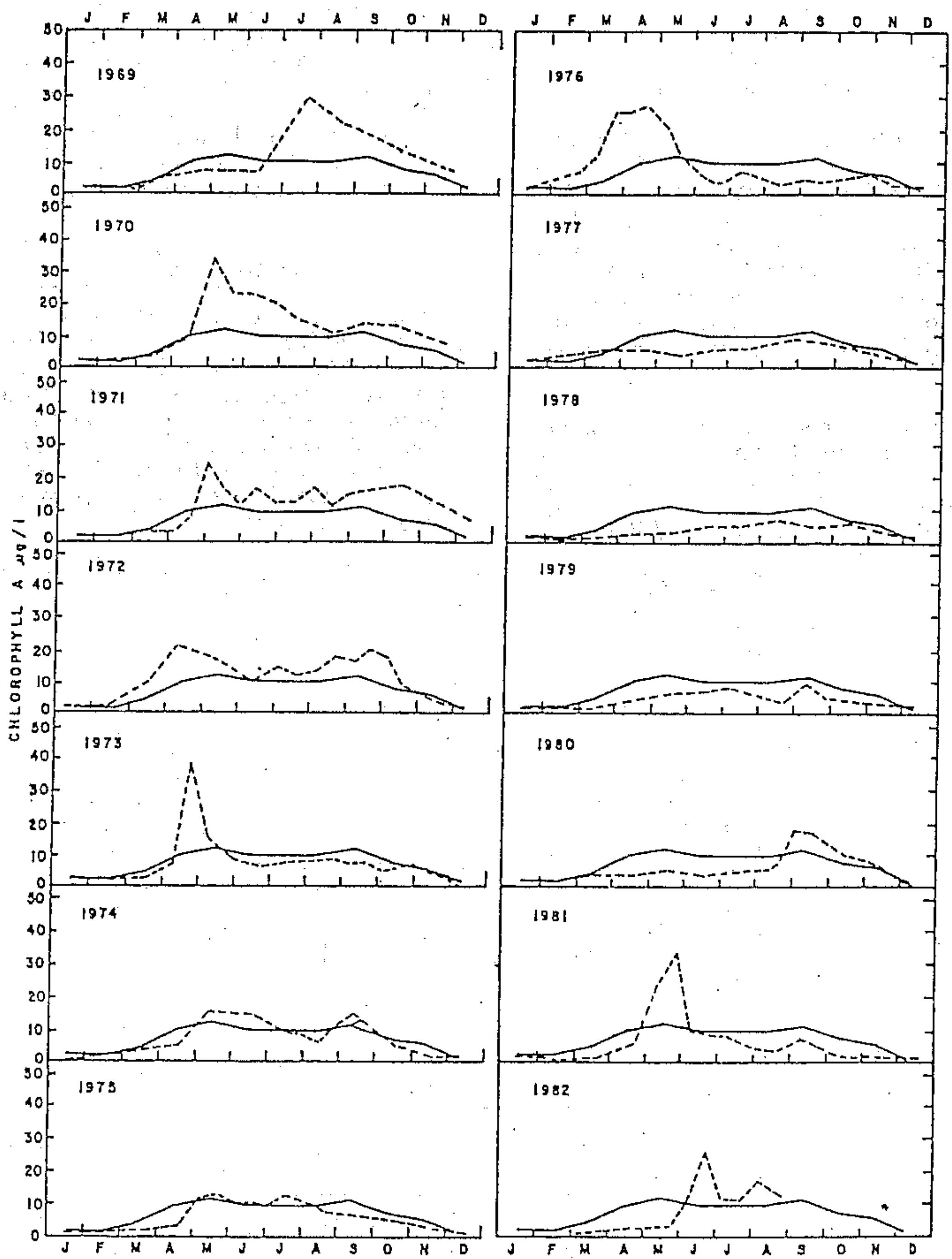


Figure 35

CHLOROPHYLL *a* CONCENTRATION IN WESTERN DELTA, 1969-1982

Suisun Bay also displayed seasonal changes in phytoplankton production, but they were more variable (Figure 36). Usually a small bloom occurred in spring (April-June) followed by a larger bloom in late summer (August-September). No bloom occurred in 1977, but populations did recover in the following years. Overall, the level of productivity in Suisun Bay is slightly higher than in the western Delta.

Solid line represents monthly mean for all years; dashed line is mean for that year.
FROM: Striped Bass Working Group 1982.

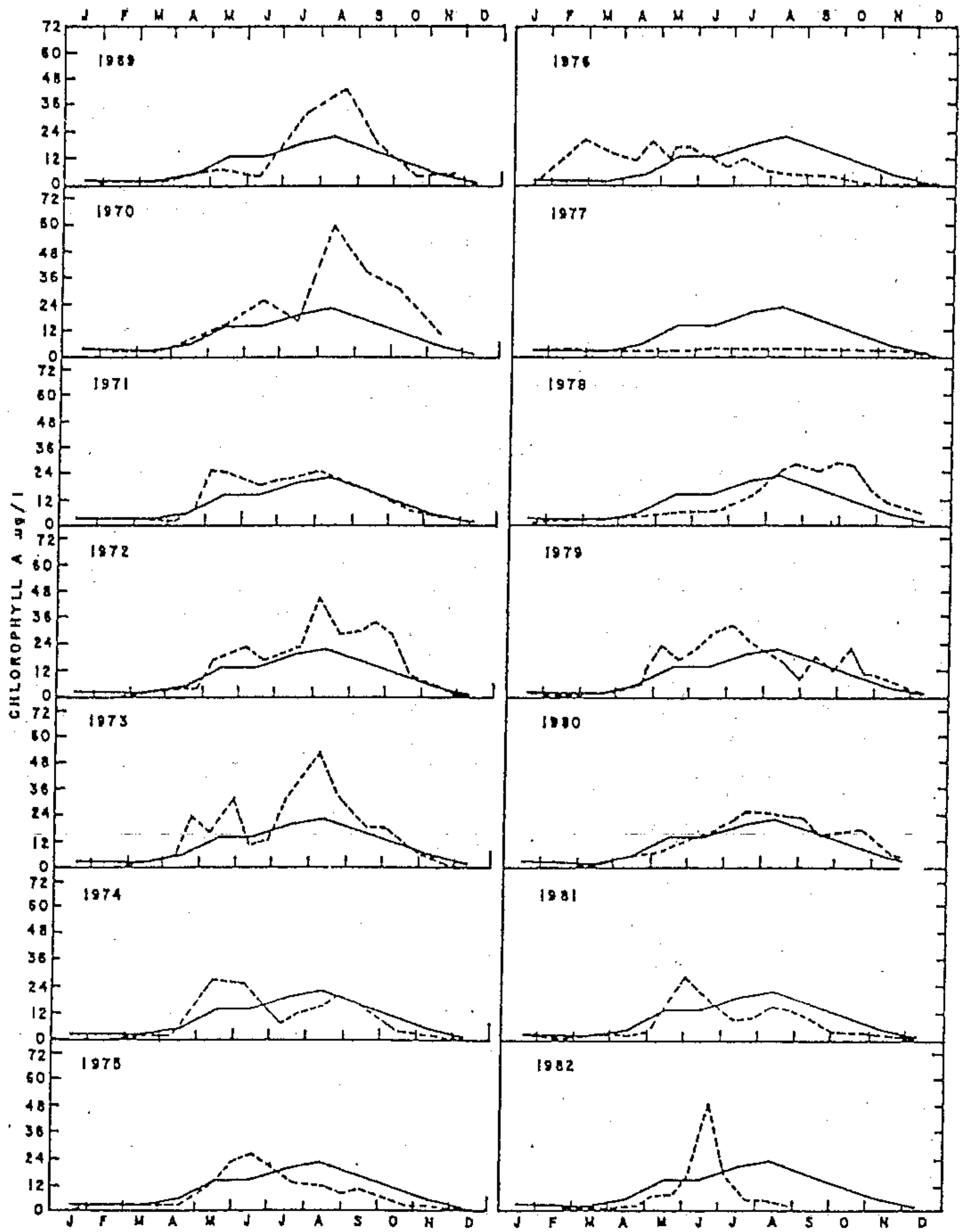


Figure 36
CHLOROPHYLL *a* CONCENTRATION IN SUISUN BAY, 1969-1982

The Striped Bass Egg and Larva Survey monitored the spatial and temporal distribution of chlorophyll *a* in several areas of the estuary (Fusfeld-Low 1986b) (Figure 37). Chlorophyll *a* concentrations were plotted by 8-day periods from April 16 to July 13, 1986. Densities of zooplankton generally increased one to two time periods (8-16 days) after an increase in chlorophyll *a* concentration. The San Joaquin River area had the highest concentrations; the lower Sacramento River, Suisun Bay, and Montezuma Slough were somewhat lower, but comparable. Montezuma Slough had slightly greater concentrations and for a longer period.

FROM: Fusfeld-Low 1986b.

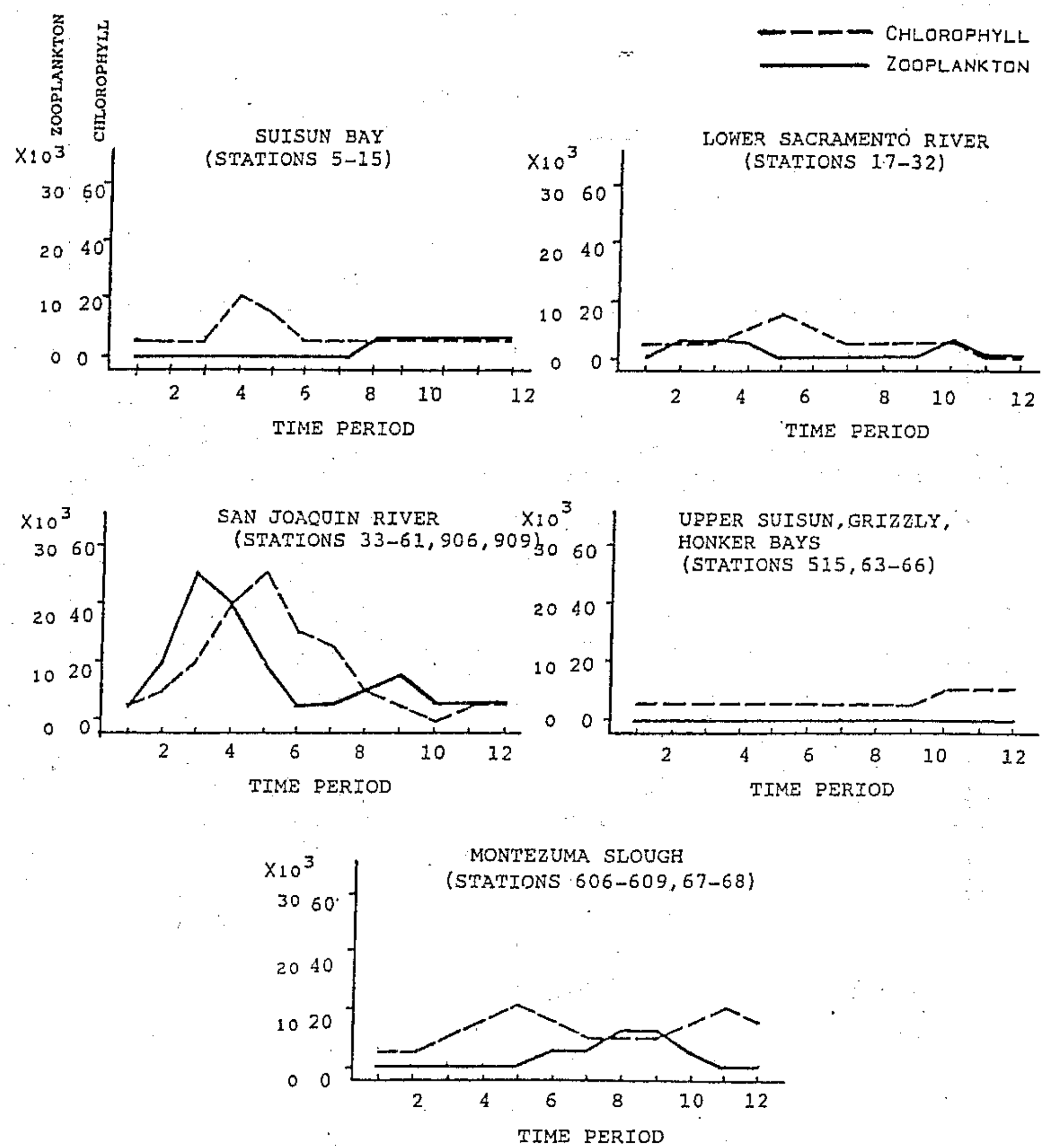


Figure 37

MEAN CONCENTRATION OF CHLOROPHYLL *a* (In micrograms per liter) AND MEAN DENSITY OF IMPORTANT ZOOPLANKTON PREY ITEMS (In numbers per cubic meter) BY 8-DAY TIME PERIODS IN FOUR AREAS OF THE ESTUARY, 1986

Chlorophyll *a* concentrations were monitored as part of the *Neomysis*/Zooplankton Survey, as well. Changes in phytoplankton abundance in Montezuma Slough were generally seasonal, with a spring bloom from May to June, and sometimes as late as July (Figure 38). A second bloom sometime from August through October was not uncommon (1978-79, 1981-82). Densities were usually less than 30 ug/L.

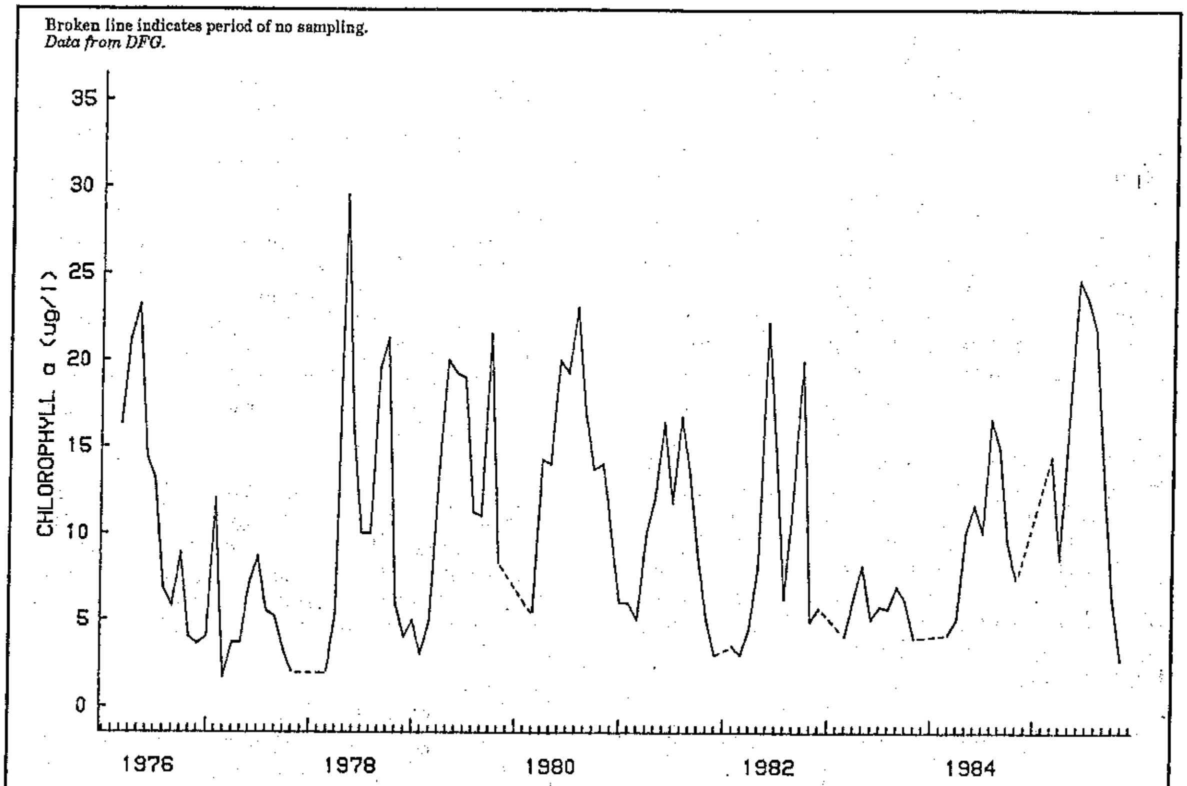


Figure 38

MEAN CONCENTRATION OF CHLOROPHYLL *a* IN MONTEZUMA SLOUGH, 1976-1985

Summary

Although data regarding Suisun Marsh fish populations are somewhat limited, the following general observations can be made.

Euryhaline species appear to dominate in Suisun Marsh and Montezuma Slough. The more abundant species are in three seasonal groups: residents, winter seasonals, and spring/summer seasonals. Striped bass were usually the most abundant fish collected; threespine stickleback, splittail, and yellowfin goby were also consistently abundant. Tule perch, threadfin shad, and Delta smelt (forage fish) were moderately abundant. In Montezuma Slough, resident species (native and introduced) dominate during summer and are least abundant during winter months. Striped bass are the most abundant fish in the slough.

- Chinook salmon fry appear in Montezuma Slough and Suisun Marsh during periods of high outflow, using this area as a migratory pathway. The fry may also use the marsh as a nursery area until they smolt and move out to sea. Some fry have been found during November and December, indicating that the marsh is also used by races other than fall run chinook salmon.

- Based on the small amount of information available, Montezuma Slough appears to be a migratory pathway for chinook salmon smolts, but the extent is not known. A few have been captured in the spring and late fall. Since part of the Sacramento River flow enters Montezuma Slough and smolts survive to adults at a much greater rate than fry, quantifying the use of the slough by smolts is important.

- Striped bass are found in Montezuma Slough and Suisun Marsh at all life stages and were the most abundant fish species captured. Peak abundance usually occurs in May-June, and lowest abundance is usually February-March. Adults and juveniles are well dispersed through the marsh, but most often are collected in the main sloughs. Montezuma Slough is particularly important to age 0 fish. Denverton Slough, a tributary of Montezuma Slough, also seems to be important to age 0 fish. The marsh appears to be used as a migratory pathway and nursery area for striped bass.

- *Neomysis* use Montezuma Slough and Suisun Marsh extensively in all but the driest years. However, considerable variation in abundance occurs between years. Seasonal abundance peaks during early summer (May-June) and is lowest in November-March.

- Phytoplankton production in Montezuma Slough is generally high, with a bloom in spring or early summer (May-June) usually followed by a second bloom in late summer (August-October).

Chapter 4. SUISUN MARSH FISH MONITORING PROGRAM

Based on the Suisun Marsh Salinity Control Gate preproject fishery resource evaluation and other sources, the Department of Water Resources has established a fish monitoring program for the marsh. In addition, interpretive reports of the monitoring are to be prepared by October 1 each year to aid in determining impacts and appropriate mitigation.

Program Elements

Except where specifically mentioned, all elements of the monitoring program described below are being carried out by the Department of Fish and Game.

Striped Bass Eggs and Larvae

The Montezuma Slough egg and larva stations will be monitored for an additional three years. Samples will be collected every four days using methods described in the 14th Annual Report of the Interagency Ecological Studies Program (Brown 1986).

Juvenile Striped Bass

The striped bass townet and midwater trawl surveys in the marsh will be continued. Sample locations, frequencies, and methods are described in Turner and Chadwick (1972). The data will be used to determine if operation of the salinity control gate adversely affects the use of Montezuma Slough by juvenile striped bass. Data from other estuarine sampling locations will be used to determine how other portions of the population are varying.

Funding of Dr. Moyle's work in the marsh will also be continued. Sampling frequency, station locations, and methods are described in Moyle et al. (1986). Slough stations on both sides of the structure are included.

Chinook Salmon Smolts

An attempt will be made to establish the importance of Montezuma Slough as a migration pathway. The general technique will be to collect midwater trawl samples in the slough at 1- or 2-week intervals during April and May for four years to estimate the use of the slough by migrating salmon. This survey will begin during spring 1987 at two or three sampling locations to be selected later. Midwater trawl surveys will be coordinated with USFWS/DFG mark-recapture studies to maximize their effectiveness.

A program has also been initiated to help determine predation losses at the structures.

Beginning in April 1987, variable mesh gill nets have been used to determine the presence of predators near the gates. Samples were collected during the day at about 2-week intervals during April and May. Stomach contents of larger potential predators were examined for salmon remains. This survey will be continued after the gates are in place and operating.

The gill net studies will be intensified near the structure and should provide evidence of losses to predators. Hydroacoustic gear purchased by DFG will be tested at the site to determine if behavior of both predators and prey can be monitored near the structure. These hydroacoustic surveys will be supplemented by midwater trawl samples and perhaps by experiments.

Neomysis

The *Neomysis* sampling conducted by DFG as part of the Interagency Ecological Studies Program will be continued. Methods and stations are described in Knutson and Orsi (1983). In addition, Dr. Moyle will use a plankton sled to make monthly estimates of *Neomysis* abundance at 17 sites in the marsh.

Since *Neomysis* and young striped bass abundances in Montezuma Slough are probably related to hydraulic conditions in the slough itself, the monitoring program will contain a hydrodynamic element. Longitudinal transects will be made through the slough at various tidal and flow conditions before and after the structure is in place. During these transects, vertical profiles of temperature, salinity and turbidity will be used to detect the presence of an entrapment zone. Timing of these runs will depend on flows and tides and will be concentrated during April, May, September, and October. The hydrodynamic element will also include the 30-day deployment of meters upstream and downstream of the structure. The first deployment will be during spring 1989, if the structure is in operation. The objective of the hydrodynamic element is to determine how operation of the gate affects velocity and density circulation in Montezuma Slough. The role of velocity and density circulation in controlling the abundance and distribution of juvenile striped bass and *Neomysis* will then be examined.

General Fish Abundance

The Department of Water Resources will continue to fund Dr. Moyle's fishery studies for at least three years after initial operation of the control structure. These efforts will provide an indication of overall fisheries trends in the marsh and may help identify problem areas. Two slough stations, above and below the structure, will be maintained as part of the sampling effort.

Determination of Impacts

The Corps of Engineers permit specified that criteria be established that could be used to determine if the control structure is causing excessive predation or significant environmental degradation. Because all populations being considered range widely through the estuary and fluctuate because of a variety of natural and cultural stresses, it is difficult to assign criteria regarding impacts of the structure itself. DWR proposes to delay development of these criteria until the data have been reviewed more thoroughly, especially the fisheries and *Neomysis* data from DFG that have had little or no formal analysis and information regarding the importance of the slough to migratory salmon. The criteria will be in place by the time the structure begins operation. An ad hoc review committee of those individuals receiving this proposal will be provided drafts of the criteria as they are developed.

Mitigation

For minor fish losses, the preferred mitigation will be to develop an agreement similar to the two-agency fish agreement to cover losses at the control structure. This agreement provides funding for Fish and Game to either replace the lost fish or use the funds for habitat improvement (with preference for nonhatchery measures).

Additional mitigation measures will depend on when and how the losses occur and then must await results of the proposed monitoring activities. At this time, the fish and *Neomysis* data, when compared to the operations schedules, indicate that some modification of May operations is the next most likely mitigation alternative. Such a proposed modification will result in a need to negotiate with waterfowl interests in an attempt to balance the fish versus birds issues.

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