Exhibit 24, entered by the California Department of Fish and Game for the State Water Resources Control Board 1987 Water Quality/ Water Rights Proceeding on the San Francisco Bay/Sacramento-San Joaquin Delta

ASSOCIATIONS BETWEEN ENVIRONMENTAL FACTORS AND THE ABUNDANCE AND DISTRIBUTION OF RESIDENT FISHES IN THE SACRAMENTO-SAN JOAQUIN DELTA

PREFACE

Interagency staff representing the California Department of Fish and Game had lead responsibility in preparing this report. Drafts have been reviewed by members of the fisheries/water quality committee of the Interagency Ecological Studies Program for the Sacramento-San Joaquin estuary.

The report reflects the fisheries/water quality committee members' agreement on most points. Committee members will provide direct testimony on areas of disagreement.

Agency management was not part of the review process and may differ on how study results can be used in managing resident fish resources.

RESIDENT FISHES

This chapter describes what is known regarding associations between environmental factors and the abundance and distribution of resident fishes in the Sácramento-San Joaquin Delta . Many of the conclusions presented herein are based on an electrofishing survey of resident fishes conducted monthly from May, 1980 to April, 1983 at randomly selected locations throughout the Delta. These surveys were designed to determine how abundance and distribution of resident fishes are associated with various environmental variables and habitat types. Electrofishing is an efficient means of sampling the shallow water shoreline zone (mean depth of our sampling sites was 4.3 feet, range 1-12 feet) occupied by many of the resident species, but it is not a good way to sample the deeper open water in mid-channel.

We consider resident fishes to be the non-migratory species which spend all of their life in the Delta. Slightly more than half of the species caught in the electrofishing surveys were these resident fishes. More than half of the species also were not native, although most were introduced to California prior to 1900 (Table 1).

Three families of fishes dominate the Delta's resident fish assemblages. One is the centrarchid family (Table 1) composed of the black basses and various sunfishes. These are all introduced species, except for the Sacramento perch which is native to the Delta but was not caught in our electrofishing survey.

TABLE 1

Species Collected in the Electrofishing Survey
of Resident Fishes from the Sacramento-San Joaquin Delta
(May, 1980 to April, 1983)

Centrarchids (Bass & Sunfish)

Largemouth Bass I,R
Smallmouth Bass #,I,R
Spotted Bass #,I,R
Bluegill I,R
Redear Sunfish I,R
Green Sunfish I,R
Warmouth I,R
White Crappie *,I,R
Black Crappie I,R
Pumpkinseed #,I,R
Sunfish Hybrids #,I,R

Cyprinids (Minnows)

Hitch #,N,R
Sacramento Blackfish N,R
Splittail *,N,R
Sacramento Squawfish N
Golden Shiner I,R
Goldfish I,R
Carp I,R
Hardhead #,N

Ictalurids (Catfish)

White Catfish I,R
Channel Catfish *,I,R
Brown Bullhead #,I,R
Black Bullhead #,I,R

Others

Sacramento Sucker N
Tule Perch N,R
Striped Bass I,A
Inland Silversides I,R
American Shad *,I,A
Threadfin Shad I,FWE
Bigscale Logperch I,R
Yellowfin Goby I,ME
Prickly Sculpin *,N
Pacific Staghorn Sculpin #,N,ME
Chinook Salmon *,N,A
Steelhead Trout *,N,A
Mosquitofish #,I,R
Three Spine Stickleback #,N,FWE
Pacific Lamprey #,N,A
Striped Mullet #,N,ME
Delta Smelt #,N,FWE
Longfin Smelt #,N,ME
Starry Flounder #,N,ME

* = Used only in PCA

= Rarely collected and not statistically analyzed.

N = Native   I = Introduced   R = Resident

A = Anadromous   FWE = Fresh water euryhaline   ME = Marine euryhaline

Largemouth bass, the most abundant of the black basses in the Delta, are solitary carnivores whose adult diet consists mainly of other fish species and crayfish (Turner 1966c) along with secondary amounts of insects and small quantities of various larger species of zooplankton. They spawn in spring when water temperatures rise above 57-61°F and continue to spawn through June at temperatures up to 75°F. Largemouth bass build nests in shallow water near submerged objects though not in colonial aggregations like other sunfishes. These nests are shallow depressions fanned out and defended by the male fish. More than one female may be attracted to the nest where spawning occurs and the eggs settle and adhere to the bottom. The male guards the nest until the young hatch and he will continue to guard them for a few days to a couple of weeks until they become too active for the male to herd and then disperse into shallow water.

Other sunfish species are also opportunistic carnivores feeding on insects, aquatic crustaceans, snails, clams, and fish (to a lesser extent than largemouth bass). Bluegill also consume significant amounts of aquatic vegetation. Most are solitary feeders as adults with the exceptions of white and black crappie and bluegill which form schools. They all spawn in shallow water during spring and summer once temperatures reach 57 to 75°F. They have spawning behavior roughly similar to largemouth bass and build nests near submerged objects or aquatic vegetation. Except for warmouth, they tend to form nesting colonies where each nest is defended by the male. Their eggs are adhesive and sink, attaching to the substrate. After the young hatch, they are guarded for awhile and then disperse to the shallows.

A second group is the cyprinid or minnow family which includes five native species (Table 1). However, the most abundant cyprinids are introduced species: carp, goldfish, and golden shiner. The splittail is a native minnow of special concern as its distribution is currently restricted to the Sacramento-San Joaquin Estuary. Throughout most of the year, splittail are most abundant in the north and west Delta in association with other native species. They can also be found much of the year in Suisun Bay, year round in the sloughs of the Suisun and Napa marshes, and occur in upper San Pablo Bay and Carquinez Strait during periods of high spring flows (Ganssle 1966; Messersmith 1966; DFG unpublished data). In the spring they are abundant in the east Delta where they congregate in dead-end sloughs, probably to spawn over beds of aquatic or flooded terrestrial vegetation (Moyle 1976).

The third dominant group is the ictalurid or catfish family (Table 1), all of which are introduced. White catfish are the most abundant of the catfishes and are more than 35 times as abundant, on average, as any other catfish species in the Delta. White catfish are carnivorous bottom feeders consuming aquatic crustaceans, molluscs, insects, and fish; amphipods and opposum shrimp are the most important food items for both juveniles and adults. White catfish spawn in the summer when water temperatures exceed 70°F. First the female uses her fins to fan out a shallow fan out a shallow nest depression in the substrate, then the breeding pair spawns and the adhesive eggs settle and stick to each other forming an egg mass. One or both parents guard the eggs and hatched young for a few weeks until the young disperse in schools.

Channel catfish and brown and black bullheads are much less abundant than white catfish, but have similar breeding behavior and food preferences with the exception that channel catfish probably consume more crayfish, clams, and fish than the other species.

Resident fish assemblages in the Delta have not been examined extensively. Catfish were studied briefly in the 1950s (Pelgen 1954; Pelgen and McCammon 1955; Borgeson and McCammon 1967), there was a one-year gill net and trawl survey at 16 sites in 1963-1964 (Turner 1966 b, c, d, e), and a cursory three-season electrofishing survey was conducted at 34 sites in the 1970s (Sazaki 1975).

Catfish, bass, and various other sunfishes, as the principal resident gamefishes of the Delta, support an important recreational fishery and are, respectively, the third, fourth, and second most commonly caught groups of gamefish in the state (Lal 1979). White catfish are probably the resident gamefish most often caught in the Delta. The miscellaneous sunfish harvest in the Delta has not been quantified but probably is secondary to the harvest of catfish. Largemouth bass are a major gamefish throughout the state and in recent years large fishing tournaments have been organized expressly for them. The harvest rate for bass in the Delta (29%) is somewhat less than in freshwater reservoirs (≥ 50%) (Pelzman et al. 1980; Van Woert 1980) but it is still substantial and indicates that an important and thriving largemouth bass sportfishery exists.

Although they are not commonly sought by anglers, the nongame fishes of the Delta still fulfill important roles. Some serve as forage for gamefish, while others compete with or prey on gamefish. Each of the native resident nongame fishes has intrinsic ecological value, and in general, our knowledge of their life histories, population dynamics, and role in the community ecology of the Delta is limited. Their principal value to man is for future scientific and educational purposes. There formerly was a small commercial fishery for splittail while another Delta native, the Sacramento blackfish, is still harvested commercially from Clear Lake. Both species have some potential for aquaculture.

Electrofishing Survey Sampling Design

Electrofishing involves using a gas-powered generator to produce electric current which is conducted into the waters of the sampling area through an electrode array. The electricity passing through the array creates an electrical field in the water. Fishes in contact with this field are stunned for a few seconds and many float to the surface.

At each survey site, a boat-mounted electroshocking unit was used to stun fish along a measured section of shoreline and the fish were dip-netted from the water as they rose to the surface. The fish were identified, counted, their length measured, and then returned to the water alive.

A random stratified sampling design was employed to choose 10 new electrofishing sampling sites each month apportioned between five areas of the Delta (Figure 1). These five areas were subjectively delineated as moderately homogeneous subareas which contained different densities of resident fish. The proportion of the 10 monthly sampling sites allocated to each area was based on our predictions of the relative densities of resident fish in each area. More samples were allocated to areas where we expected to find higher fish densities and fewer samples to areas of lower expected fish densities. Each month three sites were sampled in the east Delta, one in the north, one in the west, three in the central, and two in the south Delta. A total of 360 surveys were conducted at 280 different sites (Figure 2).

Twenty water quality and habitat variables were recorded during the surveys (Table 2) to measure water quality, bank type, channel characteristics, and shoreline and aquatic vegetation.

Abundance indices for each of the 41 species we caught (Table 1) were calculated as catch/distance sampled. Our goal was to evaluate if and how these indices were related to environmental factors.

Analytical Methods

The multivariate statistical techniques of Principal Components Analysis (PCA), Canonical Correlation Analysis (CCA),

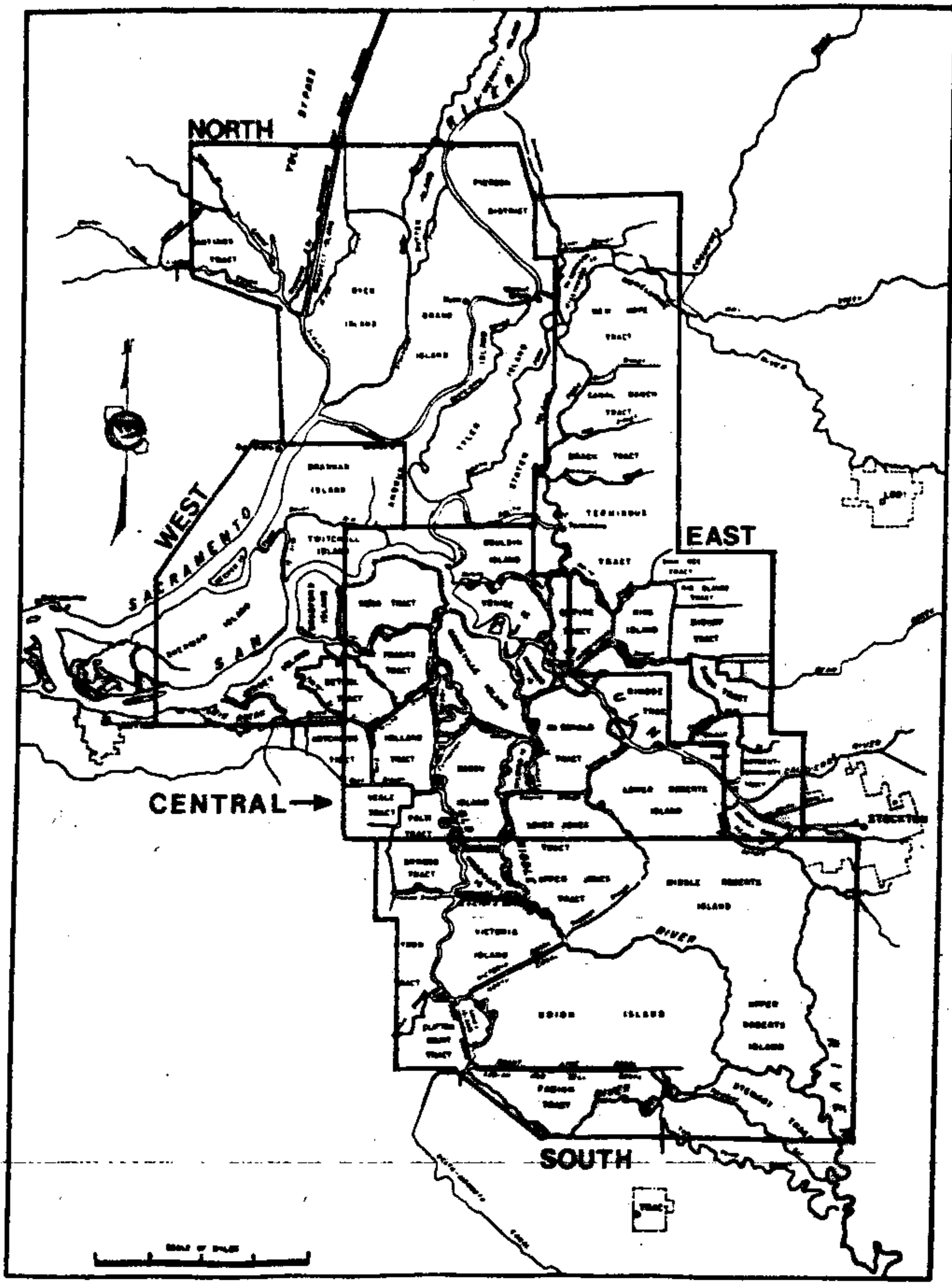


Figure 1. Subareas of the Sacramento-San Joaquin Delta used in the analyses of the resident fish survey data and in which sample sites were chosen according to a random stratified sampling design.

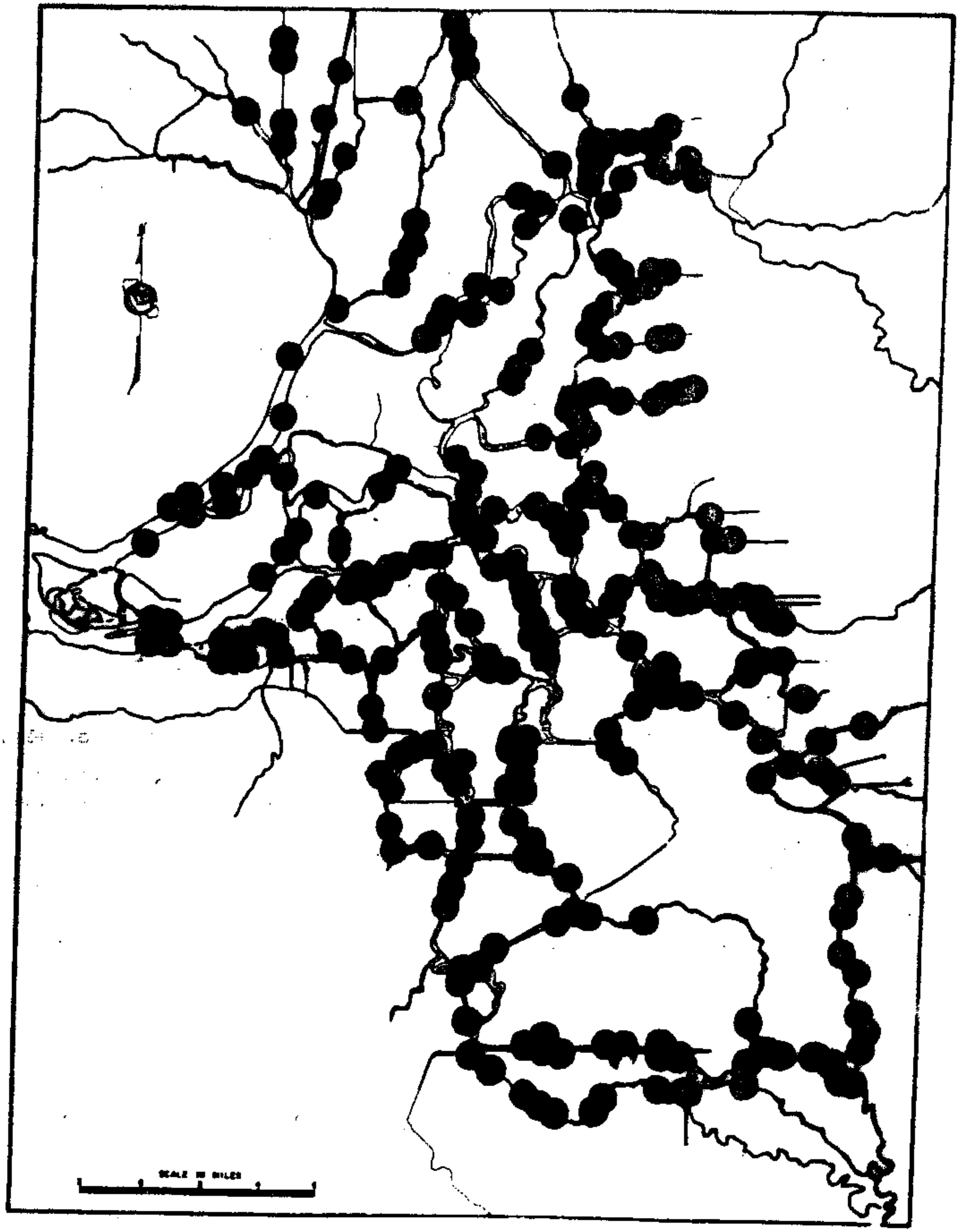


Figure 2. The 280 different sites sampled during the electrofishing survey of resident fishes in the Sacramento-San Joaquin Delta from May 1980 to April 1983.

TABLE 2

Environmental and Habitat Variables Measured During the Electrofishing Survey of Resident Fishes in the Sacramento-San Joaquin Delta (May, 1980 to April, 1983)

Variable	Scale
Day-Night	0=Day, 1=Night
Water Temperature[1/]	Centigrade
Conductivity	µmho
Dissolved Oxygen	ppm
Secchi Disk	cm
Channel Type[2/]	1=Ship Channel 2=River 3=Open Slough 4=Dead-end Slough 5=Submerged Island 6=Other
Transport Channel	0=Transport Channel 1=Non-Transport Channel
Depth	Feet
Snags	# Counted
Bare Bank	Scored 0-4 for % of Bank Covered 0=0% 1=1 to 25% 2=26 to 50% 3=51 to 75% 4=76 to 100%
Floating Vegetation	As Above
Submergent Vegetation	As for Bare Bank
Emergent Vegetation	"
Riparian Habitat	"
Bushes	"
Trees	"
Riprap Shoreline	"
Mud Bank Shoreline	"
Season	1=Winter = Dec.+Jan.+Feb. 2=Spring = Mar.+Apr.+May 3=Summer = June+Jul.+Aug.+Sept. 4=Fall = Oct.+Nov.
Area[2/]	1=East Delta 2=North Delta 3=West Delta 4=Central Delta 5=South Delta

1/ Temperature was converted from Centigrade to Fahrenheit for tables and discussions in the text.

2/ Each catagory of Channel Type or Area was recorded to a dummy variable having values of zero or one before use in any statistical analyses. 0=no/absence of characteristic, 1=yes/presence of characteristic. For example a sample in the East Delta was coded 1 for the new dummy variable created to represent "East Delta" and 0 for the four other dummy variables created to represent the other four areas.

Multivariate Analysis of Variance (MANOVA) and Descriminant Function Analysis (DFA) (Pielou 1984; Pimentel 1979) were used to summarize and test relationships among the multitude of variables measured during the electrofishing survey (Table 3, Figure 3). Natural logarithm transformations conditioned the abundance indices to meet statistical assumptions before multivariate analyses were conducted. However, some species occurred too rarely to be used in these multivariate analyses and others had frequency distributions that restricted their use to the statistically less demanding multivariate technique of Principal Components Analysis (Table 1).

Separating the exact factors that determine the distribution of the resident species cannot be achieved solely from survey data. To do so would require experimental manipulation of causal factors in field and laboratory studies and was beyond the scope of the electrofishing survey. Resident fish distribution reflects a complex combination of environmental factors, some of which vary seasonally. We were able to characterize the environment of each of the five regions of the Delta and their species assemblages, and the results of the multivariate statistical analyses indicate which groups of environmental variables are associated with each species assemblage. We also have information on the associations of species with channel types, vegetation types, and bank types which allows us to relate species abundance to channel characteristics which might be affected by water development. Thus, the results of this study are presented in the following

TABLE 3

Analyses Used to Evaluate the Various Factors Measured During the Electrofishing Survey of Resident Fishes in the Sacramento-San Joaquin Delta (May, 1980 to April, 1983)

	Statistical Techniques			
Environmental Factors:	PCA	CCA	MANOVA	DFA
Water Clarity as Secchi Disk	X	X	X	X
Conductivity	X	X	X	X
Water Temperature	X	X		
Dissolved Oxygen	X	X		
Channel Characteristics:				
Channel Type	X	X	X	X
Transport Channels			X	X
Riprap Banks	X	X		
Instream Vegetation	X	X		

DATA PROOFING: Transformation of data & elimination of rare species.

↓

PRINCIPAL COMPONENTS ANALYSIS (PCA): Summarizes the various trends in the data and shows which variables are positively or negatively associated.

↓

CANNONICAL CORRELATION ANALYSIS (CCA): Tests the correlation of environmental and water quality variables *vs*. species variables and shows the different ways in which they are related. Used a reduced set of variables from those in PCA that were found to be associated with environmental or water quality parameters.

↓

MULTIVARIATE ANALYSIS OF VARIANCE (MANOVA): Tests whether species abundance indices varied between high, medium, and low levels of water clarity and conductivity, among the three major channel types, or between transport and non-transport channels.

↓

DESCRIMINANT FUNCTION ANALYSIS (DFA): Tests which species are most characteristic of high *vs*. low conductivity or high *vs*. low water clarity environments in spite of any confounding relationship with other water quality parameters. Also used to test which species characterize the three major channel types and transport channels.

Figure 3. Flow chart of the analysis of data collected during the electrofishing survey of resident fishes from the Sacramento-San Joaquin Delta (May, 1980 to April, 1983).

sections in two different organizations: (1) an area by area discussion of environmental characteristics and their relationship to species assemblages, (2) a discussion of the relationship between channel characteristics and species abundance.

SPECIES-ENVIRONMENTAL ASSOCIATIONS BY AREA

North and West Delta

The north and west Delta are discussed together in one section because they had fairly similar habitat characteristics and very similar species assemblages. The north and west Delta habitats that we sampled are composed primarily of riverine and open slough environments (Table 4). The north Delta has some dead-end sloughs in its northwest portion and the west Delta has a flooded island called Big Break at its southern edge (Table 4 and Figure 1).

Although water which is eventually diverted to the CVP and SWP pumps flows through a number of north and west Delta channels (Table 4), these channels were not classified as transport channels in our study (see "Transport Channel" section, page 33) because the diverted water moves in the normal pattern and direction of the channels' natural flow.

The north Delta habitats that we sampled were slightly more than half riprap banks; the rest of the sampled shoreline was made up predominantly of mud banks. The west Delta habitats that we sampled were about evenly mud bank and riprap and included some stretches of sandy beach.

TABLE 4

Average Physical & Environmental Characteristics
of the Five Areas of the Sacramento-San Joaquin Delta
Measured During the Electrofishing Survey
of Resident Fishes (May, 1980 to April, 1983)
(mean values)

	East	North	West	Central	South
Water Quality					
Water Temperature (°F)	63.1	61.5	61.7	62.1	62.8
Conductivity (umho)	212	197	353	316	460
Dissolved Oxygen (ppm)	8.8	9.7	9.6	9.0	9.0
Water Transparency (cm)	50.5	61.4	46.5	55.3	44.0
Channel Composition					
% Transport	0 (12%)1/	0 (25%)1/	0 (3%)1/	39%	29%
% Ship Channels	1%	3%	3%	9%	0%
% Rivers	22%	44%	50%	31%	68%
% Open Sloughs	22%	31%	33%	39%	28%
% Dead End Sloughs	54%	14%	0%	9%	4%
% Flooded Islands	0%	0%	11%	3%	0%
% Other Channel Types	1%	8%	3%	8%	0%
Bank Type (1/4's)					
Riprap	1.8	2.1	1.6	1.6	1.9
Mud Bank	2.1	1.8	1.5	2.3	2.0
Shoreline Vegetation (1/4's)					
Bare Banks	1.1	1.5	0.8	1.0	1.5
Riparian Cover	1.9	2.2	0.7	1.1	2.0
Instream Vegetation (1/4's)					
Emergent Vegetation	1.1	0.3	2.5	2.0	0.4
Submergent Vegetation	0.1	0.0	0.1	0.4	0.2
Floating Vegetation	0.4	0.0	0.1	0.7	0.5
Number of Snags	6.7	5.7	3.9	3.0	5.7

1/ = % of channels in the area through which diverted Sacramento River water flows toward the CVP and SWP pumps in the normal direction of flow.

Areas sampled in the north Delta had more riparian cover than those sampled in the west Delta, but the latter had less area without vegetation (bare bank, Table 4) and more emergent vegetation. Neither area had much floating or submergent vegetation.

Generally, the north Delta had the lowest electrical conductivity of the five areas (Table 4 and 5). Conductivity in the west Delta varied widely according to runoff from the rivers (winter and spring) and salinity intrusion (summer and fall) from Suisun Bay (Table 5).

Water transparency in the Delta, as measured with a secchi disk, varied between 11 and 154 cm, with a mean of 51 cm. On average, Delta waters tended to be less transparent in winter and spring when suspended solids from runoff were greatest (Table 5); the north and west Delta followed this pattern. Water clarity in the west Delta improved from winter through the next fall. The north Delta was among the least transparent areas in the winter and spring but had the clearest waters in summer and fall when river flows decreased (Table 5).

The north and west Delta (Figure 1) had similar groups of resident fish species that were more abundant than elsewhere and the north Delta was second only to the east Delta in species abundance and diversity (Figure 4). In general, the west Delta had the lowest number of species and lowest species diversity of any area (Figure 4). Therefore, of the species that were more abundant in these areas than elsewhere (splittail, Sacramento

TABLE 5

Geograhical and Seasonal Differences in Water Quality
Between Five Areas of the Sacramento-San Joaquin Delta
Measured During the Electrofishing Survey
of Resident Fishes
(May, 1980 to April 1983)

Water Transparency
(Secchi Disk in cm)
($\bar{x}$+S.D.)

	East	North	West	Central	South
Winter	44.7±21.1	44.1±41.9	35.7±13.0	46.3±19.9	44.2±14.1
Spring	44.2±16.6	36.5±14.6	48.2±16.1	52.8±11.9	41.6±11.1
Summer	54.8±23.3	72.3±23.7	44.6±9.1	55.2±19.0	40.2±14.0
Fall	59.9±22.8	97.0±39.6	64.7±23.6	72.6±21.8	55.5±11.2

Conductivity
(µmho)
($\bar{x}$+S.D.)

	East	North	West	Central	South
Winter	236.7±135.0	171.8±108.5	176.7±47.8	343.4±194.0	543.1±338.5
Spring	199.5±143.6	187.5±115.2	200.6±62.0	252.8±165.7	390.9±273.2
Summer	218.8±123.0	231.6±177.1	472.4±472.1	324.0±195.4	494.4±288.1
Fall	177.4±75.1	172.8±39.5	564.7±506.7	352.8±265.9	367.9±210.1

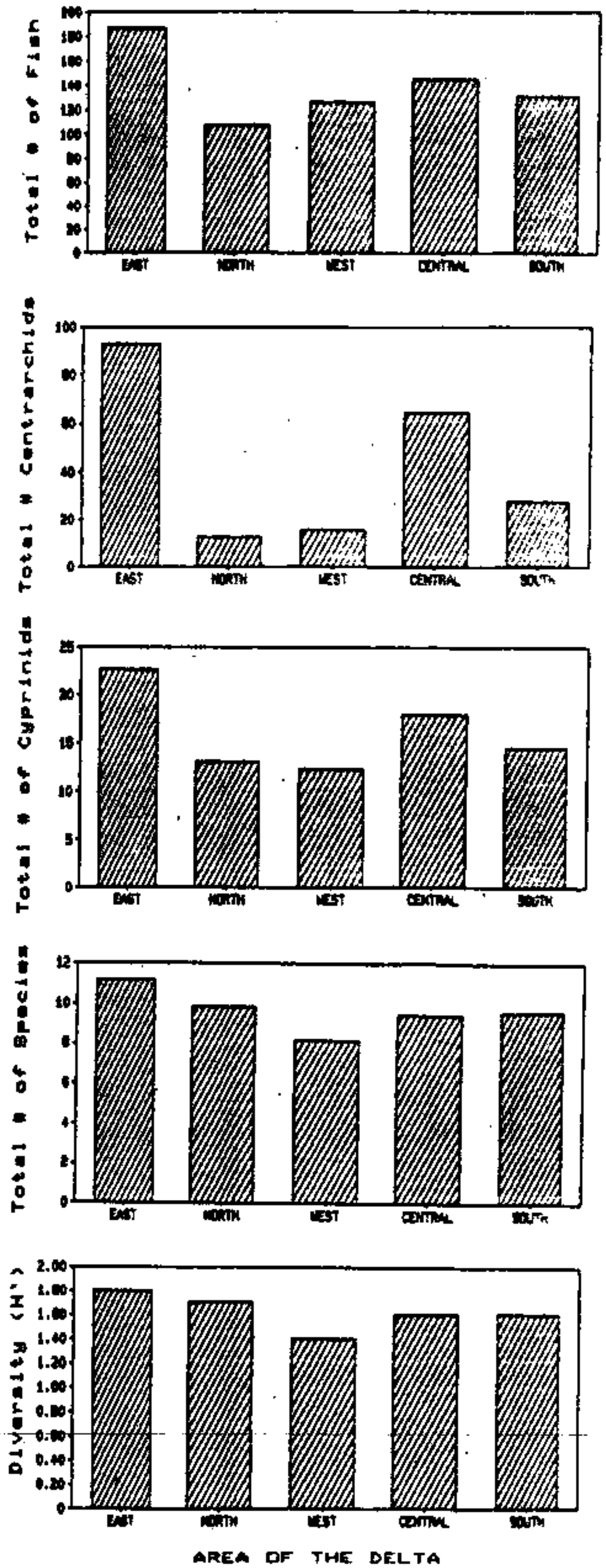


Figure 4. Resident fish community characteristics as determined by the electrofishing survey in five areas of the Sacramento-San Joaquin Delta from May 1980 to April 1983. Note that the vertical scale changes between bar graphs.

sucker, Sacramento squawfish, prickly sculpin, and tule perch) (Figure 5), the variety of species that were caught at any one time was likely to be greater in the north than in the west Delta.

In the north and west Delta the total number of species (indicated by PCA) and the abundance of tule perch (PCA, CCA, DFA), Sacramento squawfish (PCA, CCA), Sacramento sucker (PCA, CCA), splittail (PCA), and prickly sculpin (PCA) was greatest where conductivity was lowest. In contrast, Sacramento blackfish, white crappie, goldfish, and carp were abundant in Cache and Shag sloughs where conductivity was relatively high (PCA) due to agricultural drainage and minimal flushing flows.

Although the above species were statistically associated with conductivity, other factors may also have influenced their distribution. The results of the electrofishing survey cannot refute the following three alternative explanations for fish distribution: 1) If tule perch, Sacramento squawfish, Sacramento sucker, splittail, and prickly sculpin are abundant in the north and west Delta for reasons other than conductivity, their abundance would correlate with low conductivity simply because much of this area has low conductivity most of the year. For example, the Sacramento sucker also was statistically associated with high water transparency (PCA) which also characterizes the north Delta much of the year. 2) It is conceivable that suckers and squawfish were abundant in the north Delta because high winter flows transport them downstream from their spawning areas in the upper Sacramento River system. 3) It is possible that these native

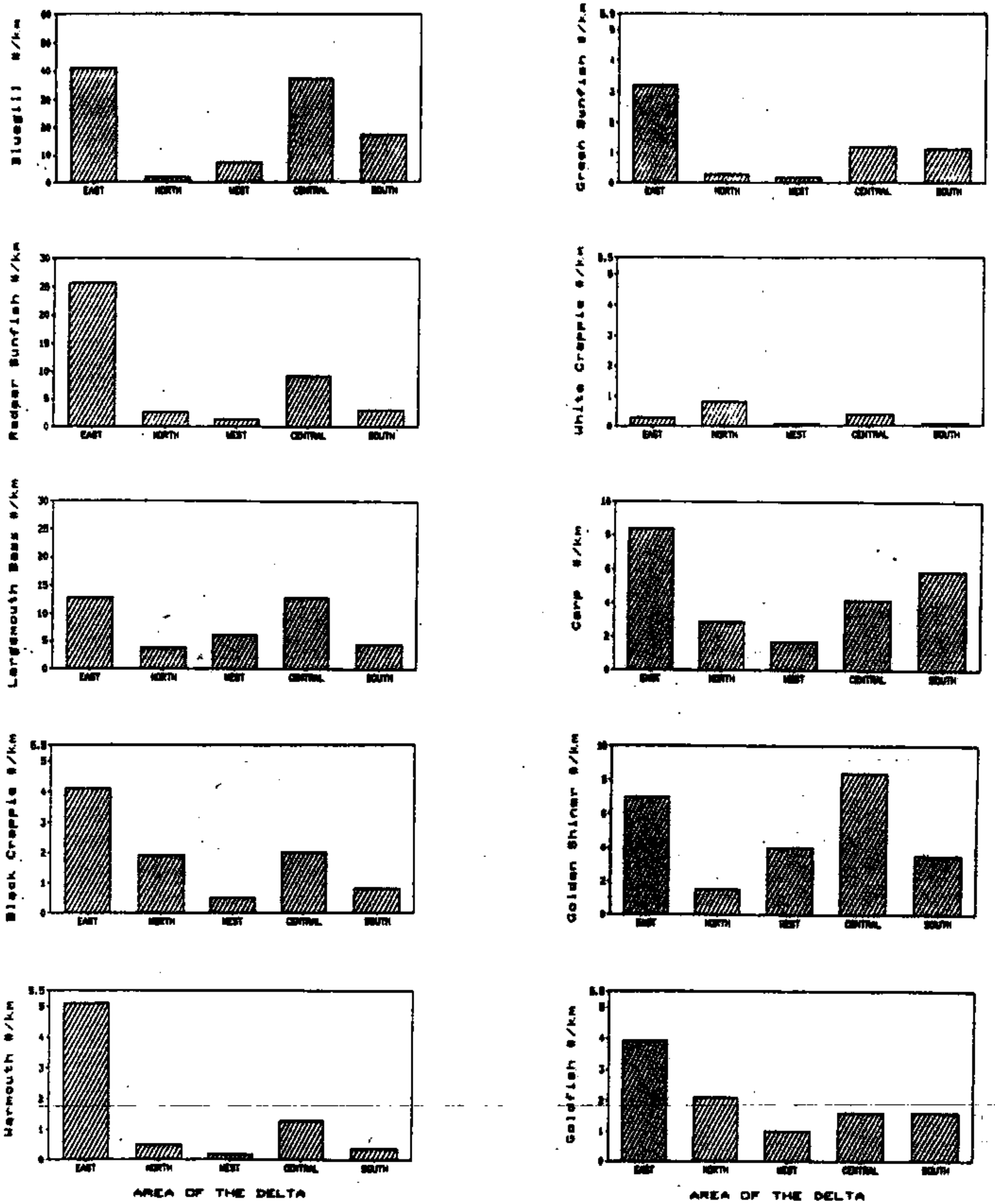


Figure 5. Differences between the five areas of the Sacramento-San Joaquin Delta in electrofishing catches of some of the more prevalent resident fishes (May 1980 to April 1983). Note that the vertical scale changes between bar graphs. Figure continued on next page.

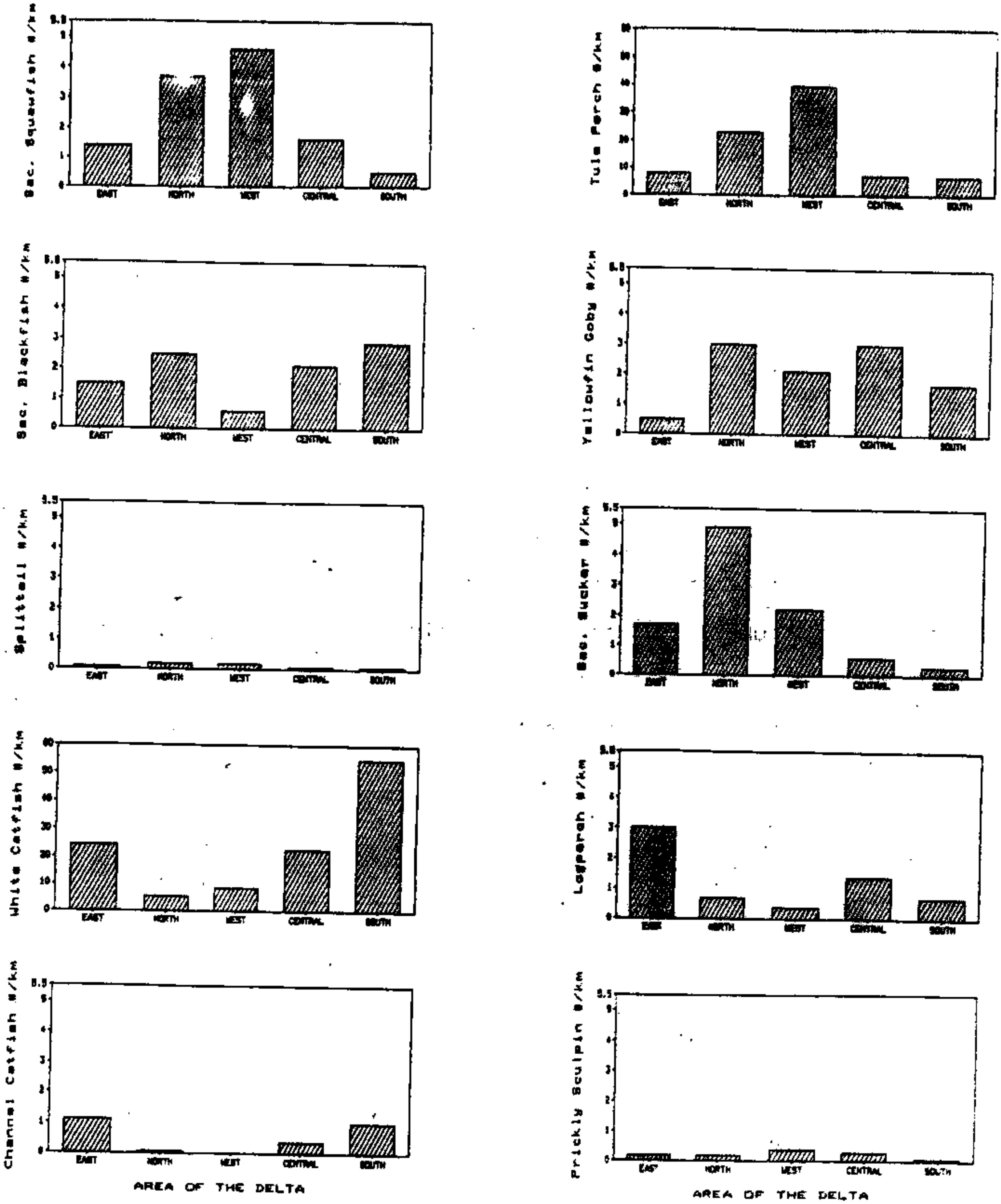


Figure 5 (cont.)

species are less abundant in other areas of the Delta due to more intense competition from introduced species. Competition with introduced species and habitat destruction are probably the two primary causes of the disappearance of the Sacramento perch from the Delta (Moyle 1976). Such competition may have excluded squawfish and suckers from certain areas in the Pit River (Moyle et al. 1982).

We also know that despite the statistical association with low conductivity, prickly sculpin, tule perch, and splittail are probably tolerant of brackish water caused by ocean salinity. All three species have been collected between Pittsburg and Crockett during high flow periods when there is a mixing of fresh and salt water (Ganssle 1966; Messersmith 1966) and tule perch and splittail are abundant in the brackish sloughs of the Suisun and Napa marshes. Perhaps the association between these species and low conductivity reflects an aversion to conductivity caused by agricultural wastes.

East Delta

The east Delta habitats that we sampled are primarily dead-end slough and, secondarily, riverine and open slough environments (Table 4). Twelve percent of our sampling sites were in channels used for cross-Delta water transport carrying water in the normal flow direction. Areas sampled had more mud bank than riprap bank and on average about half the shoreline was covered with riparian vegetation while about one quarter was unvegetated. About a quarter of the east Delta shoreline sampled was fronted by emergent vegetation and small amounts of submergent and emergent aquatic vegetation were present.

The waters of the east Delta had the second lowest annual mean conductivity of any area in the Delta (Table 4) and low to intermediate mean conductivities in each season (Table 5). Water clarity improved from the winter through the next fall.

The east Delta (Figure 1) was the area with the largest total number of species and the area of greatest species diversity (Figure 4). Its species assemblage was dominated by the sunfishes (PCA). There was greater abundance (Figure 5) of largemouth bass, bluegill, redear sunfish, green sunfish, black crappie, warmouth, carp, goldfish, and bigscale logperch here than elsewhere. Golden shiner, white catfish, and threadfin shad were also abundant in the east Delta.

Canonical Correlation Analysis indicated that the number of species, species diversity, and catches of most of the dominant species were associated with the water transparency and conductivity levels characteristic of the east Delta. These levels were intermediate between the conductivity and transparency levels of the north and south Delta (Table 4 and 5). However, it seems likely that the importance of the slower currents, increased zooplankton abundance (Turner 1966a), and vegetation (Table 6) that occur in the dead-end sloughs were not adequately represented by the tatistical results and may affect resident fish as much as the water quality of the area.

Largemouth bass were typically captured in areas where water transparency was low in spring and summer (DFA). Statistically,

TABLE 6

The Composition of Vegetation & Bank Types in the Various Types of Channels Measured During the Electrofishing Survey of Resident Fishes in the Sacramento-San Joaquin Delta (May, 1980 to April 1983) (mean values)

Vegetation & Bank Type Variables	Ship Channel	River	Open Slough	Dead-End Slough	Flooded Island	Other Channels	Non-Transport Channel	Transport Channel
Bare (unvegetated) Bank (1/4's)	3.1	1.4	0.9	1.0	0	0.6	1.5	0.9
Floating Vegetation (1/4's)	0.4	0.5	0.5	0.2	0.1	0.6	0.4	0.9
Submergent Vegetation (1/4's)	0.5	0.2	0.2	0.2	0.9	0.4	0.2	0.5
Emergent Vegetation (1/4's)	0.6	1.2	1.5	0.8	3.9	1.5	0.9	2.1
Riparian Vegetation (1/4's)	0.5	1.4	1.6	2.1	0.1	1.9	1.6	1.2
Riprapped Bank (1/4's)	3.0	2.3	1.3	1.6	0	1.1	1.6	1.9
Mud Bank (1/4's)	0.8	1.5	2.6	2.3	4.0	2.9	2.2	2.1
Snags (per Km)	1.8	5.1	3.9	7.0	1.3	6.1	4.9	2.6

green sunfish were associated with clear water along riprapped banks in dead-end sloughs, and golden shiners with lower water transparency and emergent vegetation (CCA).

As in the north Delta, Sacramento blackfish, white crappie, goldfish and carp tended to occur together and were abundant where conductivity was high (PCA), such as the Stockton Deep Water Channel and the mouth of the Calaveras River. The Stockton Deep Water Channel and the upper end of Lost Slough are the only two areas that we sampled in the east Delta with seasonally low dissolved oxygen (D.O.) (< 5 ppm) that could potentially exclude some resident fish. There have been seasonal fish kills due to low D.O. in the Deep Water Channel. However, when we sampled these areas, the Stockton Deep Water Channel had average to above average densities of the most common species for that area and season. The upper end of Lost Slough had a different species composition and lower diversity than typical for the east Delta but greater than average densities of centrarchids and cyprinids for that area and season. The low D.O. levels that occurred during our sampling at these locations were evidently not low enough to cause a major change in fish distribution or to permanently reduce abundance.

Central Delta

The central Delta habitats that we sampled (Figure 1) have the greatest variety of channel types of any area, but are still primarily riverine and open slough environments (Table 4). More than a third of our sampling sites were in channels that are used as cross-Delta water transport channels and often have reverse flows. The central Delta also contains the largest amount of flooded island habitat (Frank's Tract). The shoreline that we sampled was composed more of mud banks than riprap banks and was on average three-quarters vegetated. About half of the shoreline we sampled in the central Delta was fronted by emergent vegetation and this area had the greatest amount of submergent and floating aquatic vegetation of any of the five areas (Table 4).

Central Delta water clarity improved from winter through the next fall and the conductivity of central Delta water was intermediate between the low level of the north and east Delta and the high level of the south Delta (Table 5).

Central Delta fish populations were not particularly distinctive. However, again, Sacramento blackfish, white crappie, goldfish, and carp were associated with high conductivities (PCA), specifically in Middle River, Whiskey Slough, and Connection Slough. The central Delta was also characterized (PCA) by relatively high abundance of largemouth bass and golden shiner (Figure 5), particularly in areas with aquatic vegetation.

Burns Cut behind Rough and Ready Island was the only area that we sampled in the central Delta that had seasonal D.O. levels low enough to potentially exclude resident fish and there have been seasonal fish kills due to low D.O. in this area. However, at the time we sampled Burns Cut abundance of the most common species was greater than or equal to normal abundance for that area and season. So, as was true for the east Delta, the levels of D.O. that occurred were not low enough to permanently reduce the abundance of the more common resident fish.

South Delta

The sites that we sampled in the south Delta are mostly riverine and secondarily open slough environments (Table 4). The shoreline at our sites was on average about half mud bank and half riprap bank which was mostly vegetated. There was little emergent vegetation but some submergent and floating aquatic vegetation (Table 4).

In the south Delta, water clarity decreased from winter through summer, probably due to decreased dilution from river inflows and increased turbid agricultural runoff. It had the second lowest water transparencies in winter and spring and the lowest transparencies of the five areas in summer and fall (Table 5). The annual mean conductivity of south Delta waters was higher than in any other area due to agricultural drain water from the San Joaquin Valley (Table 4) and its seasonal average conductivity was always the highest in the Delta except for fall when ocean salinity intrusion in the west Delta caused conductivities to be higher there (Table 5).

White and channel catfish and bluegill were abundant in the low transparency waters of the south Delta (PCA). Statistically, catfish were also associated with high conductivity in the south Delta (PCA).

White catfish were more abundant in the south Delta than elsewhere and were the most abundant species in that area. The association between white catfish and the measures of water quality likely reflects true habitat preference. Catfish, in general, are adapted to living in turbid conditions as they are omnivores which feed mostly on the bottom using their sense of taste and smell to find prey, though they can feed visually (Bond 1979). White catfish, in particular, are known to be tolerant of high conductivities. In their original home range in eastern coastal streams they are commonly found in slightly brackish water (Calhoun 1966).

As in the other areas, Sacramento blackfish, white crappie, goldfish, and carp were statistically associated (PCA) with high conductivity in the south Delta, in particular, the upper reaches of the Old, Middle, and San Joaquin rivers.

The portion of Old River south of Grant Line Canal was an area with seasonally low D.O. that could potentially exclude some resident fish and, when we sampled this area, diversity and total abundance of fish was lower than normal for the area and season. White catfish and bluegill, the two most abundant species in the south Delta, had significantly lower than average abundance at this location. However, the other low D.O. locations in the east and central Delta had lower D.O. levels (3.0 - 4.9 ppm) than Old River (5 ppm) and had no clear reduction in resident fish abundance which casts doubt on low D.O. as the cause for reduced fish abundance in Old River.

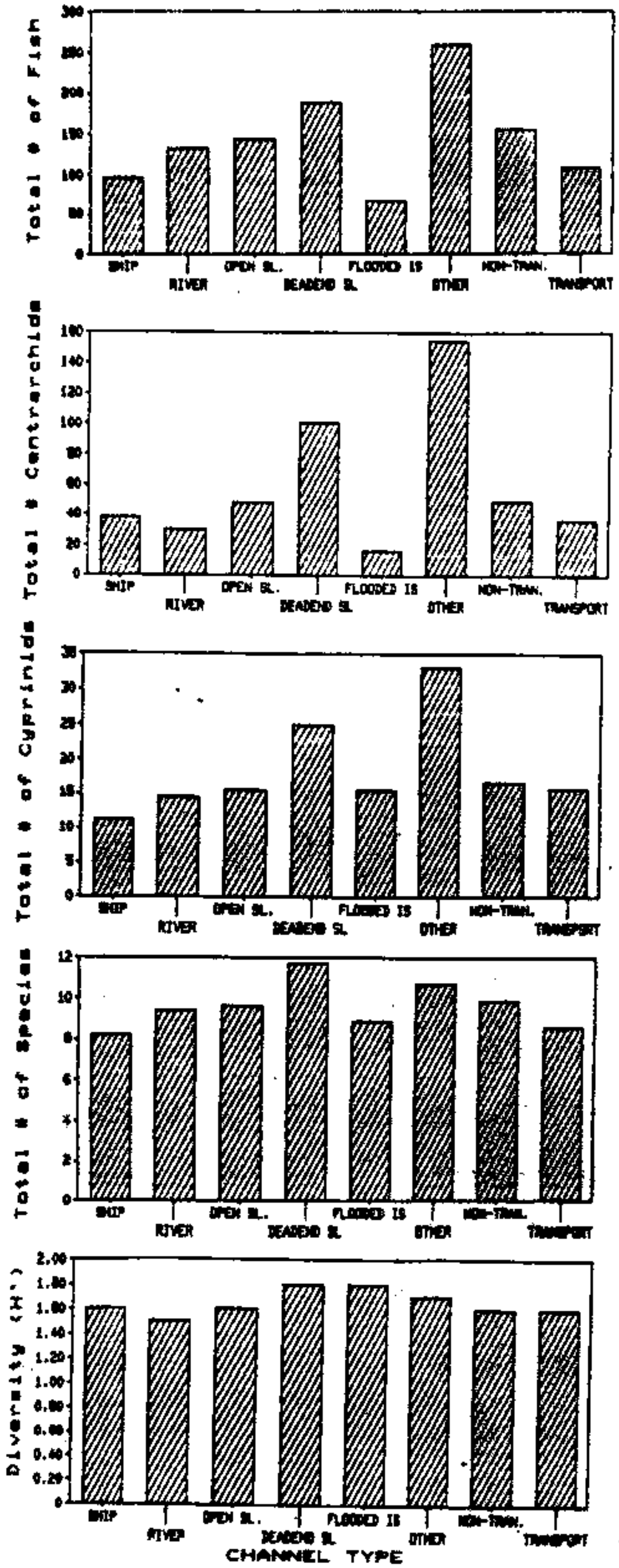


Figure 6. Resident fish community characteristics in the various channel types sampled during the electrofishing survey of the Sacramento-San Joaquin Delta from May 1980 to April 1983. Note that the vertical scale changes between bar graphs.

CHANNEL CHARACTERISTICS

Channel Type

We classified the Delta channels into six catagories: 1) large deep channels used for commercial shipping, 2) rivers, 3) open sloughs where both ends of the channel connect to other channels, 4) dead-end sloughs where only one end of the channel connects to another channel, 5) submerged islands consisting of land submerged by flooding, and 6) other types of channels that included oxbows, channels behind berm islands, and small embayments connected by one opening to a main channel.

The stagnant or slow-flowing dead-end sloughs, oxbows, channels behind berm islands, and small embayments clearly were the most productive channel types for resident fishes. These ares also tended to have intermediate to high levels of riparian or aquatic vegetation (Table 6). They had the greatest total catch and variety of species (Figure 6). The sunfishes and introduced cyprinids were very abundant and, with the exception of Sacramento sucker, splittail, and tule perch, the rest of the species had at least their second or third highest abundances in these areas (Figure 7). These qualitative observations regarding the importance of dead-end sloughs were confirmed by DFA in the case of largemouth bass and most of the other sunfishes, goldfish, carp, golden shiner, threadfin shad, and bigscale logperch.

There was not much to distinguish the relative value of the other remaining channel types for resident species, although DFA

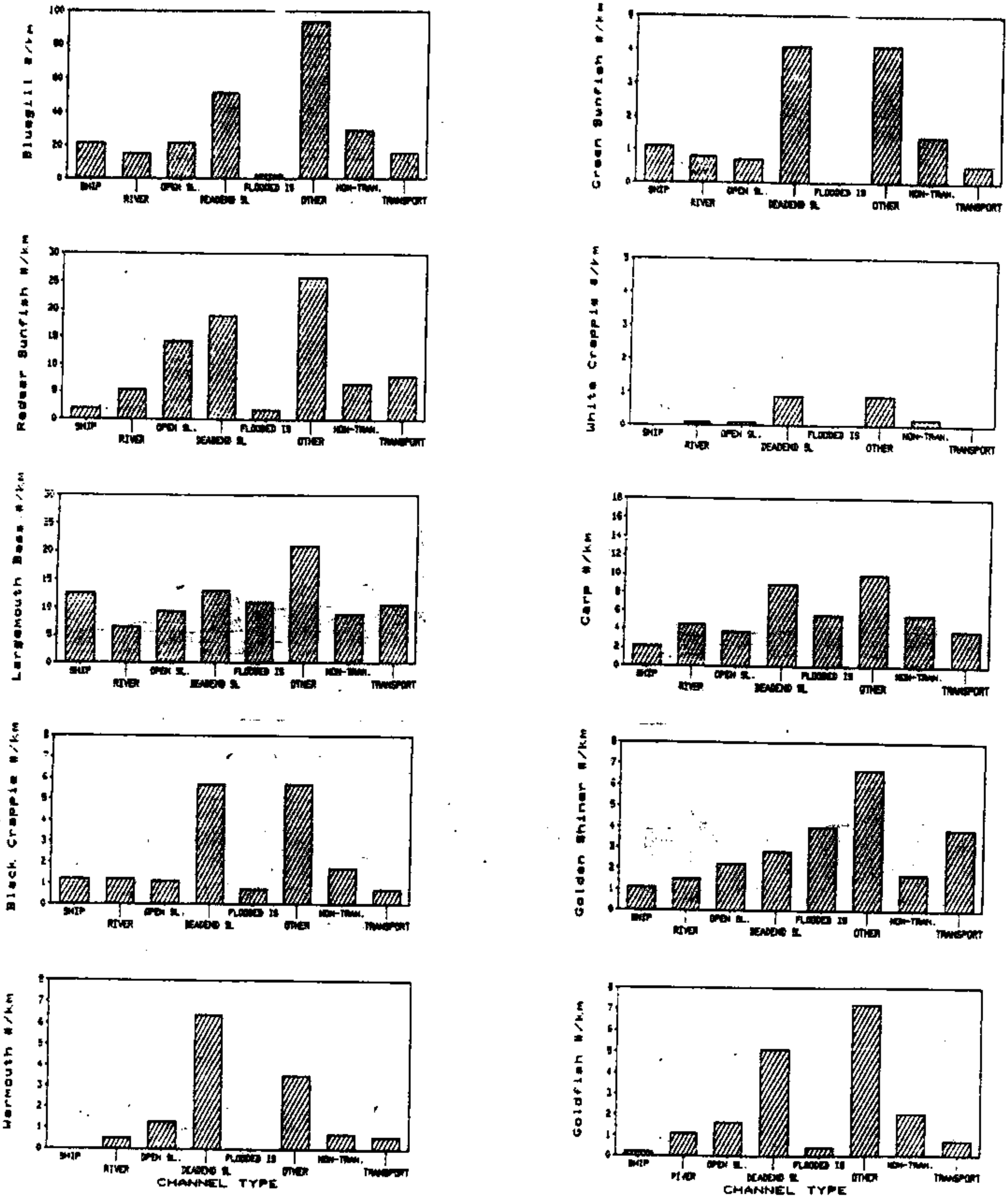


Figure 7. Mean catches of some of the more prevalent resident fishes in the various channel types sampled during the electrofishing survey of the Sacramento-San Joaquin Delta from May 1980 to April 1983. Note that the vertical scale changes between bar graphs. Figure continued (next page.

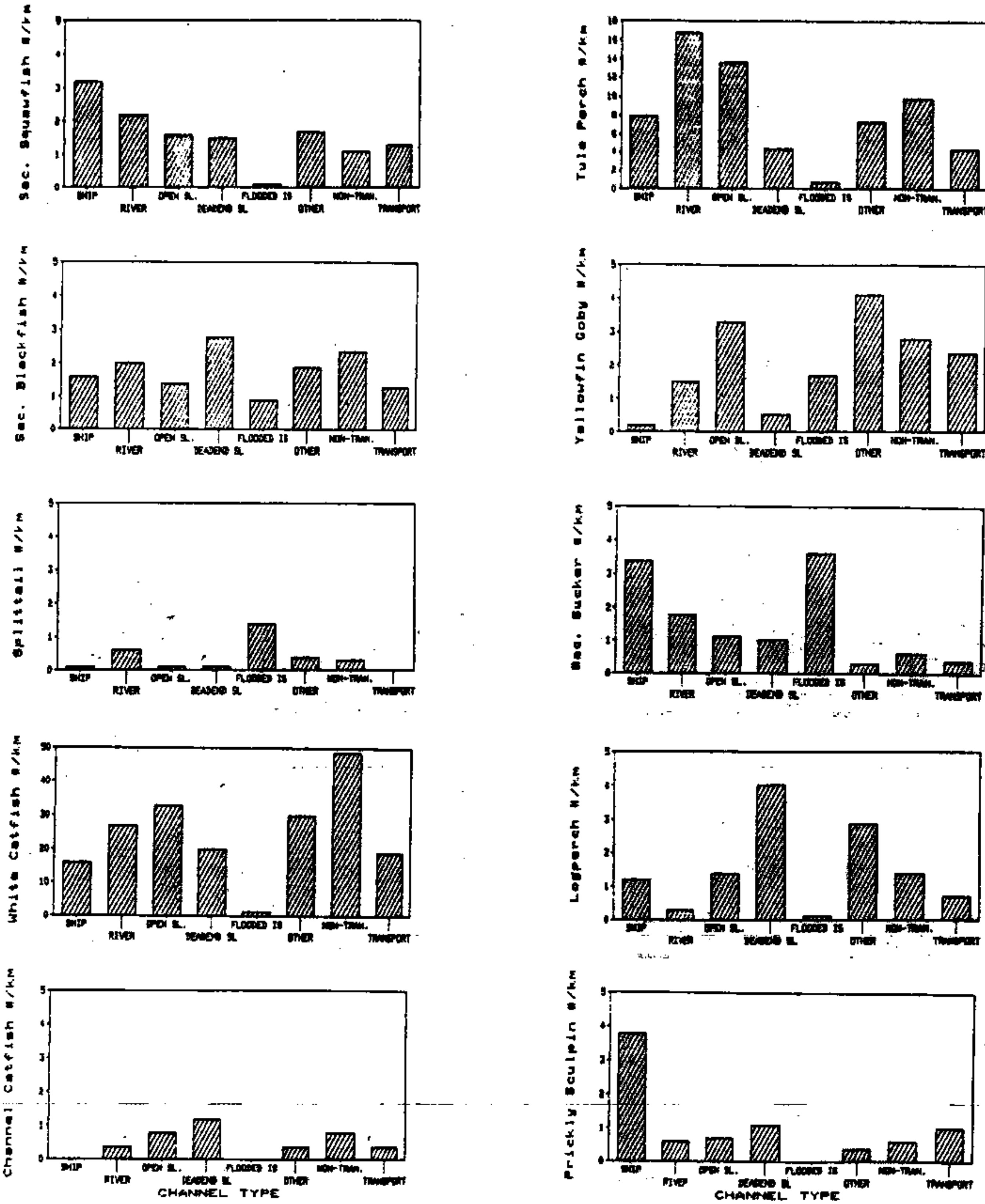


Figure 7 (cont.)

indicated yellowfin gobies were most abundant in "open sloughs" and Sacramento sucker and tule perch were associated with "rivers".

Transport channels

In addition to examining differences in resident fish abundance among the major channel types, we also wanted to evaluate effects of cross-Delta water transport and reverse flows by comparing resident fish populations in transport channels with populations in nontransport channels. Water from the Sacramento and San Joaquin rivers travels through a number of channels in the process of being exported from the Delta, but we only classified transport channels as those channels where net flow is often reversed from the natural pattern of flow and which were being used for cross-Delta transport of water to the CVP and SWP pumps (Table 4). Transport channels, as we defined them, occur only in the central and south Delta. Therefore, when comparing populations we only used data from sampling sites in the central and south Delta. We also excluded samples from dead-end sloughs as we have demonstrated that these areas are fairly unique in their species assemblages.

The most striking difference between transport and nontransport channels was the much higher abundance of white catfish in the nontransport channels (Figure 7, DFA). DFA also indicated that tule perch, black crappie, goldfish, Sacramento blackfish, Sacramento sucker, and inland silversides were significantly more abundant in the nontransport channels. Largemouth bass, redear sunfish, and golden shiner were more abundant in transport channels (DFA) which could reflect a preference for the greater amount of aquatic vegetation that was there (Table 6). However, tule perch and white catfish, which are also associated with aquatic vegetation, were more abundant in the non-transport channels. Perhaps whichever environmental parameter (aquatic vegetation or flow conditions) is most important to the fish determines where it will be found.

Instream Vegetation

The fry and juveniles of most resident fish species utilize aquatic vegetation as cover to escape predation. Larger individuals utilize it as cover to hide in and wait for passing prey. Instream vegetation is substantially reduced by dredging, channelization, and the traditional methods of riprapping. Knowledge of the associations between species and instream vegetation would indicate which resident fish are most likely to be impacted by channelization or levee work.

Aquatic vegetation appears to be most important to largemouth bass and golden shiners. Statistical analyses (PCA, CCA) indicated that both species were associated with floating and submergent vegetation in the central and east Delta. Bluegill, redear sunfish, carp, and white catfish also were associated (CCA) with floating and submergent vegetation. Golden shiners were generally more abundant where emergent vegetation existed (CCA).

Riprap Banks

The Delta levee system has been maintained and repaired by extensive rock riprapping which has the potential to impact resident fishes. The data that we collected is not completely appropriate for evaluating riprap as we did not have analagous treatment and control areas. However, it is of interest that throughout the Delta only green sunfish (PCA, CCA) and prickly sculpin (PCA) were positively associated with riprap banks and only golden shiner were less abundant in those areas containing riprap (PCA, CCA).

Despite these statistical results, the general process of riprapping, which includes removal of aquatic vegetation along the banks, must be considered harmful over the short term since most resident fish are associated with aquatic vegetation during all or part of their life cycle (Calhoun 1966, Moyle 1976). Longer term effects depend upon subsequent levee management. Our catches showed that resident fishes were abundant along old riprap where other habitat requirements were met, such as dead-end sloughs where there was aquatic vegetation fronting the levees and current velocity was low.

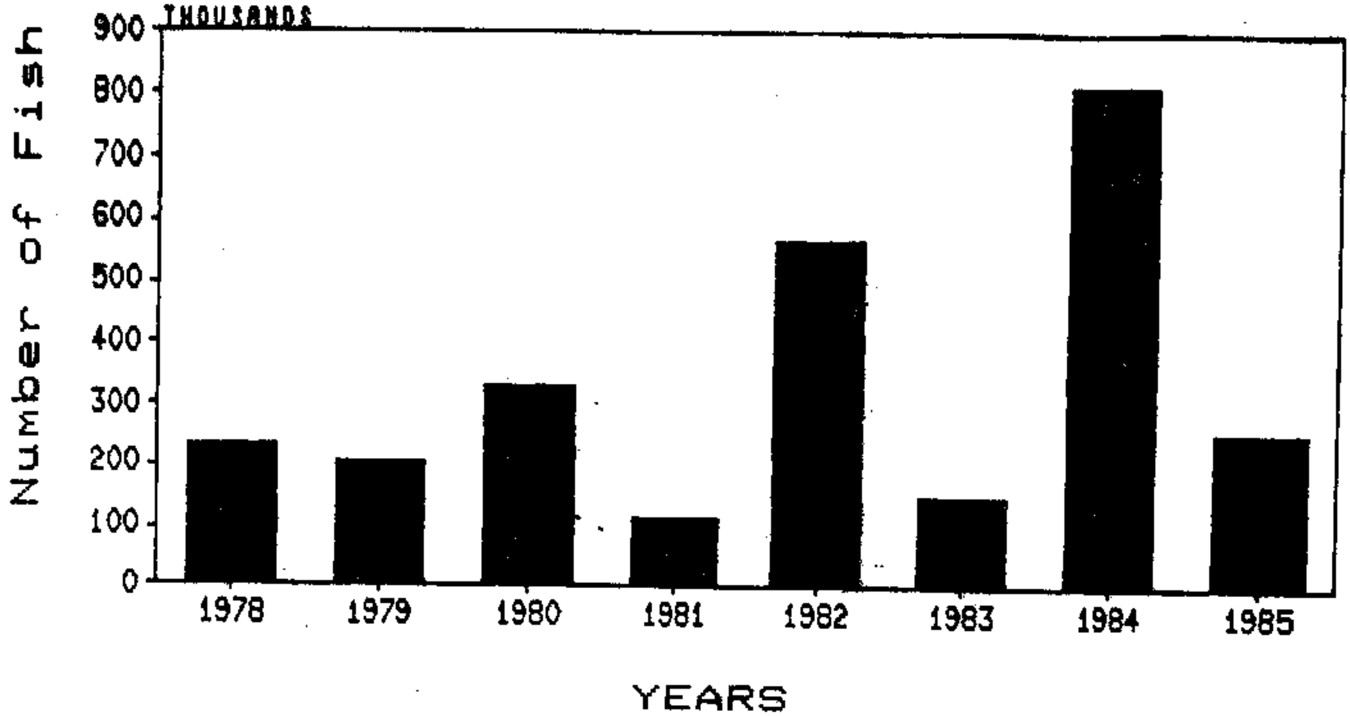
WATER DIVERSIONS

Large numbers of white catfish and threadfin shad are entrained at the water project fish screens. Data were readily available for the SWP where, on average, about 330,000 white catfish and 810,000 threadfin shad were entrained annually over the eight years from 1978 to 1985. There was no clear time trend in the annual number entrained of either fish (Figure 8), but more fish were entrained during the summer months (Figure 9). More white catfish were drawn into the SWP facilities during June through August than at any other time of year and threadfin shad were most affected during July and August. The numbers presented in the figures are based on counts of fish screened at the SWP adjusted upwards by the percentage screening efficiency of the facilities.

It is obvious from these numbers that water diversions from the Delta can entrain significant numbers of resident fish. However, since we do not know the size of resident fish populations, the screening efficiency for most resident fish, or the amount of predation that occurs around project intakes, we cannot estimate the actual impacts of diversions on resident fish populations. Given our knowledge of their life histories (Calhoun 1966; Moyle 1976) it is probable that open water pelagic fish such as threadfin shad and delta smelt are most impacted, the cyprinids and catfish less so, and that the centrarchids are least impacted.

DISCUSSION AND SUMMARY

The results of this study indicate that there are some consistent species groups that are characteristic of regions of the Delta and associated with some of the habitat and water quality variables that we measured.



THREADFIN SHAD

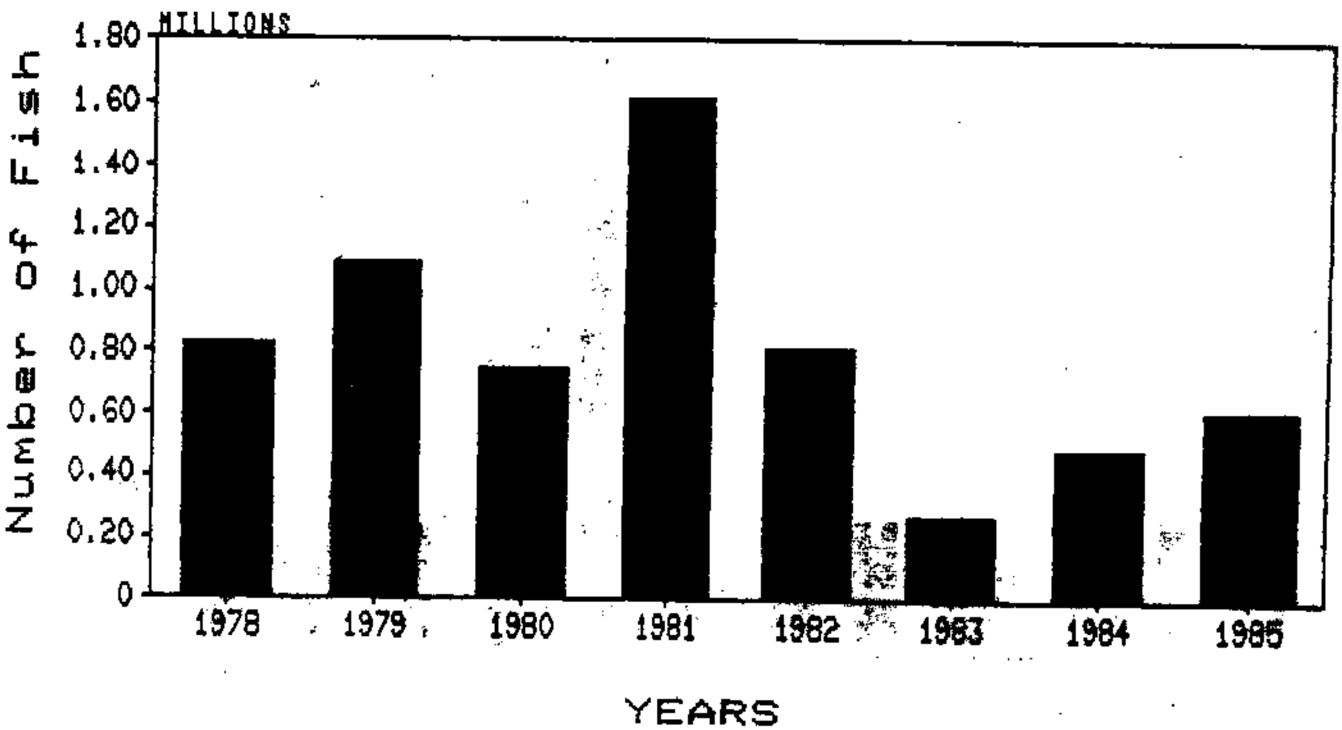
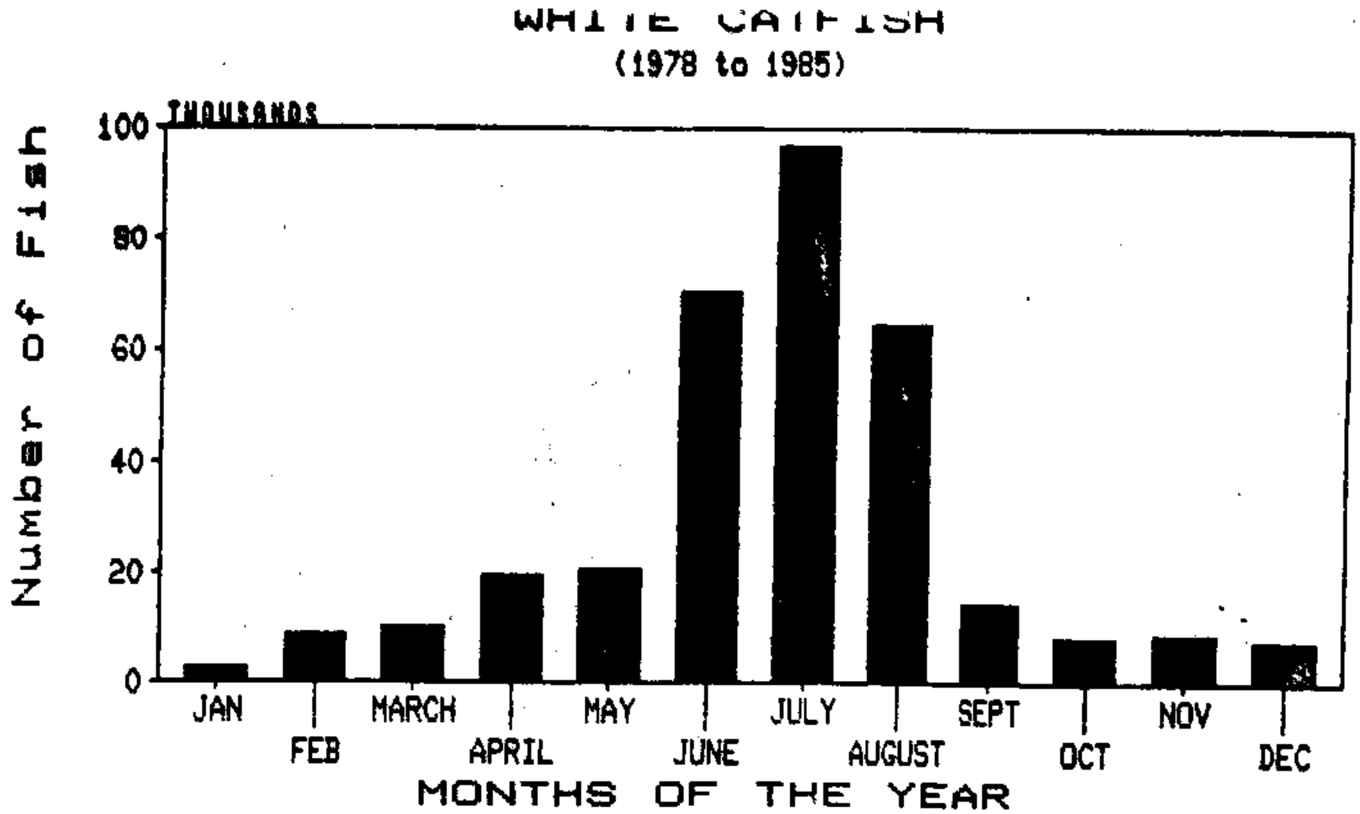


Figure 8. Annual estimates of the number of fish encountering the State Water Project's Fish Facility screens from 1978 to 1985. These numbers include fish salvaged and those lost to the system with water exported by the State Water Project.



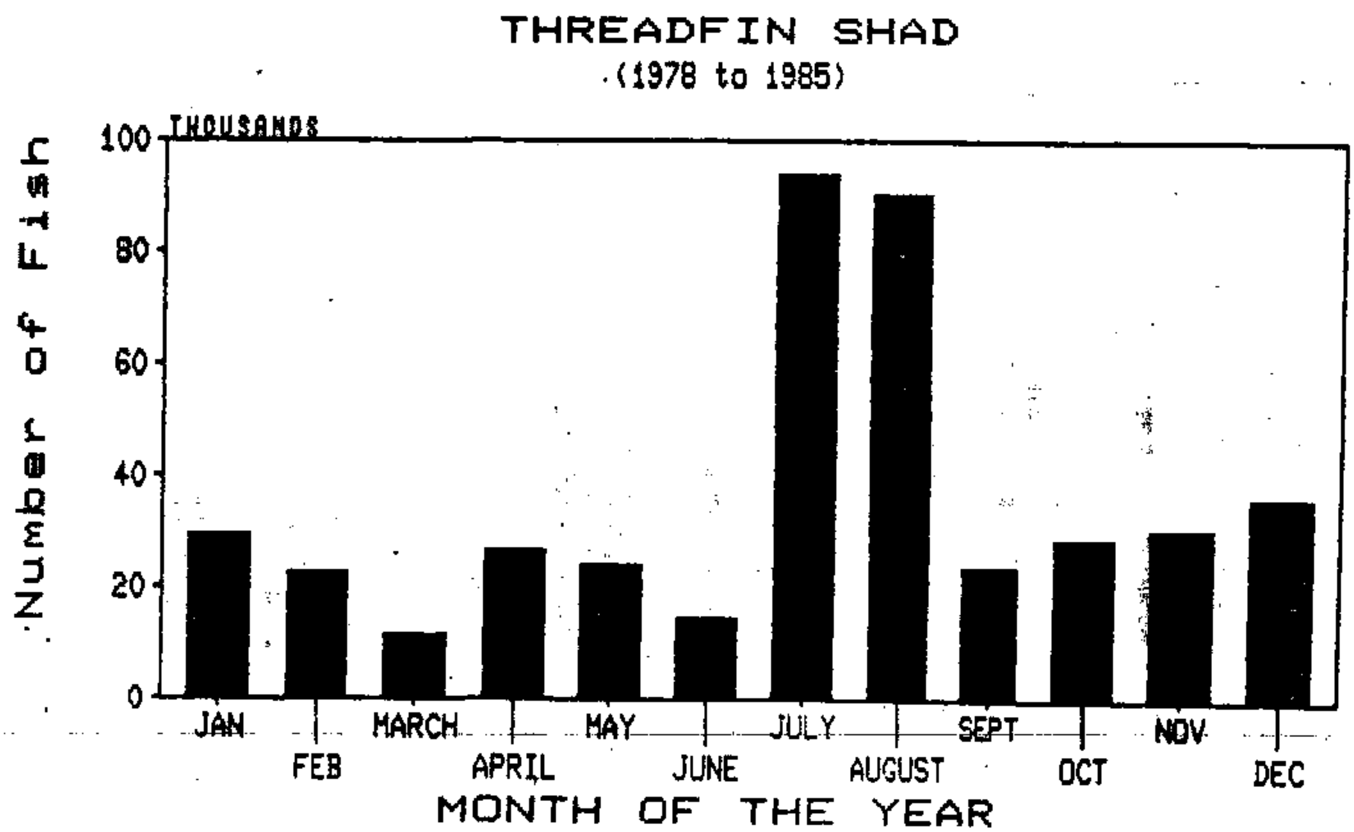


Figure 9. Monthly estimates of the number of fish encountering the State Water Project's Fish Facility screens averaged over the eight years of 1978 to 1985. These numbers include fish salvaged and those lost to the system with water exported by the State Water Project.

Notably, temperature and D.O., two water quality parameters known to affect fish, were not directly related to the abundance of any fish species or group. Seasonal differences in temperature and D.O. were related to the abundance of several fishes (PCA) but did not relate to their occurrance in any specific area or channel type. In the case of temperature, this lack of correlation reflects a tendency for temperature to be similar throughout the Delta (Table 4 & 7) and generally within the tolerances of a wide range of species.

Water temperatures during the electrofishing survey ranged from 43^{O}F to 86^{O}F with an average of 63^{O}F. Eighty-six degrees is within the preferred upper limit for most warm water fish (Alabaster and Lloyd 1980). The lowest temperatures probably only affect threadfin shad, which experience a die-off in many winters. Otherwise, with the exception of a few of the native minnows which may prefer the slightly cooler water of the north and west Delta in summer, there is no reason to believe that present temperature levels should control the distribution of resident fishes in the Delta.

Dissolved oxygen concentrations in the Delta dropped from an average of 10.4 ppm in winter to 7.9 ppm in summer. Mean D.O. concentrations in all areas of the Delta never differred by more than 2.1 ppm in any season with the north and west Delta having the highest concentrations year round (Table 4 & 7).

All of our D.O. measurements were greater than or equal to 3 ppm, a conservative generalized lethal minimum D.O. level for most

TABLE 7

Geograhical and Seasonal Differences in Water Quality Between Five Areas of the Sacramento-San Joaquin Delta Measured During the Electrofishing Survey of Resident Fishes (May, 1980 to April 1983)

Temperature
(^{o}F)
($\bar{x}$±S.D.)

	East	North	West	Central	South
Winter	49.8±4.3	50.5±3.4	49.5±4.1	49.6±5.0	50.2±3.8
Spring	61.7±5.4	58.5±5.6	58.8±4.5	59.5±4.9	60.8±4.7
Summer	74.8±4.7	71.1±4.7	71.4±3.6	72.9±4.0	74.5±4.0
Fall	61.7±4.1	60.8±3.4	62.2±3.1	62.1±3.2	60.8±2.5

Dissolved Oxygen
(ppm)
($\bar{x}$±S.D.)

	East	North	West	Central	South
Winter	10.3±1.7	10.9±0.5	11.0±0.9	10.1±1.2	10.5±1.0
Spring	9.2±1.3	10.0±0.7	9.9±1.0	9.5±1.3	9.5±1.1
Summer	7.9±1.5	8.4±1.0	8.6±0.8	7.8±1.1	7.7±1.3
Fall	8.2±1.7	10.3±1.4	9.3±1.3	9.3±0.9	8.6±1.4

resident fish (Calhoun 1966; Moyle 1976; Alabaster and Lloyd 1980). We found D.O. concentrations less than 5 ppm only seven times (less than 2% of the total). Hence, except in very localized areas, D.O. levels probably do not affect the distribution of resident fish in the Delta. During overcast days in late summer or fall, low D.O. sometimes caused fish kills to occur in areas of high biochemical oxygen demand such as the Port of Stockton turning basin.

It was not possible to separate out many of the specific factors controlling the distribution of resident fish from this survey data, but three broad conclusions can be drawn from our results: 1) Most native fish species are most abundant in the north and west Delta rivers where "water quality" is at its best (low conductivity, higher summer and fall water transparency, slightly higher D.O., slightly lower temperatures). Their preference for this area could be due to water quality, channel type (primarily riverine environment), proximity to spawning areas, or competitive exclusion from the sluggish dead-end sloughs of the east Delta where introduced species are dominant. 2) Many introduced species, the sunfishes in particular, are most abundant in the east Delta. The abundance of sunfishes and some other resident fishes is correlated primarily with the dead-end slough channel type and secondarily with the intermediate conductivities and water transparencies characteristic of this area. The fact that they are also abundant in oxbows, channels behind berm islands, and small embayments which occur in other areas besides the east Delta implies that the calmer waters and riparian or aquatic vegetation characteristic of these areas are important to these fishes. Most of the introduced species that occur here also occur in lakes and sluggish, low gradient rivers in their original home range. 3) **White catfish** is the dominant species of the south Delta. Their abundance in this area is correlated with low water transparency and conductivity, both of which are characterisitic of the south Delta year-round.

LITERATURE CITED

Alabaster, J. S. and R. Lloyd. 1980. Water quality criteria for freshwater fish. FAO. Butterworths, London-Boston. 297 pp.

Bond, C. E. 1979. Biology of Fishes. W. B. Saunders Co. Philadelphia. 514 pp.

Borgeson, D. P. and G. W. McCammon. 1967. White catfish (Ictalurus catus) of the Sacramento-San Joaquin Delta. California Fish and Game 53(4): 254-263.

Calhoun, A. (Ed.) 1966. Inland Fisheries Management. California Department of Fish and Game. 546 pp.

Ganssle, D. 1966. Fishes and decapods of the San Pablo and Suisun bays. California Department of Fish and Game, Fish Bulletin 133: 64-94.

Lal, K. 1979. California inland angling trends for 1971 through 1974. California Fish and Game 65(1): 4-22.

Messersmith, J. 1966. Fishes collected in Carquinez Strait in 1961-1962. California Department of Fish and Game, Fish Bulletin 133: 57-63.

Moyle, P. B. 1976. Inland fishes of California. University of California Press, Berkeley, California. 405 pp.

Moyle, P. B., J. J. Smith, R. A. Daniels, T. A. Taylor, D. G. Price, and D. M. Baltz. 1982. Distribution and ecology of stream fishes of the Sacramento-San Joaquin drainage system, California. University of California Publications in Zoology, Vol. 115. University of California Press. 256 pp.

Pelgen, D. E. 1954. Progress report on the tagging of white catfish (<u>Ictalurus catus</u>) in the Sacramento-San Joaquin Delta. California Fish and Game 40(3): 313-321.

Pelgen, D. E. and G. W. McCammon. 1955. Second progress report on the tagging of white catfish (<u>Ictalurus catus</u>) in the Sacramento-San Joaquin Delta. California Fish and Game 41(4): 261-269.

Pelzmann, R. J., S. A. Rapp, and R. R. Rawstron 1980. Mortality and survival of tagged smallmouth bass, <u>Micropterus dolemieui</u> at Merle Collins Reservoir, California. California Fish and Game 66(1): 35-39.

Pielou, E. C. 1984. The interpretation of ecological data: a primer on classification and ordination. Wiley-Interscience, John Wiley and Sons, New York. 263 pp.

Pimentel, R. A. 1979. Morphometrics: the multivariate analysis of biological data. Kendall/Hunt, Dubuque, Iowa. 276 pp.

Sazaki, M. 1975. Results of 1974 electrofishing survey. California Department of Fish and Game, Region II, Rancho Cordova, CA., mimeo. 20 pp.

Turner J. L. 1966a. Seasonal distribution of crustacean plankters in the Sacramento-San Joaquin Delta. California Department of Fish and Game, Fish Bulletin 133: 95-104.

Turner, J. L. 1966b. Distribution and food habits of ictalurid fishes in the Sacramento-San Joaquin Delta. California Department of Fish and Game, Fish Bulletin 136: 130-143.

Turner, J. L. 1966c. Distributions and food habits of centrarchid fishes in the Sacramento-San Joaquin Delta. California Department of Fish and Game, Fish Bulletin 136: 144-153.

Turner, J. L. 1966d. Distribution of cyprinid fishes in the Sacramento-San Joaquin Delta. California Department of Fish and Game, Fish Bulletin 136: 154-159.

Turner, J. L. 1966e. Distribution of threadfin shad, Dorosoma petenense; tule perch, Hysterocarpus traskii; sculpin spp. and crayfish spp. in the Sacramento-San Joaquin Delta. California Department of Fish and Game, Fish Bulletin 136: 160-168.

Van Woert, W. F. 1980. Exploitation, natural mortality, and survival of smallmouth bass and largemouth bass in Shasta Lake, California. California Fish and Game 66(3): 163-171.

APPENDIX I

Results of the Principal Components Analysis

The table that follows is the loading matrix, after rotation of the nine component axes for best fit, and is composed of columns of correlations between the original variables and the components.

SORTED ROTATED COMPONENT LOADINGS (PATTERN MATRIX)

	COMPONENT 1	COMPONENT 2	COMPONENT 3	COMPONENT 4	COMPONENT 5	COMPONENT 6	COMPONENT 7	COMPONENT 8	COMPONENT 9
REDEAR SUNFISH	0.728	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BLUEGILL	0.724	0.000	0.000	-0.291	0.000	0.000	0.290	0.000	0.000
TOTAL SPECIES	0.693	0.000	0.336	0.340	0.000	0.000	0.000	0.280	0.000
LARGEMOUTH BASS	0.660	0.000	0.262	0.000	0.000	-0.247	0.000	0.000	0.000
WARMOUTH	0.640	0.000	0.000	0.000	0.000	0.289	0.000	0.000	0.000
BLACK CRAPPIE	0.584	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GOLDEN SHINER	0.573	-0.360	0.000	0.000	0.000	-0.332	0.000	0.000	0.000
DIVERSITY INDEX	0.567	0.000	0.264	0.000	0.000	0.000	0.000	0.000	0.000
EAST DELTA	0.540	0.000	0.000	0.000	0.000	0.498	0.000	0.000	-0.363
RIPRAP	0.000	0.874	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MUD BANK	0.000	-0.869	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BARE BANK	0.000	0.842	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TEMPERATURE	0.000	0.000	0.865	0.000	0.000	0.000	0.000	0.000	0.000
SEASON	0.000	0.000	0.788	0.000	0.000	0.000	0.000	0.000	0.000
DISSOLVED OXYGEN	0.000	0.000	-0.714	0.000	0.000	0.000	0.000	0.000	0.000
YELLOWFIN GOBY	0.000	0.000	0.507	0.000	0.000	0.000	0.000	0.235	0.000
TULE PERCH	0.000	0.000	0.000	0.717	0.000	0.000	0.000	0.229	0.000
SACRAMENTO SQUAWFISH	0.000	0.000	0.000	0.675	0.000	0.000	0.000	0.000	0.000
EMERGENT VEGETATION	0.000	-0.309	0.000	0.000	-0.756	0.000	0.000	0.000	0.000
RIPARIAN VEGETATION	0.000	-0.446	0.000	0.000	0.733	0.000	0.000	0.000	0.000
TRANSPORT CHANNEL	0.000	0.000	0.000	0.000	0.000	0.604	0.000	0.000	0.000
CENTRAL DELTA	0.000	0.000	0.000	0.000	-0.357	-0.565	0.000	0.000	0.263
DEAD-END SLOUGH	0.461	0.000	0.000	0.000	0.000	0.551	0.000	0.000	0.000
WHITE CATFISH	0.281	0.000	0.385	0.000	0.000	0.000	0.601	0.000	0.000
SOUTH DELTA	-0.302	0.000	0.000	0.000	0.398	0.000	0.577	0.000	0.000
SECCHI DISK	0.000	0.000	0.268	-0.241	0.000	-0.293	-0.543	0.000	0.000
INLAND SILVERSIDES	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.742	0.000
STRIPED BASS	-0.232	0.000	0.305	0.000	0.000	0.000	0.000	0.673	0.000
DAY/NIGHT	0.286	0.000	0.000	0.315	0.000	0.000	0.244	0.595	0.000
SACRAMENTO BLACKFISH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.579
DEPTH	0.000	-0.294	0.000	0.000	0.000	0.000	-0.292	0.000	0.000
SACRAMENTO SUCKER	0.000	0.000	0.298	0.296	0.000	0.000	-0.419	0.000	0.000
WHITE CRAPPIE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.403
CHANNEL CATFISH	0.000	0.000	0.300	0.000	0.239	0.000	0.387	0.000	0.000
SUBMERGENT VEGETATION	0.000	0.000	0.259	0.000	0.000	-0.436	0.000	0.000	0.000
SPLITTAIL	0.000	0.000	0.000	0.391	0.000	0.000	0.000	0.000	0.000
GOLDFISH	0.338	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.391
AMERICAN SHAD	0.000	0.000	0.000	0.000	0.000	0.000	-0.412	0.357	0.000
THREADFIN SHAD	0.298	0.000	0.000	0.000	0.000	0.276	0.000	0.000	0.000
BIGSCALE LOGPERCH	0.396	0.000	0.362	0.000	0.000	0.000	0.000	0.000	0.000
FLOATING VEGETATION	0.000	0.000	0.000	-0.452	0.000	-0.409	0.000	0.000	0.000
PRICKLY SCULPIN	0.000	0.382	0.000	0.381	0.000	0.000	0.000	0.000	0.000
CHINOOK SALMON	0.000	0.000	-0.402	0.321	0.000	0.000	0.000	0.000	0.000
STEELHEAD TROUT	0.000	0.000	-0.388	0.237	0.000	0.000	0.000	0.000	0.000
SNAGS	0.000	-0.378	0.000	0.000	0.351	0.296	0.000	0.000	0.000
BUSHES	0.000	0.000	0.000	-0.267	0.395	0.000	0.000	0.000	0.000
TREES	0.000	-0.427	0.000	0.000	0.447	0.000	0.000	0.000	0.000
NORTH DELTA	0.000	0.000	0.000	0.363	0.362	0.000	-0.437	0.000	0.000
WEST DELTA	-0.302	0.000	0.000	0.244	-0.487	0.317	0.000	0.000	0.000
GREEN SUNFISH	0.408	0.458	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CARP	0.377	0.000	0.251	0.000	0.000	0.000	0.000	0.000	0.293
CONDUCTIVITY	0.000	0.000	0.000	-0.364	0.000	0.000	0.403	0.000	0.466

IN THE COMPONENT LOADING MATRIX ABOVE, THE COLUMNS APPEAR IN DECREASING ORDER OF VARIANCE EXPLAINED BY THE COMPONENTS. ROWS HAVE BEEN REARRANGED SO THAT FOR EACH SUCCESSIVE COMPONENT, LOADINGS GREATER THAN 0.5000 APPEAR FIRST. SINCE WE DID NOT INTERPRET THEM, LOADINGS LESS THAN 0.2250 HAVE BEEN REPLACED BY ZERO.

APPENDIX 2

Results of the Canonical Correlation Analysis

The two tables that follow include first the overall test of significance for CCA and a stepdown analysis to indicate the number of significant canonical variables, and second the loading matrices showing the correlations between the original variable and the cannonical variates. We did not interpret loadings (correlations) less than 0.316.

CANONICAL VARIABLE NUMBER	EIGENVALUE	CANONICAL CORRELATION	BARTLETT'S TEST FOR REMAINING CANONICAL VARIABLES		
			CHI-SQUARE	D.F.	TAIL PROB.
			1421.31	289	0.0000
1	0.63621	0.79762	1083.07	256	0.0000
2	0.55210	0.74304	814.40	225	0.0000
3	0.45957	0.67791	608.56	196	0.0000
4	0.42139	0.64914	425.55	169	0.0000
5	0.34125	0.58416	285.92	144	0.0000
6	0.22220	0.47138	201.87	121	0.0000
7	0.16612	0.40757	141.10	100	0.0043
8	0.12053	0.34718	98.14	81	0.0945
9	0.08040	0.28354	70.11	64	0.2803
10	0.06980	0.26419	45.90	49	0.5994
11	0.04839	0.21999	29.31	36	0.7774
12	0.03489	0.18679	17.43	25	0.8656
13	0.03318	0.18216	6.14	16	0.9865
14	0.01276	0.11294	1.85	9	0.9936
15	0.00481	0.06938	0.23	4	0.9936
16	0.00065	0.02541	0.02	1	0.8921
17	0.00006	0.00742			

BARTLETT'S TEST ABOVE INDICATES THE NUMBER OF CANONICAL VARIABLES NECESSARY TO EXPRESS THE DEPENDENCY BETWEEN THE TWO SETS OF VARIABLES. THE NECESSARY NUMBER OF CANONICAL VARIABLES IS THE SMALLEST NUMBER OF CANONICAL VARIABLES SUCH THAT THE TEST OF THE REMAINING CANONICAL VARIABLES IS NON-SIGNIFICANT. FOR EXAMPLE, IF A TEST AT THE 0.01 LEVEL WERE DESIRED, THEN EIGHT VARIABLES WOULD BE CONSIDERED NECESSARY. HOWEVER, THE NUMBER OF CANONICAL VARIABLES OF PRACTICAL VALUE IS LIKELY TO BE SMALLER, AND WE FOUND THAT ONLY THE FIRST FIVE CANONICAL VARIABLES WERE INTERPRETABLE.

ANONICAL VARIABLE LOADINGS

ORRELATIONS OF CANONICAL VARIABLES WITH ORIGINAL ENVIRONMENTAL VARIABLES

	FIRST CANONICAL VARIABLE	SECOND CANONICAL VARIABLE	THIRD CANONICAL VARIABLE	FOURTH CANONICAL VARIABLE	FIFTH CANONICAL VARIABLE
DAY/NIGHT	0.557	-0.112	-0.134	0.122	-0.265
EMPERATURE	0.613	0.163	0.306	0.161	-0.110
ONDUCTIVITY	0.205	0.402	-0.054	-0.580	0.289
ISSOLVED OXYGEN	-0.473	-0.304	-0.138	-0.226	0.126
ECCHI DISK	0.016	-0.065	0.637	0.155	0.385
ARE BANK	0.261	-0.236	-0.271	-0.085	0.447
LOATING VEGETATION	-0.125	0.403	0.240	-0.077	0.055
UBMERGENT VEGETATION	0.057	0.444	0.480	0.029	-0.195
MERGENT VEGETATION	-0.285	0.144	0.376	0.051	-0.436
IPRAP	0.249	-0.254	-0.083	0.093	0.440
EASON	0.576	0.031	0.482	0.073	0.168
AST DELTA	-0.093	0.279	-0.339	0.702	0.092
ORTH DELTA	-0.073	-0.591	0.015	0.172	-0.048
ENTRAL DELTA	-0.052	0.224	0.532	-0.115	-0.013
OUTH DELTA	0.276	0.236	-0.356	-0.626	-0.048
IVER	0.038	-0.301	-0.043	-0.384	-0.161
EAD-END SLOUGH	-0.043	0.272	-0.335	0.557	0.424

ORRELATIONS OF CANONICAL VARIABLES WITH ORIGINAL SPECIES VARIABLES

	FIRST CANONICAL VARIABLE	SECOND CANONICAL VARIABLE	THIRD CANONICAL VARIABLE	FOURTH CANONICAL VARIABLE	FIFTH CANONICAL VARIABLE
OTAL SPECIES	0.668	0.063	-0.109	0.561	-0.074
ARGEMOUTH BASS	0.179	0.480	0.478	0.502	0.016
LUEGILL	0.222	0.739	-0.074	0.254	0.106
EDEAR SUNFISH	-0.128	0.450	-0.037	0.614	-0.271
REEN SUNFISH	0.262	0.111	-0.267	0.363	0.490
LACK CRAPPIE	0.083	0.117	-0.129	0.451	0.286
ARMOUTH	0.041	0.260	-0.409	0.470	0.067
ARP	0.308	0.370	-0.147	0.213	-0.037
ACRAMENTO SQUAWFISH	0.084	-0.547	-0.065	0.126	-0.231
OLDEN SHINER	0.036	0.498	0.369	0.322	-0.439
ACRAMENTO SUCKER	0.269	-0.499	0.159	0.236	0.164
HITE CATFISH	0.775	0.323	-0.296	-0.084	-0.313
ULE PERCH	0.299	-0.648	-0.007	0.142	-0.290
TRIPED BASS	0.576	-0.362	0.290	-0.229	0.227
IGSCALE LOGPERCH	0.383	0.149	0.086	0.420	0.027
ELLOWFIN GOBY	0.399	-0.166	0.490	-0.017	0.091
IVERSITY INDEX	0.308	0.155	0.058	0.566	-0.002
