1984 STRIPED BASS EGG AND LARVA SURVEY IN THE SACRAMENTO-SAN JOAQUIN ESTUARY

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Chapter 1. INTRODUCTION

The abundance of young striped bass, Morone saxatilis, in the Sacramento-San Joaquin estuary has suffered an unsteady but persistent decline from high levels in the middle 1960s. The decline was particularly severe in 1977, and abundance of young striped bass has been low every subsequent year. The adult striped bass population also has fallen during the past 20 years, but the exact period over which the decline occurred and the rate of decline are not clear. The adult population is now about one-quarter of its former size, and there is little sign of recovery.

Concern about the striped bass decline led to an extensive review of potential causes by the Department of Fish and Game in 1979-80 and by the State Water Resources Control Board in 1981-82. Four factors have been identified as likely causes for the decline:

- The adult population has declined to a point where insufficient numbers of eggs are being spawned.
- The zooplankton food supply of young bass in the western Delta and Suisun Bay has been greatly reduced, possibly causing higher mortality of larval striped bass when they first begin to feed.
- Large numbers of eggs, larvae, and juveniles are entrained in water diversions.
- Toxic substances such as petrochemicals and pesticides are reducing survival of young bass or reducing survival and fecundity of adult bass.

As part of an evaluation of the various hypotheses, the Department of Fish and Game undertook an intensive effort to better understand the early life history of striped bass. This effort includes thoroughly analyzing data from past striped bass egg and larva surveys and conducting new egg and larva surveys in 1984, 1985, and 1986.

Striped bass egg and larva surveys were conducted by the Department of Fish and Game each spring from 1967 to 1977 (except in 1974) to measure abundance of eggs and the abundance, distribution, growth, and survival of larval striped bass. Similar surveys were conducted by Ecological Analysts in 1978 and 1979 to assess the impact of the Pittsburg and Contra Costa PGandE power plants on the striped bass population.

Objectives of the 1984 survey were to:

- Provide an egg abundance index to compare with past indices of egg abundance and stock fecundity estimates.
- Measure the relative use of the Sacramento and San Joaquin rivers for spawning and compare with past years.
- Measure larva abundance, distribution, growth, and survival rates and compare with past measures (1968 to 1977 surveys).
- Directly measure the food supply of larval bass to compare with stomach contents, growth, and survival rates.
- Examine effects of environmental factors (water transparency, electrical conductivity, temperature, flows, and export pumping rates) on bass survival.

This report summarizes current knowledge of the early life history of striped bass based on the egg and larva surveys from 1967 to 1984.

Chapter 2. METHODS

The 1984 survey differed from past surveys as follows:

- Phytoplankton probably is at the base of the striped bass food chain; therefore, chlorophyll *a* (a measure of phytoplankton production) and zooplankton concentrations were measured at all estuarine sampling stations with larval bass, to more fully assess the food supply hypothesis.

- The survey covered northern Suisun, Grizzly, and Honker bays and Carquinez Strait, areas not covered adequately in past surveys and that may be an important part of the nursery area.

- The survey covered the entire spawning and larval period adequately. Past surveys were sometimes started too late or ended too early, making it difficult to derive accurate abundance estimates.

- Sampling was reduced from every second day to every fourth day in areas other than spawning areas.

The survey was conducted in the estuary and the upper Sacramento River. In 1984, 43 estuarine stations were sampled (Figure 1). Stations 1 through 61, located about every second mile from the Benicia Bridge to Rio Vista on the Sacramento River and to Medford Island on the San Joaquin River, were sampled during 1967 to 1977 surveys. In 1984, these and eleven additional stations in Carquinez Strait; upper Suisun, Grizzly, and Honker bays; and Montezuma Slough were sampled.

Fish eggs and larvae, chlorophyll *a*, and zooplankton were sampled at each station every fourth day from April 16 to July 13 except on the spawning grounds (San Joaquin River, stations 33-61), where eggs and larvae were sampled every second day from April 16 to May 22. An analysis of 1967 to 1977 data indicated that every second day frequency was not required for estimation of larva abundance and survival rates, but was required for estimation of egg abundance.

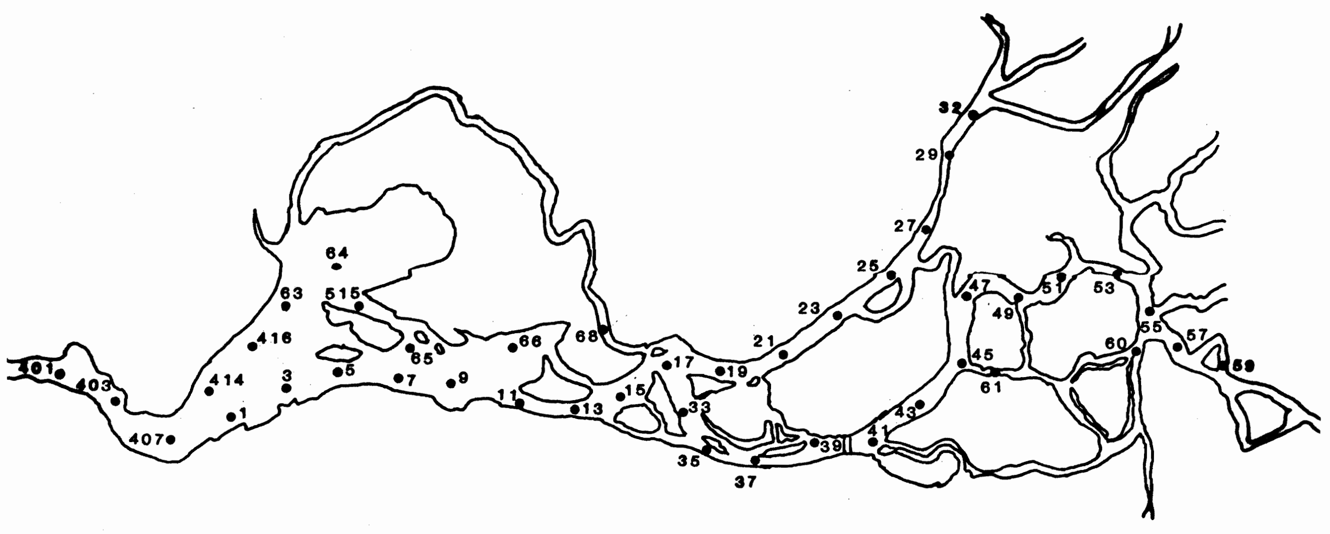


FIGURE 1. LOCATION OF ESTUARINE SAMPLING STATIONS

Three boats were used to sample the estuarine stations: one sampled stations 1-32 (Suisun Bay channel stations and lower Sacramento River); one sampled stations 33-61 (San Joaquin River); the third sampled stations 401-416, 515, and 63-68 (Carquinez Strait; upper Suisun, Grizzly, and Honker bays; and Montezuma Slough). Stations were sampled regardless of tidal stage.

Water temperature, electrical conductivity, and water transparency (secchi disk) were measured at the surface at each estuarine station.

On the upper Sacramento River, 14 stations, located about every 10 miles from Isleton to Grimes, were sampled for eggs and larvae every second day from May 2 to June 19. This portion of the survey was primarily to index the abundance of eggs spawned in the Sacramento River. These sites were also sampled in 1972, 1973, 1975, and 1977 (Figure 2). Surface water temperature and water transparency (secchi disk) were measured at each station.

In the laboratory, samples were washed to remove excess formaldehyde, and eggs and larvae were sorted from algae and detritus and then identified. Eggs were identified to species, and striped bass eggs were classified as 0-8 hours old, 9-36 hours old, or dead. Fish larvae were identified to family or species, and striped bass were measured to the nearest millimeter standard length.

Appendix A contains details of field sampling, laboratory, and data analysis methods.

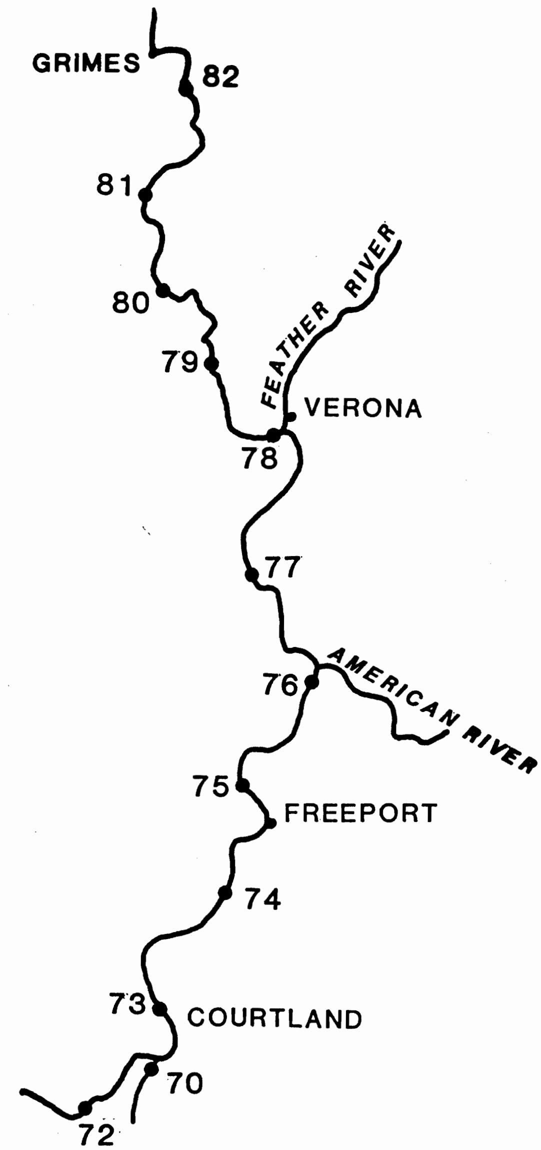


FIGURE 2. LOCATION OF SAMPLING STATIONS, UPPER SACRAMENTO RIVER.

Chapter 3. RESULTS

Larval bass abundance, growth, and mortality in 1984 were compared with the results of surveys conducted since 1968. The distribution of bass larvae, zooplankton, and chlorophyll were compared to determine the relationship of trophic levels in time and space. Larval food habits and prey selectivity were described.

Abundance

Abundance indices for bass eggs and larvae were calculated for geographical areas of the estuary. Striped bass larval abundance was correlated against midsummer abundance of bass and Delta outflow.

Larval Abundance Indices

Abundance indices for 6-8, 9-11, 12-14, and 6-14 mm larvae were calculated (Table 1) for the following areas:

- Suisun Bay ship channel
- Lower Sacramento River
- Upper Suisun, Grizzly, and Honker bays
- San Joaquin River
- Montezuma Slough
- Carquinez Strait

Due to low spring outflow in 1984, very few larvae were caught in Carquinez Strait, and there were more larvae in the Delta than in Suisun Bay. However, there were significant numbers of larvae in upper Suisun, Grizzly, and Honker bays, indicating that these areas are an important part of the nursery.

To calculate indices of abundance to compare with indices for 1968-1977, the weighted catch sums* were multiplied by two in areas and time periods where sampling was conducted every fourth rather than every second day. The indices were based on summing weighted catches for all estuarine stations except those in Montezuma Slough and Carquinez Strait. The stations included (1-66, 414, 416, and 515; Figure 1) are equivalent to the area included in indices for past years.

Table 1
ABUNDANCE OF STRIPED BASS LARVAE
1984 Survey

Area and Stations	Abundance (x 10^4) 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

*Weighted catch equals catch per cubic meter of water strained by net times amount of water represented by the sampling station.

Catch curves revealed that sampling in 1984 was started early enough and continued long enough to estimate 6-14 mm abundance without extrapolation required in previous years (Figures 3, 4, and 5).

The indices revealed that abundance was low in 1984 -- lower than in any previous year except the drought year 1977 (Table 2 and Figure 6). Abundance of 6-14 mm larvae in 1984 was only 25 percent as great as abundance in 1970 and 52 percent as great as abundance in 1979, years with similar spring outflows.

Abundance Correlations

Abundance of 6-8, 9-11, and 12-14 mm larvae was correlated against abundance of juveniles measured in the summer townet survey to determine the point at which size of the year class is set.

A poor correlation between abundance of bass larvae and abundance of juveniles measured in the midsummer townet survey (38 mm index) would suggest survival varies between these stages, whereas a good correlation suggests year class size is set in the egg or larval stage.

Abundance correlations for 6-8 mm, 9-11 mm, and 12-14 mm bass larvae and the 38 mm index are shown in Figure 7. Data for 1972, 1978, and 1979 were not included in the correlations because:

- Most of the sampling in 1978 and 1979 was conducted at night to minimize net avoidance by larger larvae (Ecological Analysts' Long River Survey). Abundance indices for large larvae were higher relative to small larvae in these years, probably due to more efficient sampling of the larger larvae at night.

- The 1984 sampling was always during daytime; hence, the 1978-1979 results are not strictly comparable to 1984.

- Data for 1972 were not included because a levee broke on Andrus Island on June 21 of that year. The rapid flooding of the island caused a sudden shift in position of the entrapment zone, probably resulting in substantial entrainment losses of larvae. Estimated mortality of larvae increased immediately after the levee break (Interagency Ecological Study Program 1973).

Excluding these data, correlation coefficients were 0.669 for 6-8 mm larvae (not significant, $p > 0.05$), 0.960 for 9-11 mm larvae ($p < 0.01$), and 0.921 for 12-14 mm larvae ($p < 0.01$). Abundance of the larger larvae size groups was more highly correlated with the midsummer index than was that for the 6-8 mm group, suggesting that while initial abundance may play a major role in determining the ultimate abundance of a year class, there is some annual variation in survival between the small and large larval stages.

Correlations between 6-8, 9-11, and 12-14 mm abundance and $\log_{10}$ mean April to June Delta outflow were not significant ($p > 0.05$, Figure 8), suggesting that other factors also affect abundance at the larval stage. Larval abundance was generally lower in later years (1978-1984) than in earlier years for a given amount of outflow.

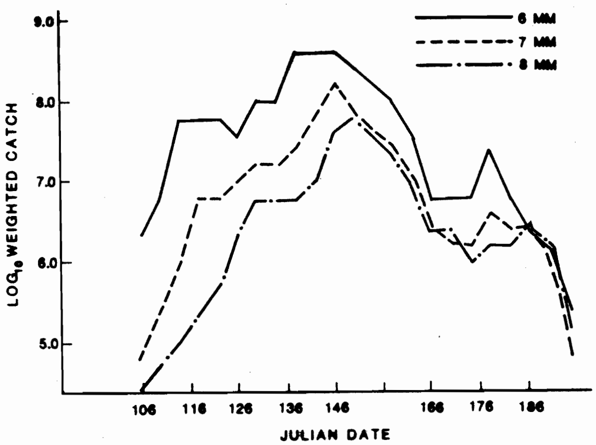


FIGURE 3. ABUNDANCE OF 6, 7, 8 MM LARVAE BY JULIAN DATE, 1984

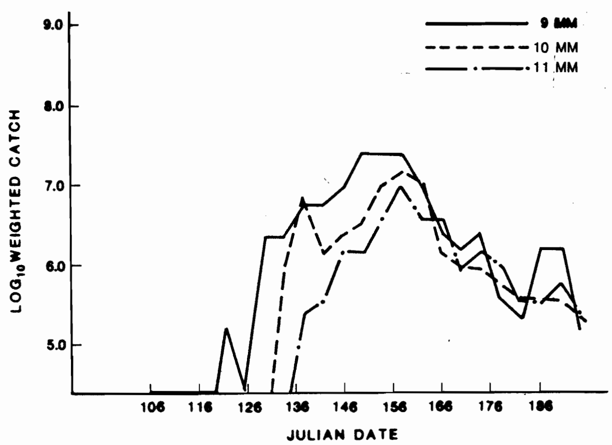


FIGURE 4. ABUNDANCE OF 9, 10, AND 11 MM LARVAE BY JULIAN DATE, 1984

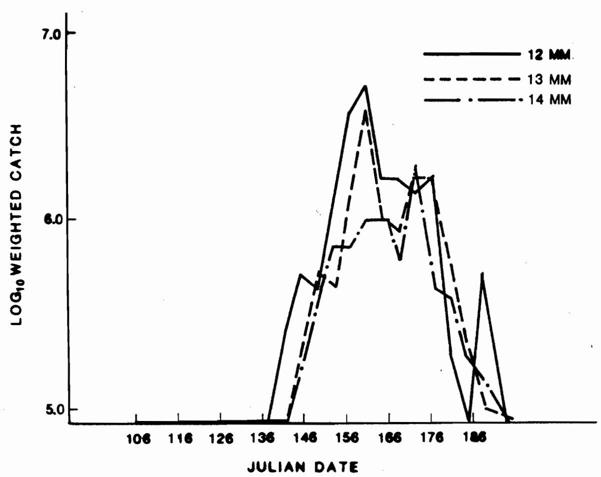


FIGURE 5. ABUNDANCE OF 12, 13, AND 14 MM LARVAE BY JULIAN DATE, 1984

Table 2
ABUNDANCE INDICES, STRIPED BASS LARVAE
1968 through 1984

Year	Index			
	6-8 mm	9-11 mm	12-14 mm	6-14 mm
1968	872,828	132,177	28,535	1,033,540
1970	2,292,883	197,831	55,254	2,545,968
1971	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
1978†	1,432,932	201,458	105,638	1,740,028
1979†	1,127,727	81,342	27,548	1,236,614
1984	588,415	43,220	7,694	639,329

Indices calculated by summing weighted catches for Suisun, Grizzly, and Honker bays, lower Sacramento River, and San Joaquin River. Data are in numbers of fish x 10^4. Data for 1968 through 1977 include time period extrapolations and extrapolations for upper Suisun Bay stations. Data for 1968 through 1973 are corrected for differences in net efficiency.

*Actual weighted catch sums; no time period extrapolations.
†Data from Ecological Analysts Long River Survey

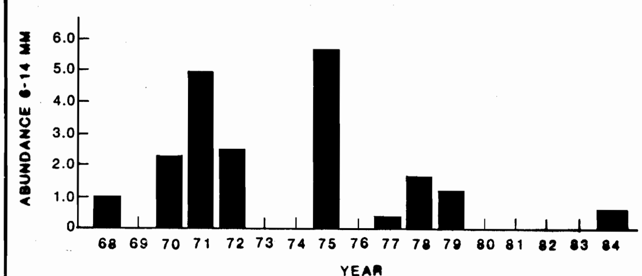


FIGURE 6. ABUNDANCE OF 6-14 MM LARVAE, 1968-1984

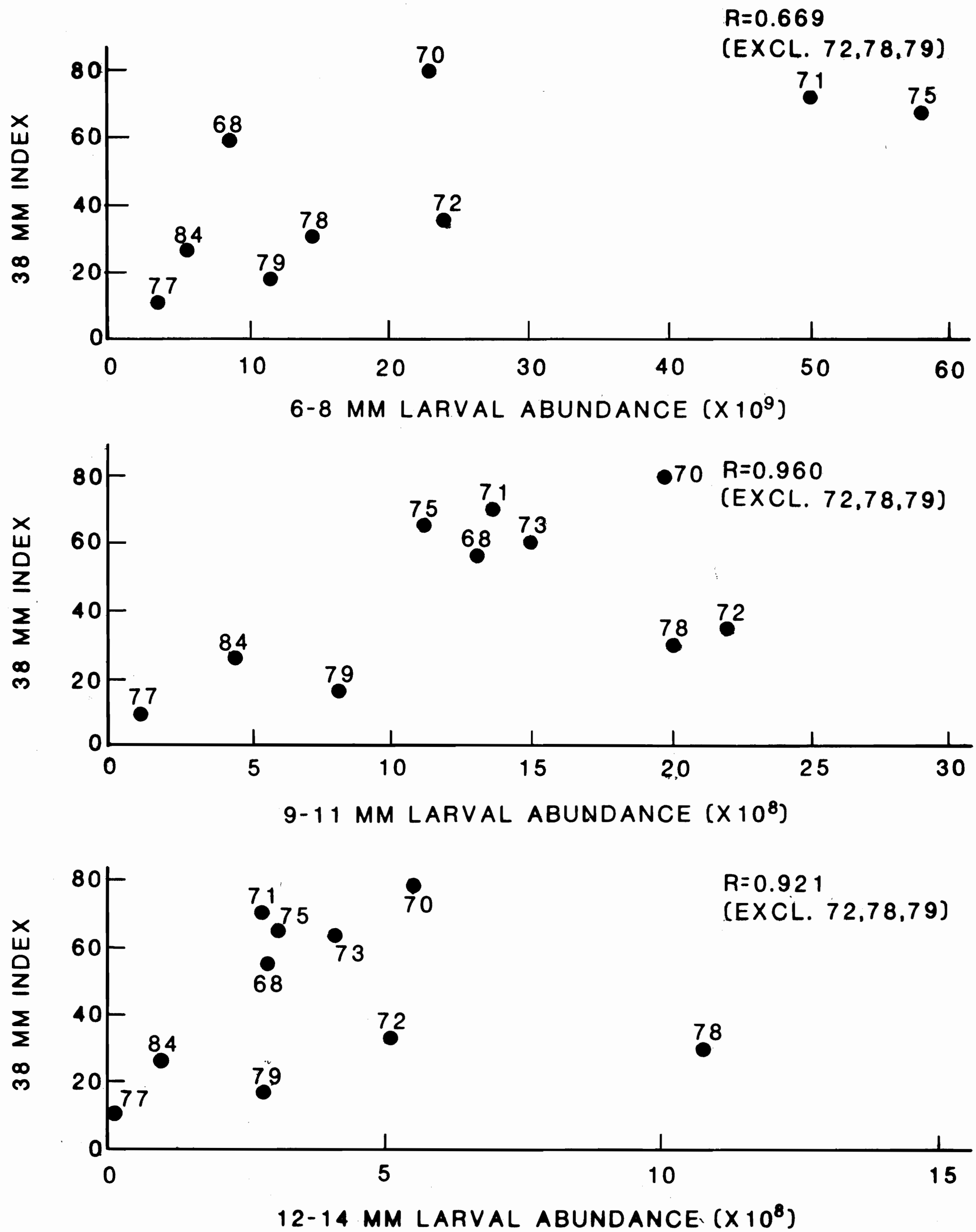


FIGURE 7. CORRELATION BETWEEN ABUNDANCE OF 6-8, 9-11, AND 12-14 MM LARVAE AND THE TOWNET SURVEY 38 MM STRIPED BASS INDEX

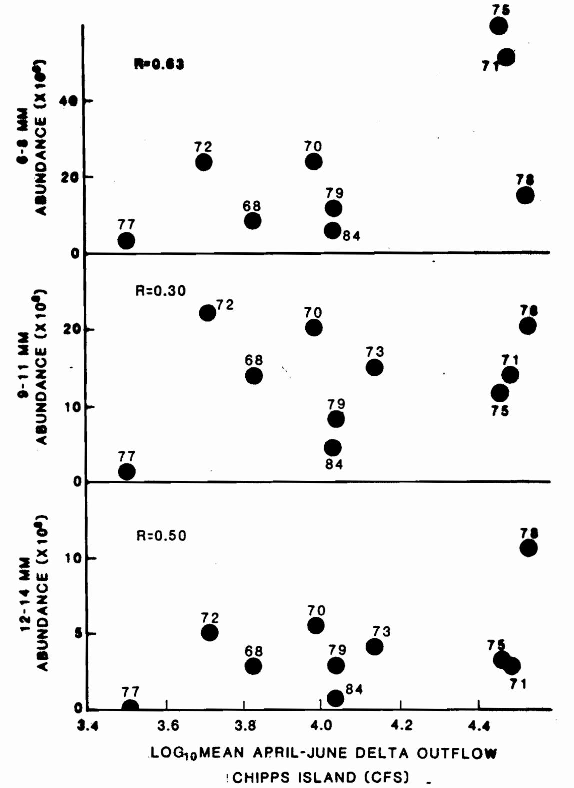


FIGURE 8. CORRELATION BETWEEN 6-8, 9-11, AND 12-14 MM LARVAL ABUNDANCE AND DELTA OUTFLOW, 1968-1984

Egg Abundance

Egg abundance was calculated by summing the weighted catches of eggs alive at time of catch for the Sacramento and San Joaquin rivers. Surveys were only conducted on the upper Sacramento River in 1972, 1973, 1975, 1977, and 1984. The San Joaquin River was sampled in these years and in 1968 and 1970.

To compare 1984 data to those from past years, weighted catch sums were multiplied by two in time periods when sampling was conducted every fourth day rather than every second day.

Egg abundance distinctly declined from 1972 to 1984 (Table 3 and Figure 9). Total egg abundance in 1984 was only about one-quarter of egg abundance in 1972 and about half of egg abundance in 1977. Egg abundance in the San Joaquin River has been more variable than in the Sacramento River, which declined consistently since 1973.

The proportion of eggs spawned in the Sacramento River (versus the San Joaquin River) was slightly lower in 1984 than in earlier years, but there was no definite trend over time (Table 4).

Table 3
EGG ABUNDANCE IN THE SACRAMENTO AND SAN JOAQUIN RIVERS

Sum of Weighted Catches of Live Eggs ($x 10^4$)

Year	Sacramento River	San Joaquin River	Total
1968	---	269,359	---
1970	---	127,221	---
1972	1,092,776	744,929	1,837,705
1973	1,678,146	---	---
1975	744,430	376,916	1,121,346
1976	---	86,263	---
1977	465,658	270,360	736,018
1984	220,678	198,436	419,113

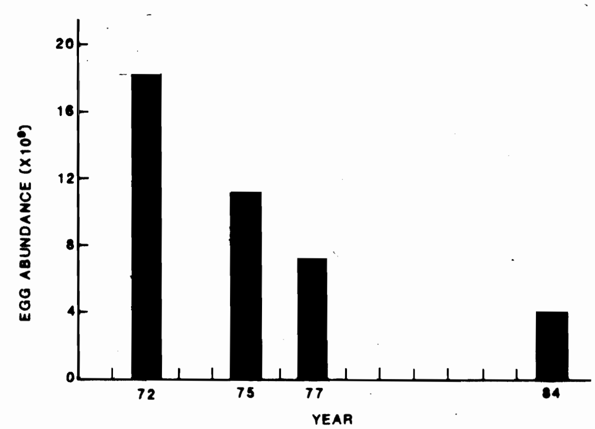


FIGURE 9. EGG ABUNDANCE IN 1972, 1975, 1977, AND 1984

Table 4
PERCENT OF EGG CATCH FROM THE SACRAMENTO AND SAN JOAQUIN RIVERS

Year	% Sacramento River*	% San Joaquin River**
1972	59.5	40.5
1975	66.4	33.6
1977	63.3	36.7
1984	52.7	47.3

* Stations 17-32 and 70-84
**Stations 33-61

Growth Rates

Growth rates for 1984 were calculated using the method described by Hackney and Webb (1978). Catch curves (Figures 3 to 5) were used to find the average date individuals in the population attained each length increment. The difference between these dates represents the time required for larvae to grow from one length increment to the next.

Since complete catch curves were not available in some past years, a modification of this method was used to calculate growth rates for 1968, 1970, 1971, and 1972. Curves were shifted forward in time by day until the best correlation was obtained between each curve and the curve for the next length group. Growth in 1979 (Ecological Analysts data) was calculated using Hackney and Webb's original method.

Since growth rates calculated by this method are relative (each length group is compared in time with the next length group) and reliable data were not available for smaller larvae (4 and 5 mm), 6 mm larvae were set to day 1, and growth from 6 to 14 mm was calculated.

Estimated growth from 6 to 14 mm is shown in Table 5 and Figure 10. Growth rates were derived from Equation 1, a logarithmic growth equation (Hackney and Webb 1978).

Equation 1: $L_t = L_{t_o} e^{G(t-t_o)}$

Where
L_t = Length at time t
L_{t_o} = Length at time o
e = Natural log function
G = Growth rate
t = Time (days)

Data for all years fit this relationship with a correlation coefficient (r) of 0.99.

Growth rates derived from Equation 1 are as follows.

Year	Growth Rate
1968	0.0446
1970	0.0440
1971	0.0361*
1972	0.0400
1977	0.0397**
1979	0.0386
1984	0.0321

* Based on 6-11 mm larvae only.
** Based on 6-9 mm larvae only.

Growth rates appear to have declined over the years. Estimated growth in 1984 was slower than in all previous years, particularly for larvae between 10 and 14 mm (Figure 10). Additional data are needed, however, to substantiate this trend.

Larval Mortality Rate

Mortality of 6-14 mm larvae was calculated based on the decline in the natural log of the total seasonal abundance over time. The estimates were based on Equation 2.

Equation 2: $N_t = N_o e^{-Z(t-t_o)}$

Where
N_t = Larval abundance at time t
N_o = Initial abundance
e = Natural log function
Z = Instantaneous mortality rate
t = Time (days)

Growth rates were used to convert lengths from 6 to 14 mm to time in days. Numbers of larvae at each length for the entire season were plotted against the age of each larval length group. Mortality rates were calculated for years of the survey for which adequate growth rates were available.

Mortality was highest in 1971 and 1977 and was intermediate in 1968, 1970, and 1972 (Table 6 and Figure 11). Mortality in 1984 was slightly lower than in any previous year.

Table 5
GROWTH OF LARVAE FROM 6 mm TO 14 mm

Length (mm)	Days 1968	1970	1971	1972	1977	1979	1984
6*	1	1	1	1	1	1	1
7	3	6	7	6	4	2.4	5.5
8	7	8	10	9	8	6	10.2
9	9	11	13	13	11	8.7	12.5
10	11	14	16	16	-	13.2	14.8
11	14	16	18	17	-	15.5	18.9
12	16	18	-	19	-	16.9	23.2
13	18	19	-	21	-	19.6	25.7
14	19	20	-	22	-	21.2	26.1

*Since data were not available for larvae less than 6 mm, 6 mm larvae were set to Day 1.

Table 6
MORTALITY RATES OF
6 to 14 mm STRIPED BASS LARVAE

Year	Mortality Rate
1968	0.223
1970	0.244
1971	0.306
1972	0.231
1975	*
1977	0.320**
1984	0.207

* Growth rate not available.
**Based on 6-9 mm larvae only.

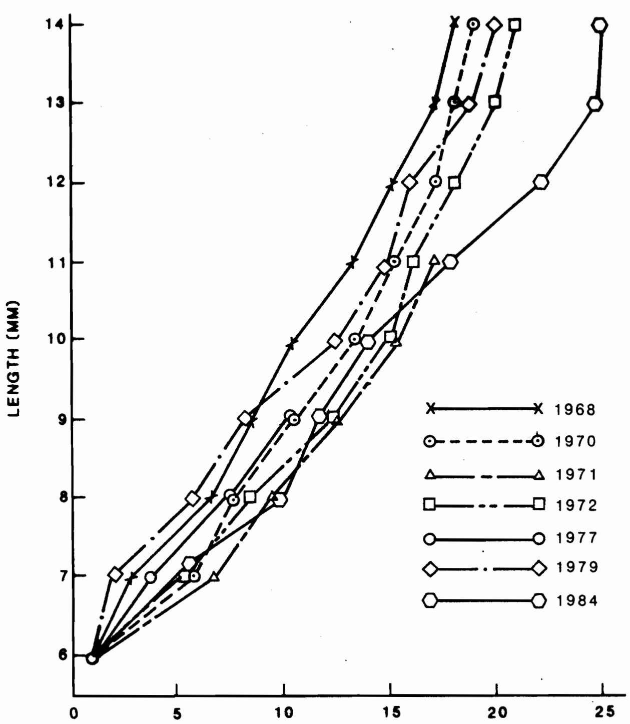


FIGURE 10. GROWTH OF LARVAE FROM 6 TO 14 MM, 1968 TO 1984

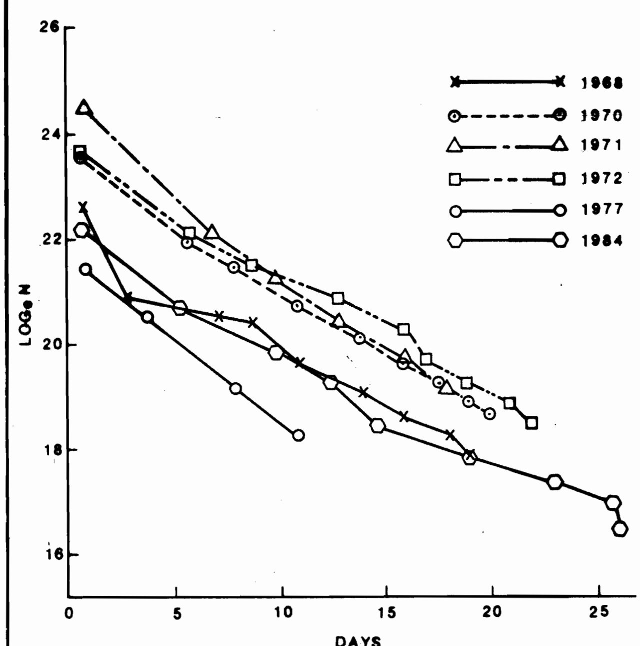


FIGURE 11. MORTALITY DECLINE IN NATURAL LOG OF ABUNDANCE OVER TIME FOR 6-14 MM LARVAE, 1968-1984

Distribution

Temporal and spatial distributions of chlorophyll a, zooplankton, and larval bass were compared to determine the relationship between organisms in the larval striped bass food chain.

Chlorophyll a and Zooplankton Distribution

The relationship between chlorophyll a and zooplankton density was examined because both are links in the larval striped bass food chain. Rather than relate chlorophyll to all zooplankton sampled, only zooplankton genera that were important prey items in larval bass stomachs were used in this analysis. Combined densities of copepods (Eurytemora and Sinocalanus) and cladocerans (Bosmina and Daphnia) were used (see Larval Food Habits, page 17). Data from Clarke-Bumpus net and pump sampling were combined.

Distributions of mean chlorophyll a concentration and mean densities of the important zooplankton prey items were plotted by 12-day time periods and 10-kilometer segments of the Sacramento River (Figure 12) and the San Joaquin River (Figure 13). Data for northern Suisun, Grizzly, and Honker bays were plotted by individual stations by 12-day time periods (Figure 14).

Zooplankton densities varied greatly from area to area and between time periods. High densities occurred in Grizzly and Honker bays in late June and early July and in the San Joaquin River from mid-May to mid-July.

In Figures 12 to 14, no correlation is apparent between distributions of chlorophyll a and zooplankton in Suisun, Grizzly, and Honker bays and the Sacramento River. On the San Joaquin River, peak concentrations of chlorophyll a and zooplankton occurred in the same areas, but chlorophyll a peaked later than did zooplankton.

To further examine the relationship between chlorophyll a concentration and zooplankton density, densities of each were plotted by 8-day periods for four areas: Suisun Bay; lower Sacramento River; San Joaquin River; and northern Suisun, Grizzly, and Honker bays (Figure 15). These plots revealed that although zooplankton densities did not increase proportionally to increases in chlorophyll a concentration, zooplankton densities usually began to increase one or two time periods (8 to 16 days) following each increase in chlorophyll a concentration. Table 7 summarizes chlorophyll a increases and subsequent increases in zooplankton density. Decreases in chlorophyll concentration, however, did not always result in decreased zooplankton densities.

Table 7
SUMMARY OF CHLOROPHYLL a INCREASES AND SUBSEQUENT INCREASES IN ZOOPLANKTON DENSITY

Area	Time Periods of Chlorophyll a Increase	Time Period at Start of Zooplankton Increase	Time Period between Chlorophyll and Zooplankton Increases
Suisun Bay	1 - 3	3	2
	7 - 8	8	1
Lower Sacramento River	1 - 3	3	2
	6 - 9	8	2
San Joaquin River	1 - 3	2	1
	6 - 8	8	2
Upper Suisun, Grizzly, and Honker Bays	1 - 4	2	1
	7 - 8	8	1
	9 - 11	11	2

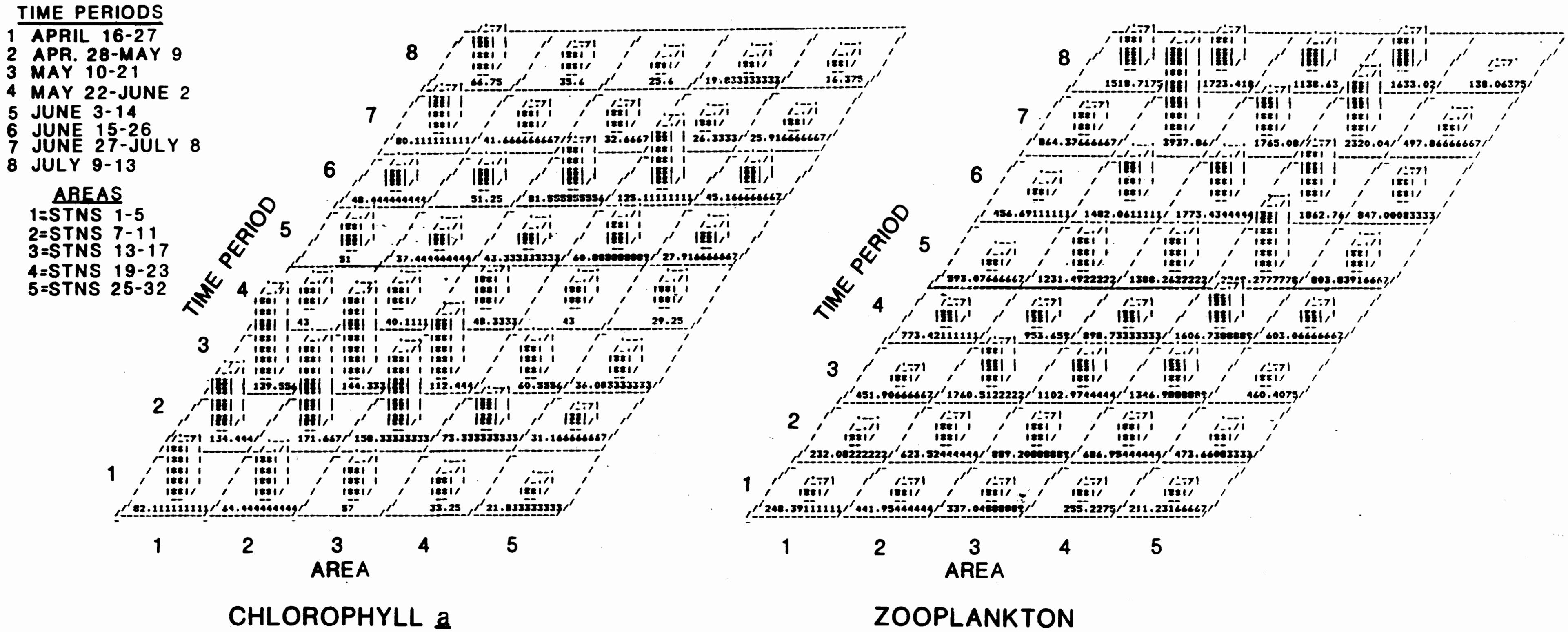


FIGURE 12. MEAN DENSITIES OF CHLOROPHYLL a (IN µg/l x 10^4) AND ZOOPLANKTON (IN ORGANISMS/M^3) IN SUISUN BAY AND THE SACRAMENTO RIVER

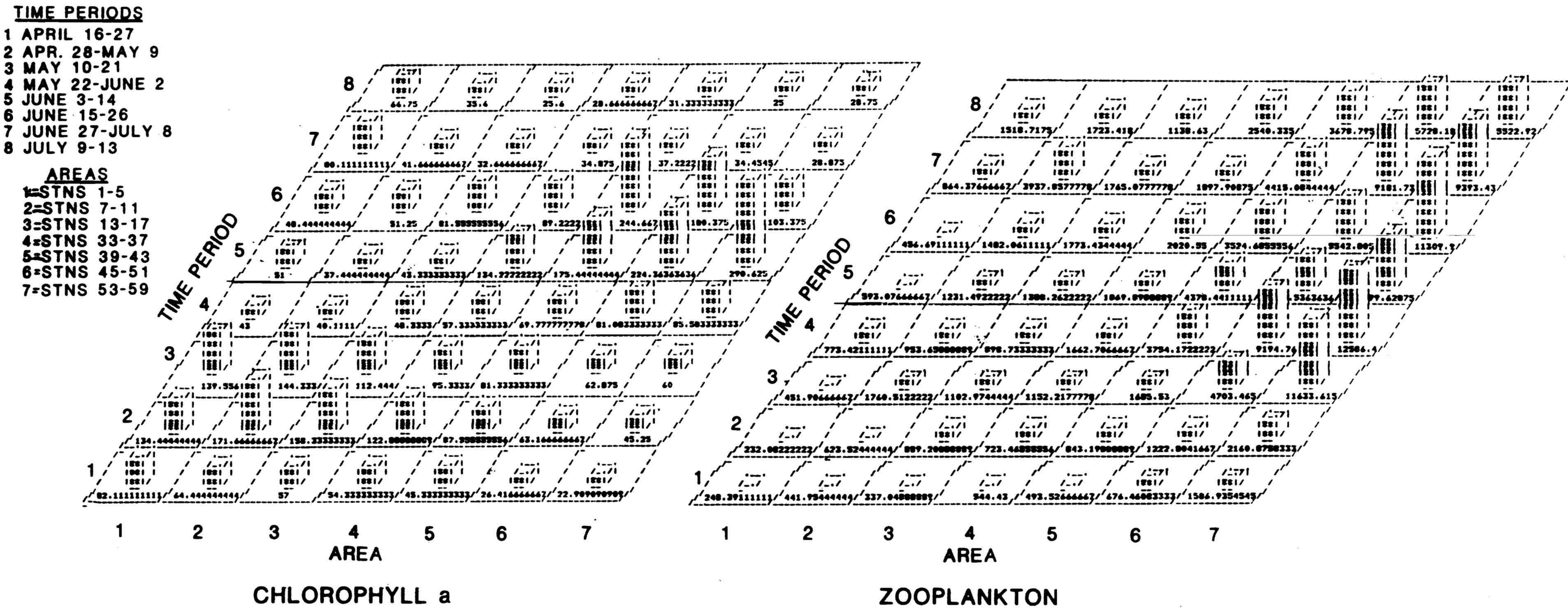


FIGURE 13. MEAN DENSITIES OF CHLOROPHYLL a (IN $\mu g/l \times 10^1$) AND ZOOPLANKTON (IN ORGANISMS/M^3) IN SUISUN BAY AND THE SAN JOAQUIN RIVER

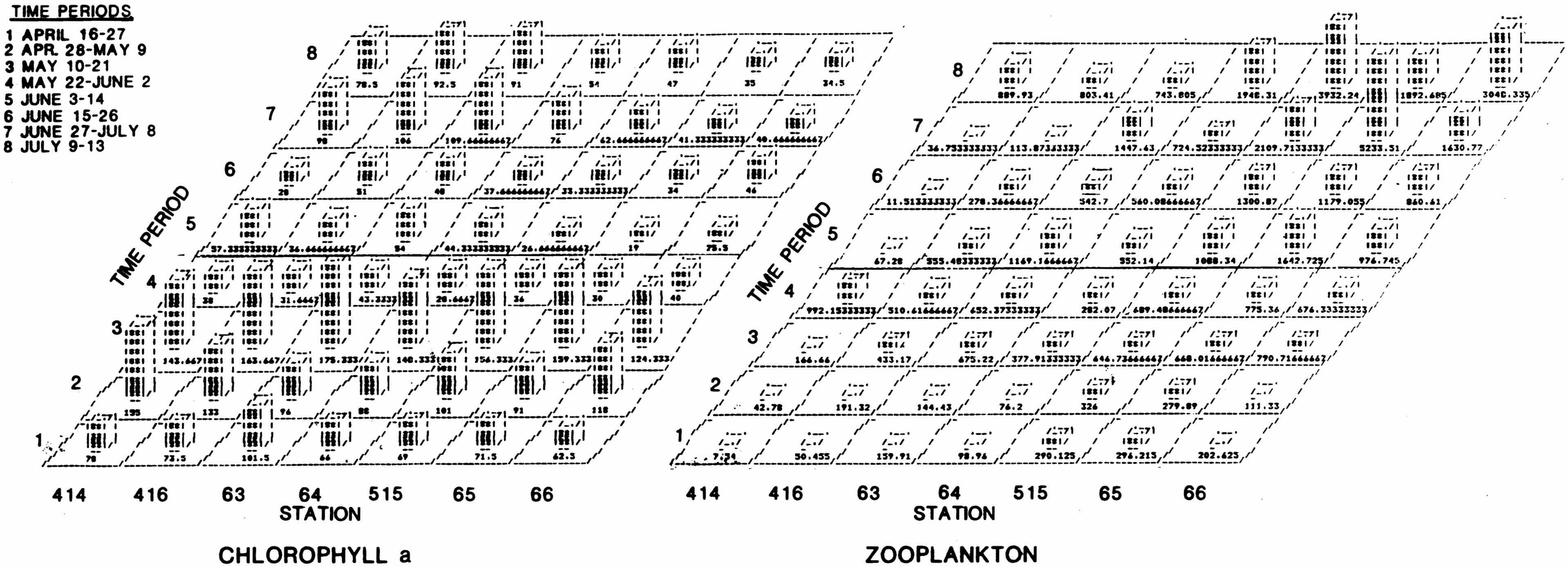


FIGURE 14. MEAN DENSITIES OF CHLOROPHYLL a (IN µg/l x 10[1]) AND ZOOPLANKTON (IN ORGANISMS/M³) IN UPPER SUISUN, GRIZZLY, AND HONKER BAYS

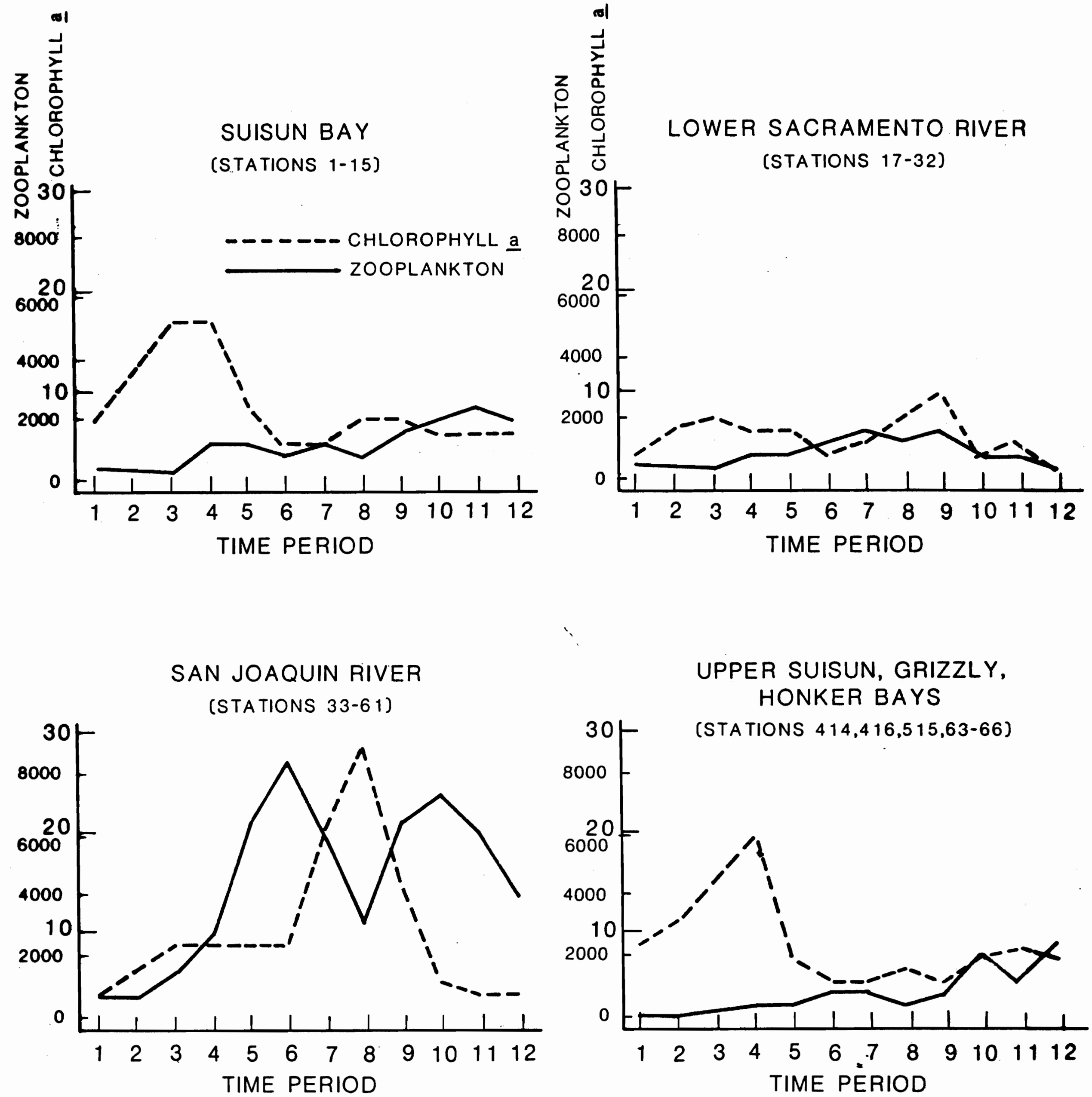


FIGURE 15. MEAN DENSITIES OF CHLOROPHYLL a (IN µg/l) AND ZOOPLANKTON (IN NUMBERS PER CUBIC METER) BY 8-DAY TIME PERIODS IN FOUR AREAS OF THE ESTUARY

Zooplankton and Larval Bass Distribution

Mean densities of main zooplankton prey items and of 6-8 mm striped bass were plotted by 12-day periods at 10-kilometer segments of the Sacramento River (Figure 16) and San Joaquin River (Figure 17). Northern Suisun, Grizzly, and Honker bay data were plotted by stations by 12-day periods (Figure 18). Carquinez Strait stations were not included, since few bass were caught there throughout the season.

The 6-8 mm bass densities were high from May 10 to June 11, peaking during May 22 to 30. Due to low outflows in spring, there were few bass downstream from station 7 in Suisun Bay and station 64 in Grizzly Bay. On the Sacramento River, 6-8 mm bass distribution was centered from station 13 to station 23. On the San Joaquin, bass were widely distributed from station 13 upstream as far as station 59. In the northern bay areas, 6-8 mm bass were abundant at stations 64, 515, 65, and 66.

Zooplankton densities varied between areas and time periods, with no consistent pattern. There was no relationship between zooplankton and 6-8 mm bass distribution in any area. More analyses are planned to determine the adequacy of food concentrations available to larval bass. Survival of bass will be related to zooplankton abundance in areas and time periods where bass were abundant for 1968 to 1977 and 1984.

Larval Food Habits

Larval striped bass diets were examined to determine prey species in 1984, to compare 1984 with previous years, and to investigate feeding selectivity.

Summary of 1984 Data

Larval food habits data were summarized for 6-14 mm larvae by four geographical areas: Suisun Bay ship channel; northern Suisun, Grizzly, and Honker bays; lower Sacramento River; and San Joaquin River.

Copepods, especially calanoid copepods, were the predominant food item in bass stomachs in all areas except the San Joaquin River, where cladocera were predominant (Tables 8 to 11). Eurytemora sp. was the most abundant copepod in stomachs in all areas and was consumed by bass in every size group. Its abundance in stomachs was highest in Suisun Bay (Figure 19). Sinocalanus sp., a recently introduced copepod, was also utilized by all size groups of bass. It was most common in upstream areas, especially the Sacramento River. Immature copepod stages, cyclopoid copepodids, calanoid copepodids, copepod nauplii, and harpacticoid copepods, were relatively low in abundance in stomachs from all areas and were rarely found in bass larger than 9 mm.

Two cladocerans, Bosmina sp. and Daphnia spp., were abundant in bass stomachs in the San Joaquin River and to a lesser extent in Sacramento River, but rarely occurred in downstream areas. Abundance of Bosmina sp., a small cladoceran, declined in the stomachs as bass size increased, whereas abundance of the larger Daphnia spp. increased with bass size (Figure 20). These relationships probably are due to prey size selection.

Rotifers were extremely rare in the diet, occurring only in a few stomachs from the San Joaquin River.

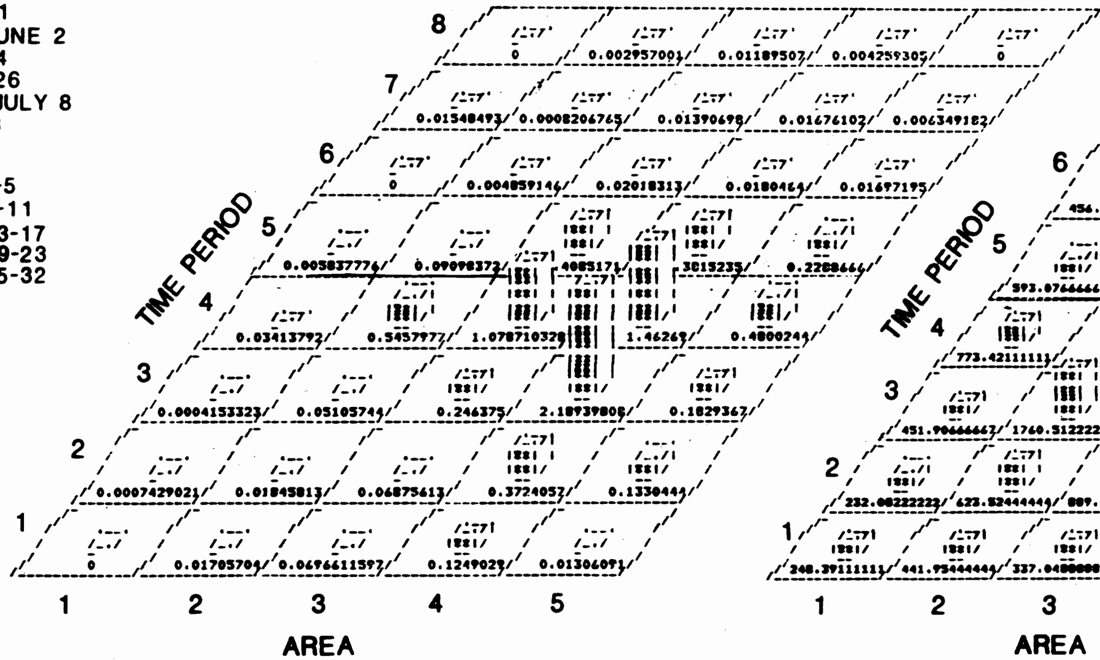
Neomysis sp. was consumed by all sizes of bass in all areas, but its occurrence was highest in the Sacramento River. The mean number of Neomysis sp. consumed increased with increasing bass size in all areas. Corophium sp., a benthic amphipod, was consumed by all sizes of bass at a relatively low level in all areas.

TIME PERIODS

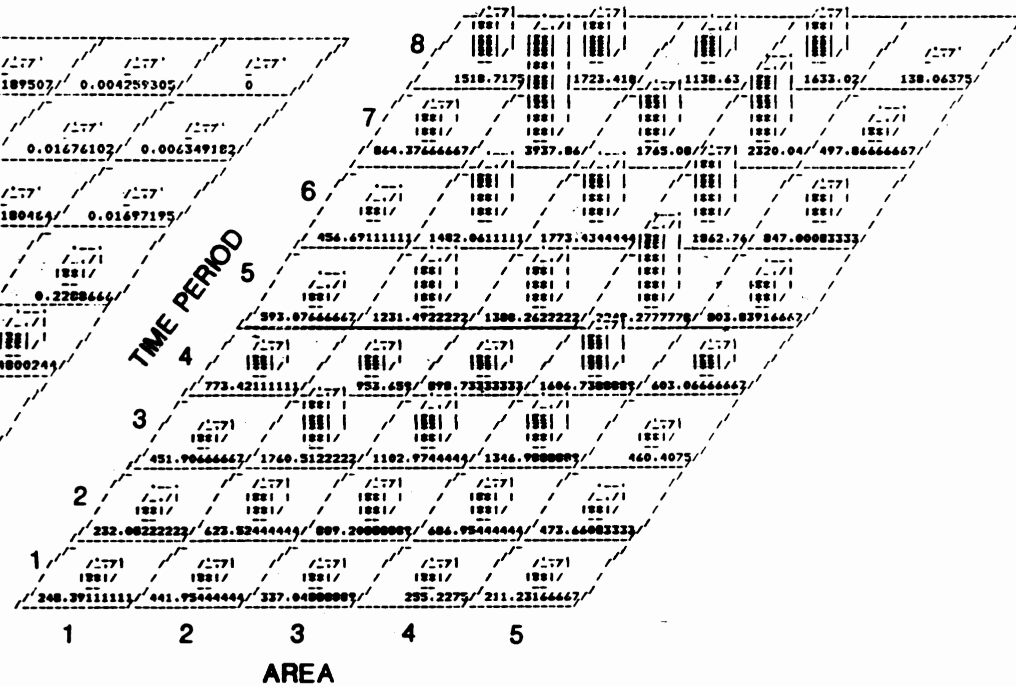
1 APRIL 16-27
2 APR. 28-MAY 9
3 MAY 10-21
4 MAY 22-JUNE 2
5 JUNE 3-14
6 JUNE 15-26
7 JUNE 27-JULY 8
8 JULY 9-13

AREAS

1=STNS 1-5
2=STNS 7-11
3=STNS 13-17
4=STNS 19-23
5=STNS 25-32



LARVAL BASS



ZOOPLANKTON

FIGURE 16. MEAN DENSITIES OF 6-8 MM LARVAE AND ZOOPLANKTON (IN ORGANISMS/M^3) IN SUISUN BAY AND THE SACRAMENTO RIVER

TIME PERIODS
1 APRIL 16-27
2 APR. 28-MAY 9
3 MAY 10-21
4 MAY 22- JUNE 2
5 JUNE 3-14
6 JUNE 15-26
7 JUNE 27-JULY 8
8 JULY 9-13

AREAS
1=STNS 1-5
2=STNS 7-11
3=STNS 13-17
4=STNS 33-37
5=STNS 39-43
6=STNS 45-51
7=STNS 53-59

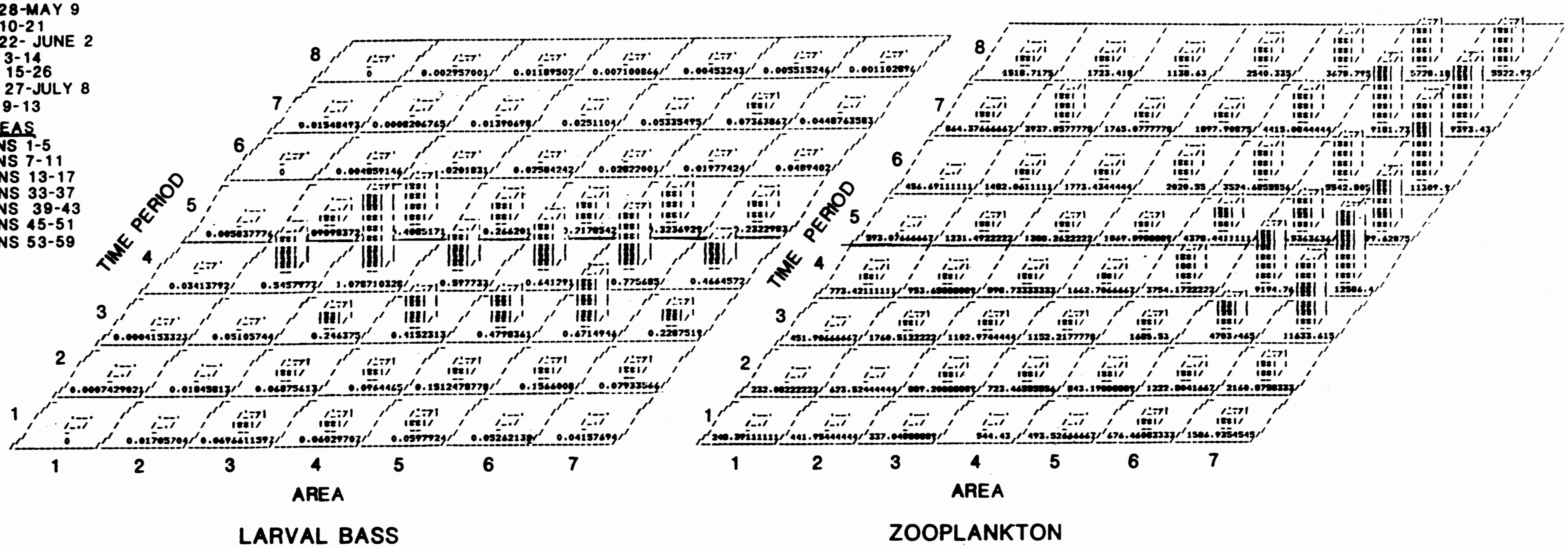


FIGURE 17. MEAN DENSITIES OF 6-8 MM LARVAE AND ZOOPLANKTON (IN ORGANISMS/M^3) IN SUISUN BAY AND THE SAN JOAQUIN RIVER

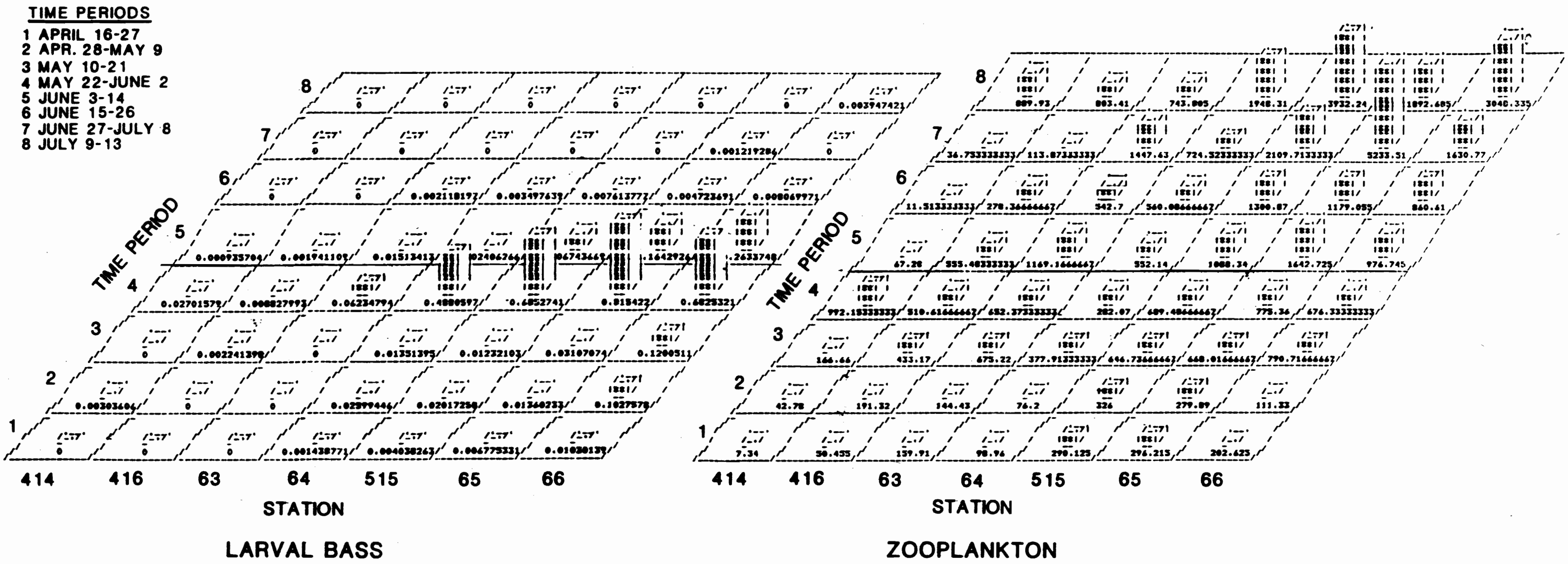


FIGURE 18. MEAN DENSITIES OF 6-8 MM LARVAE AND ZOOPLANKTON (IN ORGANISMS/M^3) IN UPPER SUISUN, GRIZZLY, AND HONKER BAYS

Table 8
MEAN NUMBER OF FOOD ITEMS CONSUMED BY 6-14 MM LARVAE, SUISUN BAY CHANNEL (Stations 1-15)

Food Items	Striped Bass Length (mm)								
	6	7	8	9	10	11	12	13	14
Copepoda									
Eurytemora affinis	0.70	1.46	2.09	2.31	2.43	2.00	1.88	0.67	--
Adult Calanoida*	0.33	0.29	0.70	0.97	0.71	0.50	0.25	--	--
Sinocalanus joerrii	0.07	0.08	0.36	0.66	0.36	0.40	0.13	--	--
Adult Cyclopidae	--	--	--	--	--	--	--	--	--
Cyclopoid Copepodids	0.23	--	--	--	--	--	--	--	--
Calanoid Copepoids	0.12	0.08	0.06	--	--	--	--	--	--
Harpacticoid	0.09	0.08	--	--	--	--	--	--	--
Copepod Nauplii	0.02	--	--	--	0.07	--	--	--	--
Diaptomus spp.	--	--	--	--	--	--	--	--	--
Acartia spp.	--	--	--	--	--	--	--	--	--
Other Copepods	0.26	0.13	0.27	0.16	0.07	--	0.13	--	--
Cladocera									
Bosmina longirostrus	0.05	--	--	--	--	--	--	--	--
Daphnia spp.	--	--	--	--	--	0.13	--	--	--
Diaphanosoma sp.	--	--	--	--	--	--	--	--	--
Other Cladocerans	--	--	--	--	--	--	--	--	--
Malacostraca									
Neomysis sp.	--	0.02	--	0.34	0.50	0.30	0.63	1.67	8.00
Corophium spp.	--	--	--	--	--	--	--	--	--
Amphipoda	--	--	--	--	--	--	--	--	--
Other Malacostraca	--	--	--	0.06	--	0.20	--	--	--
Conchostraca	--	--	--	--	--	--	--	--	--
Oligochaeta	--	--	--	--	--	--	--	--	--
Rotifera (All Rotifers)	--	--	--	--	--	--	--	--	--
Vertebrata (Fish)	--	--	--	--	--	--	--	--	--

* Composed of *Eurytemora* sp., *Sinocalanus* sp., *Acartia* spp., and *Diaptomus* spp., which could not be identified to genus.

Table 9
MEAN NUMBER OF FOOD ITEMS CONSUMED BY 6-14 MM LARVAE,
LOWER SACRAMENTO RIVER
(Stations 17-32)

Food Items	Striped Bass Length (mm) 6	7	8	9	10	11	12	13	14
Copepoda									
Eurytemora sp.	0.48	0.42	0.73	0.94	0.13	0.38	--	1.00	2.00
Adult Calanoida*	0.09	0.18	0.20	0.27	--	0.50	0.78	0.38	1.00
Sinocalanus sp.	11.00	0.17	0.24	0.42	0.53	0.88	0.67	0.63	1.50
Adult Cyclopidae	11.00	0.07	0.10	0.08	--	--	--	--	--
Cyclopoid Copepodids	0.03	0.02	0.01	--	--	--	--	--	--
Calanoid Copepoids	0.03	0.05	0.01	0.04	--	--	--	--	--
Harpacticoid	0.02	--	--	0.02	--	--	--	--	--
Copepod Nauplii	--	--	--	--	--	--	--	--	--
Diaptomus spp.	--	0.11	--	--	--	--	--	--	--
Acartia spp.	--	--	--	--	--	--	--	--	--
Other Copepods	0.09	0.08	0.17	0.19	0.20	0.13	0.11	--	--
Cladocera									
Bosmina longirostrus	0.30	0.11	0.07	--	0.13	--	--	--	--
Daphnia spp.	0.02	0.02	--	0.02	--	--	--	--	--
Diaphanosoma sp.	--	--	--	--	--	--	--	--	--
Other Cladocerans	0.09	0.03	0.01	--	--	0.13	0.11	--	--
Malacostraca									
Neomysis sp.	--	0.07	0.21	0.56	1.27	1.50	1.67	2.25	2.50
Corophium spp.	0.01	0.03	0.03	0.06	--	0.13	0.33	0.38	0.50
Amphipoda	--	--	--	--	--	--	--	--	--
Other Malacostraca	0.01	0.03	0.09	0.06	0.20	--	--	--	--
Conchostraca	0.01	--	--	--	--	--	--	--	--
Oligochaeta	0.03	0.01	--	0.02	--	--	--	--	--
Rotifera (All Rotifers)	--	--	--	--	--	--	--	--	--
Vertebrata (Fish)	--	--	--	--	--	--	--	--	--

* Composed of *Eurytemora* sp., *Sinocalanus* sp., *Acartia* spp., and *Diaptomus* spp., which could not be identified to genus.

Table 10
MEAN NUMBER OF FOOD ITEMS CONSUMED BY 6-14 MM LARVAE,
SAN JOAQUIN RIVER
(Stations 33-61)

Food Items	Striped Bass Length (mm) 6	7	8	9	10	11	12	13	14
Copepoda									
Eurytemora sp.	0.21	0.41	0.61	0.75	1.00	0.25	0.67	--	--
Adult Calanoida*	0.05	0.11	0.12	0.17	0.22	--	--	--	--
Sinocalanus sp.	0.04	0.06	0.09	0.13	0.04	0.13	0.33	--	--
Adult Cyclopidae	0.08	0.17	0.18	0.13	0.13	0.13	--	--	--
Cyclopoid Copepodids	0.08	0.07	0.04	0.06	--	--	--	--	--
Calanoid Copepoids	0.02	0.01	0.01	0.08	--	0.13	--	--	--
Harpacticoid	0.002	0.01	--	0.06	0.09	--	--	--	--
Copepod Nauplii	--	--	--	--	--	--	--	--	--
Diaptomus spp.	--	0.01	0.01	--	--	--	--	--	--
Acartia spp.	--	--	--	--	--	--	--	--	--
Other Copepods	0.04	0.06	0.07	0.19	0.13	0.13	0.33	--	--
Cladocera									
Bosmina longirostrus	1.37	0.87	1.14	0.46	0.57	0.38	--	--	--
Daphnia spp.	0.29	0.35	0.41	0.44	0.35	0.75	0.50	--	--
Diaphanosoma sp.	0.01	0.01	0.02	0.02	0.04	--	--	--	--
Other Cladocerans	0.05	0.07	0.09	0.10	--	--	0.17	--	--
Malacostraca									
Neomysis sp.	0.002	0.01	0.04	0.11	0.17	0.25	--	0.50	--
Corophium spp.	0.01	0.04	0.13	--	0.13	--	0.17	1.00	--
Amphipoda	--	0.003	0.03	0.02	0.04	--	--	2.00	--
Other Malacostraca	0.004	0.003	0.03	0.02	0.17	--	0.33	--	1.00
Conchostraca	0.002	0.01	--	--	--	--	--	--	--
Oligochaeta	0.07	0.12	0.04	0.04	0.04	--	--	--	--
Rotifera (All Rotifers)	0.09	0.03	--	--	--	--	--	--	--
Vertebrata (Fish)	--	--	--	--	0.04	--	--	--	1.00

* Composed of *Eurytemora* sp., *Sinocalanus* sp., *Acartia* spp., and *Diaptomus* spp., which could not be identified to genus.

Table 11
MEAN NUMBER OF FOOD ITEMS CONSUMED BY 6-14 MM LARVAE, UPPER SUISUN, GRIZZLY, AND HONKER BAYS
(Stations 63-66, 414-416, 515)

Food Items	Striped Bass Length (mm)								
	6	7	8	9	10	11	12	13	14
Copepoda									
Eurytemora sp.	0.88	0.86	1.39	1.43	1.23	1.50	1.29	1.43	0.50
Adult Calanoida*	0.16	0.08	--	0.21	0.09	0.29	0.14	0.29	0.50
Sinocalanus sp.	0.10	0.08	0.04	0.04	0.09	0.14	--	0.29	--
Adult Cyclopidae	--	0.02	--	--	--	--	--	--	--
Cyclopoid Copepodids	--	--	--	--	--	0.07	--	--	--
Calanoid Copepoids	0.12	0.04	0.04	0.04	--	0.07	--	--	--
Harpacticoid	0.07	0.08	--	--	--	0.07	--	--	--
Copepod Nauplii	0.05	--	--	--	--	--	--	--	--
Diaptomus spp.	0.18	--	--	--	--	--	--	--	--
Acartia spp.	--	--	--	--	--	--	--	--	--
Other Copepods	0.09	0.02	0.07	0.14	0.14	0.14	--	0.57	--
Cladocera									
Bosmina longirostrus	--	--	--	0.07	--	--	--	--	--
Daphnia spp.	--	--	--	--	--	--	--	--	--
Diaphanosoma sp.	--	--	--	--	--	--	--	--	--
Other Cladocerans	--	--	0.02	0.04	--	--	--	--	--
Malacostraca									
Neomysis sp.	--	--	0.17	0.11	0.23	0.29	0.86	0.43	2.00
Corophium spp.	--	0.02	0.02	--	--	0.07	0.14	0.29	0.50
Amphipoda	--	--	--	--	--	--	--	--	--
Other Malacostraca	--	0.02	0.04	--	0.18	0.14	0.29	0.14	0.50
Conchostraca	--	--	--	--	--	--	--	--	--
Oligochaeta	--	--	--	--	--	0.07	--	--	--
Rotifera (All Rotifers)	--	--	--	--	--	--	--	--	--
Vertebrata (Fish)	--	--	--	--	--	0.07	--	--	--

* Composed of *Eurytemora* sp., *Sinocalanus* sp., *Acartia* spp., and *Diaptomus* spp., which could not be identified to genus.

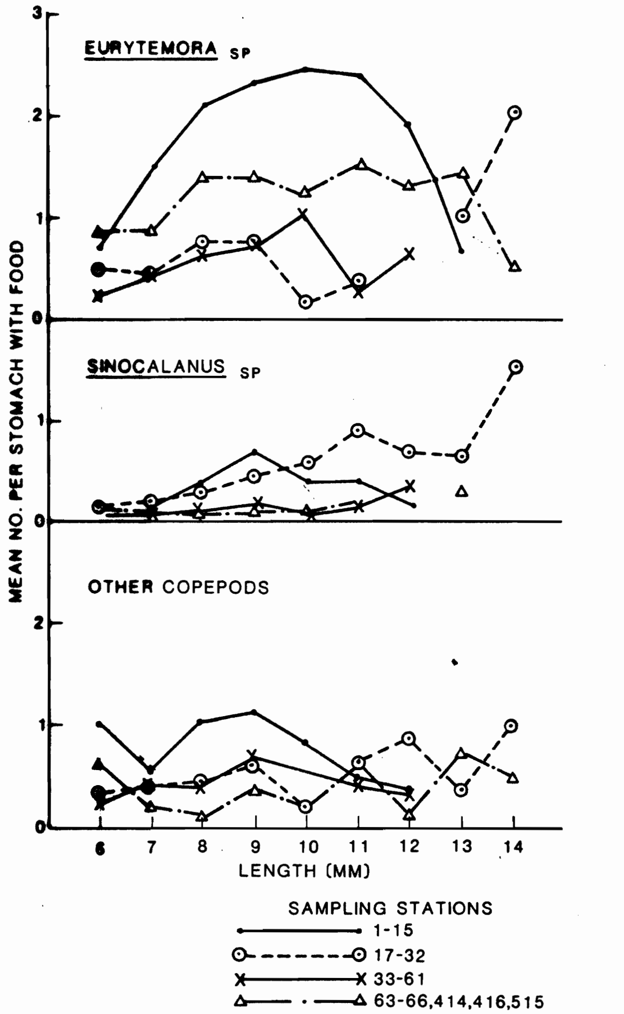


FIGURE 19.
MEAN NUMBER OF COPEPODS IN 6-14 MM STRIPED BASS STOMACHS FOR FOUR GEOGRAPHICAL AREAS

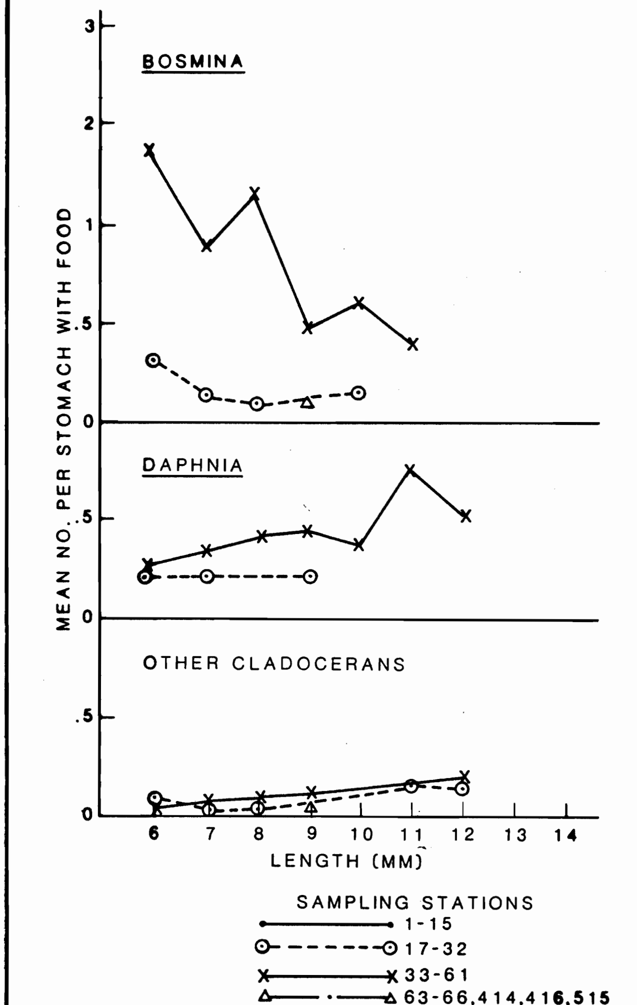


FIGURE 20.
MEAN NUMBER OF CLADOCERANS IN 6-14 MM STRIPED BASS STOMACHS FOR FOUR GEOGRAPHICAL AREAS

Comparison of 1984 With Past Years

To examine changes in diet over time, 1984 survey data for 6, 9, and 12 mm bass were compared to data collected during earlier egg and larva surveys (1966 to 1973). Comparisons were made for Suisun Bay and the San Joaquin River (Figures 21 and 22).

Corophium sp., though a minor food item, was more abundant in 1973 than in any other year in both areas. In 9 mm striped bass stomachs, cladocerans were much less abundant in 1984 in Suisun Bay, but they are a relatively minor diet item in that area.

Cladocerans in the diet in the San Joaquin River were within the range of observation for the more recent years. For 6 mm bass, the occurrence of copepods was lower in 1984 than in any previous year, but this was not true for 9 mm bass. Hence there was no consistent trend, and overall there appeared to be no marked change in diet.

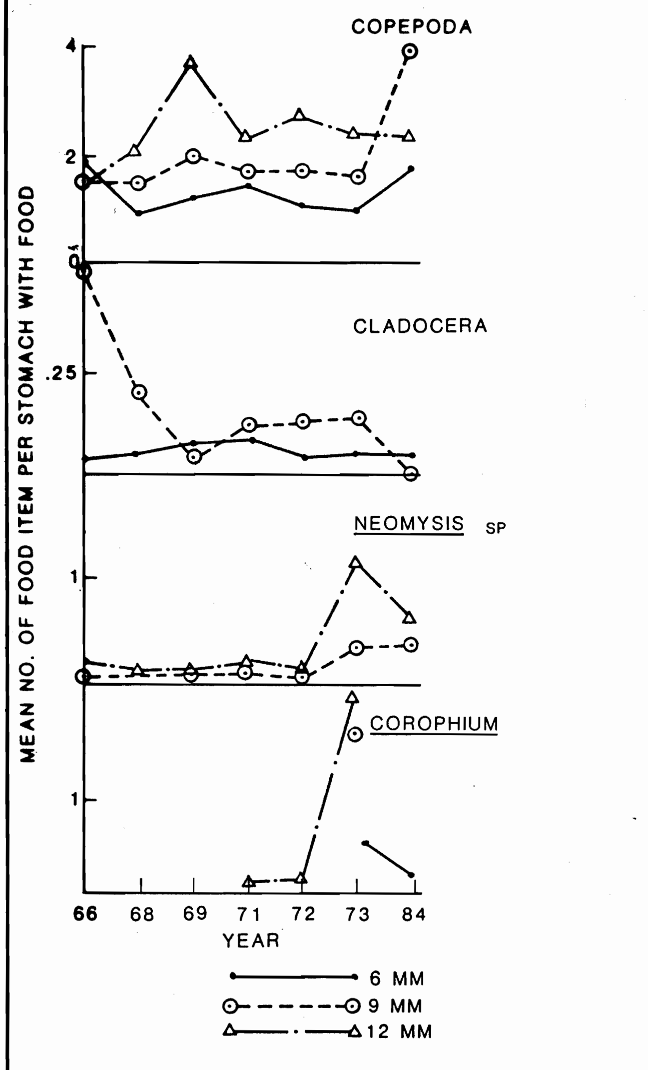


FIGURE 21.
MEAN NUMBER OF MAJOR FOOD ITEMS PER BASS STOMACH FOR YEARS OF RECORD SINCE 1966, SUISUN BAY (STATIONS 1-15)

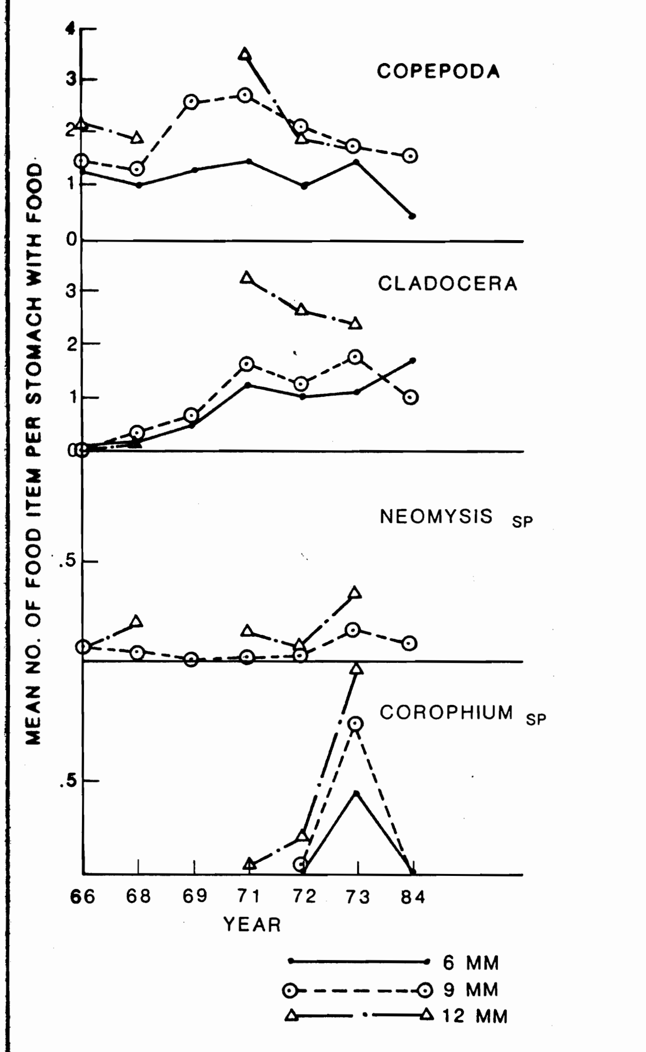


FIGURE 22.
MEAN NUMBER OF MAJOR FOOD ITEMS PER BASS STOMACH FOR YEARS OF RECORD SINCE 1966, SAN JOAQUIN RIVER (STATIONS 33-61)

Bass initiate exogenous feeding between 5 and 9 mm in length. The percent of larvae examined with food in the stomachs during this period is a crude measure of the food available. In 1984, the percent of stomachs with food for each length group was fairly low compared with past years; for 6 mm larvae, the percent with food was the lowest of any year (Figure 23). Hence, forage conditions were probably poor in 1984, but additional data are needed to evaluate this trend.

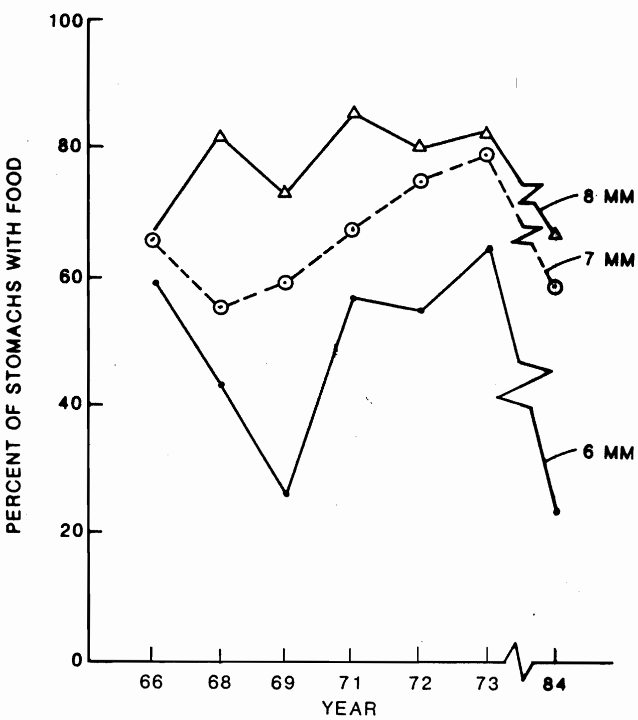


FIGURE 23. PERCENT OF 6-8 MM BASS STOMACHS WITH FOOD FOR YEARS OF RECORD SINCE 1966 (STATIONS 1-61)

Feeding Selectivity

To evaluate feeding selectivity, the mean number of zooplankton prey organisms per stomach for 6 and 9 mm striped bass were compared to their relative mean densities in the environment (Figures 24 and 25) to determine changes in prey selectivity with size. This comparison was made for the four major geographic areas. Since no larvae from stations 1, 5, 63, 414, 416, and 515 were examined for food, zooplankton densities from these stations were excluded. Only microzooplankton were used, since other species were not sampled in the environment. Data from Clark-Bumpus net and pump sampling were combined.

Prey items are grouped by size range in Figures 24 and 25. Both 6 and 9 mm larvae strongly selected for the larger prey items. At 6 mm, larvae consumed mostly prey items larger than 1.0 mm, except in the San Joaquin River, where Bosmina sp. was important. The 9 mm larvae fed almost exclusively on organisms larger than 1.0 mm also, except for Bosmina sp. in the San Joaquin River. Rotifers and copepod nauplii, very abundant in the environment, were extremely rare in the stomachs.

Within each size range of food organisms, there also appeared to be selection by larval bass. The 6 mm larvae selected for Bosmina sp. within the <0.5 mm range, Daphnia sp. and harpacticoid copepods within the 0.5-1.0 mm range, and Eurytemora sp. and, to a much lesser extent, Sinocalanus sp. in the >1.0 mm range. The 9 mm larvae selected for Bosmina sp. in the <0.5 mm range, Daphnia spp. in the 0.5-1.0 mm range, and primarily Eurytemora sp. in the >1.0 mm range. Eurytemora sp. is the food item most selected for by both 6 and 9 mm bass.

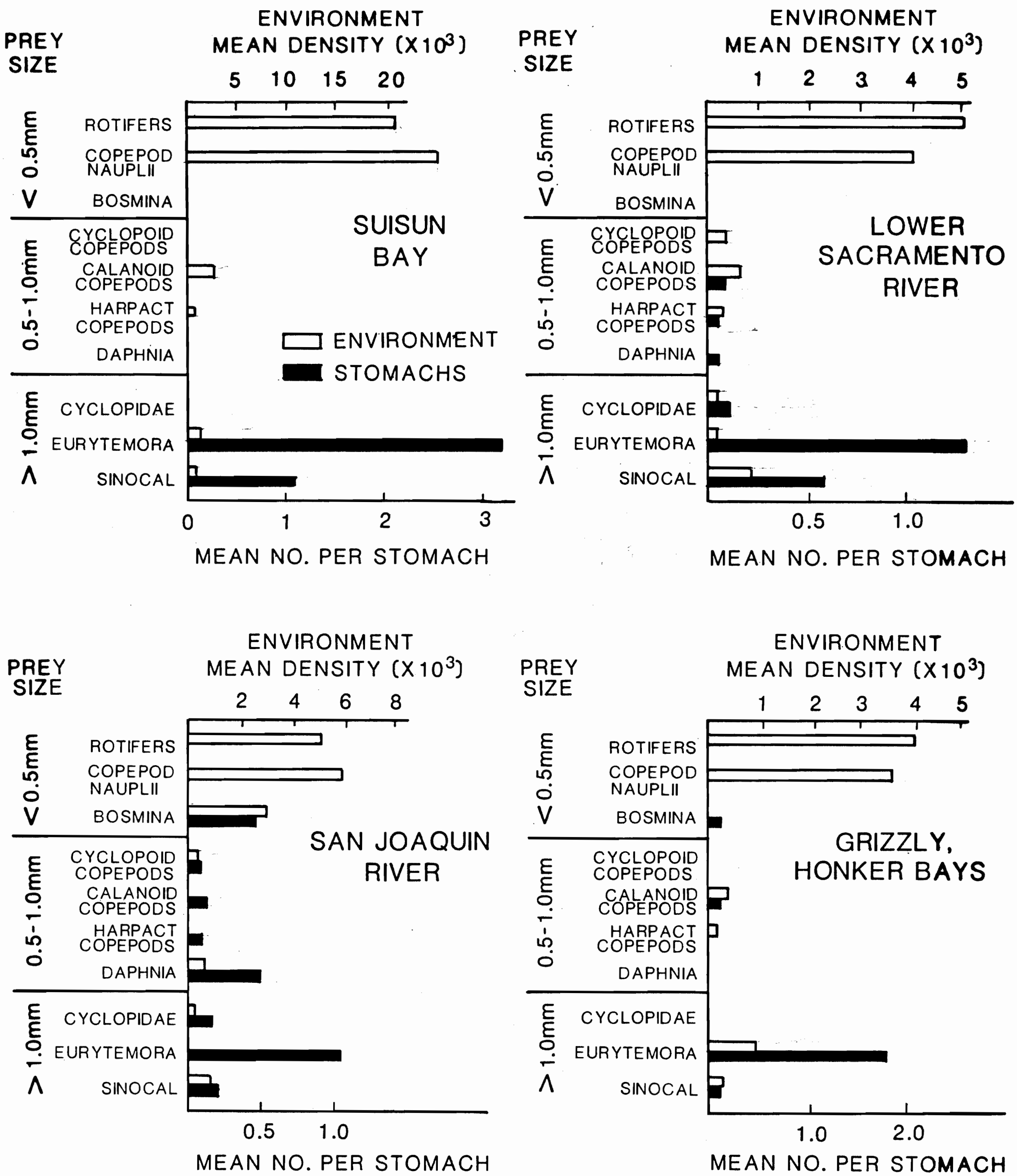


FIGURE 24. ABUNDANCE OF ZOOPLANKTON IN 6 MM STRIPED BASS STOMACHS RELATIVE TO THEIR DENSITIES IN THE ENVIRONMENT

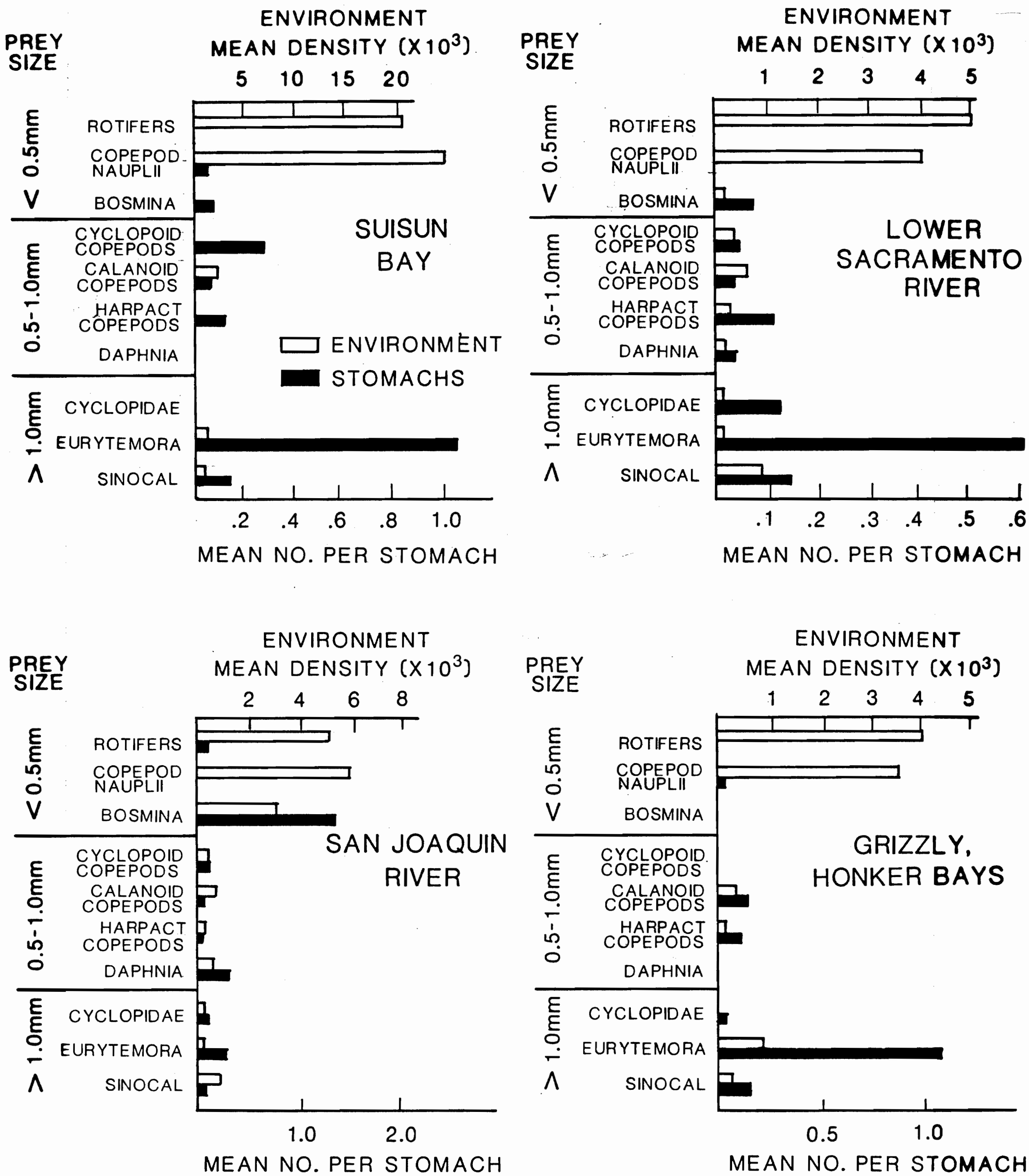


FIGURE 25. ABUNDANCE OF ZOOPLANKTON IN 9 MM STRIPED BASS STOMACHS RELATIVE TO THEIR DENSITIES IN THE ENVIRONMENT

Chapter 4. DISCUSSION

Little direct evidence was found to support the hypothesis that a shortage of zooplankton food supply in recent years has caused higher mortality of larvae. If food supply were limiting, higher mortality would be expected when larvae shifted from yolk sac reserves to exogenous feeding (between 5 and 9 mm). The estimated mortality rate in 1984 was slightly lower than in earlier years (1968 to 1977).

If food supply were limiting, the proportion of larval population feeding (percent of larvae with food in the stomach) would also be expected to be lower in recent years. In 1984, the percent of larvae feeding was slightly lower than in earlier years for 6 mm larvae, but was within the range of earlier years for 7 and 8 mm larvae. There was no evidence of an overall change in diet in 1984.

To more fully evaluate the food supply hypothesis, further analysis is planned to relate 1968 to 1984 larvae survival rates to zooplankton densities in those years.

Food chain relationships were unclear. In 1984, zooplankton appeared to increase in response to increases in chlorophyll a concentration in all areas, but these increases were not proportional to the increases in chlorophyll. Large phytoplankton blooms did not necessarily result in large increases in zooplankton populations.

Since mortality rates of larvae were not higher in 1984 than in earlier years, the 1984 survey does not suggest that toxic substances have reduced survival of young bass below earlier levels. Estimated growth rates were slightly slower, however, which could be due to a stress such as increased pollutant levels.

The 1984 survey did not provide direct evidence supporting the hypothesis that increased water diversions and entrainment of eggs and larvae have reduced striped bass abundance in recent years. If entrainment impacts were increasing, survival over the 6-14 mm size range or survival between the larval and juvenile stages (6-14 mm to 38 mm) should have decreased. Survival over this size range in 1984, however, was similar to earlier years.

Results suggest the source of the post-1976 striped bass decline is in the early life stages. When years with abnormal events (1972) and different sampling procedures (1978, 1979) are excluded, the larval data base consists of five "predecline years" (1968, 1970, 1971, 1973, 1975) and two "decline years" (1977, 1984). Larval abundance was lowest in 1977 and 1984, resulting in statistically significant correlations between the summer townet survey index (38 mm index) and the 9-11 mm and 12-14 mm indices for the seven years. Hence, within this set of observations, the decline in abundance of young bass in midsummer has stemmed from low larval abundance earlier in the year.

Correlations between the summer abundance index and the larval indices are consistent with the hypothesis that the decline in young bass abundance has resulted from the decline in adult abundance and insufficient numbers of eggs being spawned. There has been a definite decline in egg abundance over time; egg abundance in 1984 was lower than in any previous year. This decline, combined with evidence that larval mortality was slightly lower in 1984, suggests that spawning stock size has a major effect on year class strength. Data from 1985 and 1986 surveys will be necessary to substantiate this trend.

Historically, however, very strong year classes of bass have been produced from very low stock sizes both on the west coast, when striped bass were initially introduced, and on the east coast (Merriman, 1941; Cooper and Polgar, 1981). The inability of the population to recover in recent years strongly suggests that the habitat is much more limiting now than it was in the past.

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Appendix A. METHODS

Field Methods

Eggs and Larvae

Ten-minute oblique tows were made at each station with an egg and larva net mounted on a ski frame. When heavy blooms of filamentous algae occurred, tows were reduced to 5 minutes because of net clogging. Boat speeds were adjusted to keep the cable angle declination at about 71 degrees. Nets were the same size and design as those used in the 1975 to 1977 surveys. Each had a cylinder and a cone-shaped portion nearly equal in length (Miller 1977). The mouth diameter was 76cm. The nets were 505-micron mesh Nitex netting. A 32-ounce plastic collecting jar, screened with 470-micron mesh bolting cloth, was attached at the cod end.

Following each net tow, contents of the net were rinsed into the collecting jar, and the sample was preserved in a 5 percent formalin and rose bengal dye solution. Samples were preserved in 32-ounce glass jars or, when algae were abundant, in 1-gallon plastic jars.

From 1967 to 1973, a cone-shaped net with 930-micron mesh was used to sample eggs and larvae. This net was less efficient than nets of the new design. The relative efficiencies of these two nets, derived from paired net comparison tests (Miller 1977), were used to adjust the 1967 to 1973 catch data so they were comparable with 1975 to 1977 and 1984 data.

Ditigal flowmeters (Oceanics Model 2030) mounted in the net mouth were used to measure flow through the net (to compute cubic meters of water sampled). Catches were converted to numbers per cubic meter. All flowmeters were calibrated in a test flume at the end of the season and were highly consistent.

Zooplankton

To obtain estimates of larval bass food supply, zooplankton were sampled at each station in two ways:

- With pumps, efficient for small rotifers and nauplii (<0.5mm).
- With Clark-Bumpus nets, efficient for larger zooplankton (copepods and cladocerans).

The pump was a 12-volt, 1/12-horsepower marine utility pump (Teel Model 1P580D) with a 3/4-inch-diameter, 50-foot hose. The hose was lowered to the bottom and slowly raised to the surface at about 1 foot per second. A 1/2-gallon depth-integrated sample was then preserved in a 5 percent formalin and rose bengal dye solution.

The Clark-Bumpus net was #10 mesh (154-micron mesh opening) attached to a 20-centimeters-long clear plastic tube, 12 centimeters in diameter. This tube was fastened to a bracket on the egg and larva net frame; thus the net was towed simultaneously with the egg and larva net (10-minute oblique tows). A digital flowmeter (Oceanics Model 2030) was mounted in the plastic tube before the net mouth to measure flow through the net.

Following each tow, net contents were rinsed into a cod-end collecting jar screened with 149-micron mesh wire bolting cloth, and the sample was preserved in a 5 percent formalin and rose bengal dye solution.

Chlorophyll *a*

Chlorophyll *a* samples were collected from a depth of 4 feet. Two 200 mL water samples were filtered through glass fiber filters (Gelman Type AE61631) treated with magnesium carbonate solution. A 12-volt marine utility pump (Teel Model 1P580D) was used to create a vacuum for filtering. To prevent deterioration, filters were preserved immediately on dry ice and kept frozen until the laboratory analysis.

Laboratory Methods

Egg and Larva Samples

Samples were rinsed thoroughly with water in a #50 sieve (300-micron mesh) to remove formalin, excess dye, and algae. Samples were then placed in plexiglass trays, and fish eggs and larvae were sorted from extraneous material under a magnifying lens. The rose bengal dye made eggs and larvae more visible and easy to distinguish from detritus. Samples with heavy detritus or large numbers of eggs and larvae were subsampled (1/2, 1/4, or 1/16 of the total sample was sorted). Eggs and larvae were represerved in 5 percent formalin until identification.

All eggs were identified to species and counted, and striped bass eggs were classified as 0-8 hours or 9-36 hours old. Fish larvae were classified to family or, in some cases, to species, and striped bass larvae were measured to the nearest millimeter standard length. About 2.5 percent of the samples were processed twice to check accuracy of the identifications and measurements.

Food Habits Analysis

A detailed larval striped bass food habits study was conducted in 1984. Stomachs of striped bass larvae from every second station on every second sampling date were examined. From each sample, a maximum of 50 fish total or 20 fish containing food were examined for each millimeter length group from 4 mm to 25 mm.

Larval bass stomachs were removed and teased open with a sharp probe. Food organisms were identified to the lowest possible taxon, usually family or genus, under a dissecting microscope. A key to the common food items was prepared to aid in identification.

To minimize the possibility of counting the same organism more than once, only whole organisms and/or heads only were counted, unless other body parts were identifiable as distinctly different organisms. Where possible, Neomysis in the stomachs were measured to the nearest millimeter (from the eye to the base of the telson).

For each sample and length group, the total number of each food item found and the number of stomachs containing each item was recorded. Food habits were summarized by area for each length group, in mean numbers per stomach and percent frequency of occurrence.

Food habits were also analyzed in 1966 to 1973 and in 1975. Methods used in these years differed from 1984, the major differences being:

- Zooplankton prey items were identified only to order in previous years (copepods and cladocerans).

- Stomachs were grouped by major areas and time periods in previous years, rather than by individual stations and dates.

Zooplankton Samples

Clarke-Bumpus net samples were rinsed with water in a #10 zooplankton cup (0.1999 cm sieve opening) to remove formalin and dye. Samples were then washed into a graduated beaker, diluted, and a 1 mL aliquot extracted and placed on a Sedgewick-Rafter slide. Organisms were identified to genus and, in some cases, to species, using the strip method (left to right, down one field, right to left, etc.) at 100 power. At least 200 organisms were identified from each sample; the number of 1 mL aliquots necessary to reach the 200-plus count was recorded.

After identification, organisms were represerved in a 5 percent formalin and rose bengal dye solution and saved for future reference.

The counts were multiplied by subsampling factors and divided by water volumes sampled to derive zooplankton densities in organisms per cubic meter.

Pump samples were processed by first measuring the volume (in milliliters) and then filtering the sample through two screens. The first screen was 100-mesh (0.0149 cm sieve opening); the second was 325-mesh (0.0043 cm sieve opening). Contents of the first screen were discarded, as zooplankton in this size range were sampled with the Clarke-Bumpus net. Contents of the second screen were represerved in a 5 percent formalin and rose bengal dye solution for later identification.

All zooplankton from the second screen were identified. The reduced samples were again poured through a 0.0043 cm screen and the screen placed in a Pyrex crucible. Zooplankton were then removed with a small pipette, placed on a Sedgewick-Rafter slide, and counted and identified to genus using the strip method. Counts were divided by sample volumes to derive densities.

Chlorophyll *a* Samples

Filtered chlorophyll *a* samples were kept frozen until laboratory analysis. Samples were dissolved in acetone, and chlorophyll *a* and pheopigment concentration, in ug/L, were analyzed with an ultraviolet spectrophotometer (Perkin-Elmer Model 559).

Data Analysis Methods (1967-1977 Surveys)

Due to inadequacies in the study design for 1967 to 1977 surveys, it was necessary to adjust data for these years to make them comparable to 1984. The years 1967 and 1969 were not included because high flows carried a large proportion of the larvae downstream from the sampling area, and 1976 was not included because of inadequate data.

The following is a summary of data adjustments for 1968, 1970 to 1973, 1975, and 1977. Table 12 is an overall summary.

Table 12
SUMMARY OF EXTRAPOLATIONS AND NET CORRECTION FACTORS APPLIED TO 1967-1977 DATA

	Year*									
	1967	1968	1969	1970	1971	1972	1973	1975	1976	1977
Net Correction Factors Applied		X		X	X	X	X			
Time Period Extrapolations		X		X	**	X	***	X		X
Upper Suisun Bay Extrapolations		X			X	X	X	X		X
Dropped from Analysis Due to High Flows or Inadequate Data	X		X						X	

* No survey in 1974.
** 9-14 mm only.
***10-14 mm only.

Time Period Extrapolations

In some previous years, surveys were started after the start of spawning or ended while larvae were still abundant. To derive total seasonal estimates of abundance, catches in periods not sampled were mathematically estimated by fitting catch curves for each millimeter length group and extrapolating these curves before the start or after the end of the survey, as necessary. The model fit to the curves was:

$$y = \log_{10} \text{catch} = ax^b \, 10^{cx + dx^2}$$

where x = Julian date

a, b, c, d are constants

This model fit most catch curves well, with a coefficient of determination $r^2 \geq 0.9$. Sometimes data were not sufficient to reasonably extrapolate the curve. In these cases, certain length groups were either deleted from the analysis (i.e. 1973, 6-9 mm larvae) or the actual catches were used, recognizing that they probably were an underestimate (i.e. 1971, 6-8 mm larvae).

Northern Suisun Bay Extrapolations

From 1968 to 1977, stations in northern Suisun, Grizzly, and Honker bays were sampled only once in 1970, although they may be important nursery areas in high flow years. Ecological Analysts sampled these areas thoroughly in 1978 and 1979 (PGandE 1981). Thus, catches would have been in these areas in 1968, 1971, 1972, 1973, 1975, and 1977 were estimated by multiplying catches in adjacent Suisun Bay channel stations by the mean ratio of catches in the northern bays to catches in channel stations in 1978 and 1979. The estimates were a small proportion of the total, except in 1971 and 1975.

Net Correction Factors

The 900-micron mesh net used in 1968 to 1973 was less efficient than the 505-micron net used in 1975 to 1977 and 1984, especially for larvae less than 7 mm (Miller 1977). Hence, for each 1 mm length group, the 1968 to 1973 catches were multiplied by the appropriate ratio of catches in the 505-micron mesh net to catches in the 900-micron mesh net based on paired net tows. The correction factors were:

Striped Bass Length (mm)	Correction Factor
6	5.6
7	1.7
8	1.43
9	1.39
10	1.34
11	1.3
12	1.26
13	1.21
14	1.17

Reliable correction factors were not obtained for larvae shorter than 6 mm or longer then 14 mm; thus, analysis was focused on 6-14 mm larvae.

Ecological Analysts' Long River Survey

Ecological Analysts, Inc., conducted striped bass egg and larva surveys in 1978 and 1979. Although they used identical 505-micron mesh nets and towing procedures, their methods differed from Department of Fish and Game surveys in several ways:

- Stratified random sampling was used, rather than fixed site sampling.
- Sampling was conducted weekly, rather than every second day.
- To reduce net avoidance by larger larvae, much sampling was at night.

Due to these differences, the Ecological Analysts data were not used for survival or growth rate comparisons. Abundance indices were calculated, however, by multiplying mean densities stratified by area by appropriate weight factors to account for water volumes in each area, and multiplying by time difference factors to compensate for the difference in sampling frequency. No adjustment could be made for differences between night and day sampling, since no direct night/day comparisons are available. The 1978 and 1979 data were used cautiously.

Calculation of Larva Abundance Indices

For 1968 to 1977 and 1984 data, densities of larvae were calculated from the equation:

$$D = C \times S \div M$$

where D = Density of larvae, in organisms per cubic meter
C = Laboratory count of larvae
S = Laboratory subsample factor
M = Number of cubic meters of water sampled (calculated from meter readings)

Abundance at each station was then calculated using:

$$A = D \times V$$

where A = Abundance (estimated total number of larvae)
D = Density of larvae
V = Estimated volume of water (in hectare meters)

Abundance indices were then calculated by summing the weighted catches by groups.

Appendix B. DATA STORAGE

Data from the 1984 egg and larva survey now reside in SAS files on the IBM at the National Computer Center. Data have been edited and are ready to be reformatted for storage on the STORET system. Applicable SAS files are:

WQGCAFG.ELS84 (DENSITY) - Densities of eggs and larvae in organisms per cubic meter, and physical data (secchi disk [cm] temperature [°F], and electrical conductivity [umhos/cm^2]).

WQGCAFG.ELS84 (ZOOP) - Densities of zooplankton in oganisms per cubic meter for CB and pump samples, chlorophyll *a* data (chlorophyll *a* [ug/L], pheopigments [ug/L], percent chlorophyll, and all physical data.

WQGCAFG.ELS84 (ZOOP1) - Combined densities of zooplankton for CB and pump samples (in organisms per cubic meter), chlorophyll *a*, and physical data.

WQGCAFG.ELS84 (FOODHAB) - Larval striped bass food habits data.