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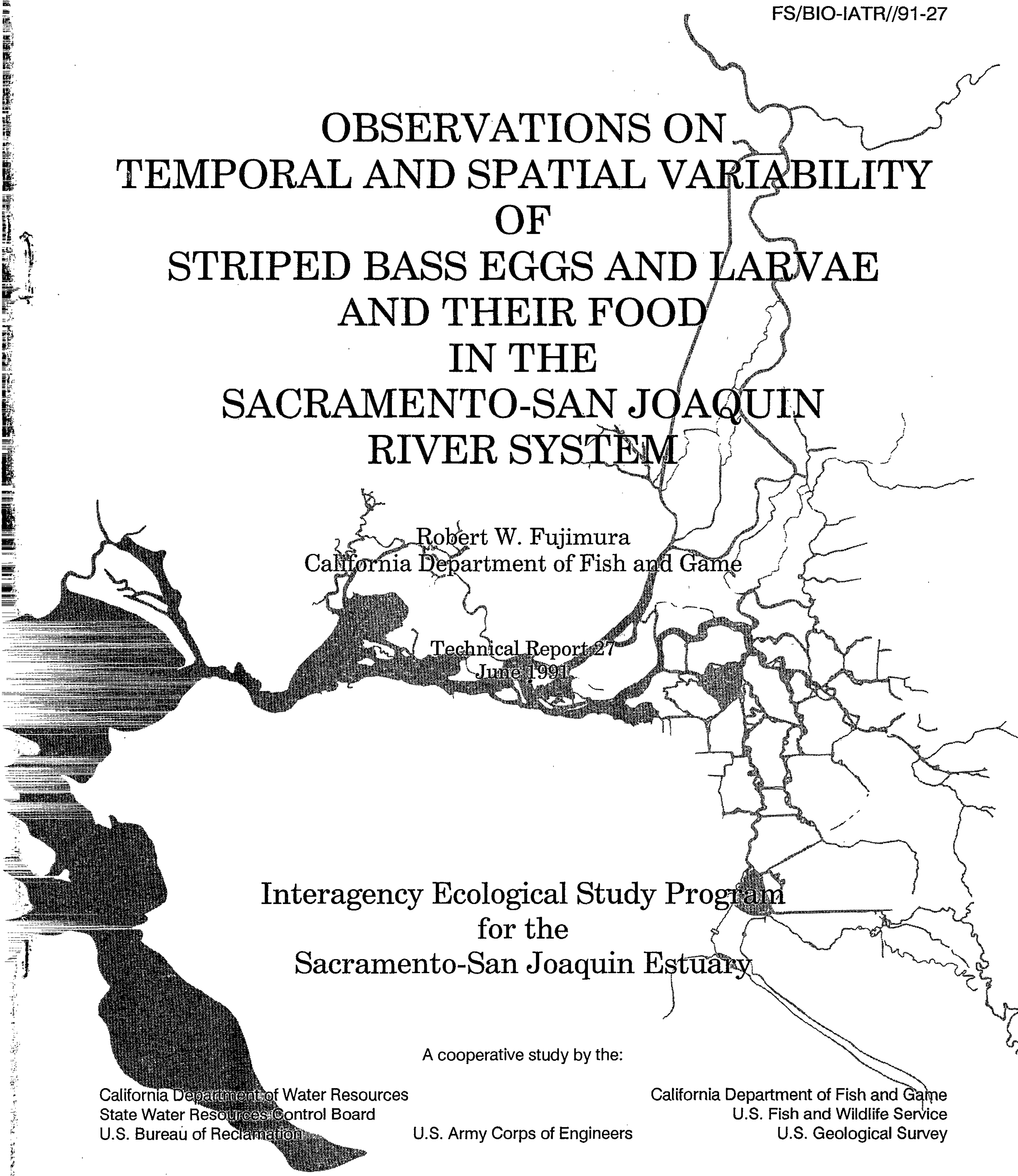

OBSERVATIONS ON TEMPORAL AND SPATIAL VARIABILITY OF STRIPED BASS EGGS AND LARVAE AND THEIR FOOD IN THE SACRAMENTO-SAN JOAQUIN RIVER SYSTEM

Robert W. Fujimura
California Department of Fish and Game

Technical Report 27
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Interagency Ecological Study Program
for the
Sacramento-San Joaquin Estuary

A cooperative study by the:

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INTRODUCTION

Since 1977, the abundance of young striped bass, *Morone saxatilis*, has declined dramatically in the Sacramento-San Joaquin estuary (Stevens *et al*, 1985). Four hypotheses have been proposed to explain this decline:

- Low egg production due to a decline in the adult stock,
- Reduced food availability,
- Entrainment of eggs and larvae in water diversions,
- Toxic pollution.

Research is being conducted to determine the validity of these hypotheses. Recent analyses have focused on data collected by the California Department of Fish and Game striped bass ELS *(egg and larval surveys)* conducted since 1968 (Low and Miller, 1986; CDFG, 1988).

The primary ELS sampling unit is a 10-minute diagonal tow of a 505-m mesh plankton net. Spatial and temporal variations in abundance of eggs and larvae may affect abundance estimates based on sampling with these nets. For example, egg abundance estimates from the ELS have consistently underestimated expected egg production based on adult striped bass abundance and fecundity estimates. Hypotheses to account for the undersampling include spatial stratification. Since accurate estimates of abundance of striped bass eggs and larvae are important for estimating mortality rates and other parameters affecting reproductive success and ultimately recruitment, I conducted field experiments during 1987 to learn more about the spatial-temporal distributions of striped bass eggs and larvae and their potential effect on abundance measures.

Also, the distribution of larval striped bass relative to the distribution of their food supply may be relevant to understanding the reason(s) for the decline in striped bass abundance. Hence, I compared the vertical distribution of striped bass larvae and zooplankton through a 24-hour cycle to evaluate whether diel changes in striped bass distribution were associated with changes in distribution of their zooplankton prey.

This report summarizes results of these investigations.

MATERIALS AND METHODS

The standard ELS nets and sled frame and 505-μm mesh nets (Low and Miller, 1986; CDFG, 1988) were used for sampling, except as otherwise noted. With the exception of the surface net used in the Sacramento River near Verona on May 11, a calibrated flowmeter (General Oceanics Model 2030) was suspended in the mouth of all ELS nets to estimate the water volume filtered through the net. I used the mean volume for surface tows on May 12 to estimate the volume for surface tows on May 11. All nets were fished for ten minutes.

Fish eggs and larvae were preserved, processed, identified, and enumerated in the same manner as during routine ELS, except that standard length measurements were made to the nearest 0.5 mm instead of 1.0 mm.

Vertical and Temporal Distribution of Eggs

The vertical and temporal distribution of striped bass eggs was investigated at two sites on the Sacramento River. One site, near Verona, was sampled May 11-12; the other site, near Walnut Grove, was sampled May 15 (Figure 1). Data from a mesh comparison study (Fujimura, 1989) were also examined for spatial/temporal distribution for one site on the San Joaquin River near Antioch (May 5 and 7).

Plots of egg abundance, by time, were evaluated by inspection. The methods varied by site as noted in the following descriptions.

Verona

About 3.2-km downstream from Verona, striped bass eggs were collected from the surface and near the bottom using two ELS nets fished simultaneously from an anchored boat. Channel depth was 4 meters.

Walnut Grove

Tows were made at three depths from one boat at ELS Station 73 on the Sacramento River upstream of Walnut Grove. At first, surface and near-bottom depths were sampled with two nets towed simultaneously. Due to low catches, I discontinued surface tows after the seventh tow and, instead, alternated tows with one net between mid-depth (4.6 meters) and near-bottom (7.6 meters).

Antioch

Three mesh sizes (335-, 400-, and 505-m) were used. All nets and net frames were of the same dimension and design as those currently used in the ELS (Fujimura, 1989). The nets were fished simultaneously from three boats at ELS Station 39 near West Island.

The boats were positioned about 30 meters apart in the center of the shipping channel and maintained in this array for the duration of each tow. Boats alternated position within the array after every tow. Because tows were oblique, no information on vertical distribution was obtained.

Vertical and Temporal Distribution of Larvae

Catch data for striped bass larvae were inspected at three sites: Walnut Grove and Rio Vista on the Sacramento River, and Antioch on the San Joaquin River. At Walnut Grove and Antioch, the samples were the same as those used to evaluate egg distribution. The site near Rio Vista was sampled May 21.

Walnut Grove

Catches of yolk-sac larvae from each depth were compared temporally, and length-frequency distributions were compared vertically by inspecting length-frequency histograms and by using the Kolmogorov-Smirnov test for significant differences between sample frequency distributions (Smith and Richardson, 1977). Mean standard length, in millimeters, was calculated for total catch at each depth.

Antioch

Since tows were oblique, only temporal variability was evaluated.

Rio Vista

The sampling site, ELS Station 29, had a mean depth of about 10 meters. Tows were oblique, so there was no information on vertical distribution. Two nets (335 m and 505 m) mounted on ELS frames were towed separately and were alternated after two or three tows.

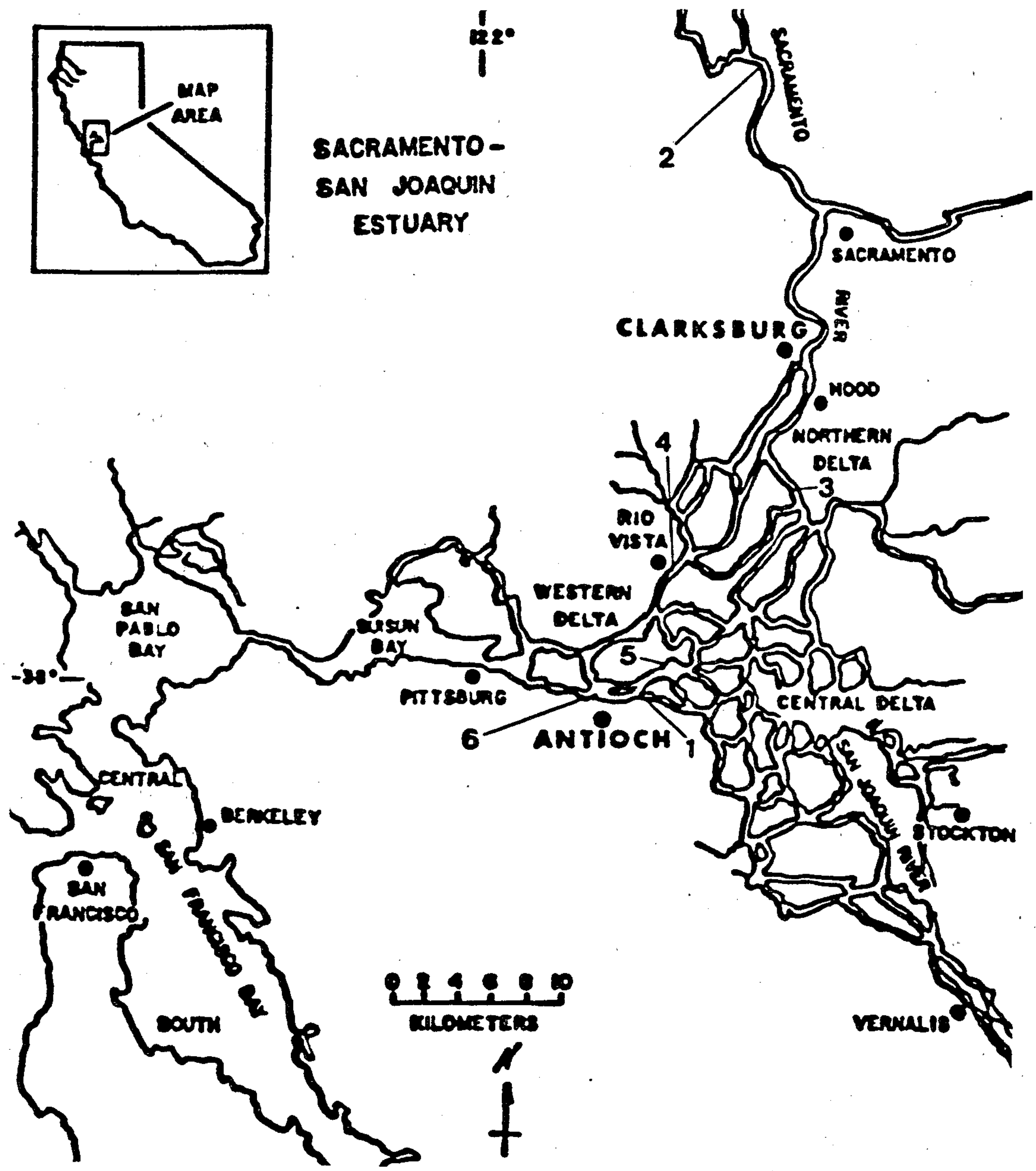
Effects of River Morphology on Spatial Distribution

Striped bass larvae were collected from a shoal and from an adjacent deep channel to determine how spatial differences associated with river depth influence abundance estimates. Sampling was conducted in the San Joaquin River between Jersey Point and the mouth of False River on June 5. The shoal section had an average depth of about 3.7 meters and was located on the northern side of the adjacent channel (about 10.7 meters deep).

Two boats with standard ELS nets made replicate oblique tows over both areas. After every fourth tow, the boats alternated positions.

Plots of abundance over time were visually compared, and means of transformed data [$\log_e$(density/1000m^3 +1)] were compared statistically using Student's t-test

Figure 1
LOCATION OF 1987 FIELD INVESTIGATIONS OF SPATIAL AND TEMPORAL DISTRIBUTION OF STRIPED BASS EGGS AND LARVAE



STUDY SITES:

1 San Joaquin River at Antioch — Mesh Size Comparison
2 Sacramento River at Verona — Vertical Distribution of Eggs
3 Sacramento River at Walnut Grove — Vertical Distribution of Eggs and Larvae
4 Sacramento River at Rio Vista — Mesh Size Comparison
5 San Joaquin River at Jersey Point — Depth Comparison
6 24-Hour Vertical Distribution Study

(SAS statistical package, version 5, 1985). The log transformation normalized and equalized sample variances. Length frequency distributions of the total catch from each area were compared by inspecting length frequency histograms and by testing frequency distribution using the Kolmogorov-Smirnov test.

Precision of Sampling

Larval fish typically have clumped or contagious distributions. I evaluated sampling precision using the replicate sampling data. Mean densities and associated variances were examined for striped bass larvae at Antioch, Rio Vista, and Jersey Point to determine statistical distribution type and to estimate the number of replicates required to detect various levels of difference between mean densities. Elliott's (1977) formula was used to calculate the dispersion parameter (coefficient of patchiness, k) as follows:

$$k = \frac{\overline{X}^{-2}}{S^2 - \overline{X}}$$

where: $\overline{X}$ = Mean Density
S^2 = Sample Variance

The number of replicate samples required to detect 5, 10, 25, and 50 percent differences between mean densities of striped bass larvae were determined using Southwood's (1966) equation, where:

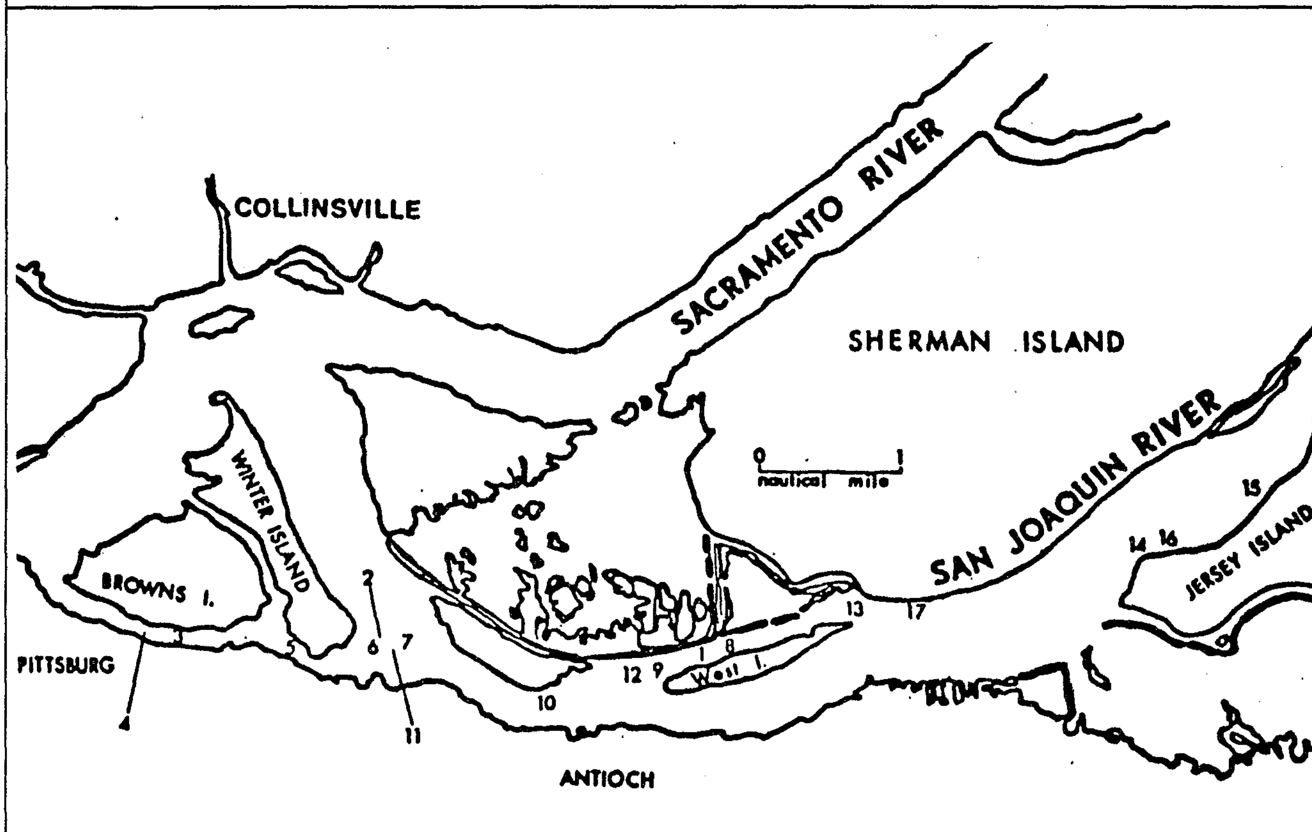
$$N = \frac{\frac{1}{m} + \frac{1}{k}}{D^2}$$

and: N = Number of Replicates
m = Mean Density
k = Dispersion Parameter
D = Level at which Differences between Means are to be Detected

Vertical Distribution of Striped Bass and Zooplankton Over 24 Hours

For purposes of comparing the vertical distribution of larval striped bass with that of their zooplankton prey, larval striped bass and zooplankton were sampled over 24 hours at 90-minute intervals in the San Joaquin River/New York Slough area between Browns Island and Jersey Point on June 10 and 11 (Figure 2).

Figure 2
LOCATION OF FIELD SAMPLING STATIONS DURING A 24-HOUR VERTICAL DISTRIBUTION STUDY, JUNE 10 AND 11, 1987
(Station numbers indicate order of sampling during the 24-hour period.)



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I attempted to sample within a specific water mass as it moved with the tide. Definition of this water mass was based on surface conductivities of 3,000 ± 200 μS/cm *(microSiemens per centimeter)*. Boat drift due to wind or tidal currents sometimes resulted in conductivity readings falling outside of the target value. This conductivity was selected to put my sampling in the upper end of the freshwater/saltwater mixing zone or "entrapment zone" (Arthur and Ball, 1979) where densities of a major food item, the copepod *Eurytemora affinis* are greater than in fresh water.

Striped bass eggs and larvae and opossum shrimp, *Neomysis mercedis,* were collected with three ELS nets fished simultaneously at the surface, mid-depth (5.2 meters), and bottom (10.7 meters) from a single tow cable. Surface and mid-depth nets, mounted on frames with the same shape and mouth opening as the standard ELS sleds, were fastened onto the tow cable with tripod bridles. The bottom net was mounted on a standard ELS sled frame. All sampling was in the ship channel.

Because the nets lacked opening and closing mechanisms, catches were corrected for fishing above their assigned depths during retrieval. The estimated incidental catch above the target depth was subtracted from the target strata catch. Incidental catch was estimated from incidental volume filtered multiplied by catch/m^3 in the net above the target strata. Incidental volume was total volume filtered multiplied by the fraction of total fishing time formed by the time a net fished above the assigned depth during retrieval. A similar correction technique was used by Orsi (1986) during a vertical distribution study of *N. mercedis*. To examine vertical distribution of *N. mercedis* in the ELS net samples, all *N. mercedis* were counted in samples containing less than 400 specimens. Samples containing larger numbers of *N. mercedis* were subsampled.

Smaller zooplankton were collected from each sample depth with a 5.7-cm-diameter by 15.2-m-long, weighted hose attached to a gas-powered pump. Water was filtered through a Clarke-Bumpus plankton net with #20 mesh (75 μm) for exactly 2 minutes. Total volume of water filtered was 330 liters per sample. Two zooplankton samples were collected from each depth. Contents of the net were preserved with 5% buffered formalin solution and stained with rose bengal dye.

Zooplankton were counted and identified (mostly to genus and sometimes to species). Some species were grouped by life stage. Counts were made by examining 1.0 mL aliquots on a Sedgewick-Rafter slide, using the strip method, at 100× magnification. When zooplankton were numerous, aliquots were examined until at least 200 adult copepods were counted. Zooplankton counts, the sample volume, and the number of aliquots were recorded for the purpose of calculating densities.

Time series plots of striped bass larvae (4-20 mm) were compared by depth to those for the total biomass (μg/m^3 dry weight) of all copepods and cladocerans, the primary food groups for young bass (Table 1) and *Eurytemora* alone. *Eurytemora* was examined separately because previous diet studies indicate it is a highly elected food item (CDFG staff, 1988). Similar plots for striped bass 21 to 38 mm long were compared with those for *N. mercedis* because it is the dominant prey of young striped bass in that size range.

Table 1
ZOOPLANKTON TAXA AND DRY WEIGHT ESTIMATES USED TO ESTIMATE BIOMASS OF POTENTIAL FOOD ITEMS OF YOUNG BASS DURING A 24-HOUR VERTICAL DISTRIBUTION STUDY

Zooplankton Taxa	Dry Weight Estimates (μg/individual)
COPEPODS	
Eurytemora adults	10
Eurytemora juveniles	5
Acanthocyclops vernalis	8
Diaptomus sp.	10
Sinocalanus adults	10
Sinocalanus juveniles	5
Harpacticoid copepods	1
Cyclopoid copepodids	2
Oithona sinensis	3
Oithona davisae	3
Limnoithona sp.	3
Calanoid copepodids	3
Acartia sp.	8
Copepod nauplii	0.3
Unidentified cyclopoids	8
Unidentified copepods	6
CLADOCERANS	
Daphnia sp.	2
Diaphanosoma sp.	3
Bosmina sp.	1
Unidentified cladocerans	1

RESULTS

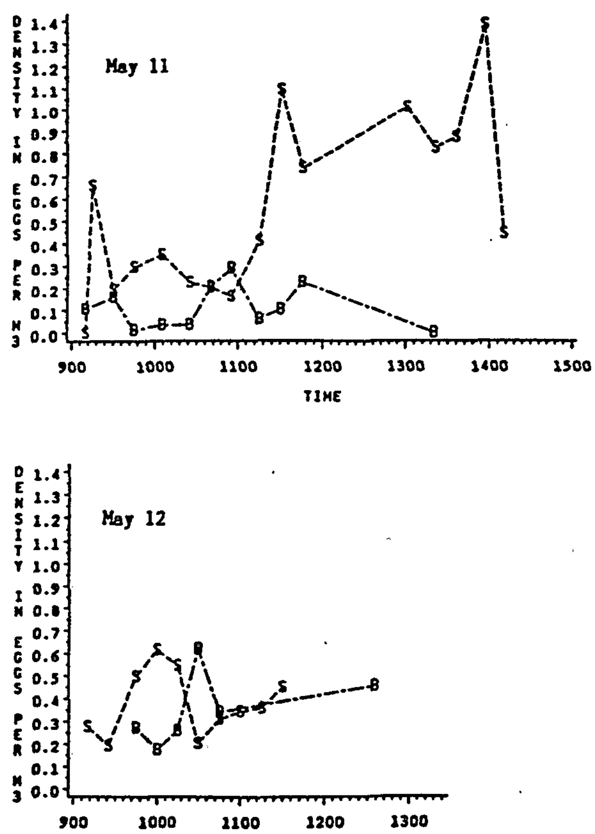
Results of studies using the ELS sampling data for 1987 are discussed in the following sections.

Vertical and Temporal Distribution of Eggs

Verona

Abundance of eggs fluctuated widely, particularly at the surface (Figure 3). Catches tended to be greater at the surface than near the bottom, and on May 11, catches increased over time, as did differences between surface and bottom. On May 12, catches were in a narrower range, and vertical differences were smaller.

Figure 3
DENSITIES OF STRIPED BASS EGGS AT TWO DEPTHS IN THE SACRAMENTO RIVER NEAR VERONA, MAY 11 AND 12, 1987

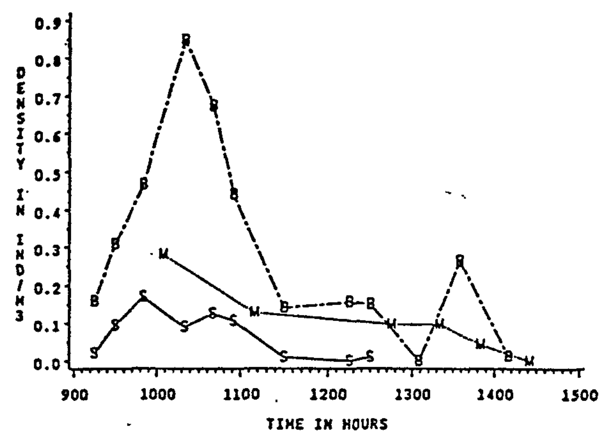


S = Surface Samples
B = Near-Bottom Samples

Walnut Grove

Differences in vertical distribution of striped bass eggs also were evident here. In contrast to Verona, however, concentrations of eggs were consistently lower at the surface than at mid-depth and near the bottom (Figure 4). During the first hour of sampling, eggs caught increased almost sixfold near the bottom; whereas, at the surface, egg densities increased only slightly. Catches at all depths diminished after 10:30 AM.

Figure 4
DENSITIES OF STRIPED BASS EGGS AT THREE DEPTHS IN THE SACRAMENTO RIVER NEAR WALNUT GROVE, MAY 15, 1987



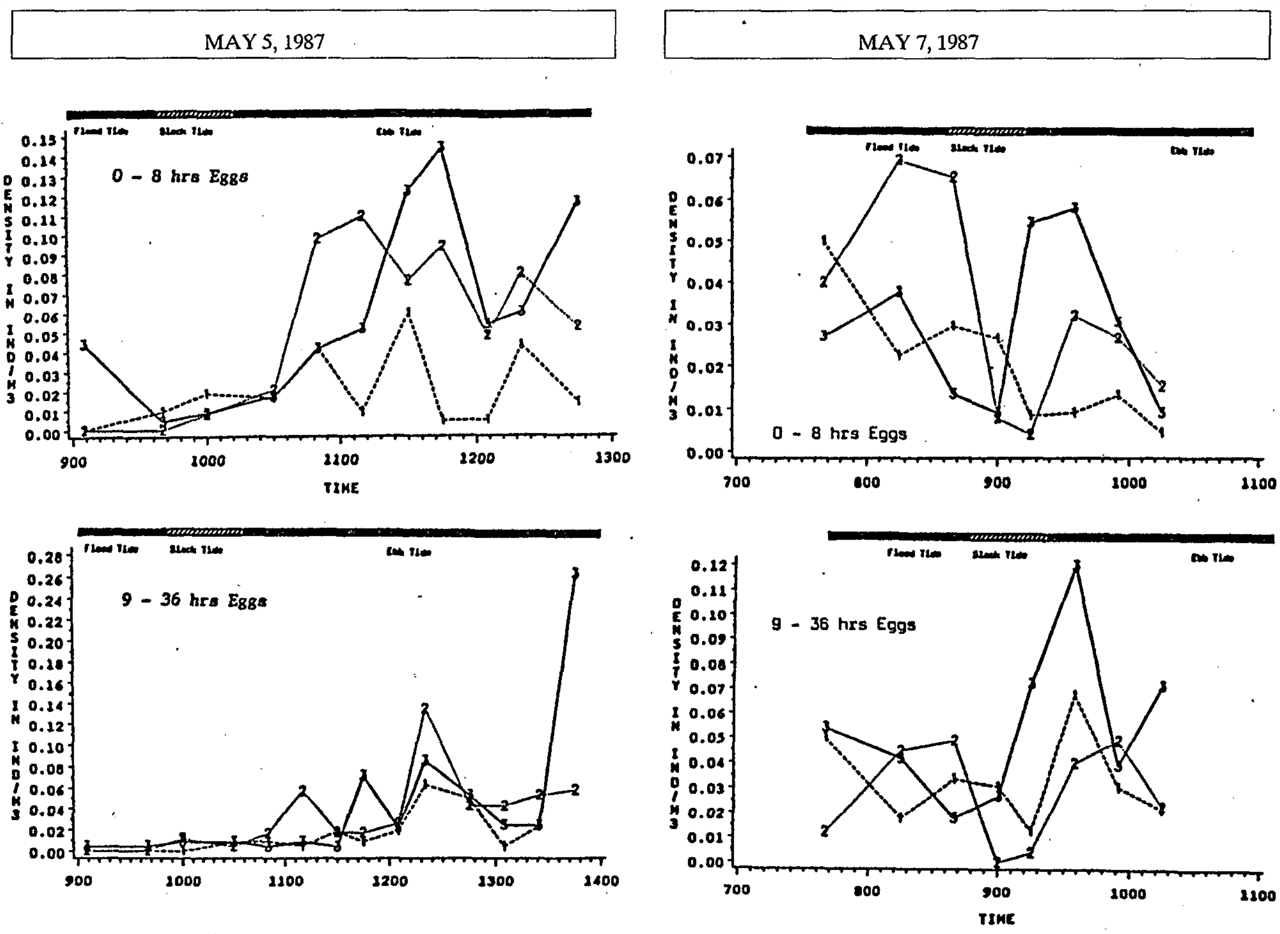
S = Surface Samples
M = Mid-Depth Samples
B = Near-Bottom Samples

Antioch

Concentrations of striped bass eggs varied considerably over time. On May 5, catches were higher in late morning and early afternoon during the ebb tide (Figure 5). On May 7, densities of young and old striped bass eggs were still highly variable but showed no definite trend with time or tide.

Figure 5

DENSITIES OF YOUNG AND OLD STRIPED BASS EGGS FROM THREE NETS IN THE SAN JOAQUIN RIVER NEAR ANTIIOCH DURING NET COMPARISON STUDIES



MESH SIZES: 1 = 335 μm, 2 = 400 μm, 3 = 505 μm

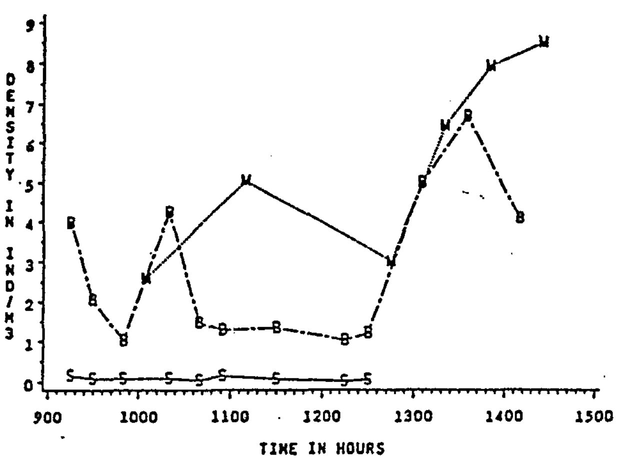
Vertical and Temporal Distribution of Larvae

Walnut Grove

Striped bass larvae had a definite vertical distribution profile (Figure 6). Surface concentrations (0.1-0.3/m^3) of larvae were very low relative to concentrations at mid-depth (2.5-8.5/m^3) and the bottom (1.7-7.0/m^3).

Also, striped bass generally were smaller at the surface than in deeper water (Figure 7). Kolmogorov-Smirnov testing demonstrated that length frequencies differed significantly by depth ($P < 0.005$) (Table 2).

Figure 6
DENSITIES OF STRIPED BASS LARVAE AT THREE DEPTHS IN THE SACRAMENTO RIVER NEAR WALNUT GROVE, MAY 15, 1987

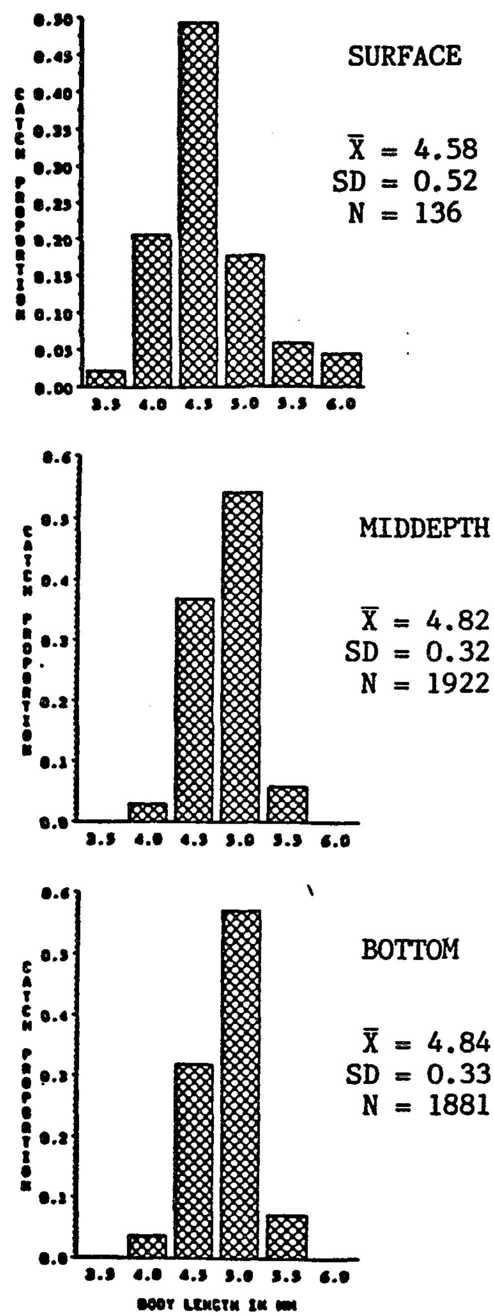


S = Surface Samples
M = Mid-Depth Samples
B = Near-Bottom Samples

Table 2
COMPARISON OF LENGTH FREQUENCY DISTRIBUTIONS OF STRIPED BASS LARVAE FROM THREE DEPTHS OF THE SACRAMENTO RIVER NEAR WALNUT GROVE, MAY 15, 1987

Comparison	D-max	
Surface vs. Mid-Depth	0.362	$P < 0.001$
Surface vs. Bottom	0.322	$P < 0.001$
Mid-Depth vs. Bottom	0.040	$P < 0.005$

Figure 7
LENGTH FREQUENCY HISTOGRAMS OF STRIPED BASS LARVAE COLLECTED FROM THREE DEPTHS IN THE SACRAMENTO RIVER NEAR WALNUT GROVE, MAY 15, 1987



X̄ = Mean Body Length
SD = Standard Deviation
N = Number of Larvae

Antioch

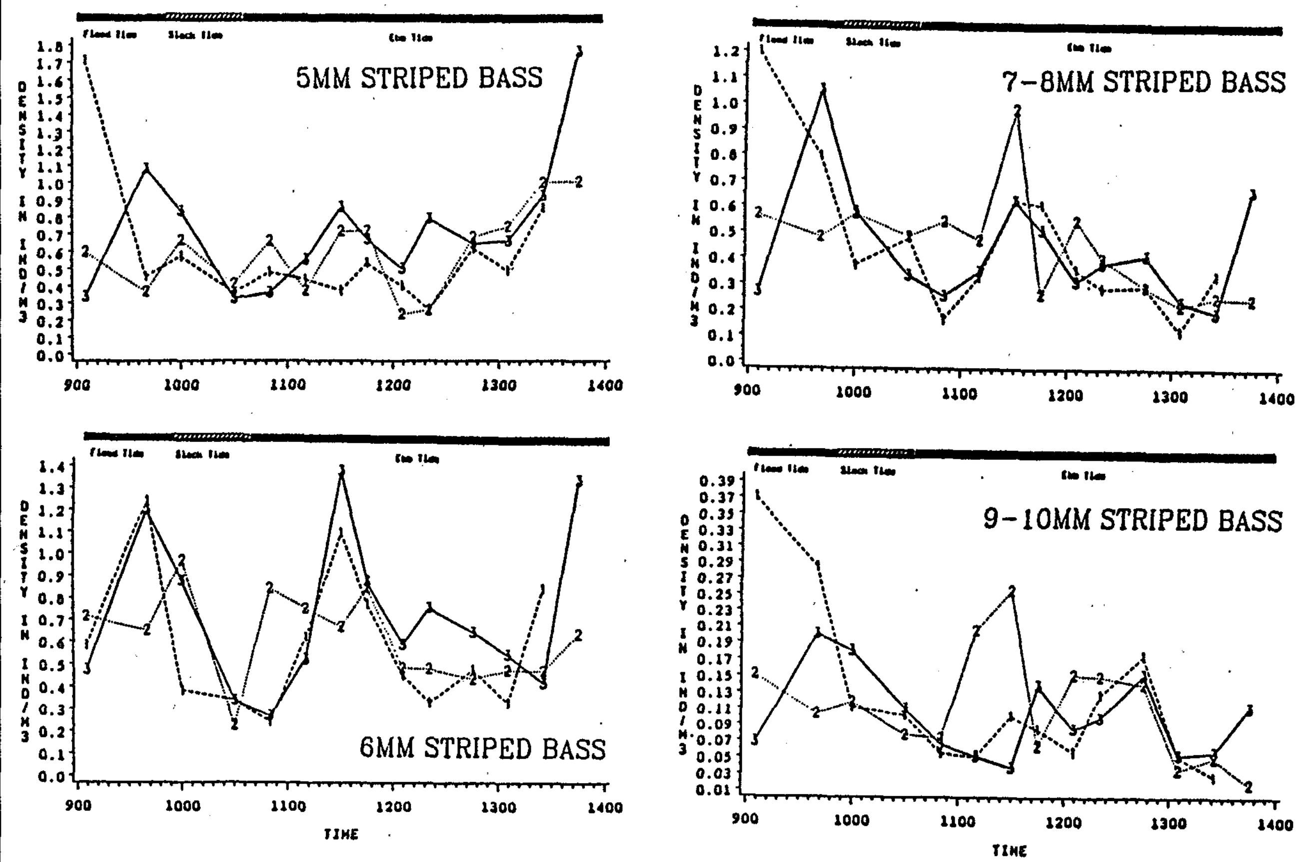
Densities of striped bass larvae varied with time and between nets. On May 5, larval striped bass density plots appeared almost as sine waves, especially for 6-mm larvae (Figure 8). Notably, catches in the three nets generally fluctuated consistently through time on this date. On May 7, striped bass catch fluctuations were less consistent among the nets than on May 5 and had no distinct trend with time or tide (Figure 9).

Rio Vista

Although the two nets were not towed simultaneously, density trends for larval bass were generally similar over time for each net (Figure 10). Peak numbers of striped bass larvae occurred in both nets about midday.

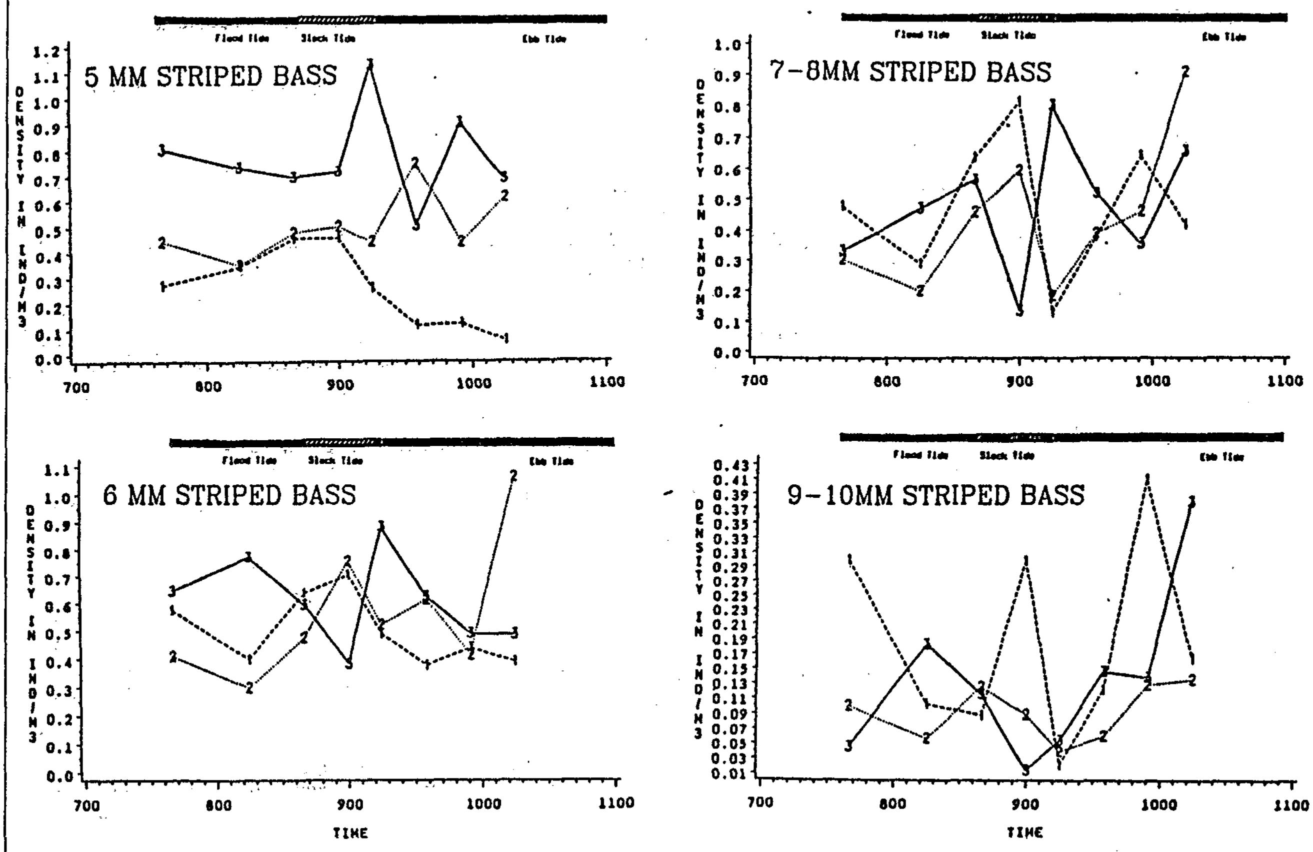
Figure 8

DENSITIES OF 5, 6, 7-8, AND 9-10mm STRIPED BASS LARVAE FROM THREE NETS IN THE SAN JOAQUIN RIVER NEAR ANTIOCH DURING A NET COMPARISON STUDY, MAY 5, 1987



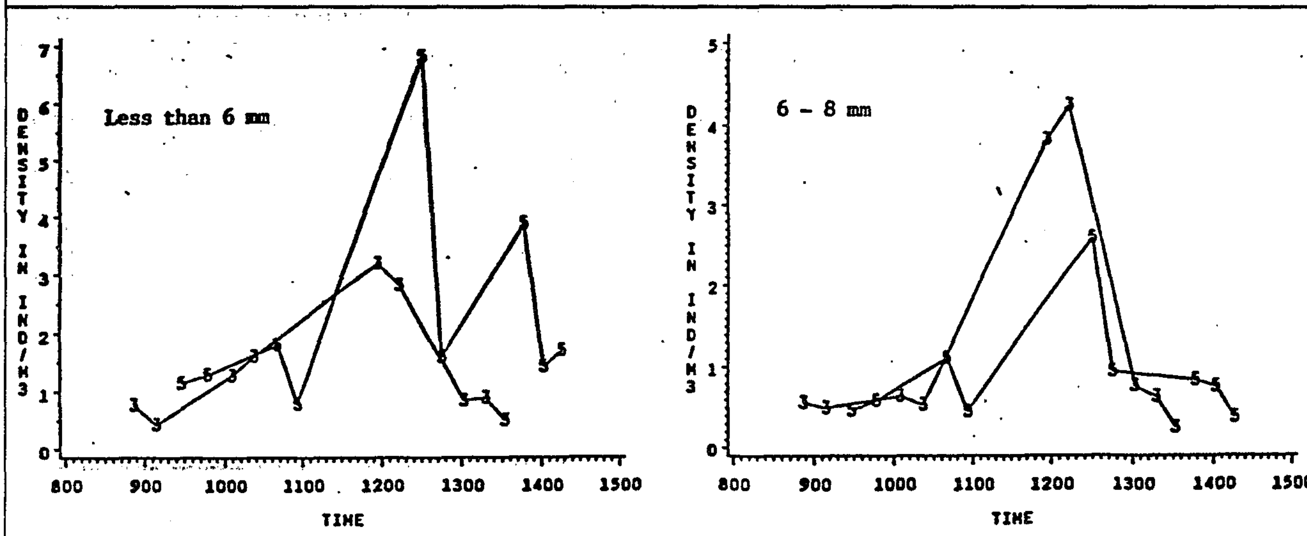
MESH SIZES: 1 = 335 μm, 2 = 400 μm, 3 = 505 μm

Figure 9
DENSITIES OF 5, 6, 7-8, AND 9-10mm STRIPED BASS LARVAE FROM THREE NETS IN THE SAN JOAQUIN RIVER NEAR ANTIOCH DURING A NET COMPARISON STUDY, MAY 7, 1987



MESH SIZES: 1 = 335 μm, 2 = 400 μm, 3 = 505 μm

Figure 10
DENSITIES OF STRIPED BASS LARVAE OF TWO LENGTH GROUPS FROM TWO NETS IN THE SACRAMENTO RIVER NEAR RIO VISTA DURING A MESH SIZE COMPARISON STUDY, MAY 21, 1987

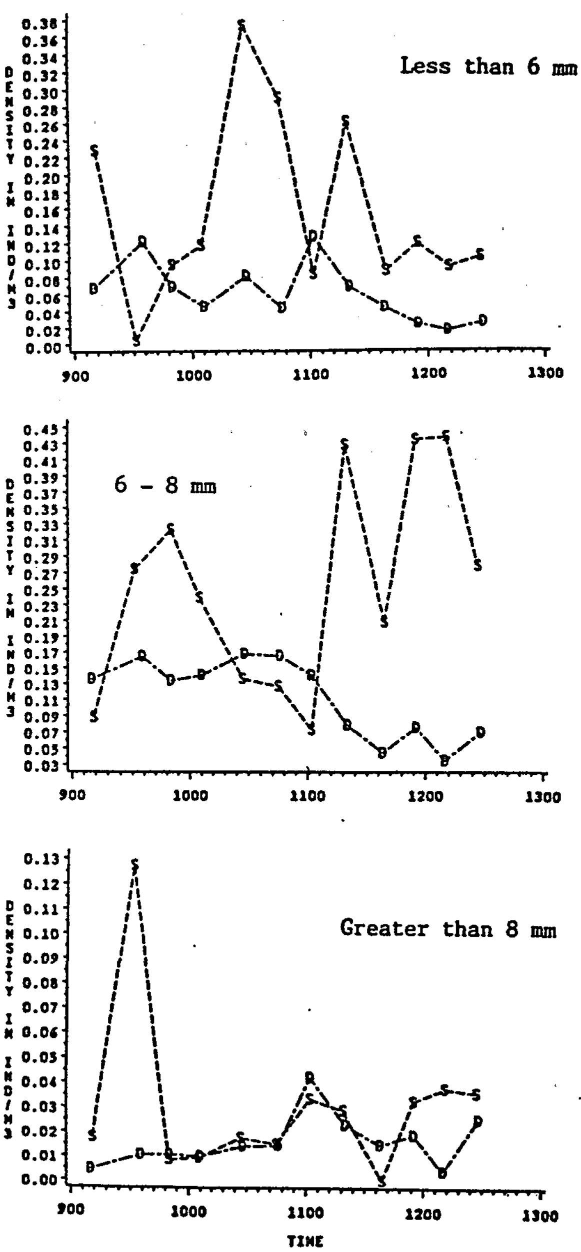


MESH SIZES: 3 = 335 μm, 3 = 505 μm

Spatial Distribution Relative to River Morphology

Both of two length groups of striped bass larvae, 8 mm or less and greater than 8 mm, were generally at higher concentrations over the shoal than in the deeper channel of the San Joaquin River near Jersey Island (Figure 11).

Figure 11
DENSITIES OF THREE LENGTH GROUPS OF STRIPED BASS LARVAE FROM TWO SECTIONS OF THE SAN JOAQUIN RIVER, JUNE 5, 1987



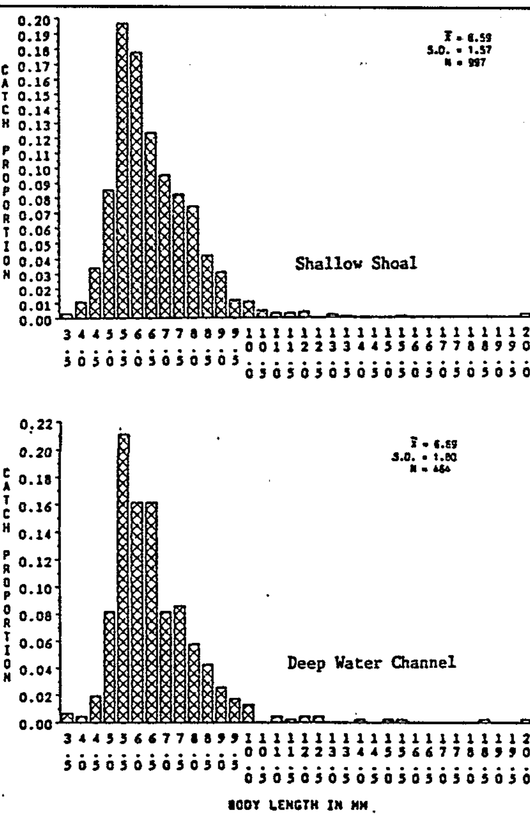
S = Shallow Shoal
D = Nearby Deep Channel

However, the difference was statistically significant only for the smaller length group (Table 3). Bass sampled from both areas had similar length-frequency distributions based on a Kolomogorov-Smirnov test (D-max = 0.023, P > 0.05) (Figure 12).

Table 3
DENSITIES OF TWO LENGTH GROUPS OF STRIPED BASS LARVAE FROM TWO SHOAL AND CHANNEL SITES ON THE SAN JOAQUIN RIVER NEAR JERSEY POINT, JUNE 5, 1987

	8 mm or less		Greater than 8 mm	
Depth	Shoal	Channel	Shoal	Channel
Mean Density	408.4**	173.6**	28.8	15.3
Standard Deviation	144.6	76.9	32.3	9.4
Number of Tows	12	12	12	12
F-test on Mean Densities	25.98		1.96	
P>F	0.0001		0.18	

Figure 12
LENGTH FREQUENCY HISTOGRAMS FOR STRIPED BASS LARVAE FROM TWO DEPTH SECTIONS OF THE SAN JOAQUIN RIVER, JUNE 5, 1987



Precision of Replicate Sampling

Comparison of mean densities of the different sizes of striped bass with their variances indicated distributions were contagious (Table 4). Sample variances were much greater than means at all locations and for all length intervals, and sample means and variances were highly correlated (r = 0.91).

The number of replicates required to distinguish 5, 10, 25, and 50 percent differences in densities of striped bass larvae varied with larval abundance, size, time, and location (Table 4). For example, for striped bass 5 to 8 mm long at Antioch on May 5 and 7, one sample was sufficient to detect a 50 percent difference in mean density; whereas, at Rio Vista on May 21, 2 to 8 samples were needed for the same discrimination. To detect a 10 percent difference in abundance, 6 to 35 replicates would have been required at Antioch, and 54 to 203 replicates would have been required at Rio Vista, depending on size group.

Table 4
ESTIMATED DISPERSION PARAMETER AND THE NUMBER OF SAMPLES REQUIRED TO DISCRIMINATE BETWEEN IMPORTANT CHANGES IN DENSITY FOR VARIOUS PERCENTAGE LEVELS OF DIFFERENCE FOR SELECTED LENGTH CLASSES OF STRIPED BASS LARVAE DURING FIELD TRIALS WITH REPLICATE SAMPLES, 1987

Location (Date)	Size	Density *(per 1,000 m^3)*	S^2	K	0.05	0.10	0.25	0.50
Antioch (5/5/87)	5 mm	734	139,400	3.88	104	26	4	1
	6 mm	729	128,400	4.16	97	24	4	1
	7 mm	251	19,400	3.29	123	31	5	1
	8 mm	190	12,440	2.95	137	34	5	1
Antioch (5/7/87)	5 mm	773	32,990	18.52	22	6	1	1
	6 mm	610	26,070	14.63	28	7	1	1
	7 mm	314	24,170	4.13	98	25	4	1
	8 mm	165	9,547	2.90	140	35	6	1
Rio Vista (5/21/87)	5 mm	2,274	3,657,000	1.41	283	71	11	3
	6 mm	831	372,200	1.86	216	54	9	2
	7 mm	67	6,008	0.75	536	134	21	5
	8 mm	6	70	0.54	813	203	33	8
Jersey Point (6/5/87)	<8 mm	408	20,900	8.13	50	13	2	1

24-Hour Vertical Distribution Study

The "Water Mass"

I attempted to sample one "water mass" by changing sampling locations as the mass moved with the tide. Although sampling was kept within a relatively narrow range of surface specific conductance, changes in the specific conductance depth profile indicated the sampled water column was not from a discrete mass (Figure 13). During the first 6 hours, conductivity readings were constant with depth, indicating the water column was uniform and well-mixed. However, after that initial period, conductivity readings for three depths sharply diverged and generally remained different until sampling ended.

Sampling locations traversed a distance of more than 15 km (Figure 13). Water transparency did not vary greatly.

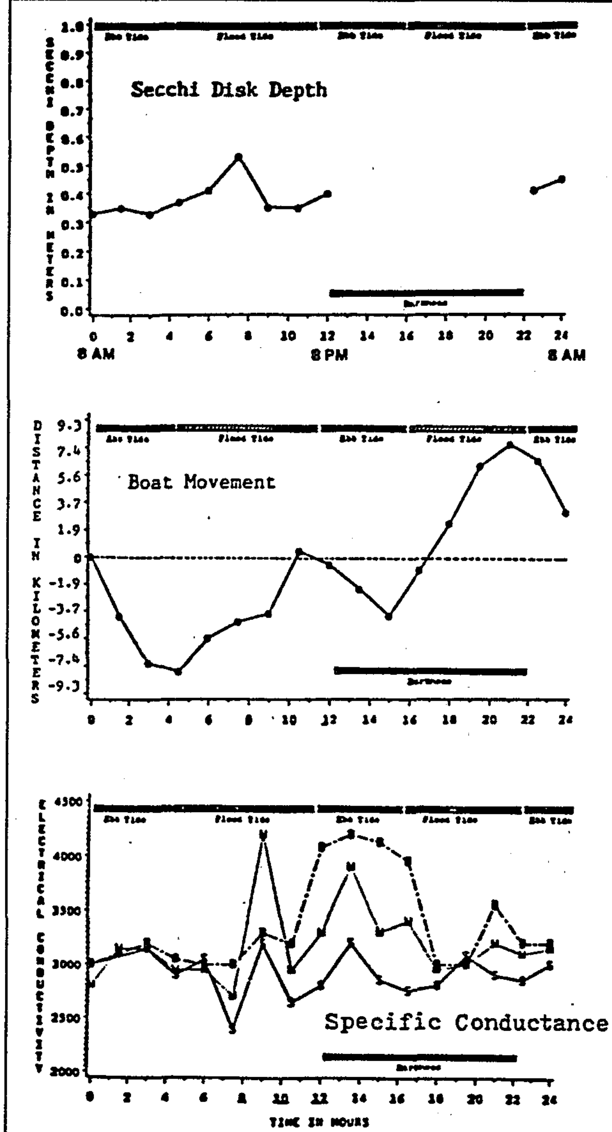
Vertical Distribution of Young Striped Bass

Except for brief peaks at mid-depth and bottom, catches of striped bass larvae were less than 0.05 fish per cubic meter for all depths throughout the sampling period (Figures 14-16). Despite the low concentrations, several tendencies were apparent. Striped bass were least abundant at the surface, and this tendency was most pronounced for the larger bass. No striped bass larger than 20 mm was caught at the surface (Figure 17). On average, striped bass smaller than 11 mm and larger than 20 mm were most abundant near the bottom during the day and at mid-depth at night; whereas, striped bass between 11 and 20 mm SL were most abundant at mid-depth throughout the 24-hour period (Figure 17). Tidal stage had no apparent effect on the vertical distribution of young striped bass.

Effect of Zooplankton Distribution

Variations in the vertical distribution of young striped bass were not consistent with those of their common zooplankton prey, either collectively (Figure 14) or, in general, individually (Figures 15, 16, and 17). An exception is that the largest striped bass and their major prey, opossum shrimp, tended to vary together at the bottom (Figure 16).

Figure 13
SECCHI DISC DEPTH, BOAT MOVEMENT, AND SPECIFIC CONDUCTIVITY PROFILE DURING A 24-HOUR VERTICAL DISTRIBUTION STUDY, JUNE 10 AND 11, 1987

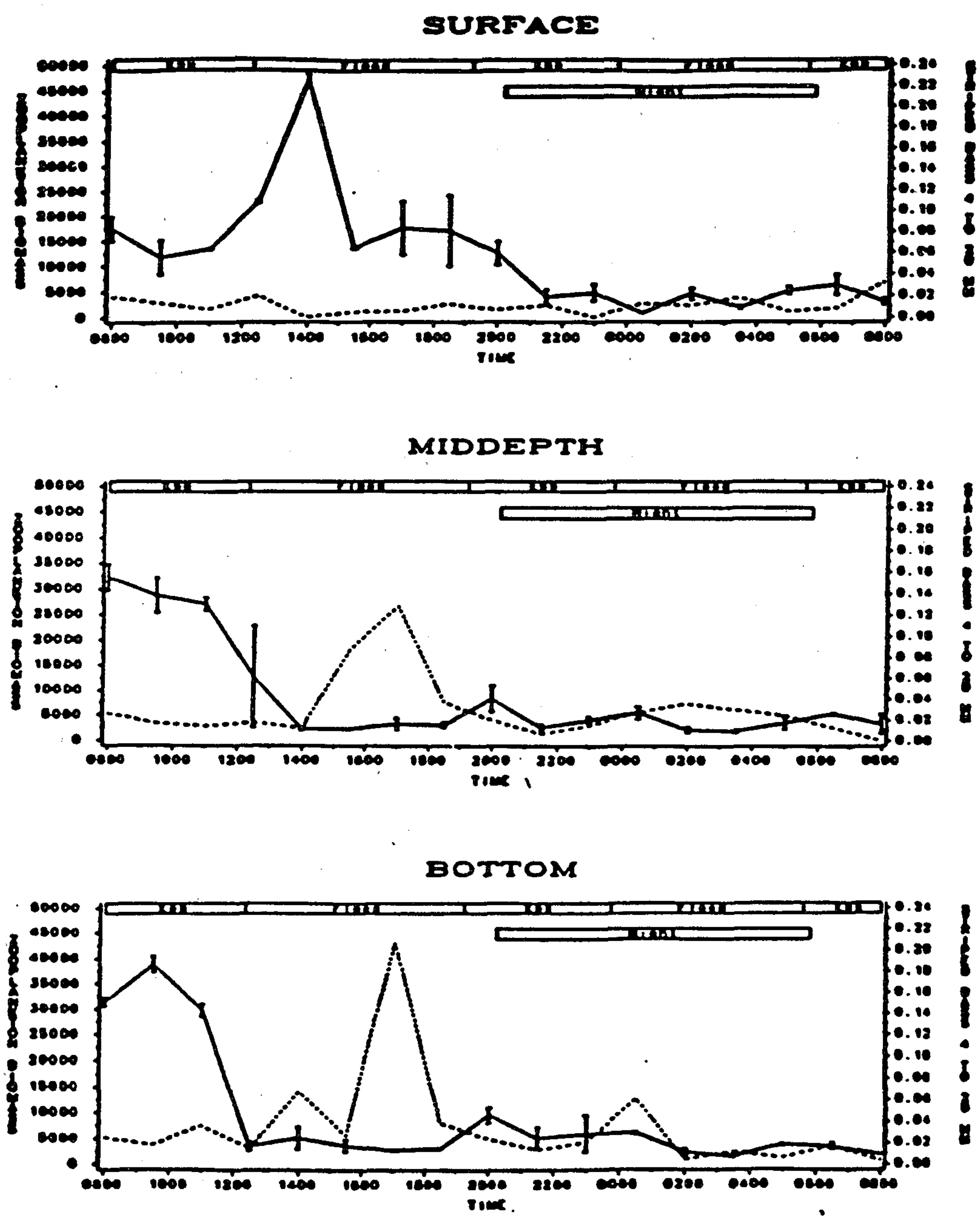


Boat movement (an index of surface tidal movement) was measured as the distance from the starting point, with negative values denoting downstream movement.

S = Surface
M = Mid-Depth
B = Bottom

Figure 14

MEAN BIOMASS ($\mu g/m^3$) OF COPEPODS AND CLADOCERANS AND DENSITY OF 4- TO 20-MM-LONG STRIPED BASS COLLECTED FROM THREE DEPTHS DURING A 24-HOUR VERTICAL DISTRIBUTION STUDY, JUNE 10 AND 11, 1987



Solid line = zooplankton biomass and broken line = striped bass. Bars indicate range of replicate samples.

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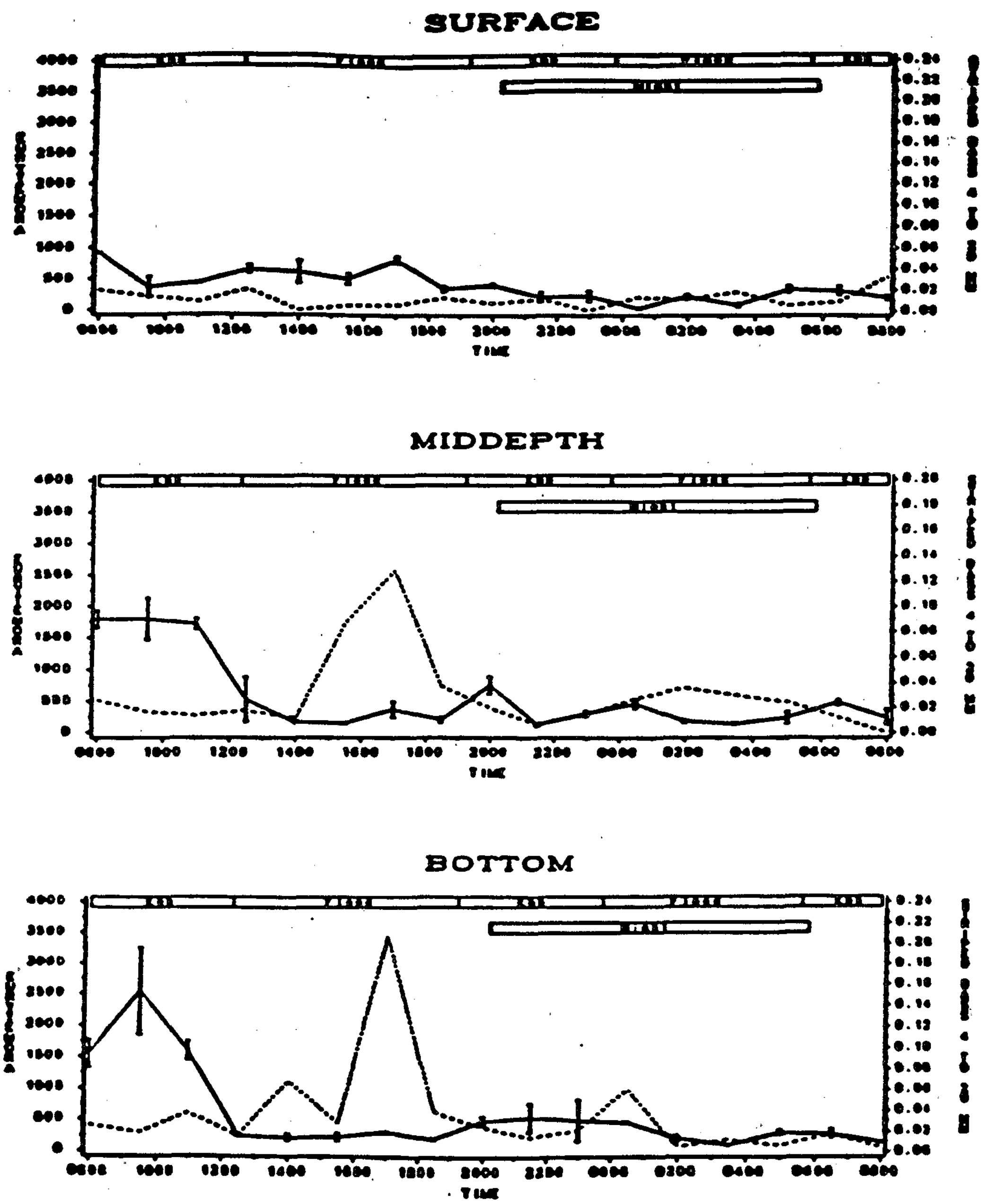
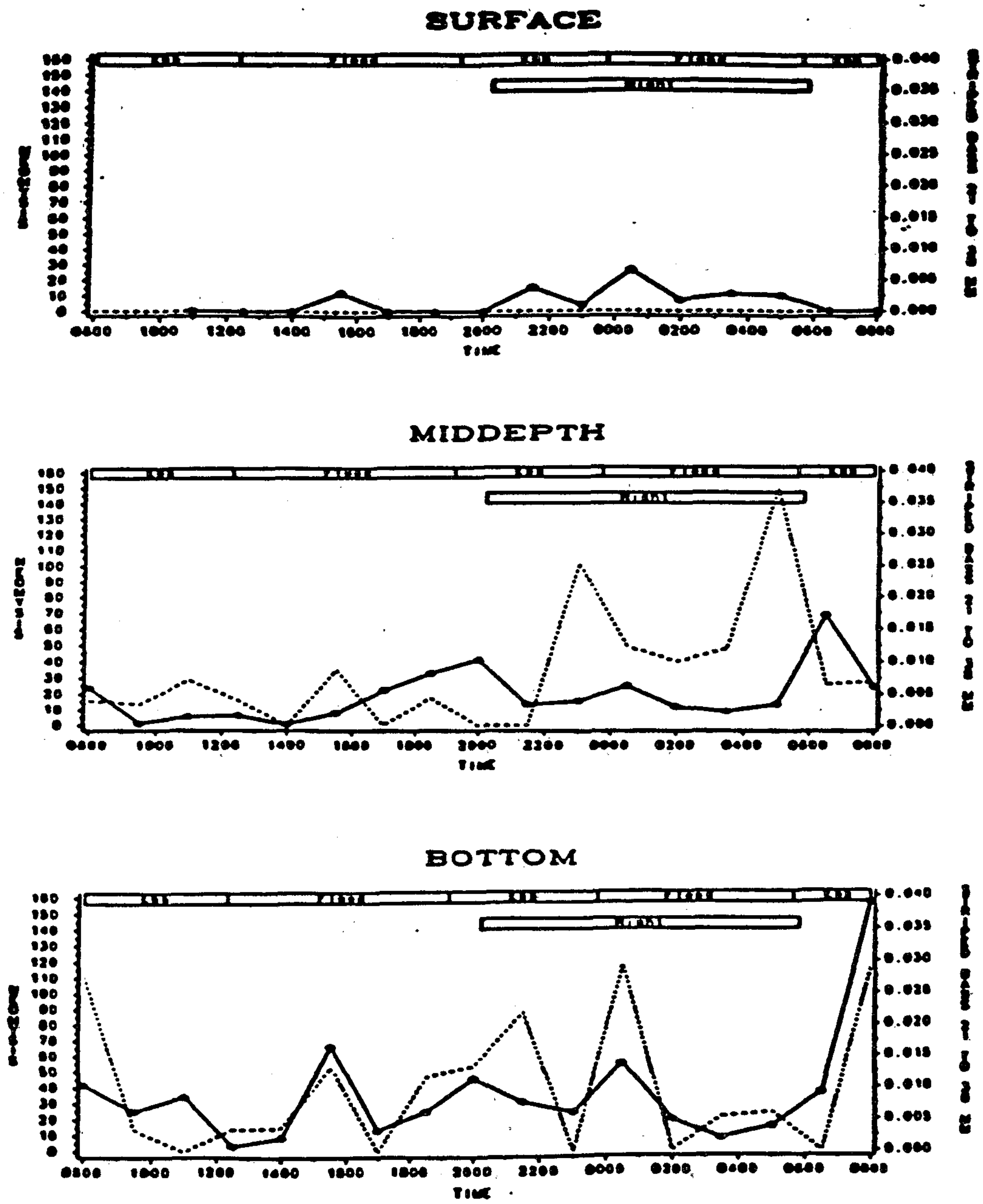
Figure 15
MEAN DENSITY OF *EURYTEMORA* (organisms/m^3) AND
DENSITY OF 4- TO 20-MM-LONG STRIPED BASS COLLECTED FROM THREE DEPTHS
DURING A 24-HOUR VERTICAL DISTRIBUTION STUDY,
JUNE 10 AND 11, 1987



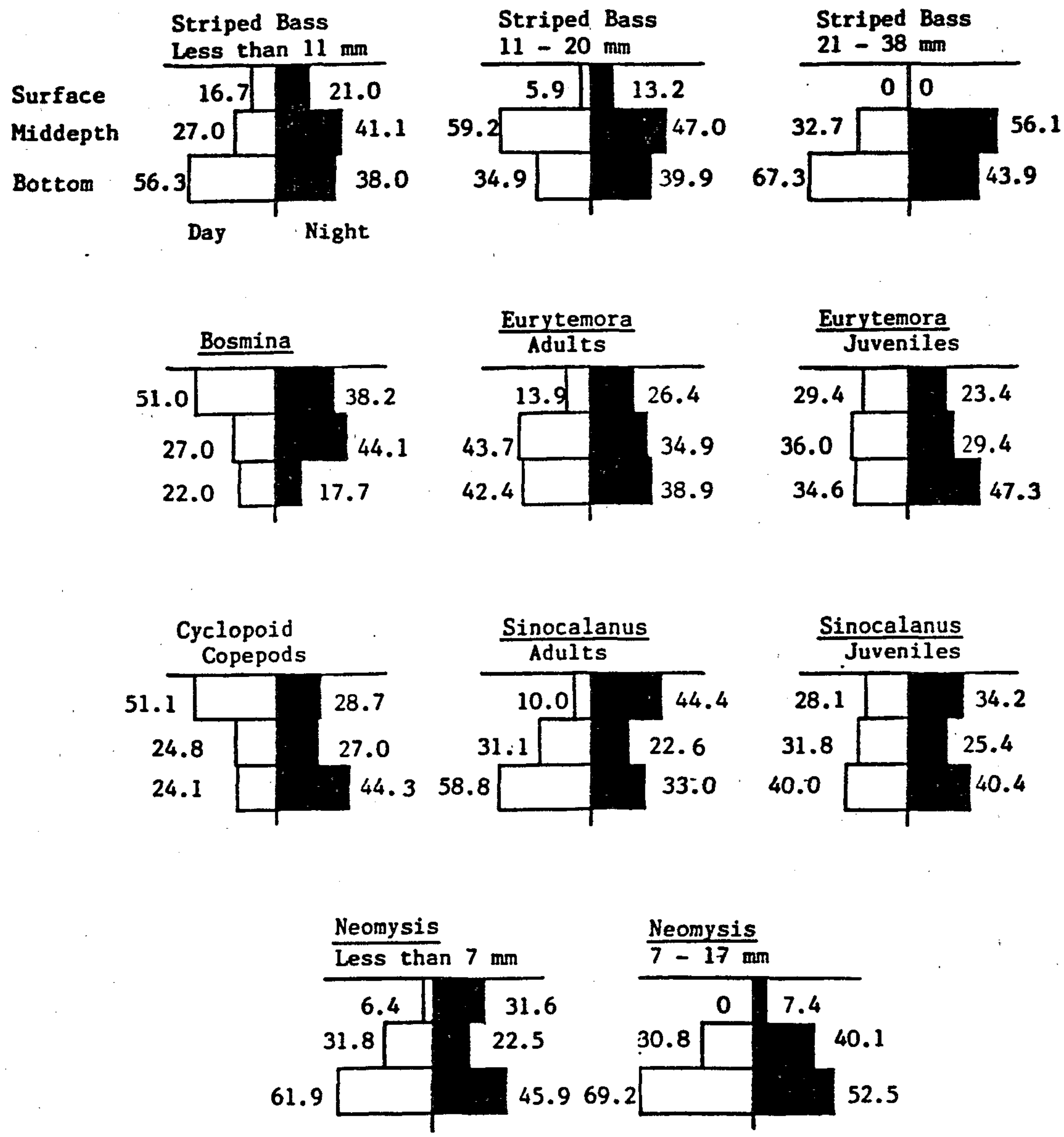
Solid line = Eurytemora and broken line = striped bass. Bars indicate range of replicate samples.

Figure 16
MEAN DENSITY OF OPOSSUM SHRIMP (organisms/m^3) AND
DENSITY OF 21- TO 38-MM-LONG STRIPED BASS COLLECTED FROM THREE DEPTHS
DURING A 24-HOUR VERTICAL DISTRIBUTION STUDY,
JUNE 10 AND 11, 1987



Solid line = opossum shrimp and broken line = striped bass. Bars indicate range of replicate samples.

Figure 17
VERTICAL DISTRIBUTION OF YOUNG STRIPED BASS AND SOME ZOOPLANKTERS BY PERCENT DURING DAY AND NIGHT TOWS DURING A 24-HOUR VERTICAL DISTRIBUTION STUDY, JUNE 10 AND 11, 1987



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DISCUSSION

My studies showed that spatial and temporal variations in abundance of striped bass eggs and larvae contribute to sample variability. Simultaneous replicate sampling and sequential catches of eggs and larvae varied greatly over small distances or within minutes. Vertical and spatial distribution sampling indicates catches are influenced by life stage and site-specific environmental factors such as river morphology, depth, and distance from spawning site. However, despite the variable nature of the catches, precision estimates suggest sampling is usually sufficient to detect a 25 to 50 percent difference in mean densities. In 1984 through 1986, a similar analysis indicated that, survey-wide, striped bass ELS sampling generally was sufficient to detect 25 to 50 percent differences in mean daily densities of striped bass eggs and larvae stratified by 1-mm size intervals (CDFG staff, 1988). In an independent survey (CDFG, 1987) correlations between abundance of larvae and abundance at the 38-mm stage also indicated that, in general, survey-wide sampling provides representative measures of larval striped bass abundance.

The sample variability and vertical distribution patterns for striped bass eggs are consistent with expectations based on knowledge of striped bass biology and hydrodynamics.

The difference in vertical distribution of striped bass eggs at the two Sacramento River sampling sites probably was greatly influenced by the proximity of these sites to the main spawning areas and the nature of the river at each site. At Verona, close to the spawning area, the river was relatively narrow and shallow, with more turbulent flow. Here, egg densities were highly variable but tended to be greatest at the surface where bass spawn. Conversely, downstream, closer to Walnut Grove, the river was wider and deeper, with longer and straighter reaches and more uniform and laminar flow. There, currents slow substantially when flood tides back up against the downstream river flow. At Walnut Grove, although abundance varied greatly over a few hours, eggs generally were most concentrated at mid-depth and the bottom, probably due to the periods of reduced current and minimal turbulence and the tendency of striped bass eggs to slowly sink as they drift downstream from the spawning area.

Hydrodynamics of the San Joaquin River at Antioch are more complex than at the Sacramento River sampling sites due to salinity gradients and greater tidal influences. Egg catches tended to increase during an ebb tide on the first day; spawning probably had occurred upstream. Two days later, there was no such trend with time or tide.

As striped bass grow, they are capable of greater control over their position in the water column and apparently actively avoid the surface, as catches of striped bass larvae decreased at the surface and increased at mid-depth and the bottom as their size increased. Results from the 24-hour sampling cycle suggest negative phototaxis is not the primary surface avoidance mechanism.

Channel depth apparently influences the distribution of young striped bass. Densities of small larvae were greater over shoals than in the adjacent channel, and sample variability was also greater over the shoals. Sasaki (1966) reported that larger juvenile striped bass also concentrate over shoals.

Diel patterns of distribution did not show a close association between young striped bass and their zooplankton prey. Hence, striped bass do not appear to move vertically in conjunction with their prey, and they are probably affected by factors other than feeding.

Recently there has been renewed interest in how the estuary's freshwater/saltwater mixing zone, or "entrapment zone" influences striped bass year class success. Young striped bass tend to accumulate in or just upstream of this zone, and this region is critical nursery habitat. The design of any new studies of the entrapment zone's role should consider spatial and temporal variability in striped bass catches. Concurrent sampling of environmental variables such as tidal velocity including differences between spring and neap tides and intertidal current variations, salinity, and light may help interpret such variability and interactions between young striped bass and their environment.

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