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FACTORS INFLUENCING DISTRIBUTION OF FISH EGGS AND LARVAE OVER EIGHT 24-HR SAMPLINGS IN RICHARDSON BAY, CALIFORNIA [1]

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To determine the factors affecting the day-night distribution of ichthyoplankton, a series of eight 24-hr samplings was conducted in Richardson Bay, California. Slightly modified channel nets were fished in two locations and collections made for each half-tide stage. Of the different larval taxa collected, *Clupea harengus pallasi, Engraulis mordax* and Gobiidae comprised 98% of the total catch. The most speciose family was Cottidae.

Densities of larvae and eggs were positively correlated with tide stages of the fastest currents and with night conditions. Analysis of the catch results suggests the most determinant factor in the distribution of eggs and larvae is tidal currents.

Interesting occurrences of 10 species of offshore spawned larvae is reported, and a possible explanation for their presence within the bay is discussed.

INTRODUCTION

Ichthyoplankton surveys along the west coast have centered around the CalCOFI (California Cooperative Oceanic Fisheries Investigations) cruises which began in 1949 and concentrated on the ichthyoplankton of the California current (Ahlstrom 1965). Only geographically scattered, recent studies have attempted to understand the inshore, estuarine ichthyoplankton (Eldridge and Bryan 1972; Blackburn 1973; Pearcy and Myers 1974). The only study in the central California coastal area was that of Chadwick (1958) who sampled in the Sacramento-San Joaquin Delta area, upstream from San Francisco Bay. This work dealt principally with the eggs and larvae of striped bass, *Morone saxatilis,* and freshwater species. Pearcy and Myers (1974) are the only researchers to date to study the diel distribution of ichthyoplankton in a Pacific coast estuary. Their study took place over three 24-hr periods, in a comparatively narrow Oregon estuary.

Public and governmental concern over the deteriorating environmental quality of San Francisco Bay principally was responsible for a series of three comprehensive studies which began in 1964 (Pearson, Storrs, and Selleck 1970; Kaiser Engineers 1969; Brown and Caldwell 1971). The main objective of these studies was the evaluation of water quality, primarily the physico-chemical conditions throughout the bay. Research on the finfish population in San Francisco Bay has been limited to juvenile and adult fishes and confined to deeper channel stations (Aplin 1967). Studies were begun by staff members of the Tiburon Laboratory in 1972 in Richardson Bay, a small embayment within San Francisco Bay, to provide comprehensive information on the finfish populations of a shallow, estuarine tidal basin. The project included sampling phytoplankton, ichthyoplankton, and juvenile and adult fishes. Part of the ichthyoplankton survey was

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concerned with temporal distribution of fish eggs and larvae over short time periods. This work is the subject of the present paper. The major part of the ichthyoplankton survey covered the entire Richardson Bay at weekly intervals over a 1-year sampling period. The results of that survey will be reported later.

Diurnal and nocturnal rhythmic behavior has been documented in adult estuarine fishes (Gibson 1969). Likewise, larvae have exhibited varying diel distribution patterns in open-ocean waters (Isaacs 1964; Bridger 1956) and inshore areas (Lewis and Wilkens 1971; Lewis and Mann 1971; Richards and Kendall 1973; Pearcy and Myers 1974). Since day-night differences in distribution can bias survey results, an effort was made to determine factors affecting distribution of Richardson Bay ichthyoplankton. This paper reports the results of eight 24-hour samplings conducted at two locations from March 23, 1972, to February 9, 1973.

DESCRIPTION OF THE STUDY AREA

Richardson Bay is approximately 11 km (8.0 miles) north of the San Francisco Peninsula (Figure 1). Its total area covers approximately 12.9 km² (4.9 miles²). This surface area changes 10–13% during spring tide conditions indicative of the shallow depth of the bay which averages only 0.45 m (1.4 ft). The only channel of notable depth averages 6m (19.2 ft) and is a minor ship channel adjacent to the city of Sausalito.

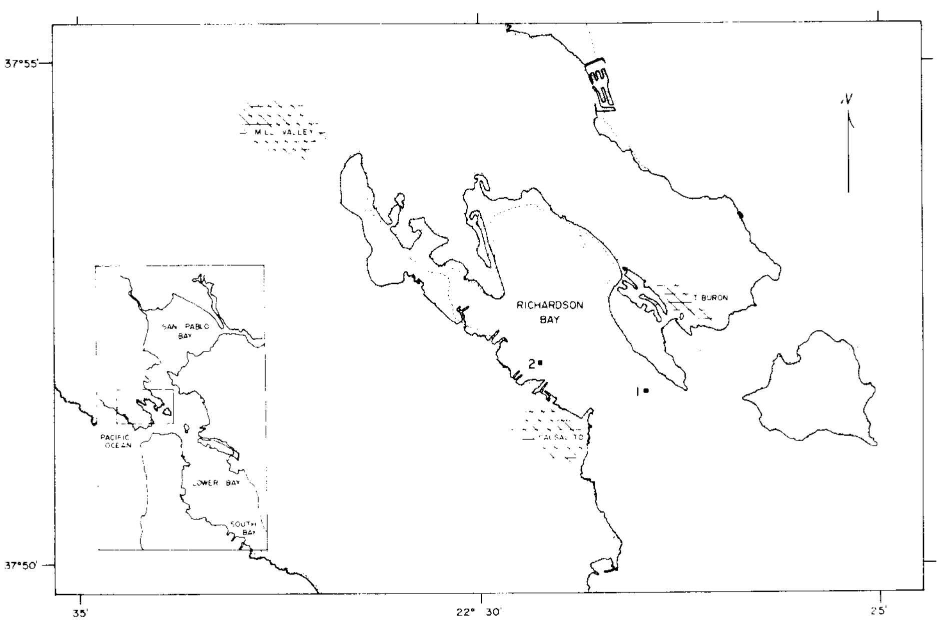

FIGURE 1. Map of Richardson Bay, California, showing the two sampling stations used in the study of the diel distribution of fish eggs and larvae. Short-dashed lines represent the 10-m contours. Long-dashed lines represent water level at zero feet tide level.

Sediment types in Richardson Bay may be described generally as soft marine sediments of "bay mud" with more sandy mixtures in the mud flat drainage channels. Some rocky shore areas are located near the entrance to the bay.

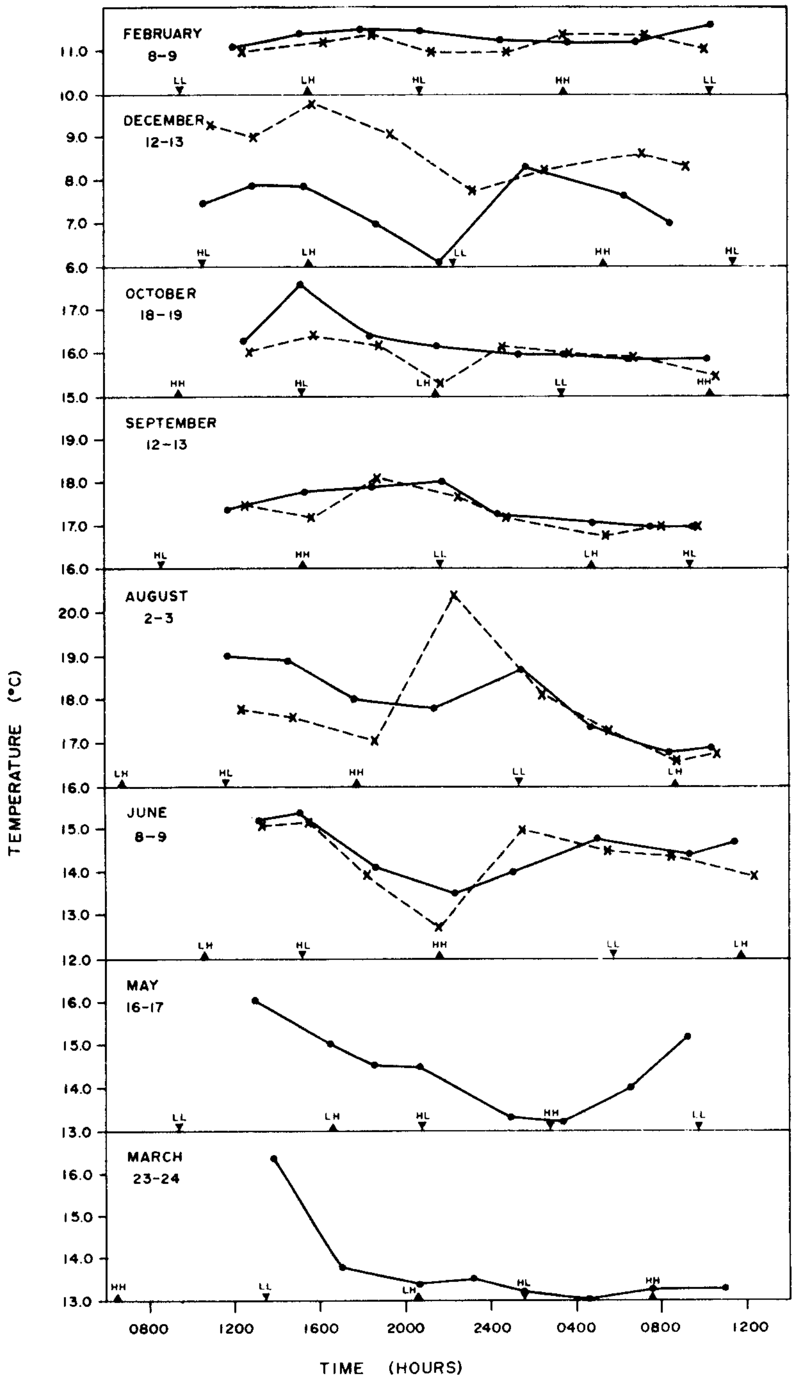

FIGURE 2. Water temperature measured in the study of fish eggs and larvae of Richardson Bay, California. Solid line represents Station 2 and dotted line Station 1. Different tide stages are indicated by triangles with appropriate symbols (LL = lower low tide; HL = higher low; LH = lower high; HH = higher high).

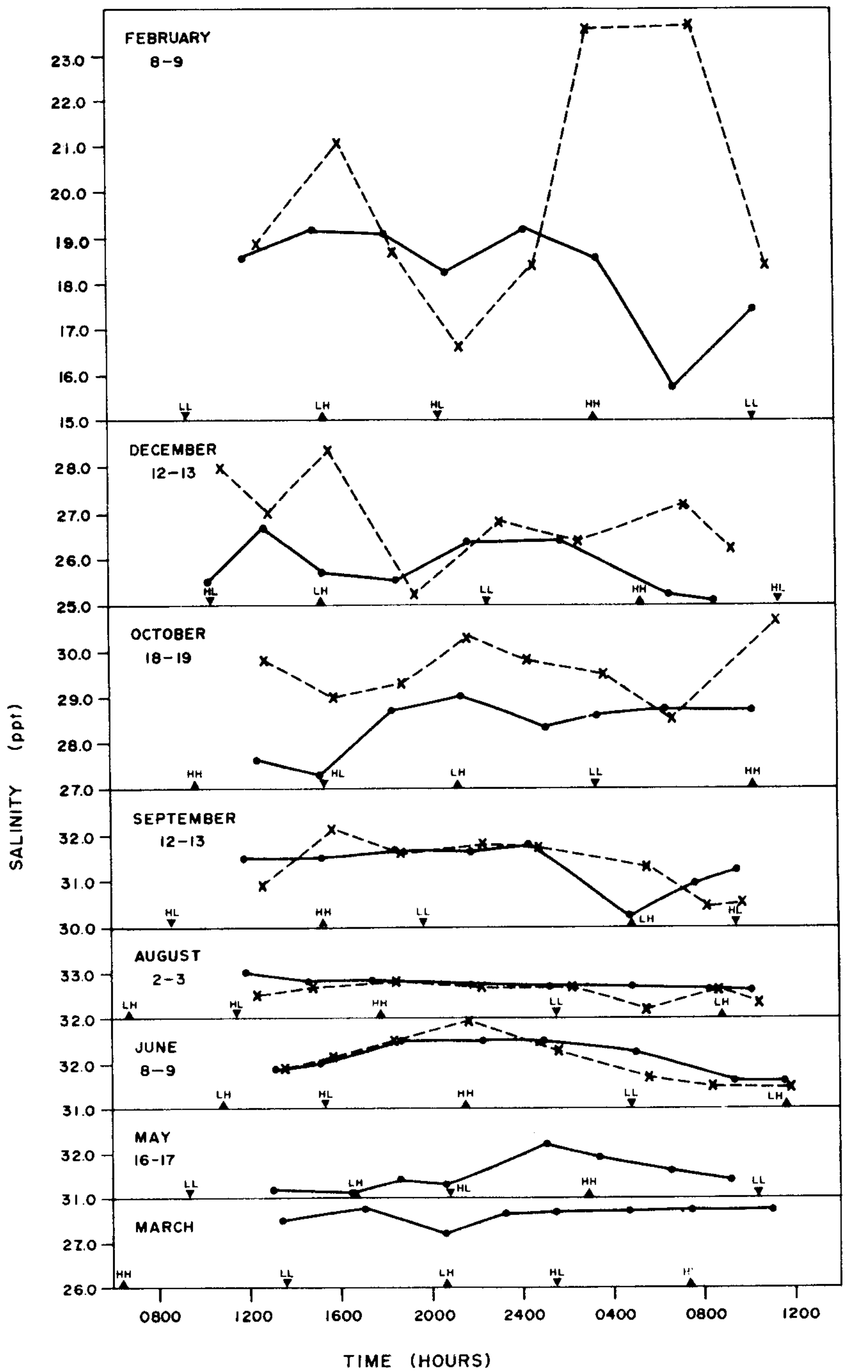

FIGURE 3. Salinities measured in the study of fish eggs and larvae of Richardson Bay, California. Solid line represents Station 2 and dotted line Station 1. Different tide stages are indicated by triangles with appropriate symbols (LL = lower low tide; HL = higher low; LH = lower high; HH = higher high).

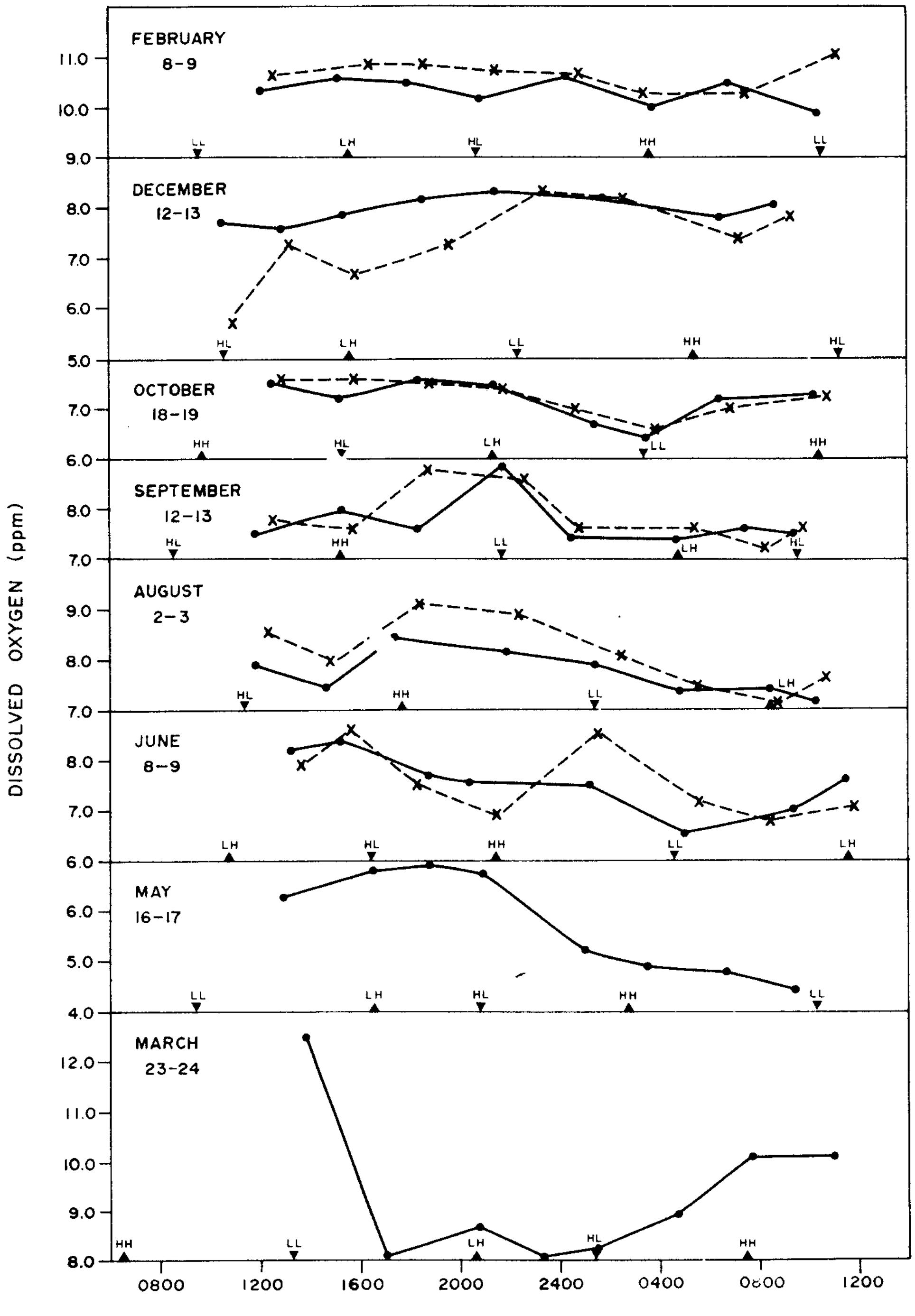

FIGURE 4. Dissolved oxygen concentrations measured in the study of fish eggs and larvae of Richardson Bay, California. Solid line represents Station 2 and dotted line Station 1. Different tide stages are indicated by triangles with appropriate symbols (LL = lower low tide; HL = higher low; LH = lower high; HH = higher high).

Frolander (1964) considered an estuary to be two-layered or stratified when conductivity, as a measure of salinity, changed by four or more units within a 1-m (3.3-ft) depth. By that definition Richardson Bay would be considered a vertically well-mixed estuary. Only during periods of high winter rainfall, near the entrance to the bay, did any evidence of stratification occur. Freshwater inflow into the bay comes mainly from two small creeks which drain a watershed area of approximately 45.7 km² (17.6 miles²). Also two sewage treatment plants discharge 11.67×10^8 gallons of primary treated effluent per year into the bay.

Temperature, salinity, and dissolved oxygen levels were monitored throughout the sampling period (Figures 2, 3, and 4). The overall physico-chemical conditions were a function of the tide, season, and freshwater runoff. In winter the marine water entering the bay tended to moderate the colder, turbid upstream water. Conversely, in summer upstream water temperatures were generally warmer, and salinities were at their annual highs. At times the bay became a "hypersaline" or "negative" type estuary as described by Frolander (1964).

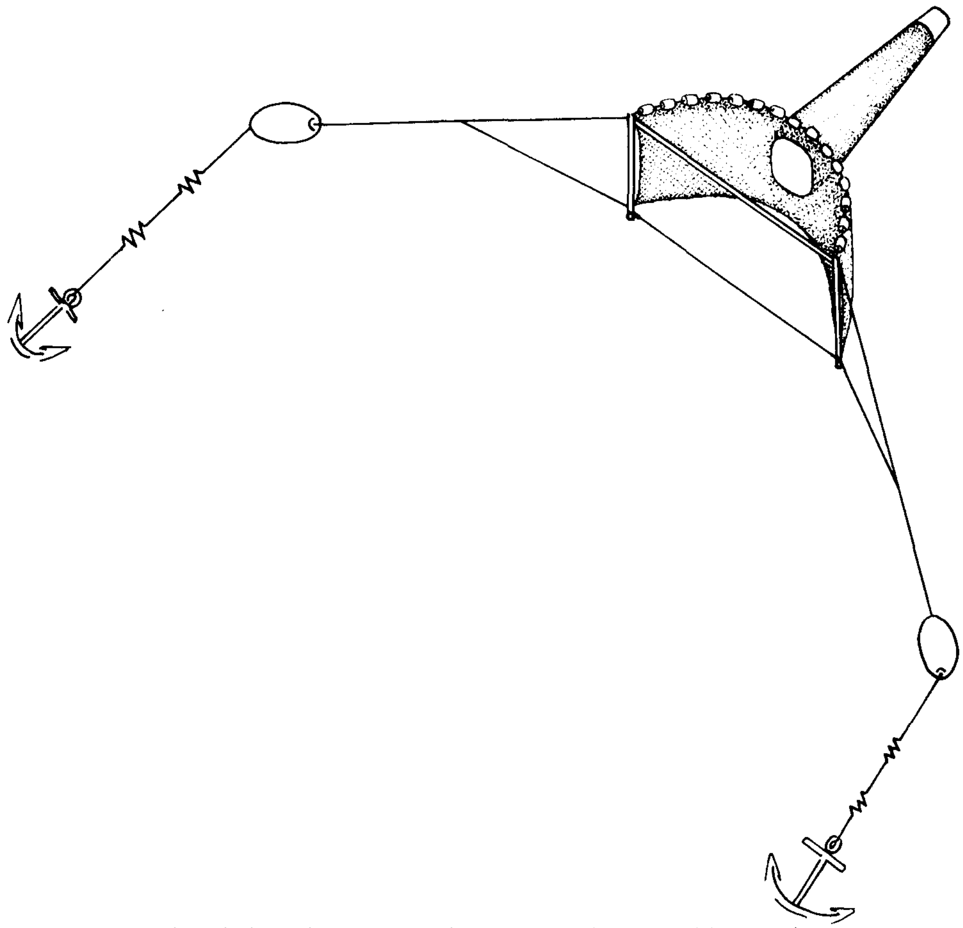

FIGURE 5. Anchored channel net used in the study of fish eggs and larvae. Flow meter (not shown) was mounted eccentrically in round 0.5 m net opening.

METHODS

Sampling of the ichthyoplankton was carried out during eight 24-hr periods (Table 1) using a modified version (Figure 5) of a channel net (Lewis, et al. 1970). The net was fished in a stationary position, anchored in place, facing the tidal current. The tail bag consisted of a 0.5-m (1.7-ft) plankton net of 333 μ mesh. The wing dimensions were approximately 1 x 3-m (3.3 x 9.9 ft) with ⅛-inch square nylon webbing. Digital flowmeters (Model 2030, General Oceanics, Inc.[2]) were mounted eccentrically in the mouth of each net to estimate the amount of water filtered. In the samplings of May 16, 17 and February 8, 9, numerous difficulties were encountered, i.e., clogging of the flowmeters, malfunctions, etc. Because many volume measurements of these two studies were questionable, I decided not to use the data for comparisons of catch (numbers of larvae/m^3). Nets were placed in two locations in Richardson Bay (Figure 1); one in the ship channel in the middle part of the bay (Station 2), and the other near the entrance (Station 1). The water depths ranged from 1.0 to 2.0 m (3.3 to 6.6 ft) at Station 2 and 2.0 to 4.4 m (6.6 to 14.5 ft) at Station 1. For the first two studies (March 23–24 and May 16–17) only Station 2 was fished. To remove bias with respect to time (and weather conditions) the sampling dates were randomly selected ahead of time by means of a random numbers table, choosing two dates per season.

The sampling schedule for each 24-hr period was divided according to tide stages; the objective being to sample separately the first and second halves of each tide stage (Figure 6). The net was allowed to fish for the entire half-tide stage, then it was washed down, the plankton sample removed, and the net replaced for the next half-tide stage. For simplification in the succeeding text,

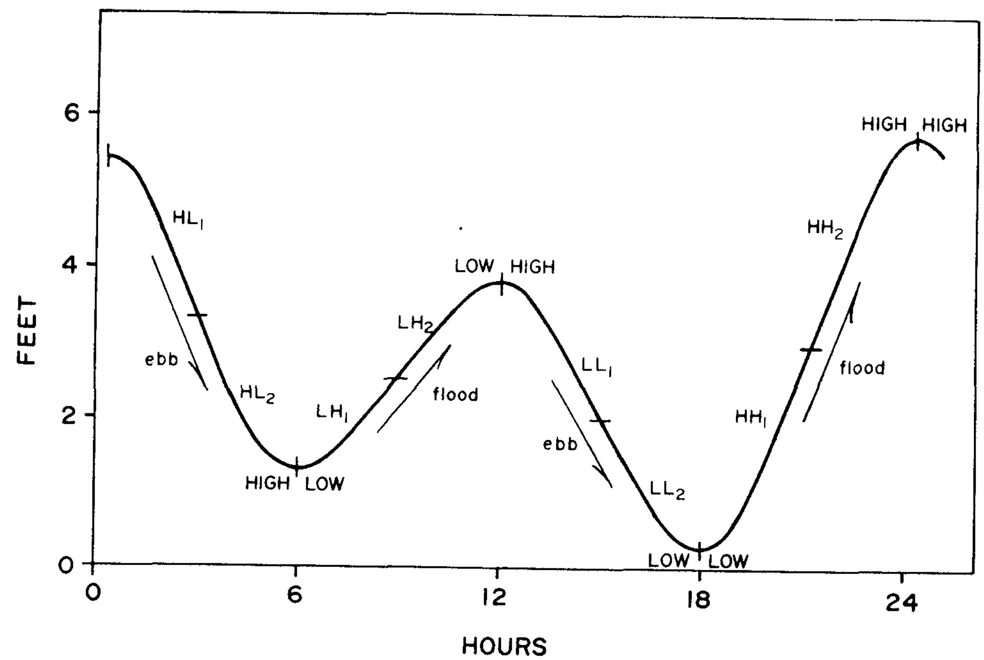

FIGURE 6. Typical tide curve and coding of sampling periods used in each 24-hr study.

the different half-tide stages are represented as follows: high high tide stage = HH_1 (first half) and HH_2 (second half); low high = LH_1 and LH_2; high low = HL_1 and HL_2; and low low = LL_1 and LL_2.

Concurrent to net samplings, the following physico-chemical parameters of bay water were measured: dissolved oxygen, temperature, salinity, pH, and turbidity. Vertical profiles of all parameters were made in front of each net. The values presented in Figures 2, 3, and 4 represent measurements taken in the mouth of each net. The ichthyoplankton samples were preserved in 5% buffered formaldehyde. Processing of samples followed procedures described by Kramer (Kramer, et al. 1972).

Component factor analyses (Rummel 1970) were used to determine the different relations between dependent and independent variables. This statistical method first calculated a correlation coefficient matrix of all possible combinations of variables. Then by matrix rotation it organized groups of related variables into distinct factors, which are independent of each other. Combined data for the entire year and data within each study were analyzed in this manner. Related variables were subsequently analyzed by analysis of variance.

RESULTS

Species Composition and Abundance

Among the eight different sampling periods a total of 38,226 larvae were caught, representing 39 separate taxa (Table 1). Twenty-six larval types were identified to species. Of the remaining larvae, two were identified to genus and 11 to family. *Clupea harengus pallasi* (Pacific herring), *Engraulis mordax* (northern anchovy), and Gobiidae larvae comprised 98% of the total catch. The next most abundant types were *Cynoscion nobilis* (white seabass), *Leptocottus armatus* (staghorn sculpin), and *Hypsopsetta guttulata* (diamond turbot).

The most speciose family was Cottidae (seven species) followed by Pleuronectidae with five species. Large catches which occurred mostly in the fall and winter studies were due to Pacific herring spawning. When the herring were not spawning, Gobiidae replaced them as the most abundant type. Gobiid 1, the unidentified Gobiid larvae, was the only type caught in all eight samplings.

Temporal Distribution

Results of factor analysis and correlation analyses of all eight studies combined throughout the year showed the following significant relations between variables within factors:

i. the number of larvae positively correlated ($P = .05$) with ebbing tides.
ii. the number of species showed a significant ($P = .01$) increase on ebb tides.
iii. the catch (number of larvae/m^3) was significantly ($P = .05$) higher during ebb tide conditions.

Within individual 24-hr samplings similar analyses indicated varying results. During March ebb tides the plankton volumes and the number of species were the highest. The catches (number of larvae/m^3) in June consisted mostly of Gobiidae. The number of eggs and the number of species were directly related to catch (number of larvae/m^3). In August, during flood tides, the number of species and the number of eggs increased, and the catches of *Hypsopsetta*

TABLE 1. Numbers of Larvae of Different Fish Species Caught According to Location (Station 1/Station 2), date, and half tide stage.

Taxa	March 23, 24	May 16, 17	June 8, 9	Aug. 2, 3	Sept. 12, 13	Oct. 18, 19	Dec. 12, 13	Feb. 8, 9	LL 1	LL 2	HL 1	HL 2	LH 1	LH 2	HH 1	HH 2	Total
Clupeidae																	
Clupea harengus pallasi	-/1094						857/14,800	171/3,795	2,116	1,860	291	746	218	51	9,346	89	20,717
Engraulidae																	
Engraulis mordax	-/4			114/20	95/72	95/72	1,810/65	365/27	1,097	349	480	501	29	56	58	135	2,705
Osmeridae																	
Spirinchus thaleichthys			1/0				1/0		2								2
Allosmerus elongatus								1/0	1								1
Osmerid 1	-/6				0/1			1/1	1	3	1	2	1	1			9
Osmerid 2			1/0											1			1
Batrachoididae																	
Porichthys notatus						0/1	2/0		1	1		1					3
Ophidiidae																	
Brosmophycis marginata			2/0	2/0					2					2			4
Atherinidae																	
Atherinopsis californiensis	-/1			1/0			1/0			2		1					3
Atherinops affinis						0/3	9/3		1	10			2		2		15
Syngnathidae																	
Syngnathus leptorhynchus					1/1	13/23	4/1	1/0	27	10		1	1	4	1		44
Sciaenidae																	
Cynoscion nobilis	-/1				1/0	37/17	9/3	54/5	67	7		18	2	3	21	9	127
Embiotocidae																	
Cymatogaster aggregata				1/1								1	1				2
Clinidae																	
Clinid 1	-/1		1/0					1/0	2	1							3
Clinid 2								1/2	1			1			1		3
Stichaeidae																	
Stichaeid 1		-/1			3/0	1/0			1			3	1				5
Stichaeid 2								1/0				1					1
Pholidae																	
Pholid 1								1/0				1					1
Ammodytidae																	
Ammodytes hexapterus								7/0	4			2			1		7

TABLE 1. (Continued)

Taxa	March 23, 24	May 16, 17	June 8, 9	Aug. 2, 3	Sept. 12, 13	Oct. 18, 19	Dec. 12, 13	Feb. 8, 9	LL 1	LL 2	HL 1	HL 2	LH 1	LH 2	HH 1	HH 2	Total
Gobiidae Clevelandia ios					0/3	0/4	0/25		1	3		1	3		23	1	32
Ilypnus gilberti					0/3								3				3
Gobiid 1	-/2,412	-/1,193	257/34	922/1,260	1,553/895	2,180/2,055	548/299	331/248	4,781	2,975	1,097	706	1,772	1,345	1,274	237	14,187
Stromateidae																	
Peprilus simillimus						1/0									1		1
Scorpaenidae																	
Sebastes spp.				1/0		4/1	14/6	20/1	10	12	9	7	2		5	2	47
Hexagrammidae																	
Ophiodon elongatus								7/0	4	1		2					7
Cottidae																	
Scorpaenichthys marmoratus								4/0	1	1						2	4
Leptocottus armatus	-/21				0/1	1/0	38/14	40/6	46	16	25	5	7	5	13	4	121
Oligocottus maculosus	-/2						4/0	2/0	1		1	4	2				8
Oligocottus snyderi						1/0			1								1
Cottid 1						0/1									1		1
Cottid 2							2/1					1	2				3
Cottid 3								2/1	1	1		1					3
Bothidae																	
Paralichthys californicus						11/0			10	1							11
Citharichthys spp.				0/1	7/1	6/6		0/1	6	1	2		6	1	5	1	22
Pleuronectidae																	
Lyopsetta exilis								1/0				1					1
Parophrys vetulus								1/0	1								1
Hypsopsetta guttulata			1/0	6/13	5/3	24/17		1/0	36	5	2	3	4	12	10	8	80
Platichthys stellatus	-/5			0/2						1	1		2	1		2	7
Psettichthys melanostictus								38/5	6	10		3	23		1		43
Total									8,228	11,269	1,910	2,015	2,077	1,484	10,763	490	38,236

guttulata were higher. Larval catches in number of larvae/m³ correlated directly with the Gobiidae and *Engraulis mordax*. Catches of December's and February's samplings were comprised mostly of *Clupea harengus pallasi* and the highest numbers were caught duiing HH_1 stage. The greatest number of species (14 taxa) occurred on the LL_1 stage in February.

TABLE 2. Summary of Number of Larvae, Percentage of Total Catch, and Catch in Number of Larvae/m³ According to Tide Stage

	Ebb				Flood			
	LL_1	LL_2	HL_1	HL_2	LH_1	LH_2	HH_1	HH_2
No. of Larvae	8,828	11,269	1,910	2,015	2,077	1,484	10,763	490
Percent of Catch	21.5	29.5	5.0	5.3	5.4	3.9	28.1	1.3
No./m³	6.109	11.262	1.761	1.458	5.030	1.479	9.926	.439

An examination of the results for the entire year according to half-tide stages (Table 2) demonstrates that both highest numbers of larvae captured and the highest density of larvae took place in LL_2, HH_1 and LL_1, respectively. Combin-

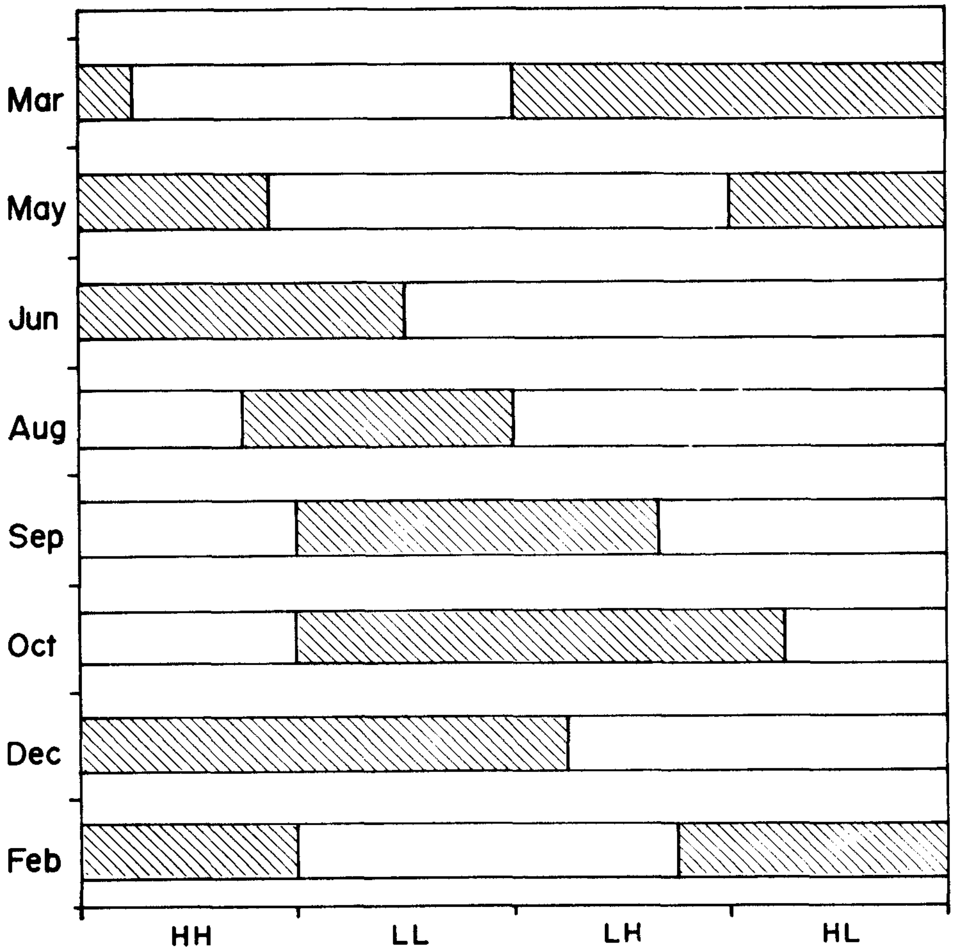

FIGURE 7. Relative amount of day and night conditions according to tide stage and individual 24-hr sampling. Hash marked portions represent night.

ing the catches of the two halves of each tide stage, 51% of all larvae were taken at the LL tide stage. These results indicate that larval densities were highest during the periods of high current, either HH flood or LL ebb.

In six of the eight 24-hr samplings in which accurate density measurements could be compared, much greater larval densities occurred during night conditions than in daylight (Table 3). The LL stage usually occurred at night (Figure 7). Two exceptions to these concurrences were March and June's samplings. Low low tide (LL) happened during daylight hours in March, and one-half of June's LL tide occurred during daylight. Interestingly enough, the only times when there were greater larval fish catches during the day were in March and June. This suggests that larval densities were related to current velocities. There is also a demonstrated positive relation between density and night condition.

TABLE 3. Comparison of Larval Fish Catches (Number of Larvae/m³ at Night Versus Day)

	March	*May*	*June*	*August*	*Sept.*	*Oct.*	*Dec.*	*Feb.*	*Overall Average*
Day	3.1517	–	0.791	0.4889	4.0960	0.5393	1.1098	–	1.4612
Night	2.2138	–	0.6315	3.4370	7.330	13.7850	10.9410	–	7.2566

Conclusions about seasonal distribution of eggs and larvae must be considered preliminary and generalized due to the infrequency of sampling with only two samples per season. The number of species was greater in the winter samples. Winter sampling times were characterized by periods of high fresh-water inflow and precipitation, low water temperatures, low salinities, and high dissolved oxygen concentrations. The catch also was highest in winter during the periods with the greatest tide range.

Spatial Distribution

Only limited conclusions can be drawn about spatial distribution because of infrequent sampling and because Station 2 only was fished in the March and May studies. In the six paired studies, more species were collected at Station 1, near the entrance of the bay. Higher catches of specific fishes occurred as follows:

i. In June more *Citharicthys* spp., and *Hypsopsetta guttulata* were found at Station 1.
ii. In September, both the catch and the number of species were higher at Station 1.
iii. October and February's studies showed higher catches of *Sebastes* spp., and *Scorpaenichthys marmoratus* at Station 1.

Individual Species

Clupea harengus pallasi—Adult *C. h. pallasi* historically have entered San Francisco Bay for spawning from November through March, and they spawn on the rocky shorelines near the entrance to Richardson Bay (Eldridge and Kaille 1973). I have noted the demersally spawned eggs on vegetation in upstream portions of the bay as well, but these spawnings were minor in both density and area of spawn. Catches of larvae occurred only during winter months (March, December, and February) and were correlated with the lowest temperatures recorded in all 24-hr samplings. The highest numbers of *C. h. pallasi* were caught on HH_1 (Table 1), indicating that the larvae were carried in on flood tides from areas outside or adjacent to Richardson Bay.

Engraulis mordax—Pelagic eggs of *E. mordax* have been collected every month of the year in the California current (Frey 1971) with peaks of abundance in late winter and early spring and another minor peak in early fall. Adult *E. mordax* normally are found in San Francisco Bay in greatest abundance from midsummer through early fall. Larvae were netted in samplings from August through March. The highest density occurred in December. The majority (91%) of larvae were captured at Station 1, suggesting that the main spawning occurred outside or near the entrance to Richardson Bay.

Gobiidae—A minimum of seven gobiid species have been known to inhabit San Francisco Bay (Aplin 1967; Ruth 1969; U.S. Fish and Wildlife Service 1970; Green 1975). There was difficulty in identifying this study's gobiid larvae because of a limited number of larval descriptions and the overlap of larval characters. Although most of the goby larvae could not be identified with certainty to species, the majority were very likely *Clevelandia ios,* the most commonly found goby in Richardson Bay.

Gobiid larvae comprised the only taxon found in all eight studies. They were also evenly distributed between the two stations (52% of all gobiid larvae were from Station 1). Over half (54%) of all Gobiidae were caught on LL ebb tide.

Others—Both *Syngnathus leptorhynchus* and *Leptocottus armatus* are common, year-round residents of San Francisco Bay. Both species of larvae were caught in the LL ebb currents (85% and 78%, respectively). There have been eight species of adult *Sebastes* caught in San Francisco Bay (Ruth 1969). Their larval presence in Richardson Bay was seasonal (all but one in October, December, and February) and they evidently entered the small bay from outside; 83% of all *Sebastes* larvae were from Station 1.

Three fishes (*Cynoscion nobilis, Hypsopsetta guttulata, Psettichthys melanostictus*), which most likely spawn pelagic eggs outside San Francisco Bay, were netted in fair numbers (Table 1) in Richardson Bay. *Cynoscion nobilis* and *Psettichthys melanostictus* were caught principally at Station 1 (72% and 88%, respectively) while *Hypsopsetta guttulata* appeared more generally dispersed between the two stations. In no San Francisco Bay surveys, to my knowledge, have sexually ripe adults of these three species been found.

DISCUSSION

From the catches of all larvae and individual species, and from plankton volumes and numbers of species, it appears that the single most influential factor determining the density of fish larvae was tidal current. The highest larval densities occurred when tidal currents were the fastest; that is, on LL ebb and HH flood (Table 2). The fact that larval fish catches were markedly higher at night would appear to conflict with the tidal factor until one realizes the concurrence of strong LL ebb currents and night conditions. It is altogether likely and probable that light is a factor affecting distribution of larval fishes. Lewis and Wilkins (1971) found occurrences of three estuarine fishes (*Leiostomus xanthurus, Brevoortia tyranus,* and *Logodon rhomboides*) had highly significant relations with the amount of light and tidal currents. Results of this study, however, indicate that between tidal and light factors tidal influence is more determinant with regard to distribution of fish eggs and larvae.

Associations of larvae with various physico-chemical parameters were found to correspond with variables which characterized either an upstream water mass being carried out with ebb tide or outside marine water entering with flood tide. For instance, May's flood tide water was associated with high salinity, low temperature, and high amounts of stratification detected in vertical profiles. In winter, December's lower salinity and temperature values occurred on ebbing tides. This resulted from heavy runoff from local rains and low air temperatures.

An interesting correlation which arose was a highly significant ($P = < .01$) negative correlation between the number of species and the coastal upwelling index. The indices used in this comparison are those described by Bakun (1973). A negative upwelling index signifies downwelling of surface water at the coast and a net shoreward movement of surface water. Coastal upwelling values were obtained from NMFS, Pacific Environmental Group (Monterey, California) and averaged for the 2-week periods prior to each study date. The types of larvae which were associated with negative upwelling indices are those which were most likely spawned offshore or, at least outside the entrance to San Francisco Bay. They were: *Cynoscion nobilis, Sebastes* spp., *Paralichthys californicus, Citharichthys* spp., *Lyopsetta exilis, Parophrys vetulus, Hypsopsetta guttulata* (weakly associated), *Platichthys stellatus,* and *Psettichthys melanostictus.* Four of these species were caught in such small numbers, it is most likely their presence is a fortuitous occurrence. This is especially true for *Peprillus simillimus* whose population centers off southern California (Hart 1973).

Although there have been few larval fish studies along the estuaries and coastal areas of the U.S. Pacific coast, two surveys (Eldridge and Bryan 1972; Pearcy and Myers 1974) compare well with this study in terms of species composition and catch (Table 4). *Clupea harengus pallasi,* gobiid and cottid species appeared abundant in all three locations, and *Cottidae* was the most speciose family. *Engraulis mordax* is the single most abundant adult fish both in biomass and individual numbers in San Francisco Bay (Aplin 1967). The pelagic eggs and larvae were evidently not a major constituent of the ichthyoplankton in the other, more northern bays.

TABLE 4. Results of Three Larval Fish Studies in Estuaries of the Pacific North Coast Area of the United States

	Number taxa	*Number families*	*Most speciose family*	*Three most abundant taxa*
Richardson Bay, California (Eldridge 1977)	39	20	Cottidae	*Clupea harengus pallasi* *Engraulis mordax* *Gobiidae*
Humboldt Bay, California (Eldridge and Bryan 1972)	37	17	Cottidae	*Lepidogobius lepidus* *Clupea harengus pallasi* *Leptocottus armatus*
Yaquina Bay, Oregon (Pearcy and Myers 1974)	45	17	Cottidae	*Clupea harengus pallasi* *Lepidogobius lepidus* *Cottus asper*

The limited scope of this particular study in space and time does not permit any conclusions regarding the degree or extent of dependence on the estuary by fishes. Results show that at least 39 different fish taxa including many species with offshore dwelling adult stages, were present in the bay. Among the three most abundant larval types, *C. h. pallasi* and *E. mordax* spawned in or near Richardson Bay and represent commercially fished species. Pearcy and Myers

(1974) concluded that although Yaquina Bay was an important nursery for the young of several marine fish species, their larval fish survey showed only *C. h. pallasi* to be abundant. This study's results differed principally in the relative abundance of *E. mordax*. An extensive survey conducted in oceanic areas adjacent to San Francisco Bay and simultaneous sampling inside the bay would establish whether the center of the anchovy population was located in the bay or outside.

ACKNOWLEDGMENTS

Each 24-hr study required a minimum of six persons. The working conditions were often uncomfortable, the hours long, and the weather inclement.

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