ABUNDANCE OF SOUTHERN CALIFORNIA NEARSHORE ICHTHYOPLANKTON: 1978-1984

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ABSTRACT

More than 150 ichthyoplankton taxa were collected in the nearshore zone of the Southern California Bight between 1978 and 1984. Aspects of the abundance patterns of six taxa of sport and commercial value in the nearshore zone are presented: northern anchovy (*Engraulis mordax*), which constituted 67% of total larvae; white croaker (*Genyonemus lineatus*), 6.6%; Pacific sardine (*Sardinops sagax*), 5.9%; queenfish (*Seriphus politus*), 2.1%; California halibut (*Paralichthys californicus*), 1.0%; and sea basses (*Paralabrax* spp.), 0.6%.

Greatest abundances of northern anchovy larvae occurred along the 75-m isobath, whereas larvae of the other fishes occurred chiefly from 36-m shoreward. Northern anchovy, white croaker, and California halibut spawned all year, but most intensely in late winter and spring. Queenfish spawned mainly in spring and summer, Pacific sardine chiefly in late summer and fall, and sea basses of the genus *Paralabrax* only in summer. Abundance of sardine eggs and larvae increased by 2-3 orders of magnitude between 1980 and 1982.

RESUMEN

Más de 150 taxa de ictioplancton fueron colectados en la zona costera de la Bahía del Sur de California entre 1978 y 1984. Se presentan los patrones de abundancia de seis taxa de importancia recreativa y comercial: *Engraulis mordax* (anchoveta del Norte) constituyó el 67% de las larvas presente; *Genyonemus lineatus*, 6.6%; *Sardinops sagax* (sardina), 5.9%; *Seriphus politus*, 2.1%; *Paralichthys californicus* (lenguado), 1.0%; y *Paralabrax* spp., 0.6%.

Las mayores abundancias de larvas de la anchoveta del Norte fueron encontradas a 75 m de profundidad y las otras larvas a 36 m de profundidad. La anchoveta del Norte, *Genyonemus lineatus*, y *Paralichthys californicus* desovaron durante todo el año y más intensamente a fines de invierno y en primavera. *Seriphus politus* desovó principalmente en primavera y verano, la sardina a fines de verano y en otoño, y el género *Paralabrax* sólo en verano. La abundancia de huevos y larvas de sardina aumentó 2 a 3 órdenes de magnitud entre 1980 y 1982.

INTRODUCTION

Systematic sampling for fish eggs and larvae in the waters off California has been conducted by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) for more than three decades. One of the primary purposes for conducting these surveys is to draw conclusions about the abundance of adult fish populations and their distribution at the time of spawning, which can be determined from the distribution and abundance of the larval stages. Larval rather than adult stages are used because they can be sampled with less cost and fewer biases (Ahlstrom 1965, 1967).

CalCOFI surveys in the Southern California Bight have principally been conducted in offshore waters, and have emphasized distributions and abundances of offshore, commercially important fishes, e.g., northern anchovy (*Engraulis mordax*), hake (*Merluccius productus*), and jack mackerel (*Scomber japonicus*) (Ahlstrom 1965; Loeb et al. 1983). A two-year study by Gruber et al. (1982) entailed quarterly sampling of three transects from the inner shelf (<50 m) out to deep water (>1,000 m), providing a preliminary look at the abundance and seasonality of shelf species. Our surveys, begun in 1978 (Brewer et al. 1981), are coastal and bightwide in scope (Brewer and Smith 1982), and like that of Barnett et al. (1984) provide data to assess medium-to-long-term temporal and spatial patterns of fishes on the continental shelf. Some species—e.g., white croaker (*Genyonemus lineatus*) and queenfish (*Seriphus politus*)—absolutely depend on nearshore waters. Other fishes occur in both offshore and nearshore regions (e.g., northern anchovy and Pacific sardine [*Sardinops sagax*]); knowledge of the distribution, abundance, and interannual variation of their larvae in coastal waters will allow evaluation of the nearshore region as a potential area for spawning and larval survival.

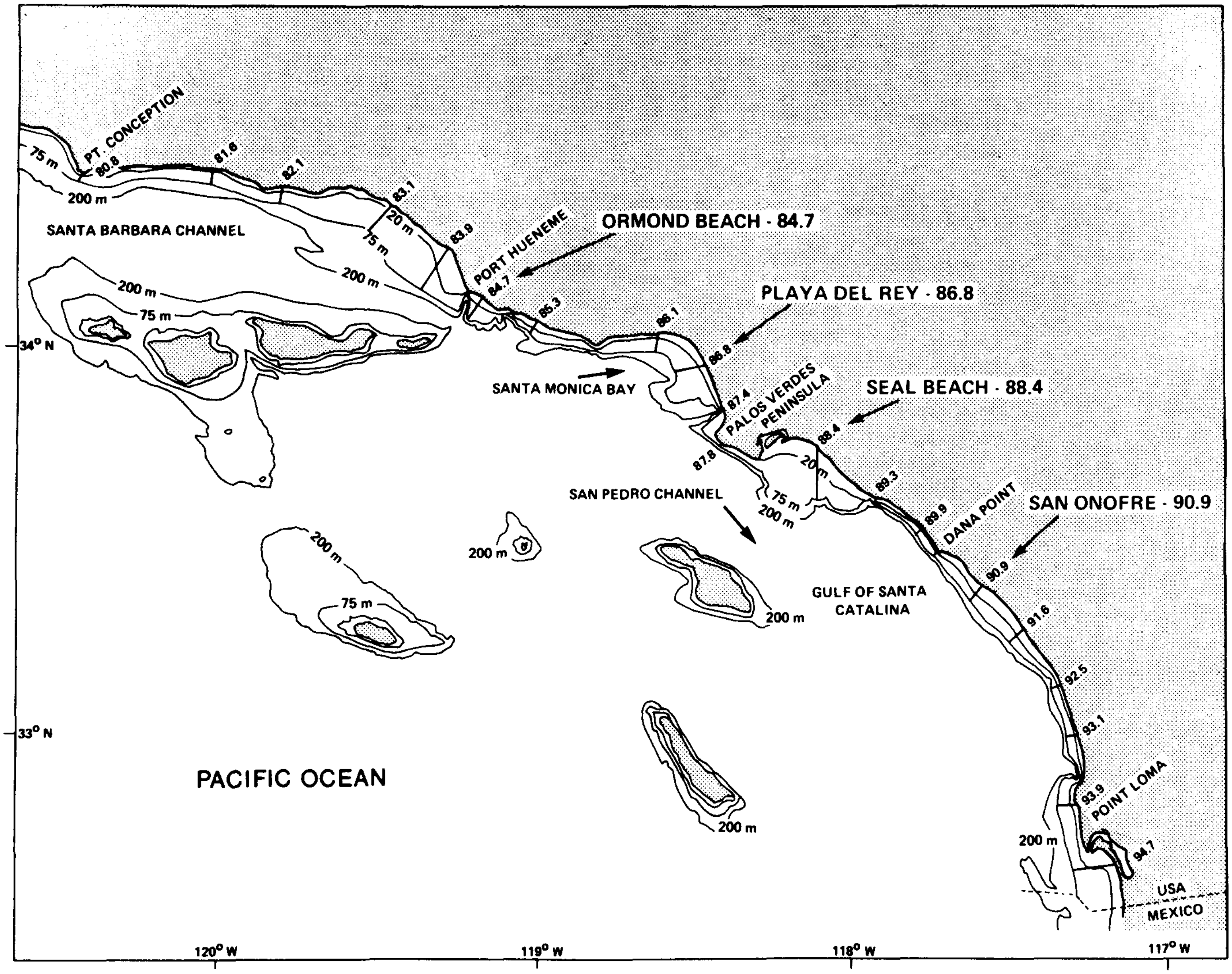

Figure 1. Location and CalCOFI line-number designations for all transects sampled between 1978 and 1984 in the Southern California Bight.

This report presents bightwide estimates of egg and larval abundance for the dominant nearshore species, northern anchovy and Pacific sardine; and larval abundance only for white croaker, queenfish, California halibut (*Paralichthys californicus*), and sea basses —which include kelp bass (*Paralabrax clathratus*), barred sand bass (*Paralabrax nebulifer*), and spotted sand bass (*Paralabrax maculatofasciatus*). Longshore and cross-shelf patterns of distribution, interannual variation, and seasonality of abundance are described. Concurrent with the egg and larval surveys, physical, nutrient, and zooplankton biomass data were collected and analyzed (Petersen et al. 1986).

METHODS

Field techniques and laboratory procedures for samples taken between June 1978 and July 1980 (cruises 1 to 26) are described by Brewer and Smith (1982). Ichthyoplankton studies in the coastal zone resumed in 1981 after a 7-month hiatus. The 1981 collections have not been worked up. Many aspects of the earlier program (1978-80) have remained unchanged, although cruises were taken every two months in 1982-84 (cruises 34 to 52), replacing the monthly sampling of 1979-80. Sampling dates and locations are presented in Figure 1 and Tables 1 and 2.

For compatibility, transect designations previously identified by numbers and letters were changed to CalCOFI line numbers, a change made retroactive to 1978 in this report. Sampling protocols are as described by Brewer and Smith (1982), except that when the *Vantuna* began collecting in 1982 the use of the instrumented trawl block and depth transducer was discontinued. All data treated here are from oblique tows of a 70-cm bongo sampler (333-μ mesh) fitted with wheels so that tows started right at the bottom (gauged by vibrations transmitted through the towing wire), a known layer of concentration of certain taxa

TABLE 1
Coordinates of Stations Occupied During 1982-1984

Transect (CalCOFI line)	Station (m)	N. Latitude	W. Longitude
Ormond Beach (84.7)	8	34°07.5′	119°16.6′
	15	34°07.0′	119°11.0′
	22	34°06.6′	119°11.7′
	36	34°06.0′	119°12.8′
	75	34°04.5′	119°11.9′
Playa del Rey (86.8)	8	33°57.0′	118°27.1′
	15	33°57.0′	118°27.9′
	22	33°56.9′	118°28.6′
	36	33°57.0′	118°30.1′
	75	33°57.2′	118°34.0′
Seal Beach (88.4)	8	33°42.4′	118°04.3′
	15	33°41.2′	118°04.8′
	22	33°39.6′	118°05.1′
	36	33°37.3′	118°05.7′
	75	33°34.8′	118°08.9′
San Onofre (90.9)	8	33°21.7′	117°33.8′
	15	33°20.9′	117°34.1′
	22	33°20.4′	117°34.7′
	36	33°19.9′	117°35.0′
	75	33°18.5′	117°35.6′

(Schlotterbeck and Connally 1982; Barnett et al. 1984). Net retrieval rates were about twice those employed from August 1979 to July 1980 (Phase II sampling as described by Brewer and Smith 1982), but replicates were not combined, i.e., the nets filtered about 6-8 m^3 of water per meter of depth. Procedures and assumptions for processing fish eggs and larvae were the same as those described by Brewer and Smith (1982), except that no aliquots were taken. Samples were 100% sorted from either the port or starboard side of the bongo plankton sampler.

Species of the genus *Paralabrax* are not separable at all stages (Butler et al. 1982) and have therefore been treated together as a single taxon. However, progress has been made in the identification of *Paralichthys californicus* larvae[1], and the abundance of this species as reported here is for the first time uncontaminated with that of the similar *Xystreurys liolepis*.

Areal Estimates

The transects sampled during this project are assumed to be representative of the coastal zone shoreward of 75 m in the Southern California Bight. Thus an estimate of the magnitude of ichthyoplankton populations in the narrow band of nearshore waters along the coast can be based on data from these transects.

[1]Carlson-Oda, D. Description of the early life history of the California halibut, *Paralichthys californicus*, with comparisons to other members of the family Bothidae. Abstract presented at CalCOFI annual conference, 1985.

TABLE 2
Dates of Collection, Cruises 1-52

Cruise no.	Month and year	Cruise no.	Month and year
Monthly programs (10 transects)		(20 transects)	
1	June 1978	15	August 1979
2	July 1978	16	September 1979
3*	August 1978	17	October 1979
4	September 1978	18	November 1979
5	October 1978	19	December 1979
6*	November 1978	20	January 1980
7	December 1978	21	February 1980
8	January 1979	22	March 1980
9*	February 1979	23	April 1980
10	March 1979	24	May 1980
11	April 1979	25	June 1980
12*	May 1979	26	July 1980
13*	June 1979		
14*	July 1979		
Bimonthly program (4 transects)			
34	February 1982 (January 30)		
35	March-May 1982 (31-11)		
36	June 1982		
37	August 1982		
38	October 1982		
39	December 1982		
40	February 1983		
41**	March 1983		
42	April 1983		
43	June 1983		
44	August 1983		
45	October 1983		
46	December 1983		
47	February 1984		
48	April 1984		
49	June 1984		
50	August 1984		
51	October 1984		
52	December 1984		

*Collections not worked up
**Nonstandard cruise

The Apple Graphics Tablet was used to determine the areas bounded by depth contours on National Ocean Survey bathymetric maps (nos. 1306N-15, -16, -19, and -20). The maps were juxtaposed, and a composite made that had 10-m intervals out to 100 m. The 75-m contour was drawn in (Figure 1). We drew the 20 sampling transects approximately perpendicular to the 75-m contour, then drew lines perpendicular from the midpoints between the intersections. The latter set of lines defined 20 blocks, centered on the transects, on which all areal determinations were based. Block 1 (CalCOFI line 80.8 off Cojo Bay) was bounded on the northwest by a line extending from Point Conception perpendicular to the 75-m contour, and block 20 (CalCOFI line 94.7 off Imperial Beach)

TABLE 3
Bightwide Estimates of Area in Square Kilometers

Transects	Depth contours (in meters) 0-10	10-20	20-30	30-40	40-50	50-60	60-75	Totals
80.8	11	19	11	11	10	13	15	90
81.6	14	18	11	13	13	26	52	147
82.1	20	16	11	11	14	33	46	150
83.1	27	30	40	73	59	42	58	329
83.9	14	69	94	34	11	9	15	246
84.7	11	25	19	16	10	8	8	97
85.3	13	18	10	12	7	13	18	91
86.1	18	26	18	21	16	21	16	136
86.8	11	16	16	15	20	37	33	148
87.4	11	13	9	8	5	6	12	64
87.8	26	22	18	12	12	5	9	104
88.4	35	75	114	54	39	28	16	361
89.3	11	17	7	5	6	7	3	56
89.9	12	10	6	9	6	10	7	60
90.9	29	37	18	12	11	15	20	142
91.6	20	31	14	12	7	9	12	105
92.5	11	14	3	7	5	6	9	55
93.1	12	12	11	6	10	7	9	67
93.9	12	17	17	3	9	16	28	102
94.7	30	65	38	38	29	22	24	246
Totals	348	550	485	371	299	333	410	2796

TABLE 4
Bightwide Estimates of Area (in km²) for Sampling Depth Strata*

Block number	Depth contours (in meters) 0-8	8-15	15-22	22-36	36-75	Totals
1	88	120	137	258	549	1152
2	31	35	36	60	185	347
3	67	79	91	163	180	580
4	91	111	108	129	278	717
Totals	277	345	372	610	1192	2796

Block 1 comprises CalCOFI lines 80.8 (Cojo, 80); 81.6 (DR); 82.1 (Goleta, 81.5); 83.1 (RN); 83.9 (Ventura, 83); 84.7 (OB); 85.3 (Trancas, 85).
Block 2 comprises CalCOFI lines 86.1 (Malibu); 86.8 (PR, 87); 87.4 (RB).
Block 3 comprises CalCOFI lines 87.8 (PV); 88.4 (SB, 88); 89.3 (Balboa); 89.9 (Laguna, 90).
Block 4 comprises CalCOFI lines 90.9 (SO); 91.6 (Pendleton, 91); 92.5 (Carlsbad); 93.1 (Del Mar, 93); 93.9 (MB); 94.7 (San Diego, 95).
*based upon data from Table 3.

was bounded on the south by the Mexican border. The 20 blocks were combined into 4 bigger blocks representative of the four transects sampled in recent years. Areal determinations for sampling depth strata were determined by linear interpolation of the raw data (Tables 3 and 4).

The 1982-84 nearshore sampling zone is considered to extend from near Point Conception to the Mexican border and seaward from shore to the 75-m contour, an area of 2,796 km^2. Although the coastal part of the Southern California Bight includes almost all of the coastal portion of CalCOFI region 7, it constitutes about 4% of its total area. The 1978-80 area, which extends seaward only to the 36-m contour, has an area of 1,604 km^2. Brewer and Smith's (1982) estimate of 2,652 km^2 for the area to the 43-m isobath was obtained by extrapolating the average seaward distance of the stations along the 8-, 15-, 22-, and 36-m isobaths. We estimate the same area to be 1,834 km^2 based upon linear interpolation of actual measurements from charts of areas to the 40- and 50-m contours.

For analysis, all species data were scaled to numbers of individuals under 10 m^2 of sea surface (Smith and Richardson 1977). Confidence intervals on mean abundance for each cruise were determined by a nonparametric method known as the bootstrap (Efron 1982), which has been shown to be a reasonable approach for these data (Jahn MS). Temporal trends of abundance are presented graphically as extrapolated "bightwide" abundances, calculated as the mean of all stations to the 36-m contour multiplied by the 0-36-m area (1,604 km^2). For the years 1982-84 the mean 75-m abundance was multiplied by the area between 36 and 75 m (1,192 km^2) to estimate a bightwide abundance for this outer-shelf band.

The presentation of alongshore pattern is incomplete in that not all data sets were statistically analyzed. Plots showing the three-dimensional (alongshore, cross-shelf, time) disposition of all species and life stages were visually examined for obvious trends. Only when these plots showed obvious differences among transects were the data subjected to further analysis. In such cases, the effects of station depth, transect, and year were tested with 3-way ANOVA using log-transformed ($\ln \{x + 1\}$) scaled (no. per 10 m^2) abundance. Only the 1982-84 data were so treated, because earlier sampling designs were nonuniform. Seasonal effects were not tested, since these were readily apparent in all graphs. The ANOVA results are supported by the original three-dimensional plots as well as by graphs of mean annual transect abundance, expressed as number per m^2.

RESULTS

Over the seven-year period more than 1,400 zooplankton collections were sorted for fish eggs and larvae. Among these we identified 152 fish taxa (80 to species; 40 to genus, family, or order; 32 to an unknown fish type), which approaches 70% of the inshore fish fauna of the Southern California Bight. One

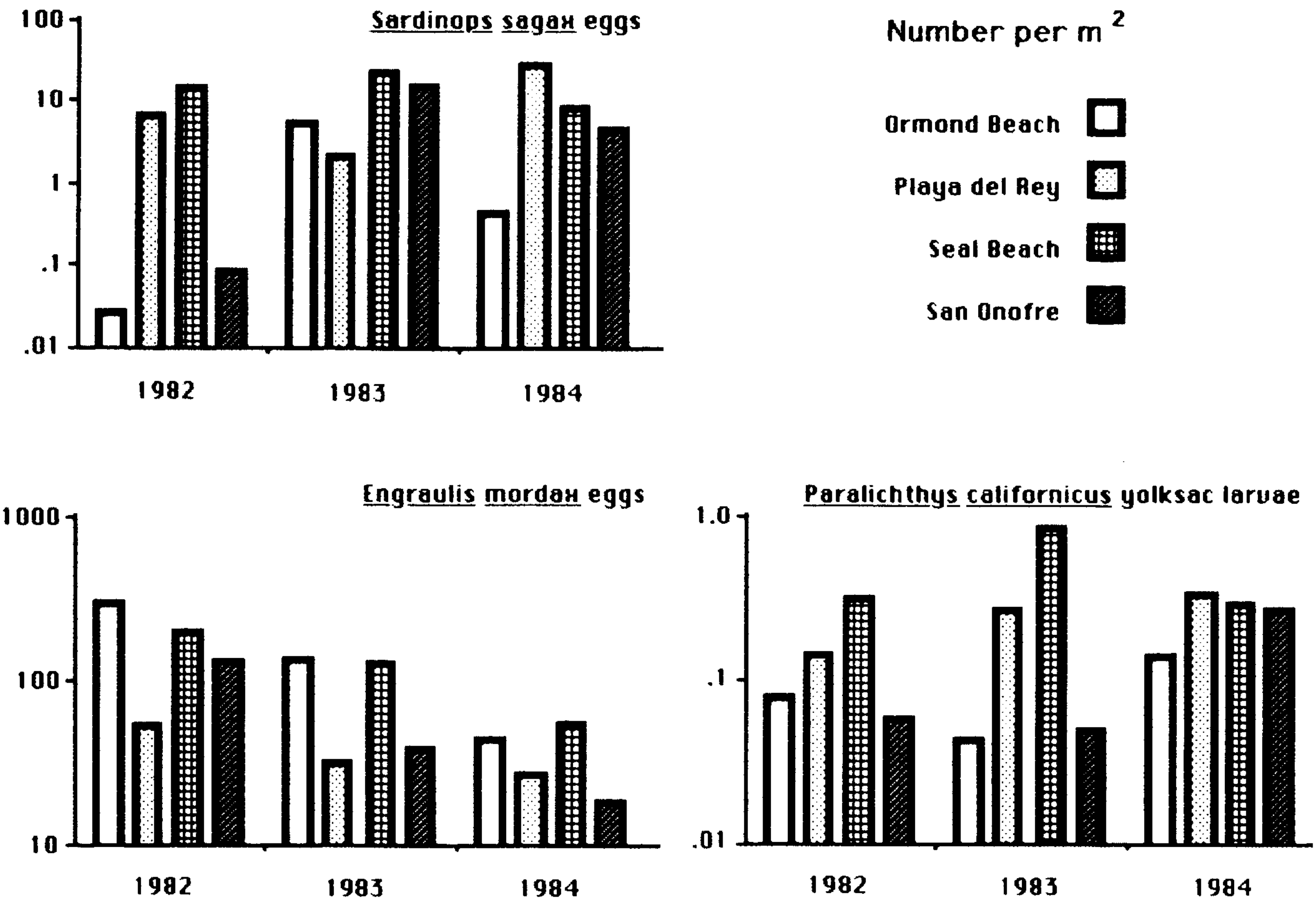

Figure 2. Mean annual transect abundance for eggs of *Sardinops sagax* and *Engraulis mordax*, and yolk-sac larvae of *Paralichthys californicus*, 1982-84.

planktivorous species that had not previously been sampled in our nearshore survey region, round herring (*Etrumeus acuminatus*), suddenly appeared in the samples in August 1983. Round herring larvae occurred in Santa Monica Bay and off Seal Beach in densities approaching 10 per m^2. There was also an unusually high number of unidentified larval types collected in 1983. Although the number of unidentified types subsided in 1984, *Etrumeus* larvae were noted again from June through October at the same locations and in about the same abundance as in 1983.

Northern anchovy always ranked first in abundance, and—except for 1984—white croaker was second. In 1978-79 sardine was not among the 15 most abundant taxa, but increased to third in 1982. Sardine remained third in 1983 before becoming the second most abundant taxon in 1984, replacing white croaker. Queenfish was steadily surpassed by other species, dropping from third most abundant in 1978-79 to fifth in 1984. Halibut consistently had a rank between fifth and seventh, while sea bass ranked between eighth and eleventh. In the following sections these six important species are discussed in some detail.

As stated above, we visually inspected abundance plots of all species and life stages for indications of differences among transects. In most cases, there were no apparently nonrandom differences in abundance among transects. Exceptions were early stages of three species—eggs of sardine, eggs and yolk-sac larvae of anchovy, and yolk-sac larvae of halibut. Eggs of sardine and anchovy, and yolk-sac larvae of halibut were therefore tested and found to show statistically significant depth (station location) and transect or years × transect "effects" (Table 5). These are discussed below in the species accounts. Mean yearly transect abundance (Figure 2) supports our initial impression that spawning of these three species tends to be above average at Seal Beach, and spawning of anchovy is above average at Ormond Beach.

In the species accounts, the mean abundance of larvae for each cruise is scaled up to the area of nearshore habitat with the implicit assumption that the mean abundance at the sampled locations is representative of the Southern California Bight's entire nearshore zone. The validity of this assumption is presently under scrutiny, and no defense for it is offered here.

TABLE 5
Results of Three-Way ANOVAs

	Factor						
	Depth (D)	Year (Y)	Transect (T)	D × Y	D × T	Y × T	D × Y × T
Sardine eggs	***	—	—	NS	NS	*	NS
Anchovy eggs	*	—	—	NS	NS	*	NS
Halibut yolk-sac larvae	***	NS	***	NS	NS	NS	NS

NS Not significant at $P = .05$; * $P < .05$; *** $P < .001$; -*f*-ratio not tested because of significant first-order interaction effect involving this factor.

However, given that the 20 to 46 collections from each cruise can serve as a random sample to estimate the bightwide population mean, the precision of such estimates can be easily addressed. The bootstrapped confidence intervals (Table 6) suggest that the estimated populations could be low by a factor of 1/2 or high by a factor of generally 2 to 5, depending on abundance.

Sardinops sagax

Pacific sardine (*Sardinops sagax*) dramatically increased in numbers in the bight between 1980 and 1982 (Figure 3). The expansion of the sardine population may have begun in 1981, but no data are available from that year. The order-of-magnitude increases of sardine larvae in the spring and fall of 1982 compared to 1979-80 signal the presence of many spawning adults. Between 1982 and 1984 sardine were seasonal spawners in the bight, eggs and larvae being most abundant in summer-fall. After the 1982 expansion, annual abundance of larval sardine remained relatively constant (Figure 3).

Abundances and average densities of sardine eggs were low off Ormond Beach in the north and San Onofre in the south, particularly in 1982 (Figures 2 and 4). High numbers of eggs were consistently recorded off Seal Beach, where they were taken in all of our samples, except for February 1984. In 1982 and 1983 sardine spawning appears to have been concentrated at the Seal Beach transect (Figure 2), and closer inshore than offshore (Figure 4). The significant year-by-transect interaction (Table 5) for sardine egg densities

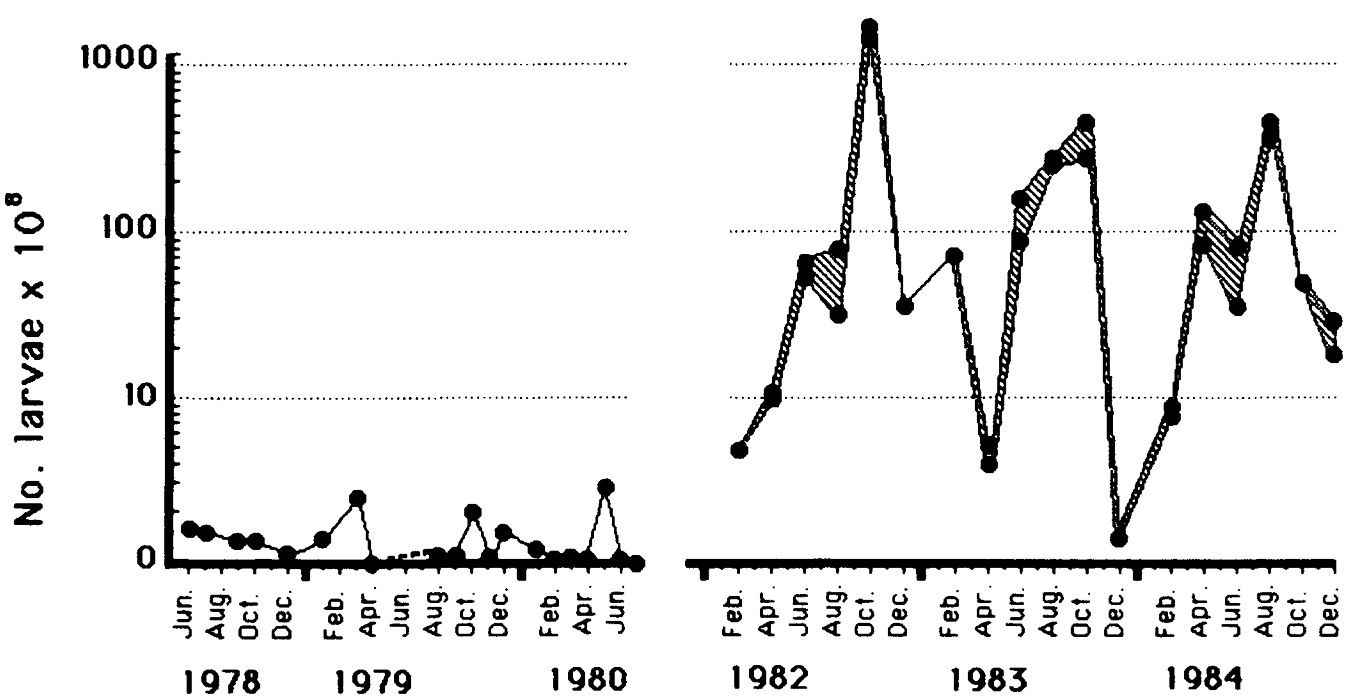

Figure 3. Estimated abundance of Pacific sardine (*Sardinops sagax*) larvae in the Southern California Bight between the shore and the 36-m contour (1978-80 data, and lower line of 1982-84 data). Hatched area represents abundance between the 36- and 75-m contour (1982-84 only). There are no data for 1981.

TABLE 6
Means with Confidence Limits of 2.5 and 97.5 Percentage Points of Bootstrapped Means, no./10m², Based on 1,000 Runs

Cruise		*Sardinops sagax*		*Engraulis mordax*		*Paralabrax* spp.		*Genyonemus lineatus*		*Seriphus politus*		*Paralichthys californicus*	
		Mean	2.5-97.5%	Mean	2.5-97.5%	Mean	2.5-97.5%	Mean	2.5-97.5%	Mean	2.5-97.5%	Mean	2.5-97.5%
1	1978	1.0	.2-2.1	246	143-381	.7	.01-1.5	.1	.01-.2	34	16-58	(Cruises 1-33:	
2		.6	.01-1.7	92	52-143	2.6	.4-5.6	.1	.01-.3	89	45-143	data not	
4		.4	.1-.9	123	71-188	22	12-34	23	7-43	41	20-70	available)	
5		.4	.1-.9	164	73-303	.6	.18-1.0	44	12-89	2.2	.7-4.1		
7		.1	.01-.4	310	185-465	.1	.01-.2	75	46-109	0	-		
8	1979	.4	.1-.9	254	176-336	0	-	165	69-280	0	-		
10		1.6	.3-3.4	663	406-987	0	-	358	190-555	2.7	1.2-4.7		
11		0	-	832	375-1438	0	-	27	15-43	22	5-50		
15		1.7	.4-3.9	137	90-193	29	16-45	.1	-	27	18-39		
16		2.8	1.4-4.7	134	77-213	2.4	1.1-4.2	4.4	1.7-7.9	29	17-44		
17		14	5-28	29	19-43	0	-	9.7	5.7-14.2	.6	.3-1.3		
18		1.8	.7-3.0	14	5-25	0	-	17	7-29	0	-		
19		4.0	1.3-7.2	63	35-97	0	-	156	76-267	0	-		
20	1980	2.4	1.1-4.2	511	274-784	0	-	324	178-490	0	-		
21		.3	.1-.6	722	460-1029	0	-	182	110-273	.3	.1-.6		
22		1.0	.4-1.8	1378	1013-1778	0	-	991	603-1431	70	38-108		
23		1.1	.2-2.4	368	271-481	0	-	290	171-443	43	27-61		
24		16	1-46	172	100-264	.2	.01-.5	46.6	10-103	30	19-46		
25		.4	.1-.9	62	36-96	0	-	3.2	.9-6.3	19	9-31		
26		0	-	16	10-23	0	-	.3	.1-.7	25	14-37		
34	1982	2.4	.1-5.8	2900	1870-4100	0	-	269	159-396	.4	.01-1.1	12	7-18.1
35		4.0	1.6-7.0	2065	1490-2730	1.2	.1-3.2	211	84-361	229	42-477	30.0	12-54
36		28	7-60	668	307-1131	27	16-40	5.2	2.1-8.9	58	22-106	8.7	1.4-18.5
37		24	9-45	322	202-459	23	4-51	1.5	.2-3.1	8.2	3.7-14.7	3.5	1.3-6.5
38		381	115-725	307	195-439	0	-	43	22-66	.8	.2-1.9	15	6-28
39		19	3-45	50	24-81	0	-	136	17-293	0	-	5.9	2.1-11.2
40	1983	36	2-83	1754	670-2920	0	-	346	143-633	23	4-48	54	24-95
42		3.5	1.0-7.1	2242	1280-3360	.2	.01-.5	58	24-102	4.6	1.6-8.0	4.8	1.8-8.6
43		54	11-113	130	82-193	28	13-45	4.8	.3-11.7	40	14-73	2.2	.6-4.1
44		125	65-201	55	23-102	9.7	3.2-16.9	.1	.01-.4	1.9	.4-3.7	3.7	1.7-6.0
45		168	67-300	127	57-207	0	-	.1	.01-.5	2.6	.8-5.2	3.2	.3-7.4
46		.7	.01-1.5	301	182-437	0	-	29	9-54	0	-	3.8	.4-9.0
47	1984	4.0	1.2-7.2	1514	580-2830	0	-	71	42-106	.9	.01-2.1	17	11-25
48		52	17-97	1625	870-2510	.3	.01-.9	47	28-71	32	18-50	26	10-49
49		30	9-58	130	73-190	6.0	2.3-10	.2	.01-.7	31	16-52	2.6	1.0-4.5
50		211	78-383	114	66-173	39	22-56	1.9	.1-4.8	30	9-58	4.6	1.7-8.2
51		26	6-59	58	26-96	.7	.01-.9	4.6	.4-9.1	.7	.01-1.6	2.1	.1-5.6
52		8.2	2.8-14.7	185	45-404	0	-	142	71-224	0	-	2.6	.3-6.0

can be seen in Figure 2. Spawning was greatest in Santa Monica Bay during 1984 but reached maxima at Seal Beach and San Onofre in 1983.

Sardine larvae occurred in nearshore rather than offshore waters (Figure 3). Sardine appeared to spawn onshore, for their eggs were found inside of 75 m. There was a significant effect of station depth upon egg density during 1982-84 (Table 5). During this 3-year period, average density of eggs at the 75-m station was 12.7 eggs per m^2, but it increased to 195.3 per m^2 at the 8-m isobath.

Engraulis mordax

Northern anchovy (*Engraulis mordax*) larvae were present year-round in the bight, and showed a consistent winter-spring pattern of high abundance (Figure 5). The significant year-by-transect interaction (Table 5) is probably due to the unusually intense spawning off San Onofre in April 1982 (Figure 6). Of the four transects, San Onofre in the south had the lowest mean annual abundances through time, followed closely by Playa del Rey (Figures 2 and 6). Anchovy yolk-sac larvae showed a bightwide pattern similar to that described for the eggs: high at Ormond Beach and low at Playa del Rey and San Onofre. There was no indication of longshore pattern after yolk-sac absorption.

Abundances of larval northern anchovy increased with depth. Brewer and Smith (1982) demonstrated that the number of northern anchovy larvae increased linearly with increasing depth to 36 m. Our data show a substantial contribution to the total larvae seaward of the 36-m contour (Figure 5), in keeping with earlier observations.

Although mean annual anchovy egg abundance at the four transects declined steadily from 1982 to 1984 (Figure 2), the peak annual abundance of larvae in the nearshore waters of the bight has been relatively constant from 1978 through 1984 (Figure 5).

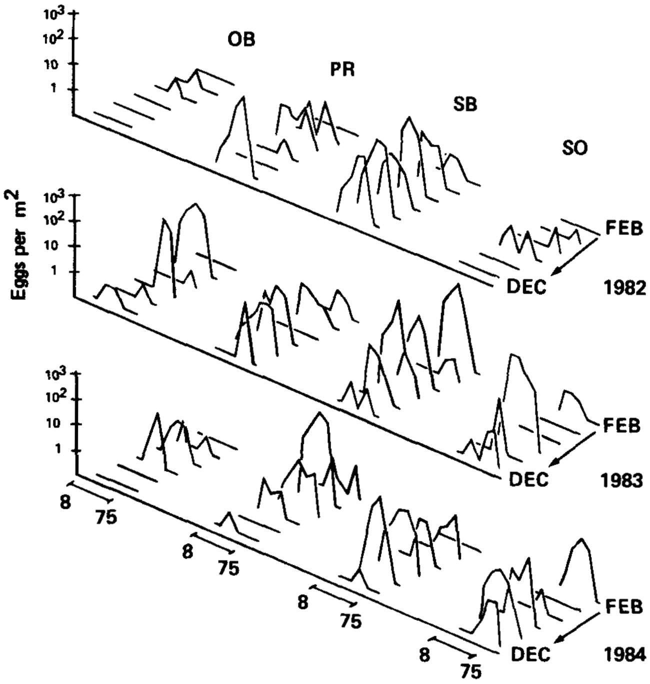

Figure 4. Density of Pacific sardine eggs at Ormond Beach (OB: transect 84.7), Playa del Rey (PR: transect 86.8), Seal Beach (SB: transect 88.4), and San Onofre (SO: transect 90.9), 1982-84. Each graph shows a year of bimonthly sampling at all four transects, with density at 8, 15, 22, 36, and 75 m plotted left to right. For continuity, each individual plot begins and ends on the baseline, but zero density at 8 and 75 m is always represented by a short segment parallel to the baseline; e.g., February through August 1984 75-m densities at San Onofre were zero, but the October and December values were not *(lower right)*.

Paralabrax *spp.*

Larvae of sea basses (*Paralabrax* spp.) were the most seasonal among the six taxa discussed here. The major spawning effort of sea bass began in early summer and peaked in August (Figure 7). During the period of peak abundance, larval *Paralabrax* were found throughout the bight. Smith and Young (1966) found that *P. clathratus* began to mature in April and had ripe eggs and sperm from June through September. Little or no spawning was detected in June and July 1980, when exceptionally cool temperatures prevailed (Petersen et al. 1986). *Paralabrax* spawns mostly inside the 36-m contour (Figure 7).

Genyonemus lineatus

White croaker (*Genyonemus lineatus*) larvae, like northern anchovy, were present year-round but most abundant in winter-spring (Figure 8). Spawning centered on March agrees with data on gonad maturation (Love et al. 1984). Love et al. (unpublished) show a strong correlation between the numbers of larvae and the numbers of trawl-caught adults in this species. The small contribution of the 75-m stations to total larvae is consistent with the general pattern of nearshore spawning in white croaker (Barnett et al. 1984; Love et al. 1984).

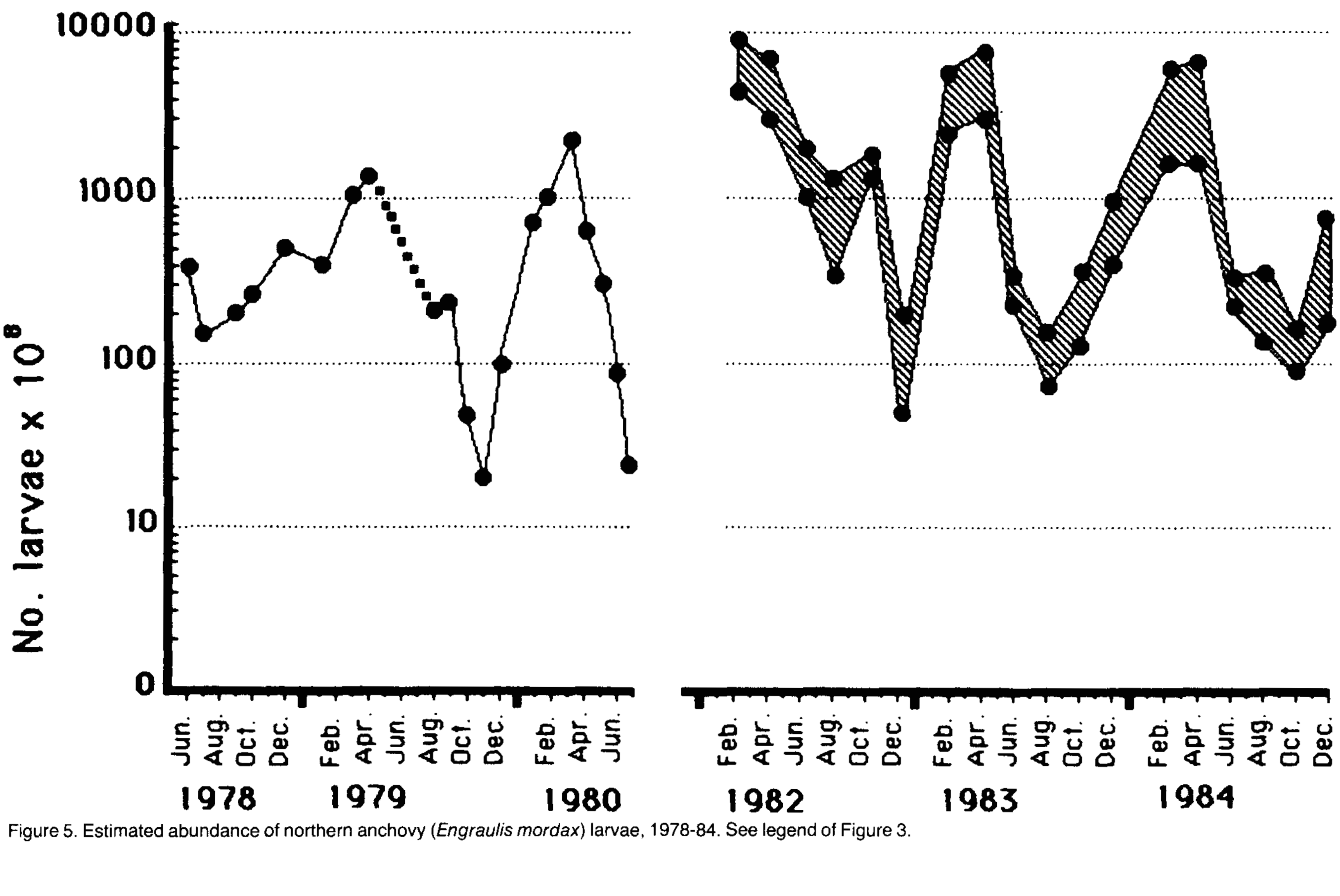

Figure 5. Estimated abundance of northern anchovy (*Engraulis mordax*) larvae, 1978-84. See legend of Figure 3.

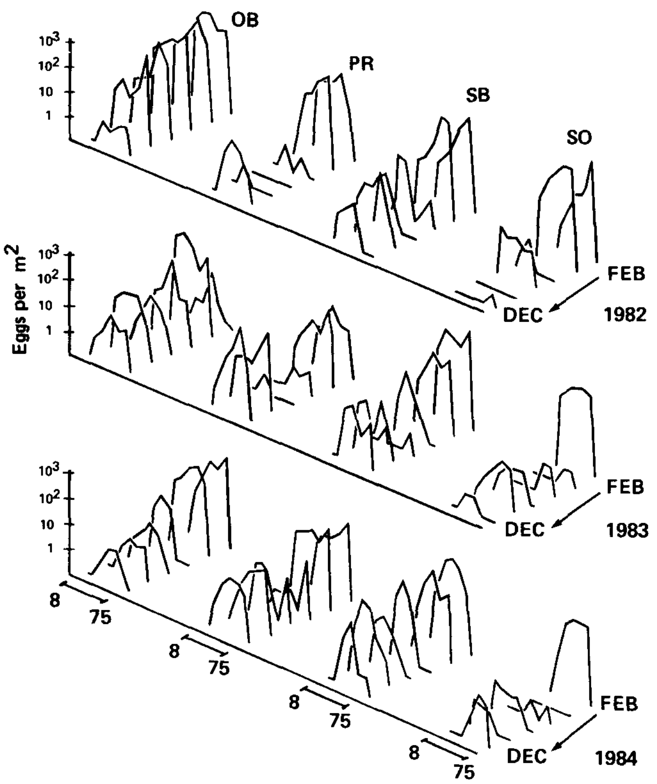

Figure 6. Density of northern anchovy (*Engraulis mordax*) eggs, 1982-84. See legend of Figure 4.

Seriphus politus

Queenfish (*Seriphus politus*) larvae were abundant mainly in spring-summer (Figure 9). Annual abundance was quite similar in all six spawning seasons represented here, the peak in April 1982 being mostly due to high abundance at a single transect (Ormond Beach). Although queenfish spawn during nocturnal seaward migrations (DeMartini et al. 1985), their larvae were distributed about as near shore as any (Figure 9; see also Barnett et al. 1984).

Paralichthys californicus

California halibut (*Paralichthys californicus*) larvae were found year-round in the bight, showing a consistent winter-spring pattern of high abundance (Figure 10). Halibut spawning appeared to be concentrated in the central bight at Seal Beach, especially in 1983 when larval abundance at the other transects was particularly low (Figures 2 and 11). The summer minimum of spawning effort was apparent throughout the bight. *P. californicus* spawns mainly inshore of the 75-m contour, as evidenced by the highly significant (Table 5) station-depth effect on distribution of yolk-sac larvae (Figure 11) and the low contribution of larval abundance at 75-m to the total (Figure 10).

DISCUSSION

Five taxa (*Sardinops*, *Paralabrax*, *Genyonemus*, *Seriphus*, *Paralichthys*) predominantly occurred inside 36 m, and only one offshore beyond 36 m (*Engraulis*). Though longshore pattern was not a strong feature of these data, there were indications that Seal Beach was a somewhat special place. The 1982 resurgence of sardine was centered at the Seal Beach transect; anchovy spawning was consistently intense there; and the contracted spawning of halibut in 1983

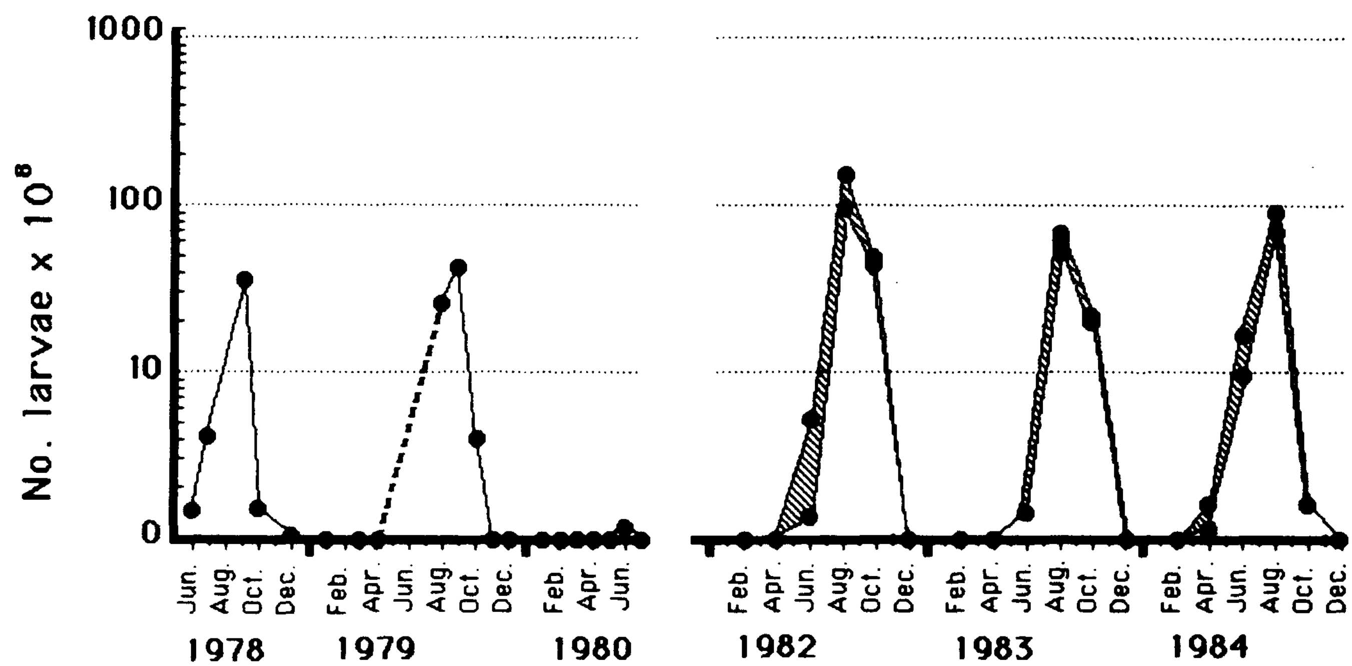

Figure 7. Estimated abundance of sea basses (*Paralabrax* spp.) larvae, 1978-84. See legend of Figure 3.

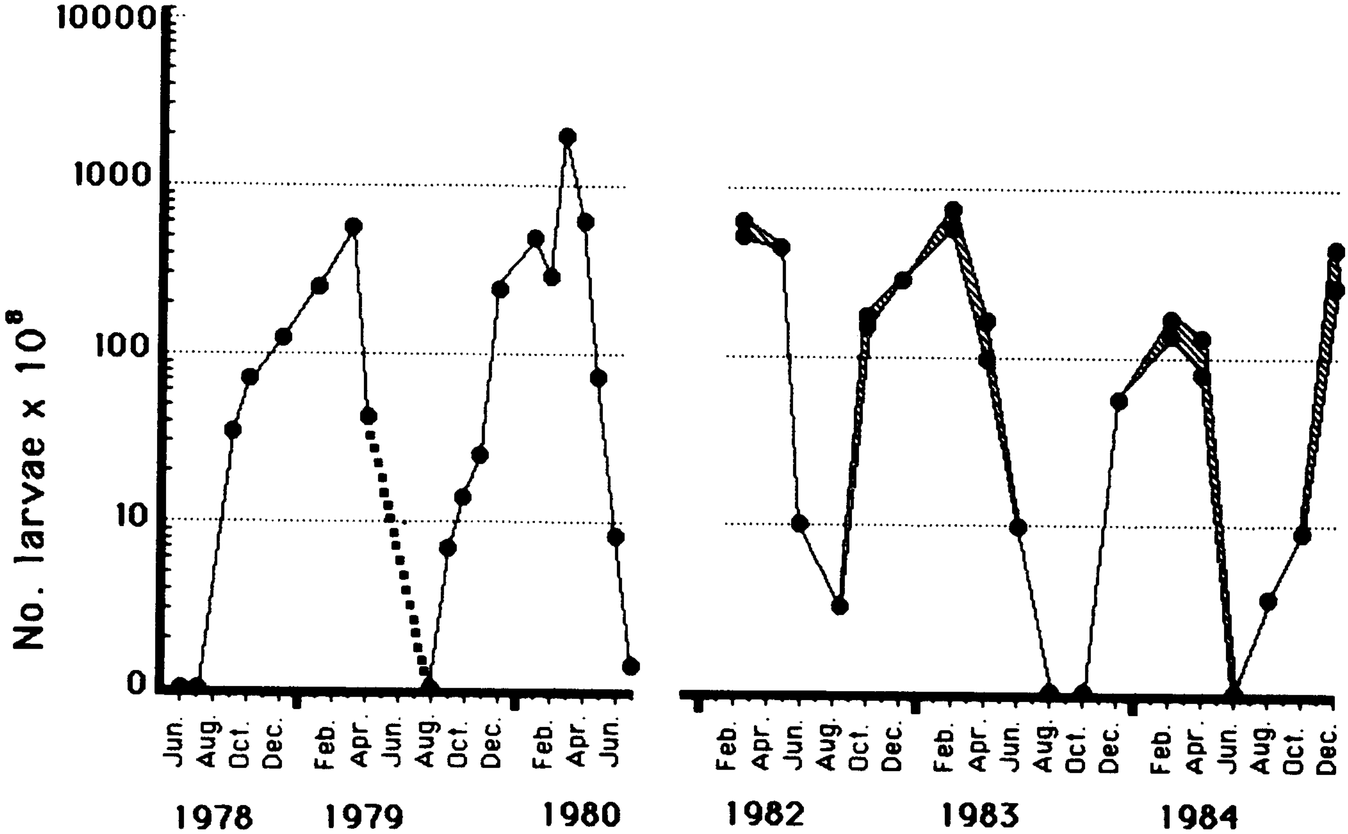

Figure 8. Estimated abundance of white croaker (*Genyonemus lineatus*) larvae, 1978-84. See legend of Figure 3.

was concentrated in this area, in the lee of the Palos Verdes Peninsula. Although northern anchovy is a wide-ranging, common, planktivorous fish that spawns extensively in the bight, its effort in the south off San Onofre is poor. Barnett et al. (1984) remarked on the low abundances of *E. mordax* eggs off San Onofre, concluding that the large number of excess larvae must come from outside the sampling area. Our

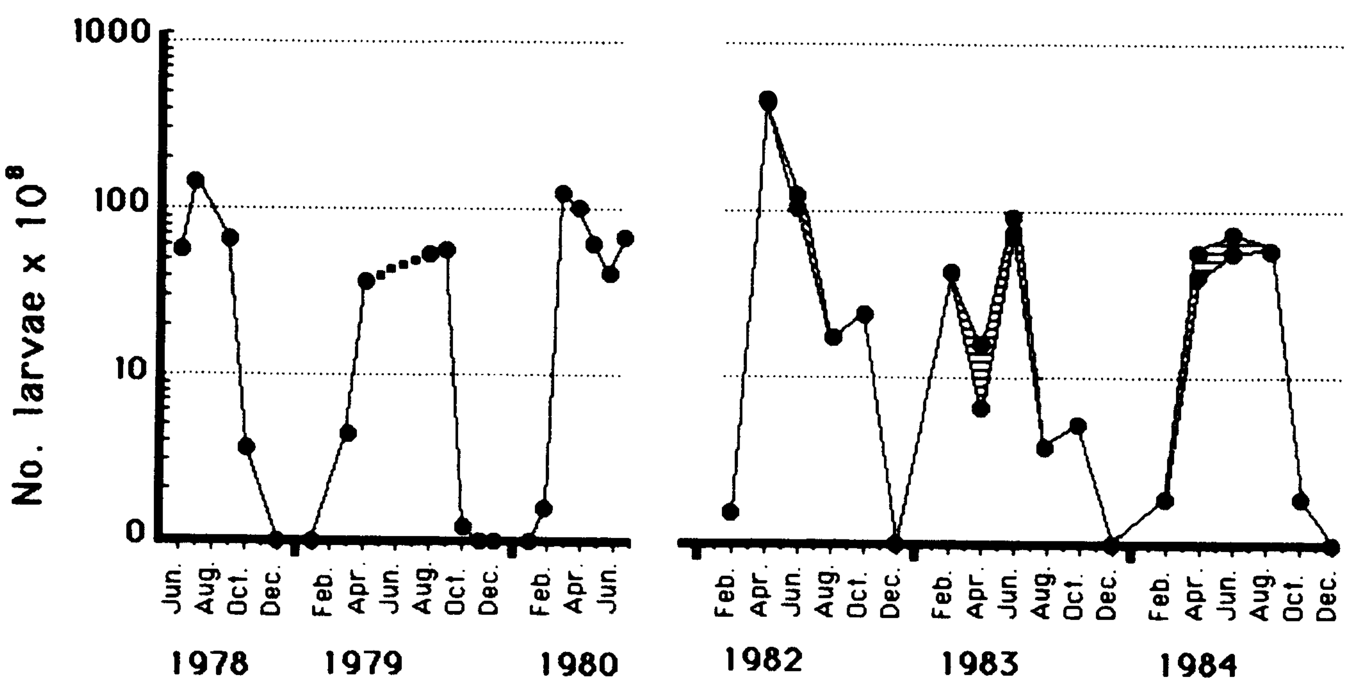

Figure 9. Estimated abundance of queenfish (*Seriphus politus*) larvae, 1978-84. See legend of Figure 3.

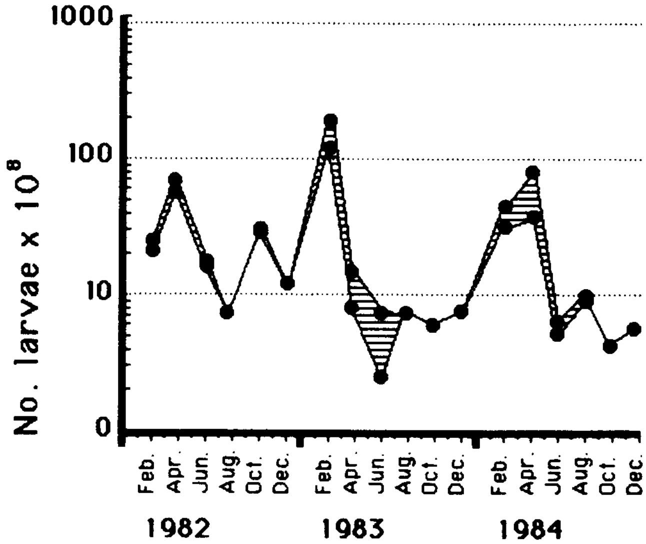

Figure 10. Estimated abundance of California halibut (*Paralichthys californicus*) larvae, 1982-84. At the time of this writing, earlier counts (1978-80) of this species were contaminated with those of fantail sole, *Xystreurys liolepis*. The hatched area represents abundance between the 36- and 75-m contours.

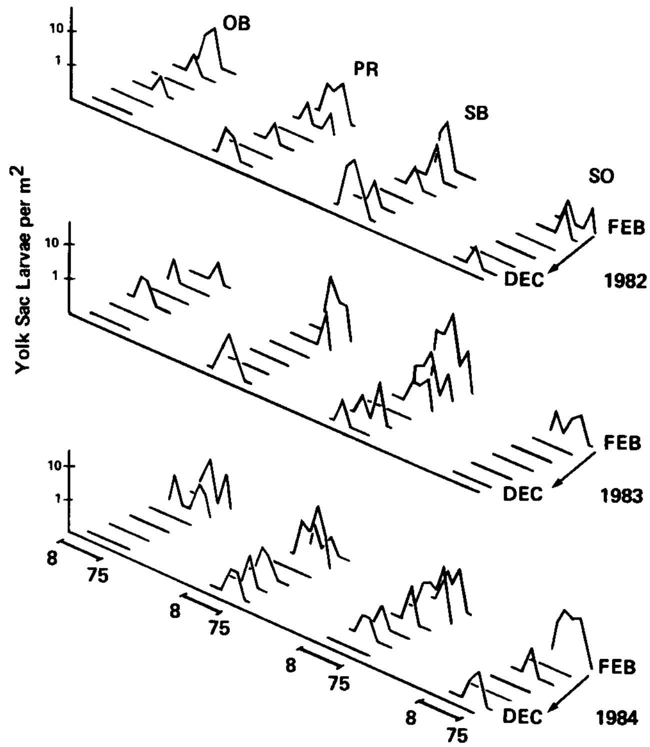

Figure 11. Density of California halibut yolk-sac larvae, 1982-84. See legend of Figure 4.

data of northern anchovy egg distributions support their conclusion.

McCall (1983) predicted that as the spawning biomass of a planktivorous fish stock shrinks, the spawning should tend to contract into a few favorable nearshore locations. Pacific sardine, which once was an important commercial fish in offshore waters, is such a depleted stock, its spawning biomass having reached particularly reduced values between 1974 and 1978 (Wolf 1985). Sardine larvae were first encountered in nearshore waters in the central portion of the bight at Seal Beach, and as the intensity of their spawning increased they spread into surrounding coastal waters. Our data suggest that MacCall's model for a recovering fish stock may apply to this species.

Ahlstrom (1967) reported spring and fall spawning of Pacific sardine, the spawning during the second half of the year being confined to a southern subpopulation in waters adjacent to central Baja California. Because the spawning effort of the recovering sardine stock has primarily been in late summer and fall, the springtime egg production noted by Wolf and Smith (1985) probably underestimates the adult stock off southern California. It is not known whether the large increases of sardine eggs and larvae in the bight in the fall of 1982 were due to a shift in seasonality of a recovering northern stock, or whether a fall-spawning southern stock moved northward, or both.

There were apparent manifestations of the California El Niño in these ichthyoplankton data. In the fall of 1983 round herring suddenly appeared in the bight. This fish had not previously been identified from our samples, and normally occurs in waters well to the south of the bight. Pacific sardine spawning intensified, and was sustained over a long season (June-October). The number of larval taxa increased in 1983. There was also a reduced level of spawning of California halibut, which was contracted into the area off Seal Beach, as mentioned above. The 1982 recovery of sardine corresponded with the onset of El Niño conditions in the tropics, but preceded by a year the full development of anomalous hydrographic conditions in the Southern California Bight (McGowan 1984; Petersen et al. 1986). One of us (G.E.M.) is currently investigating the relationship between spawning intensity and aspects of the ocean environment.

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