ABUNDANCE OF SOUTHERN CALIFORNIA NEARSHORE ICHTHYOPLANKTON: 1978-1984

ROBERT J. LAVENBERG, GERALD E. MCGOWEN, ANDREW E. JAHN, JAMES H. PETERSEN
Los Angeles County Natural History Museum
Section of Fishes
900 Exposition Boulevard
Los Angeles, California 90007

TERRY C. SCIARROTTA
Southern California Edison
System Planning and Research
P.O. Box 800
Rosemead, California 91770

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.

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.
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-µm 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

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

TABLE 2
Dates of Collection, Cruises 1-52

<table>
<thead>
<tr>
<th>Cruise no.</th>
<th>Month and year</th>
<th>Cruise no.</th>
<th>Month and year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>June 1978</td>
<td>15</td>
<td>August 1979</td>
</tr>
<tr>
<td>2</td>
<td>July 1978</td>
<td>16</td>
<td>September 1979</td>
</tr>
<tr>
<td>3*</td>
<td>August 1978</td>
<td>17</td>
<td>October 1979</td>
</tr>
<tr>
<td>4</td>
<td>September 1978</td>
<td>18</td>
<td>November 1979</td>
</tr>
<tr>
<td>5</td>
<td>October 1978</td>
<td>19</td>
<td>December 1979</td>
</tr>
<tr>
<td>6*</td>
<td>November 1978</td>
<td>20</td>
<td>January 1980</td>
</tr>
<tr>
<td>7</td>
<td>December 1978</td>
<td>21</td>
<td>February 1980</td>
</tr>
<tr>
<td>8</td>
<td>January 1979</td>
<td>22</td>
<td>March 1980</td>
</tr>
<tr>
<td>9*</td>
<td>February 1979</td>
<td>23</td>
<td>April 1980</td>
</tr>
<tr>
<td>10</td>
<td>March 1979</td>
<td>24</td>
<td>May 1980</td>
</tr>
<tr>
<td>11</td>
<td>April 1979</td>
<td>25</td>
<td>June 1980</td>
</tr>
<tr>
<td>12*</td>
<td>May 1979</td>
<td>26</td>
<td>July 1980</td>
</tr>
<tr>
<td>13*</td>
<td>June 1979</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14*</td>
<td>July 1979</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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.

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)

(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 m³ 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 larvae1, and the abundance of this species as reported here is for the first time uncontaminated with that of the similar Xystreurys fiolepis.

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.

---

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 km². 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 km². Brewer and Smith's (1982) estimate of 2,652 km² 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 km² 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 m² 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 km²). For the years 1982-84 the mean 75-m abundance was multiplied by the area between 36 and 75 m (1,192 km²) 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 m²) 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 m².

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...
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 m². 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

<table>
<thead>
<tr>
<th>Factor</th>
<th>Depth (D)</th>
<th>Year (Y)</th>
<th>Transect (T)</th>
<th>D × Y</th>
<th>D × T</th>
<th>Y × T</th>
<th>D × Y × T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sardine eggs</td>
<td>***</td>
<td>—</td>
<td>—</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>NS</td>
</tr>
<tr>
<td>Anchovy eggs</td>
<td>*</td>
<td>—</td>
<td>—</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>NS</td>
</tr>
<tr>
<td>Halibut yolk-sac larvae</td>
<td>***</td>
<td>NS</td>
<td>***</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

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
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 m², but it increased to 195.3 per m² 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

<table>
<thead>
<tr>
<th>Cruises</th>
<th>Sardina sagax</th>
<th>Engraulis mordax</th>
<th>Paralabrus spp.</th>
<th>Genyonemus lineatus</th>
<th>Seriphus politus</th>
<th>Paralichthys californicus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>1.0</td>
<td>2.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1979</td>
<td>0.6</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1980</td>
<td>0.4</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1981</td>
<td>0.4</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1982</td>
<td>1.0</td>
<td>2.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1983</td>
<td>0.6</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1984</td>
<td>0.4</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

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

ACKNOWLEDGMENTS

Many people gave freely of their time and assistance over the 5-year span of this project, particularly the crews and support staffs of the Sea Watch, University of Southern California, and Vantuna, Vantuna Research Group, Occidental College, especially Mickey Singer and Gary Jordan.

We owe a great debt to our dedicated fraternity of sorters and identifiers who had the difficult tasks of sorting and identifying the thousands of ichthyoplankters. We thank particularly Steven Caddell, Dennis Chandler, Donna Eto, Richard Feeney, Dena Gadomski, Sue Goodman, Lauma Jurkevics, Debra
Oda, James Rounds, Sharon Shiba, Nancy Singleton, Michael Sowby, Delaine Winkler, and Richard Woodsum. Assistance in larval identifications has been provided from time to time by H.J. Walker and William Watson, and we are thankful.

For data processing efforts we thank Donna Cooksey, Terry Garrett, Sue Ryan, and Gary D. Brewer, who also served as co-principal investigator for the first three years of the project.

For assistance over the years we thank the staff of the Southwest Fisheries Center, especially Elbert Ahlstrom, Reuben Lasker, H. Geoffrey Moser, and Paul Smith, and their larval fish staff, chiefly Elaine Sandknop, Betsy Stevens, and Barbara Sumida. We thank the research and development staff of Southern California Edison Company for technical assistance, especially E. Grey, R. Grove, B. Mechelas, J. Palmer, I. Straughan, J. Stock, and J. Yuge.

For financial support we thank the Southern California Edison Company and the NOAA Office of Sea Grant, Department of Commerce, under grant numbers 04-8-M-01-186, NA79AA-D-00133, and NA80AA-D-00100, through the University of Southern California.

LITERATURE CITED


Smith, C.L., and P.H. Young. 1966. Gonad structure and reproductive cycle of the kelp bass, Paralabrax clathratus (Girard), with comments on relationships of the serranid genus Paralabrax. Calif. Fish Game. 52:283-292.

