

# Fine-scale distribution of nearshore, suprabenthic fish larvae

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**ABSTRACT:** A large-volume pump was used to sample larval fish and zooplankton at approximate heights of 30, 60, and 100 cm above the bottom over the 7 m isobath during a 12 h period. Zooplankton biomass increased exponentially with proximity to the bottom, as did Gobiidae Type A larvae (a complex consisting of *Ilypnus gilberti*, *Quietula ycaudata*, and *Acanthogobius flavimanus*) during the day. At night, the gobiids became more or less evenly distributed in the lower meter. Larval queenfish *Seriphus politus* were taken in high numbers (~65 per 100 m<sup>3</sup>) in daytime nearest the bottom, but in very low numbers in the 2 higher strata (~1 per 100 m<sup>3</sup>). At night, *S. politus* was more abundant at all depths, but still 3 times more abundant near the bottom than at higher levels. During the day, but not at night, there was an offshore component to near-bottom currents. This change in the sluggish (<20 cm s<sup>-1</sup>) current field, associated with the tide and changes in temperature and other water properties, probably confounded day/night abundance changes with advective ones. Abundance peaks of several taxa were most parsimoniously attributed to the advection of patches through the fixed station. A progressive vector analysis of current measurements made within the bottom meter indicated length scales of 1 to 2 km for the apparent patches.

## INTRODUCTION

Increased numbers and biomass of zooplankton near the bottom of the ocean are commonly observed over various bottom types, divergent latitudes, and all depths (Brunel 1979, Wishner 1980, Sainte-Marie & Brunel 1985). Some taxa, notably pelagic mysid shrimps (Clutter 1969, Hargreaves 1985), are more or less permanently planktonic within a few meters or less of the bottom, but much of the near-bottom fauna is temporary, migrating periodically from the benthos (Porter & Porter 1977, Alldredge & King 1985). An important taxonomic group comprising temporary, pelagic members of the near-bottom plankton is late-stage larval fishes. On the southern California continental shelf, the near-bottom pattern is especially strong in the families Gobiidae, Gobiesocidae, Sciaenidae, and, to a lesser extent, Engraulidae (Brewer et al. 1981, Schlotterbeck & Connally 1982, Watson 1982, Barnett et al. 1984, Brewer & Kleppel 1986).

The 5 studies just cited are the only published

accounts of vertical distribution of nearshore southern California fish larvae, and all used either a wheeled 70 cm Bongo net or the MBC Auriga\* net to sample near-bottom. The Auriga was designed to sample over the cobble bottoms common to the region, in a zone approximately 17 to 67 cm above the substrate. This 50 cm thick stratum thus defines the limit of vertical resolution in the above-cited studies, which all used one or a series of oblique bongo net tows to sample the midwaters. Though fine-scale layering within the bottom meter of the water column is of interest in its own right, there were also important sampling questions regarding use of the Auriga net in population surveys. As noted by Barnett et al. (1984), the accuracy and precision of population estimates of fish larvae will depend in part on whether or not the Auriga net encompasses the depth zone in which the larvae are concentrated. If, for instance, the zone of concentration were 1 or 2 m thick, the brief excursion of an oblique bongo tow through the upper half of the layer would result in highly variable catches, and failure of the oblique tow to commence at the exact height of the Auriga net would result in either over- or undersampling of the near-bottom concentration of larvae.

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The work reported here involved vertically fine-scale (10's of cm) pump sampling of fish larvae over a 12 h (noon to midnight) period in shallow water on the southern California shelf. The efficacy of large-volume pumps as larval fish samplers has been discussed by Taggart & Leggett (1984). The main advantage of a pump in this study was the relatively fine control of sampling head height above the bottom. Our primary purpose was to define precisely the near-bottom vertical distribution of larval queenfish *Seriphus politus*, an abundant species known to concentrate near shore and near the bottom. A secondary purpose was to look for differences in vertical distribution as a function of daylight and direction of cross-shelf currents. Though diel vertical migration has not been found to be an important attribute of larval fish in the system, there has been speculation that vertical migration in response to internal tides might contribute to the near-shore concentration observed in several species (Barnett et al. 1984). Close coupling of biological sampling and current measurements also allowed us to estimate the length scale of larval fish patchiness in the system.

The duration and spatial coverage of this work were both quite limited. However, the results – both intended and fortuitous – show in some detail how things were, or may have been, on one d at one place. Practical implications for the design of future studies in southern California or similar nearshore systems were a major motivation for presenting this report.

## METHODS

On 10 August 1984, the Research Vessel *Westwind* was stationed at 3-point anchor over the 7 m depth contour off Seal Beach, California (Fig. 1). A Nielsen model NCH fish pump, rated at  $227 \text{ m}^3 \text{ h}^{-1}$  at 2 m head, was used to pump water from depth. The end of the intake hose was fitted with a velocity cap and suspended between weights and submerged floats, so that the height of the hose end above the bottom could be adjusted by divers. A new, calibrated General Oceanics digital flow meter was placed under a clear plastic window in the intake manifold (internal diameter = 15.24 cm). The outflow of the pump was seived through a  $333 \mu\text{m}$  mesh plankton net with a custom-made collar that prevented loss of sample by splashing. Nominal sampling heights were 25, 50, and 100 cm above the bottom, the actual heights differing somewhat because of imprecision in tying knots, and varying with wave surge transmitted from the vessel through the stiff hose. Divers measured the range of hose opening height (lowest excursion of bottom of opening to highest excursion of top of opening) when adjustments were made and occasionally between samples. Maximum range was 40 cm (90 to 130 cm at night); at other times, observed ranges were from 10 to 25 cm. Heights reported here for biological data are medians.

Sampling design called for 3 replicates at each

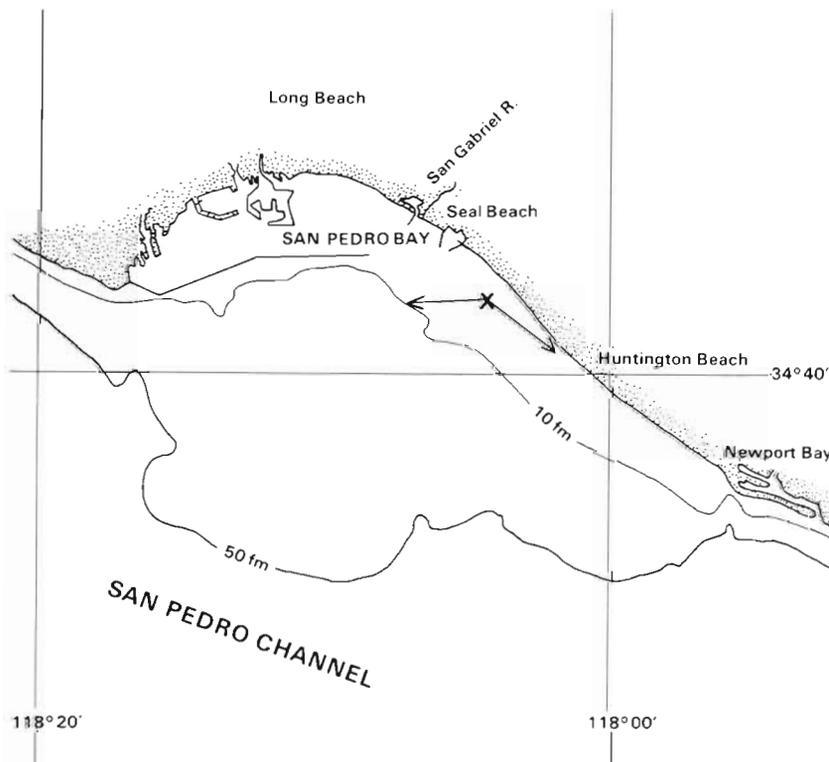


Fig. 1. Study site (X) and mean near-bottom current direction before (west) and after (southeast) the beginning of flood tide

sampling height both before and after sunset. A 50 cm sample was lost during the day, and an attempt to replace it resulted in one twilight sample from this height. The flowmeter could not be read while the pump was running, so samples were timed (20 min) to achieve a target volume of 50 m<sup>3</sup>. This target volume was chosen 9 d earlier, when preliminary near-bottom sampling by diver-assisted plankton net revealed concentrations of postflexion *Seriphus politus* on the order of 1 larva m<sup>-3</sup>. Actual volumes sampled by the pump (range = 34 to 49 m<sup>3</sup>) were determined from flowmeter counts. Samples were preserved in 5 % buffered formalin.

Currents and temperature were measured with an Endeco type 110 remote-reading current meter. The meter was lowered by hand at approximately 20 min intervals, and readings of depth, temperature, speed, and direction were taken from near bottom to 1 or 2 m below the surface at usually 1 m intervals (Fig. 2). Nominal accuracy of speed was  $\pm 3\%$  of full scale, 0 to 5 knots (0 to 2.58 m s<sup>-1</sup>); of temperature,  $\pm 0.5^\circ\text{C}$ ; of pressure,  $\pm 2\%$  of full scale, 0 to 100 ft (0 to 30.5 m); of direction,  $\pm 3\%$  (0 to 360°). Direction data were corrected for magnetic declination (14°).

In the laboratory, displacement volume of entire plankton samples was measured, then all fish larvae were removed, identified, and measured to the nearest 0.5 mm. Yolksac (YS) larvae were enumerated separately from older, yolkless larvae (LV). Specimens that were too damaged for positive identification were designated as fragments (FR). In some cases, e.g. clupeid FR specimens, the final species list was such that only a single species was likely to be represented; in such cases, numbers of FR specimens were apportioned among the appropriate taxa (e.g. *Sardinops sagax* YS and LV) before data analysis.

Fish eggs were identified from aliquots (usually 10 %) of sufficient size to produce at least 50 eggs. Though we were not interested in the vertical distribution of eggs, their identification and enumeration was necessary to evaluate increases in abundance of yolk sac larvae, particularly *Sardinops sagax*, through the course of the experiment. *S. sagax* specimens believed to have been mechanically hatched during sample processing, as evidenced by their extreme curvature and the high abundance of late stage eggs in some samples, were nevertheless counted as yolk sac larvae, our standard procedure for embryos without chorions.

Cluster analysis of collections was done using the unweighted pair-group, or 'group-average', method of Sokal & Michener (1958), except that the algorithm clustered distance rather than similarity. The distance measure was the Canberra metric, with the denominator adjusted for pairs of zeros (Clifford & Stephenson 1975, p. 59). This measure, the average of

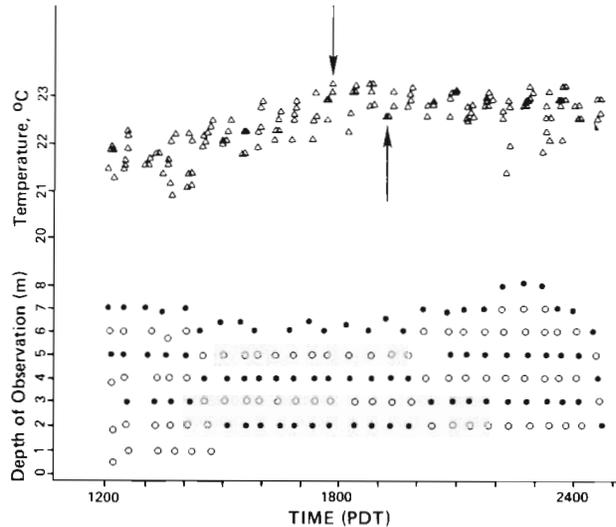


Fig. 2. Temperature (upper graph) and depth of temperature and current observations (lower graph) as a function of time. Maximum depth of observations varied with tidal height. Observations at approximately constant heights above the bottom (filled symbols) were used in constructing progressive vector diagrams (Fig. 6)

the ratios of between-sample differences to sample pair sums for each species, was chosen for its equitable contribution from all species regardless of absolute abundance. Larval taxa (YS and LV) chosen for analysis were those that occurred in more than 4 of the 18 collections.

Variation in time of larval abundance was used in conjunction with current meter data to estimate length scales of larval patchiness. Speed and direction data were extrapolated over the time interval between current observations to produce progressive vector diagrams. The length scale of a parcel of water passing the vessel during a period of steady (non-reversing) flow was taken as the resultant of near-bottom flow. Time and direction were measured quite accurately for this purpose, but at the low current speeds encountered ( $\sim 15\text{ cm s}^{-1}$ ) the uncertainty of speed data was roughly  $\pm 50\%$  (3 % of full scale). Assuming error was random and mostly due to instrument inaccuracy, we estimated the likely range of length of the resultant of a number ( $n$ ) of vectors as  $\pm 50\% n^{-2}$ .

## RESULTS

Thirty-two larval categories and 14 egg types were encountered (Table 1). Ten larval taxa occurred in more than 4 samples and so were chosen for analysis. These are listed in Table 2 along with zooplankton displacement volume and other collection information. Only in *Seriphus politus* and *Paraclinus integripinnis*

Table 1. List of taxa identified, life stage, total specimens, and frequency of occurrence in 18 pump samples. EG: egg; YS: yolk sac larva; LV: post yolk sac larva; J: juvenile; A/J: adult or juvenile; FR: larval fragment

| Taxon                              | Life stage | No. of specimens | Freq. of occurrence |
|------------------------------------|------------|------------------|---------------------|
| <i>Anchoa delicatissima</i>        | EG         | 30               | 2                   |
| <i>Atractoscion nobilis</i>        | YS         | 1                | 1                   |
| <i>Citharichthys</i> spp.          | EG         | 55               | 4                   |
| <i>Cheilotrema saturnum</i>        | LV         | 3                | 3                   |
| <i>Chromis punctipinnis</i>        | LV         | 1                | 1                   |
| Clupeidae                          | FR         | 1693             | 7                   |
| Clupeidae                          | EG         | 155              | 4                   |
| Clupeiformes                       | FR         | 100              | 5                   |
| Engraulidae                        | FR         | 1                | 1                   |
| <i>Engraulis mordax</i>            | EG         | 160              | 13                  |
| Gobiidae Type A                    | LV         | 228              | 16                  |
| Gobiidae Type A                    | YS         | 3                | 1                   |
| Gobiidae Type A                    | FR         | 1                | 1                   |
| Gobiidae Type C                    | LV         | 1                | 1                   |
| <i>Halichoeres semicinctus</i>     | YS         | 1                | 1                   |
| <i>Hypsoblennius</i> spp.          | LV         | 33               | 15                  |
| <i>Hypsoblennius</i> spp.          | YS         | 1                | 1                   |
| <i>Hypsopsetta guttulata</i>       | LV         | 1                | 1                   |
| Kyphosidae                         | LV         | 1                | 1                   |
| <i>Medialuna californiensis</i>    | LV         | 1                | 1                   |
| <i>Menticirrhus undulatus</i>      | LV         | 71               | 17                  |
| <i>Mugil cephalus</i>              | EG         | 20               | 1                   |
| <i>Ophidion scrippsae</i>          | LV         | 1                | 1                   |
| <i>Paraclinus integripinnis</i>    | LV         | 389              | 13                  |
| <i>Paraclinus integripinnis</i>    | YS         | 1                | 1                   |
| <i>Paraclinus integripinnis</i>    | FR         | 1                | 1                   |
| <i>Paralabrax</i> spp.             | YS         | 8                | 4                   |
| <i>Pleuronichthys coenosus</i>     | EG         | 5                | 1                   |
| <i>Pleuronichthys ritteri</i>      | YS         | 1                | 1                   |
| <i>Pleuronichthys ritteri</i>      | EG         | 688              | 18                  |
| <i>Pleuronichthys verticalis</i>   | EG         | 10               | 1                   |
| <i>Sardinops sagax caeruleus</i>   | LV         | 226              | 17                  |
| <i>Sardinops sagax caeruleus</i>   | YS         | 893              | 15                  |
| <i>Sardinops sagax caeruleus</i>   | FR         | 18               | 2                   |
| <i>Sardinops sagax caeruleus</i>   | EG         | 7865             | 17                  |
| Sciaenidae Complex I               | LV         | 1                | 1                   |
| Sciaenidae Complex II              | LV         | 5                | 4                   |
| Sciaenidae Complex II              | YS         | 3                | 2                   |
| <i>Scomber japonicus</i>           | LV         | 208              | 18                  |
| <i>Scomber japonicus</i>           | YS         | 107              | 12                  |
| <i>Scomber japonicus</i>           | EG         | 7260             | 12                  |
| <i>Seriphus politus</i>            | LV         | 327              | 14                  |
| <i>Seriphus politus</i>            | YS         | 3                | 2                   |
| <i>Sphyræna argentea</i>           | LV         | 66               | 14                  |
| <i>Sphyræna argentea</i>           | YS         | 1                | 1                   |
| <i>Sphyræna argentea</i>           | EG         | 135              | 10                  |
| <i>Symphurus atricauda</i>         | YS         | 3                | 3                   |
| <i>Symphurus atricauda</i>         | EG         | 60               | 4                   |
| ICHS Type 106                      | YS         | 1                | 1                   |
| Egg Type 32                        | EG         | 10               | 1                   |
| Egg Type 38                        | EG         | 230              | 9                   |
| Unident. yolk sac larvae           | YS         | 29               | 6                   |
| Unidentified eggs                  | EG         | 11455            | 18                  |
| Larval fragments                   | FR         | 118              | 14                  |
| <i>Sphyræna argentea</i>           | J          | 1                | 1                   |
| <i>Branchiostoma californiense</i> | A/J        | 3                | 3                   |

were the majority of specimens beyond the flexion stage.

### Vertical distribution

Zooplankton biomass increased exponentially in the bottom meter, as did Gobiidae Type A larvae (a complex consisting of *Ilypnus gilberti*, *Quietula ycaudata*, and *Acanthogobius flavimanus*) during the day (Fig. 3, Table 2). At night, the gobiids became more evenly distributed in the lower meter. Larval queenfish *Seriphus politus* were taken in high numbers (~65 per 100 m<sup>3</sup>) in daytime nearest the bottom (Fig. 3), but in very low numbers in the 2 higher strata (~1 per 100 m<sup>3</sup>). At night, *S. politus* was more abundant at all depths, but still 3 times more abundant near the bottom than at 50 or 100 cm above the bottom. Only 17 of 321 specimens were smaller than 4 mm, the size at which notochord flexion occurs in *S. politus*. The remaining 8 taxa, as described below, all varied with time to such a degree that height of sample appeared unimportant (Table 2).

### Changes through time

The predominance of time over sample height in the majority of species shows in the clustering of the 18 samples (Fig. 4). Two samples (Nos. 6 and 19) were outliers; the rest fell into 3 groups at the .4 to .6 distance interval, i.e. Group 1 = sample Nos 1 to 5 (sample No. 3 was lost), Group 2 = 11 to 18, Group 3 = 7 to 10. All groups contain mixtures of sampling heights, yet each is a set of consecutive samples.

Temporal changes in abundance, typically by a factor of 10 over 2 to 3 h (Table 2), appear to have driven the clustering presented in Fig. 4. With the exception of *Sardinops sagax* yolk sac larvae, none of the taxa were represented by individuals young enough to have been suddenly hatched during the sampling, and suddenly intense predation of several species in succession seems implausible. Because the upper and middle portions of the water column were not sampled, vertical excursions of larvae are a possible explanation, as is horizontal advection of patches. There are 2 general classes of abundance change – those that coincide with sunset and those that do not. In both cases, evidence making horizontal advection the more parsimonious working hypothesis will be presented.

The difference between day and night vertical distribution of Goby Type A and the nighttime increase of *Seriphus politus* larvae coincided with a marked increase in water clarity, noted by us and another diver (T. Garrett) and with a temperature increase of some 1.2 C° associated with the tide (Fig. 2). There was also a nighttime shift to somewhat larger larvae in *S. politus*

Table 2. Zooplankton displacement volume and fish larvae per 100 m<sup>3</sup>

| Sample No. | Height (cm) | Time (h) |      | Disp. vol. (ml) | <i>Seriphus politus</i> | Goby Type A | <i>Sardinops sagax</i> |       | <i>Sphyræna argentea</i> | <i>Scomber japonicus</i> |      | <i>Menticirrhus undulatus</i> | <i>Hypsoblennius</i> spp. | <i>Paraclinus integripinnis</i> |
|------------|-------------|----------|------|-----------------|-------------------------|-------------|------------------------|-------|--------------------------|--------------------------|------|-------------------------------|---------------------------|---------------------------------|
|            |             | Start    | End  |                 | (LV)                    | (LV)        | (YS)                   | (LV)  | (LV)                     | (YS)                     | (LV) | (LV)                          | (LV)                      | (LV)                            |
| 1          | 55          | 1407     | 1422 | 51.1            | 2.6                     | 21.0        | 0.0                    | 21.0  | 0.0                      | 2.6                      | 21.0 | 13.1                          | 5.2                       | 0.0                             |
| 2          | 55          | 1425     | 1446 | 70.5            | 0.0                     | 16.1        | 7.0                    | 73.4  | 8.0                      | 4.0                      | 76.3 | 20.1                          | 2.0                       | 0.0                             |
| 4          | 32          | 1547     | 1606 | 206.6           | 93.4                    | 97.7        | 8.5                    | 19.8  | 0.0                      | 6.5                      | 13.0 | 6.5                           | 2.2                       | 4.3                             |
| 5          | 32          | 1632     | 1652 | 127.9           | 41.1                    | 82.2        | 2.6                    | 18.0  | 0.0                      | 2.3                      | 9.1  | 2.3                           | 2.3                       | 6.9                             |
| 6          | 32          | 1659     | 1719 | 113.2           | 60.6                    | 95.5        | 0.0                    | 9.3   | 9.3                      | 2.3                      | 11.7 | 0.0                           | 0.0                       | 34.9                            |
| 7          | 100         | 1738     | 1758 | 11.0            | 0.0                     | 2.4         | 54.3                   | 45.9  | 26.2                     | 28.6                     | 0.0  | 4.8                           | 2.4                       | 0.0                             |
| 8          | 100         | 1802     | 1822 | 14.7            | 0.0                     | 0.0         | 31.7                   | 112.4 | 9.5                      | 33.1                     | 0.0  | 7.1                           | 2.4                       | 68.5                            |
| 9          | 100         | 1828     | 1845 | 20.8            | 2.8                     | 2.8         | 159.3                  | 0.0   | 11.4                     | 37.0                     | 0.0  | 5.7                           | 2.8                       | 65.4                            |
| 10         | 59          | 1931     | 1951 | 31.5            | 0.0                     | 4.8         | 0.0                    | 64.5  | 7.2                      | 26.3                     | 0.0  | 2.4                           | 2.4                       | 720.9                           |
| 11         | 60          | 2055     | 2115 | 65.1            | 14.4                    | 36.0        | 145.7                  | 104.1 | 12.0                     | 88.9                     | 9.6  | 19.2                          | 7.2                       | 4.8                             |
| 12         | 60          | 2118     | 2138 | 70.6            | 52.5                    | 11.9        | 117.0                  | 59.7  | 23.9                     | 76.4                     | 4.8  | 14.3                          | 9.6                       | 14.3                            |
| 13         | 60          | 2143     | 2203 | 52.7            | 19.0                    | 19.0        | 61.7                   | 23.7  | 21.4                     | 61.7                     | 38.0 | 16.6                          | 9.5                       | 4.7                             |
| 14         | 35          | 2229     | 2249 | 140.6           | 223.7                   | 23.6        | 199.0                  | 48.3  | 9.4                      | 51.8                     | 0.0  | 4.7                           | 2.4                       | 7.1                             |
| 15         | 35          | 2251     | 2311 | 85.4            | 83.1                    | 9.5         | 617.9                  | 41.8  | 4.8                      | 23.7                     | 30.9 | 19.0                          | 19.0                      | 0.0                             |
| 16         | 35          | 2314     | 2334 | 78.4            | 67.1                    | 7.2         | 1,300.2                | 58.9  | 2.4                      | 21.6                     | 16.8 | 2.4                           | 4.8                       | 2.4                             |
| 17         | 110         | 2359     | 2419 | 40.5            | 5.0                     | 0.0         | 1,479.4                | 42.3  | 10.0                     | 22.4                     | 2.5  | 10.0                          | 5.0                       | 0.0                             |
| 18         | 110         | 2422     | 2439 | 59.5            | 96.2                    | 75.8        | 1,119.2                | 52.5  | 2.9                      | 5.8                      | 8.7  | 11.7                          | 0.0                       | 2.9                             |
| 19         | 110         | 2447     | 2507 | 39.5            | 22.2                    | 37.1        | 1,065.2                | 118.4 | 0.0                      | 7.4                      | 0.0  | 9.9                           | 0.0                       | 0.0                             |

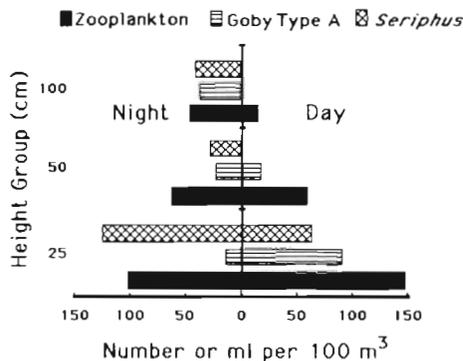


Fig. 3. Abundance (fish larvae) and biomass (zooplankton) as a function of height above bottom and time

(Fig. 5). While these changes took place, sardine yolk sac larvae began to increase in abundance in early afternoon, becoming extremely abundant (> 1000 per 100 m<sup>3</sup>) after dark (Table 2). This was not simply due to hatching of eggs present earlier, because egg abundance followed the same temporal increase (Table 3). Older sardine larvae similarly, though less dramatically, increased in numbers at night. It seems reasonable to suggest that these abundance shifts had more to do with the advection of a new (clearer, warmer) water parcel than with vertical movement, particularly since 2 categories – eggs and yolk sac larvae of *Sardinops sagax* – are not likely vertical migrators.

Abundance changes of other species cannot be

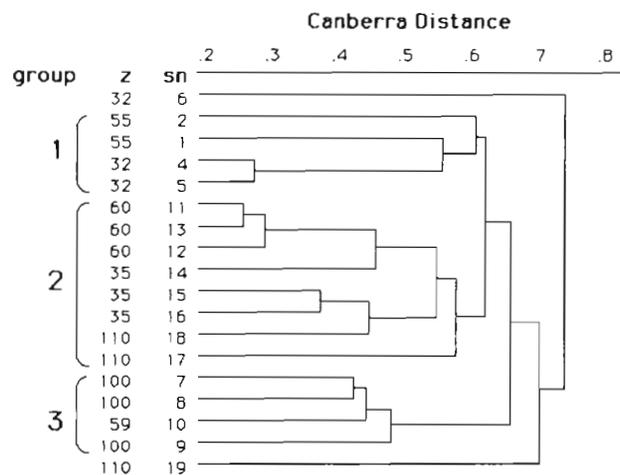


Fig. 4. Group-average clustering of 18 samples of 10 taxa. sn: sample number, z: median height above sea bed. Time and species data are given in Table 2

associated simply with sunset (Table 2). The peak abundances of Pacific barracuda *Sphyræna argentea* and Pacific mackerel *Scomber japonicus* LV from late afternoon (1738 h) to midnight, of combtooth blennies *Hypsoblennius* spp. from evening (2055 h) to midnight, and of reef finspot *Paraclinus integripinnis* from afternoon (1632 h) to evening (2138 h) encompass all sampling heights, do not resemble diel movements, and are most easily understood as the results of patches

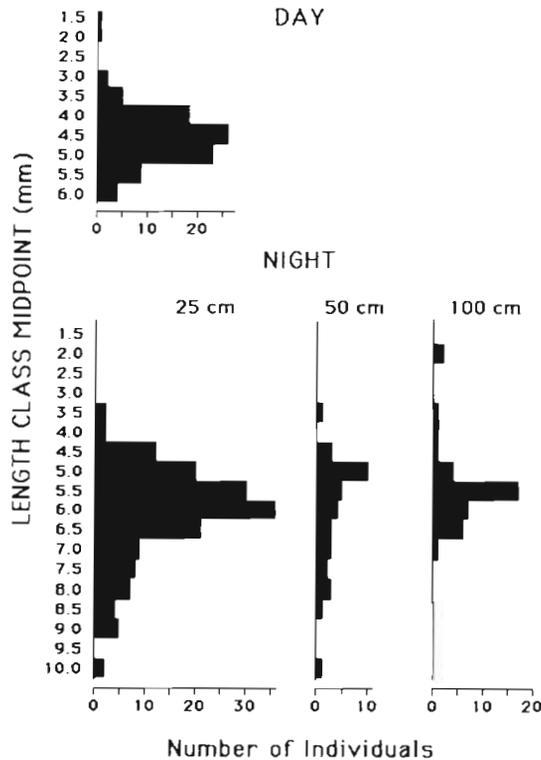


Fig. 5. *Seriphus politus*. Length frequency histograms of larvae. In daylight, all but 2 individuals were taken at the lowest sampling height (nominally 25 cm)

Table 3. Abundance (no. per  $m^3$ ) of *Sardinops sagax* eggs

| Sample | Eggs $m^{-3}$ | Sample | Eggs $m^{-3}$ |
|--------|---------------|--------|---------------|
| 1      | .3            | 11     | 6.5           |
| 2      | .4            | 12     | 5.8           |
| 4      | 0             | 13     | 25.6          |
| 5      | .7            | 14     | 15.5          |
| 6      | .2            | 15     | 27.3          |
| 7      | 2.1           | 16     | 37.6          |
| 8      | 3.3           | 17     | 40.3          |
| 9      | 5.7           | 18     | 12.2          |
| 10     | 4.8           | 19     | 3.7           |

of larvae drifting horizontally through the station. Although the absence of yolk sac stage *Scomber japonicus* larvae at 100 cm during the day (Table 2) might be construed as a vertical effect, its continued absence at 59 cm in the evening (its level of highest abundance during the day) is more consistent with the notion that a new parcel of water, with reduced abundance of *S. japonicus* yolk sac larvae, had occupied the station. California corbina *Menticirrhus undulatus* had a temporal pattern similar to that of yolk sac *S. japonicus*.

## Currents and patch size

As can be seen in Fig. 2, temperature rose steadily during low tide until about 1730 h at the surface to 1900 h at the bottom (arrows). These were about the times of turnabout in the near-surface and near-bottom currents (Fig. 6). From 1650 until 1913 h, near-surface and near-bottom currents flowed in essentially opposite directions. During this period of opposing flow, and for the next 2 h (beginning of flood tide), mid-depth currents, represented in Fig. 6 by observations approximately 2.5 m above the bottom, were so variable that the operators suspected the compass of malfunctioning. Temperature changed little throughout this 4 h period of high mid-depth turbulence. Although cooler near-bottom temperatures were measured on 3 separate lowerings between 2200 and 2400 h, there was no apparent cyclic return to noontime conditions (Fig. 2). Before 1700 h, current speeds were about the same at all measured depths, as judged by the lengths of resultant vectors from the origin. Currents near the bottom had an offshore component as this time (Fig. 1), perhaps due to Ekman veering (cf. Nakata 1981). After about 2100 h, direction was parallel to shore and essentially the same at all depths, though currents were somewhat slower and more variable near the bottom.

The peak abundance of *Paraclinus integripinnis* larvae (1632 to 2138 h) nearly coincided with the period of increased midwater shear and turbulence during early flood tide. During this period, resultant flow near the bottom ( $z \approx 0.5$  m, Fig. 6) was estimated as 1200 to 1900 m west (calculated as follows: the straight line distance from Point A [1650 h] to Point B [2115 h]  $\approx 1525$  m [broken line, Fig. 6]; A to B is composed of 5 segments;  $1525 \pm 50\% \div 5 = 1184$  to  $1866 \approx 1200$  to 1900 m), then 500 to 850 m southeast. Similar estimates for the apparent patch of *Scomber japonicus* (LV) and *Sphyræna argentea* larvae (1738 to 0019 h) are 800 to 1400 m west then 1500 to 2000 m southeast, and for *Hypsoblennius* spp. (2055 to 0019 h), 1100 to 1600 m southeast. Length scale estimates for the clusters of consecutive collections (Fig. 4) are: Collections 1 to 5, 1150 to 1700 m west; Collections 7 to 10, 600 to 1100 m southwest (then 200 to 600 m east); Collections 11 to 18, 1200 to 1750 m southeast.

## DISCUSSION

### Vertical distribution

The species of principal interest in this study, *Seriphus politus*, was captured chiefly within the bottom 50 cm, with a mode at 25 to 35 cm. Like zooplank-

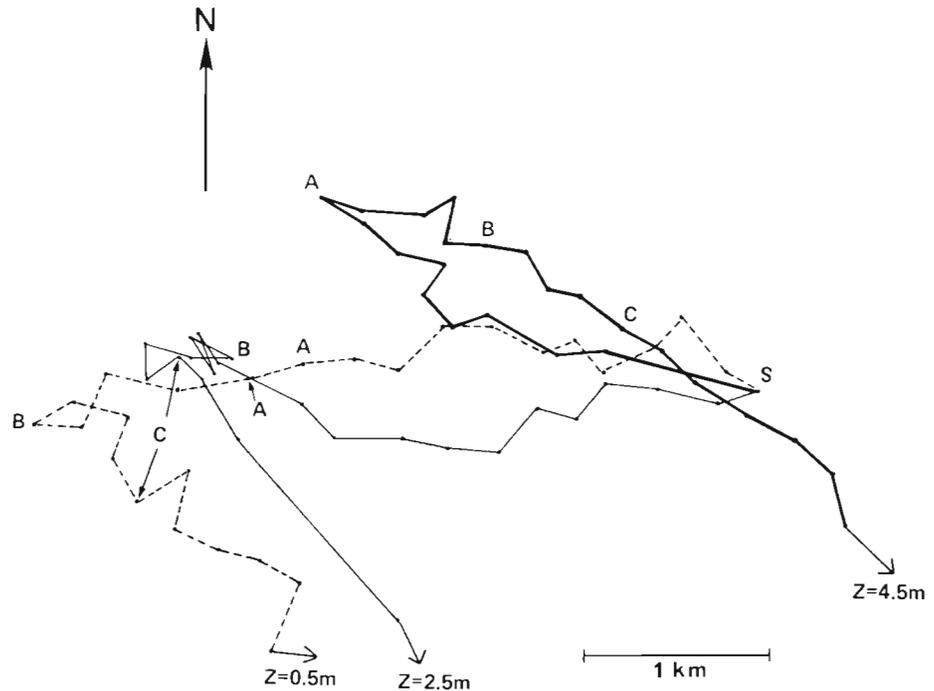


Fig. 6. Progressive current vectors at 3 heights ( $z$ ) above the sea bed. Letters mark approximately contemporaneous points: S  $\approx$  1200 h; A  $\approx$  1650 h; B  $\approx$  1915 h; C  $\approx$  2115 h PDT

ton biomass, the logarithm of *S. politus* abundance increased approximately linearly with proximity to the bottom, both day and night. Such logarithmic profiles mirror the logarithmic decay of velocity in the bottom meter (Sverdrup et al. 1941, Nowell & Jumars 1984). The importance of the logarithmic layer to planktonic organisms on the narrow southern California shelf may well be that, since the flow on the shelf is largely dispersive (Winant & Bratkovich 1981), living near the bottom means being dispersed less. Species like *S. politus* that concentrate near shore probably are better able to do so in the more sluggish near-bottom flow.

Barnett et al. (1984) reported that most of the flexion and postflexion stage larval population of *Seriphus politus* lived shoreward of the 9 m contour and within approximately the lower 50 cm of the water column, where only some 6% of preflexion larvae were captured. These authors cited the work of Weinstein et al. (1980), who showed that certain sciaenids migrated vertically with the tide, apparently taking advantage of the benthic boundary layer in order to achieve and maintain position within an Atlantic coast estuary. Barnett et al. (1984) conjectured that *S. politus* might use the cross-shelf velocity component of internal tides to achieve and maintain its remarkably nearshore distribution pattern. The more strictly suprabenthic distribution early in the present study, when currents were approximately due west, was in line with the expectation that larvae would remain in the boundary layer during seaward flow and perhaps less so at other times. However, the change in current direction from west to southeast (parallel to shore) coincided more or

less with sunset and a change in water properties, as well as an overall increase in the abundance of *S. politus* and several other species. Brewer & Kleppel (1986) reported that larvae of another sciaenid displaying the near-bottom habit, *Genyonemus lineatus*, were vertically more diffuse at night. Because of these complications, it is impossible to address the interesting question of whether or not there is vertical migration in response to changes in across-shelf current components. Although the major frequency of across-shelf current reversal is tidal, the changes are not in phase with the surface tide and therefore not so predictable (Winant & Bratkovich 1981). Answering questions about larval fish behavior with regard to these currents will accordingly require a major sampling effort, designed to separate the effects of tide and daylight.

Besides protection from physical dislocation afforded by the benthic boundary layer, there is the possibility of a nutritive advantage as well. Nearshore zooplankton species and phytoplankton pigments tend to be concentrated near the bottom on the southern California shelf (Barnett & Jahn in press), as was zooplankton biomass in this study. It is notable that some near-bottom concentrations of mysid shrimps, grossly similar to larval fishes in vertical distribution, motility, and even appearance (Clutter 1969, McFarland & Kotchian 1982) have been attributed to the exploitation of a near-bottom abundance of food (Hargreaves 1985). Nothing is known of the diet of larval *Seriphus politus*. However, there is evidence that descent toward the bottom in *Genyonemus lineatus*, an abundant sciaenid which as a larva looks and seems to behave much like

*S. politus*, begins well before any change in diet that can be ascribed to a suprabenthic resource (Brewer & Kleppel 1986, Jahn, Gadomski & Sowby unpubl.). Trophic significance of the near-bottom habit of certain sciaenids and other larval fishes therefore remains to be demonstrated.

### Sampler effectiveness

The data presented here do indicate that nets designed to sample the 50 cm layer immediately above the bottom are probably adequate for estimating the suprabenthic abundance of at least 2 larval fishes – *Seriphus politus* and Gobiidae Type A. Such nets (e.g. the MBC Auriga net) certainly would have served to estimate the near-bottom abundance of these fishes on 10 August 1984 off Seal beach. The pump system used in this study is capable of sampling only 1 depth at a time, making extensive surveys impractical. An extensive sampling effort aimed at defining near-bottom layering for various species and times of year might better use a multi-tiered net system such as that described by Clutter (1969) for mysids or that of Brunel et al. (1978) for amphipods, but modified for the larger volumes needed to sample the much less abundant larval fishes.

### Patch size

This study was designed to resolve vertical distributions within the bottom meter, and, as stated earlier, the treatment of horizontal patch scale was unplanned. Because most of the water column was not sampled, vertical movements of larvae could possibly have confounded the results. However, the appearance of multiple abundance peaks would require numerous vertical migrations of the various taxa, in response to largely unknown cues. The few changes that were associated with sunset (*Seriphus politus* and *Sardinops sagax*) also coincided with changes in water properties, as described above. Increased size and abundance of *S. politus* larvae at night might be due to lessened avoidance of the sampler, but most individuals of *S. sagax*, also more abundant at night, were precompetent, making significant avoidance improbable. It is possible that abundance of each taxon varied for a different reason, but since horizontal advection would simply explain all the changes it is the mechanism we favor.

The horizontal length scale of near-bottom larval fish aggregations suggested here ranges from 600 to 1100 m for Collection Group 3 to 1500 to 2000 m for the *Scomber japonicus/Sphyaena argentea* patch. At the current speeds encountered, the minimum resolvable

patch would be about 200 m in a 20 min sample. This minimum is larger than the tens-of-meters scale of mysid shoals reported by Clutter (1969), and it therefore cannot be said whether mysid and suprabenthic larval fish distributions are similar in the horizontal as they are in the vertical. The scale of larval fish patches inferred from the present data (1 to 2 km) is comparable to that found for newly-hatched northern anchovy beyond the continental shelf, but an order of magnitude smaller than that expected of food aggregations that must remain intact over a significant fraction (several weeks) of the course of early development (Smith & Hewitt 1985). The 1 to 2 km range is also smaller than most of the coastal plankton structures described by Star & Mullin (1981). It is possible the inferred patches are actually details of some much larger structure, unresolvable in the scope of the present study. It may also be that biological dynamics (e.g. production of food, social interactions) are intense enough within these small patches to outpace physical dispersion. The approximation given here should serve to indicate the scales of sampling designed further to investigate the matter.

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