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ESTIMATION BY HISTOLOGICAL METHODS OF THE PERCENT OF STARVING LARVAE OF THE NORTHERN ANCHOVY (*ENGRAULIS MORDAX*) IN THE SEA

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One of the goals of pelagic fish stock investigations is to predict how large year-classes will be at the time of recruitment to the adult population. While the primary approach to this problem for the northern anchovy (*Engraulis mordax*) is the estimation of larval mortality rates on the basis of abundance estimates from egg and larval surveys, other methods are being sought for corroborative purposes, or to reduce time and costs. The approach described in this report is estimation by histological methods of the proportion of larvae in the sea showing symptoms of starvation. If based on adequate sampling, such a proportion could be an indicator of ultimate year-class success.

In March 1977, 64 special net tows were taken over the Southern California Bight from the NOAA R/V *David Starr Jordan*. Net tows, about 3 min long and to a depth of 20 m, were taken with a 1-m net fitted with a quick-release plexiglass cod end. Contents of the cod end from each tow were concentrated in a small seive and immediately fixed in Bouin's fluid.

Three hundred eighteen larvae, about six from each tow, were sectioned and stained with hematoxylin and eosin-phloxine B. The mounted specimens were put in random order and masked in respect to standard length and net tow origin before microscope examination.

HISTOLOGICAL VARIABILITY

Specimens ranging from 2.5 to 10 mm SL showed anomalies in the trunk musculature and notochord, and occasionally also in the pancreas, that closely resembled effects of starvation in laboratory material (O'Connell, 1976). The musculature was considered anomalous if fibers showed some degree of separation, more or less throughout. In the more extreme cases the fibers were widely separated with degraded fibril clarity, and intermuscular matrix tissue was greatly reduced. The notochord in such specimens was usually irregular in profile.

The foregut was considered anomalous if the profile was irregular in lateral view. The mucosa usually showed reduced thickness and variable cell shape. In the worst cases the cells were reduced to little more than the nucleus, and the lumen sometimes contained sloughed cells.

The midgut was judged anomalous when little or no lumen could be traced, or when a traceable lumen was filled with loose nuclei and necrotic debris of mocosa cells with the mucosa proper fragmenting. This kind of dissociation was not observed in laboratory-starved material, perhaps because the laboratory specimens were starved without even having the opportunity to feed, whereas virtually all of the ocean specimens showing symptoms of emaciation had been feeding previously. The midgut thus may have been in a more vulnerable physiological conditon.

Of the 318 larvae examined, 26 were classified as severely or moderately emaciated on the basis of such anomalies. Another 11 were classified incipient emaciation; these are not included in the emaciated or starving contingent.

VARIABILITY OF SAMPLES

In regard to standard length, emaciated larvae were distributed almost proportionately over the range 2–10 mm, but did not occur among larger larvae (some specimens as large as 20 mm were examined). A few of the smallest larvae (less than 3 mm) appeared to be shrunken from a somewhat larger size.

The number of anchovy larvae in the tows varied

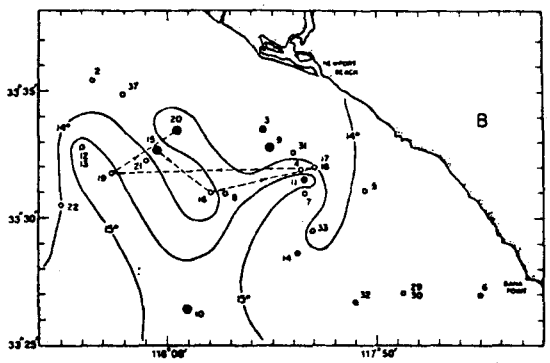

Figure 1. The locations and sequence numbers of tows taken in the Newport Beach area. The larger dark circles with open centers indicate tows with a high proportion of emaciated larvae and the small dark circles indicate tows with a low proportion of emaciated larvae. The isotherms show that there was considerable temperature variation in the area. The dashed line is the cruise track for one 24-h period, and it suggests that the presence of emaciated larvae was a relatively stable feature.

from 0 to 400. Over half of the tows were concentrated in a relatively small area of high larval abundance near shore, while the remainder were spread over a large offshore area where abundance tended to be very low. Some of the emaciated larvae occurred as isolated cases from the offshore-low abundance area, but three-quarters of the total were from six tows from the nearshore-high abundance area (Fig. 1). These concentrations suggest the presence of one or more "patches" of emaciated larvae. Subsequent examination of unsectioned larvae remaining from all net tows strengthened the impression of patches. In tows containing largely healthy larvae, the specimens were full-bodied and regular (Fig. 2). In those containing largely emaciated larvae, the specimens had angular body bends, and trunks and digestive tracts that were lumpy and sinuous (Fig. 3). They were also less intensely colored by the fixing solution.

There was no relationship between the occurrence of emaciated larvae and temperature, but the area where samples with a high proportion of emaciated

Figure 2. A portion of the larvae from tow 23, which shows generally good body form.

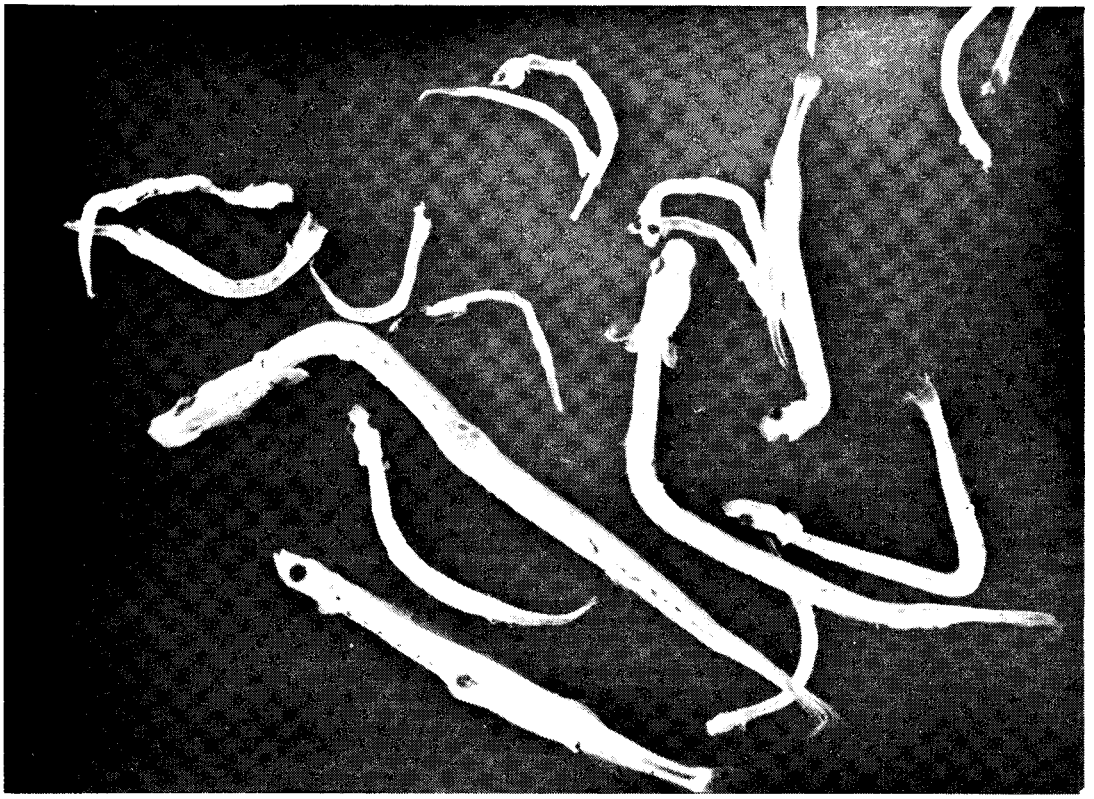

Figure 3. A portion of the larvae from tow 9, which shows generally irregular body form.

larvae occurred was one of considerable small-scale temperature fluctuation.

Number of larvae and plankton volume (larvae excluded) tended to be related for the nearshore samples of high larval abundance (Fig. 4). The tows with a high proportion of emaciated larvae conform to the trend, but they are at the low end of the scale. Plankton volume did vary widely for the offshore samples, but larval abundance tended to be low in all of them.

The proportion of emaciated larvae and other sample data is shown below for the nearshore set of samples, the offshore set, and for the entire cruise pooled.

The nearshore set was distributed over much of the San Pedro Channel area, perhaps 1200 square miles, but it should be noted that most of the emaciated larvae came from four tows in each of which the proportion of emaciated larvae was very high. The offshore set represents an area of perhaps 6000 square miles. The 8% proportion of emaciated larvae for the pooled array tenatively applies to the Southern California Bight as a whole for March 1977.

DISCUSSION

The most significant result of this study is that anchovy larvae showing symptoms indicative of

Sample set	No. tows	Larvae/ tow	No. larvae examined	No. larvae emaciated	Percent emaciated	95% confidence limits
Nearshore	37	81.3	220	21	10	±4
Offshore	27	6.3	98	5	5	±4
Total cruises	64	50.0	318	26	8	±3

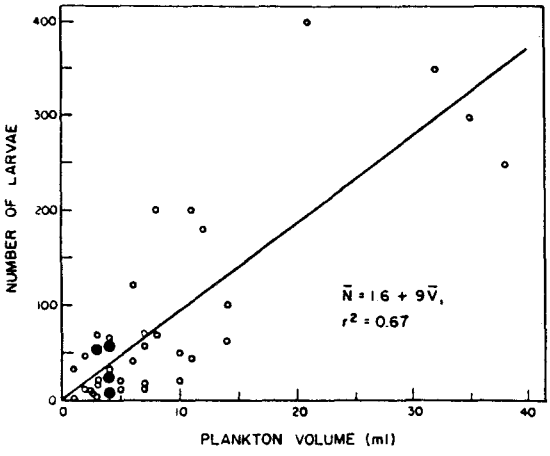

Figure 4. A regression of number of anchovy larvae on displacement volume of plankton (larvae excluded) for the inshore tows, 1–37. The enlarged points indicate the four tows with a high proportion of emaciated larvae.

starvation were found in the ocean, and could be identified on the basis of their individual appearance. The condition of these larvae is similar to that induced in the laboratory by total starvation, which implies that circumstances of insufficient food were responsible for their occurrence in the ocean, especially where samples contained many such larvae. The high variability of plankton volume and temperature in the vicinity of these samples suggests that such circumstances could have existed.

The proportion of larvae observed to be starving may be a useful indicator of ultimate year-class success. It is directly visible and it may reflect a substantial part of total daily mortality of the larvae. Zweifel and Smith (this volume) have estimated that average daily mortality rate for anchovy larvae of slightly less than 10 mm SL in the San Pedro Channel area was 21% over a period of years. The proportion of emaciated larvae in the present survey could be considered a net daily mortality from starvation of 8%, which is 40% of the average daily mortality mentioned above. If starvation contributes this substantially to total mortality, the proportion observed to be starving may relate reasonably well to eventual recruitment.

How well the proportion of starving larvae will relate to recruitment will only be evident from correlation of the two variables for at least a few years. As for the 1977 year-class, a recent estimate from catch data indicates that it is of moderate size, as compared to a large 1976 year-class and small 1974 and 1975 year-classes (Sunada, pers. comm.). Since the 8% starving larvae estimated in this study is associated with a year-class of intermediate size, both higher and lower occurrences of starving larvae can be expected to appear in subsequent years.

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