based on continued monitoring is necessary to confirm this point. Periodic increases in shark attacks of the magnitude found in these two studies may be related to several possible factors: The well-documented increase in elephant seals (Le Boeuf and Bonnell 1980), an increase in abundance of sharks, or to one or a few relatively inept predators at work.

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VERTICAL STRATIFICATION OF THREE NEARSHORE SOUTHERN CALIFORNIA LARVAL FISHES (*ENGRAULIS MORDAX*, *GENYONEMUS LINEATUS*, AND *SERIPHUS POLITUS*)

Length measurements of larval fish are most frequently used in describing life stages (Moser and Ahlstrom 1974), and the subsequent development of population estimates (Kumar and Adams 1977). Field and laboratory observations are used to construct growth models of larval fishes, which are useful in predicting rates of growth under various environmental conditions (Hunter 1976). When combined with observations of larval abundance and distribution, length measurements can be indicators of both larval and adult ecology. Larval length-frequency data provide information about adult distribution and abundance, spawning periodicity, food preferences, and behavioral transitions that occur during development (Gjøsaetor and Saetre 1974; Tanaka 1974).

Larval length-frequency distributions of three species of fish were determined in conjunction with a study of the effects of a power plant offshore cooling water intake on local nekton populations. The three species chosen [northern anchovy, *Engraulis mordax* (Engraulididae); white croaker, *Genyonemus lineatus* (Sciaenidae); queenfish, *Seriphus politus* (Sciaenidae)] are among the most abundant adult fishes in the area, and are important links in the local trophic structure. The northern anchovy is important as forage for larger fishes and is fished commercially for manufacture of fish meal and oil. While the two sciaenid species have less commercial value, both are important as forage for larger species.

Materials and Methods

Samples were collected as part of a program of preoperational environmental studies at San Onofre Nuclear Generating Station (Fig. 1). In the area near the generating station (designated "treatment"), two transects extended over depths of 8 to 11 m and 12 to 15 m. Transects were also located in a "reference" area 5.8 km northwest. The two areas are similar in bottom topography and in the presence of a kelp bed just south of the outer transects. Each transect was 760 m in length. The two treatment transects and the two reference transects were each separated by 150 m. Monthly collections were made every 30±2 d from March 1978 through July 1979. Results for March through July samples for 1978 and 1979 are presented as mean values for the 2 yr combined.

Three vertical water column levels were sampled. The neuston was sampled, using a Manta net (Brown 1979). This net has a rectangular mouth (86 cm × 15 cm) and is designed to sample the upper 14 cm of the water column. The net filtered a volume of approximately 100 m^3 during each tow.

Midwater samples were taken with paired opening-closing 60 cm diameter circular bongo

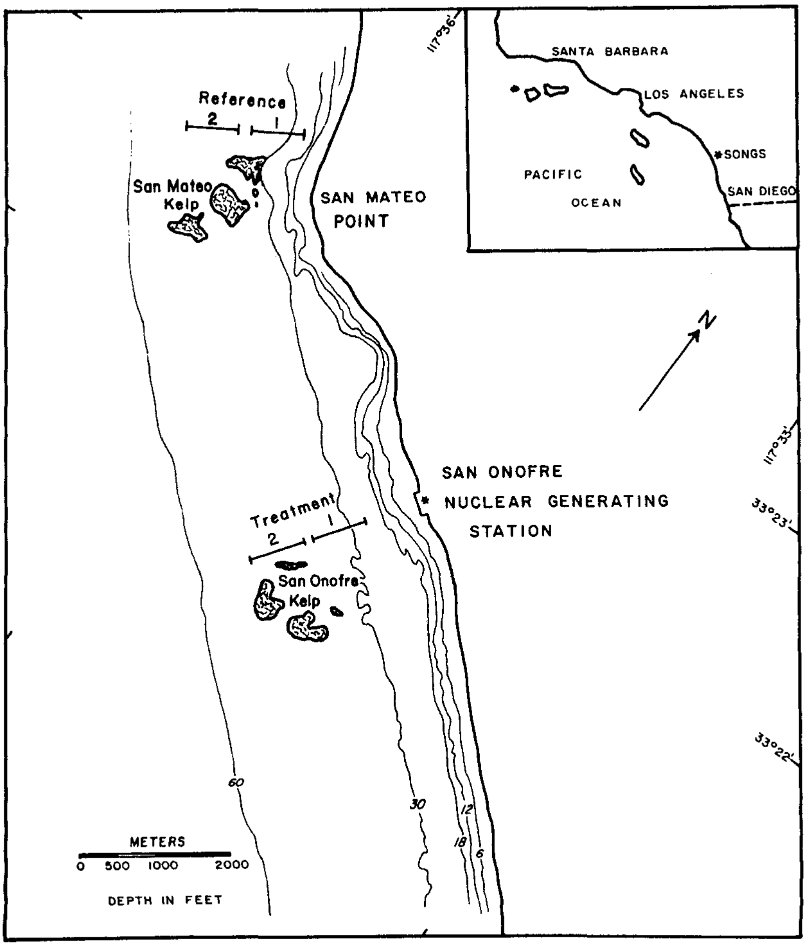

FIGURE 1.—Location of sampling stations offshore San Onofre Nuclear Generating Station ("treatment") and San Mateo Point ("reference"). Inset locates the area in relation to southern California.

nets (McGowan and Brown 1966) towed obliquely through the entire midwater column (about 0.5 m below the surface to 1.0 m above the bottom). Each side of the paired net filtered a volume of about 200 m^3/tow.

Samples from the epibenthos were collected using an Auriga[1] net specially designed for sampling over rock-cobble bottoms. The net has a rectangular mouth, 0.5 m × 2.0 m, and filtered about 800 m^3 during each tow.

Each net was equipped with two flowmeters for volume determinations. Mesh size of each net was 0.333 mm, to facilitate collection of both eggs and larvae (Bolin 1936). Four replicates were collected by each gear at night at each of the four transects.

Due to shrinkage of the larvae during preservation (4% buffered Formalin-seawater), lengths of the individuals at hatching were smaller than those observed for unpreserved specimens (Theilacker 1980), ranging from 1.9 mm for white croaker to 2.5 mm for northern anchovy. The fish were considered to become juveniles after the development of adult fin rays and spines, which was taken as a length of 30 mm for all three species. Larvae were divided into 10 size classes of 3 mm each.

Results

Engraulis mordax

The major spawning period for northern anchovy was observed to be from December through May (Fig. 2). Length-frequency distributions in neuston samples indicated a pattern of high concentrations of small larvae during heaviest spawning periods (March and December 1978), followed by months of relatively even distributions from 0 to 15 mm. Larger larvae appeared and often became the major larval component in the neuston 2 to 3 mo after heavy spawning periods. Midsize larvae (12 to 18 mm) were often observed in reduced numbers in comparison with smaller or larger larval sizes. Low spawning activity during late summer was reflected in reduced numbers of larvae in neuston samples.

Midwater collections of northern anchovy were characterized by larval concentrations in the 6 to 18 mm size range, with abundance of 0 to 6 mm larvae fluctuating with spawning activity of adults. Except in the heavy spawning months of March and December 1978, midsize larvae generally outnumbered 2.5 to 6 mm larvae and composed the majority of midwater larvae taken. Significant numbers of larvae >21 mm were taken in the midwater samples only at the end of the main spawning season.

Collections of northern anchovy from epibenthic samples indicate consistent dominance of the distribution by 6 to 18 mm larvae during most months, with distributions shifted toward larger larvae during midsummer months. Overall concentrations in epibenthic samples were consistently the highest among the three levels.

Genyonemus lineatus

The major spawning period for white croaker was from December to May (Fig. 3). Larvae taken in the neuston were generally low in abundance and rarely larger than 6 mm, while midwater concentrations were also generally restricted to 0 to 6 mm larvae. Larvae were observed in these levels mainly from December through April. Most white croaker larvae were taken in epibenthic samples, especially late in the spawning season. In contrast to the upper two levels, larvae were relatively abundant from October through June. While small larvae were frequently taken in epibenthic samples during the major spawning months, the epibenthos was generally dominated by larvae in the 3 to 12 mm size range. Larvae >15 mm were rarely taken.

Seriphus politus

Queenfish, like white croaker, is highly seasonal in its spawning habits, with the main spawning period extending from March to September (Fig. 4). Significant numbers of larvae were taken in neuston collections only in March and April, and were restricted to 0 to 6 mm size classes. Midwater collections followed a similar trend, although slightly larger larvae persisted through September. The majority of queenfish larvae were taken in epibenthic samples, with numbers of individuals in each size class decreasing from 0 to 3 mm through 15 to 18 mm groups. As was observed in white croaker samples, individuals >18 mm were rarely collected.

[1]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

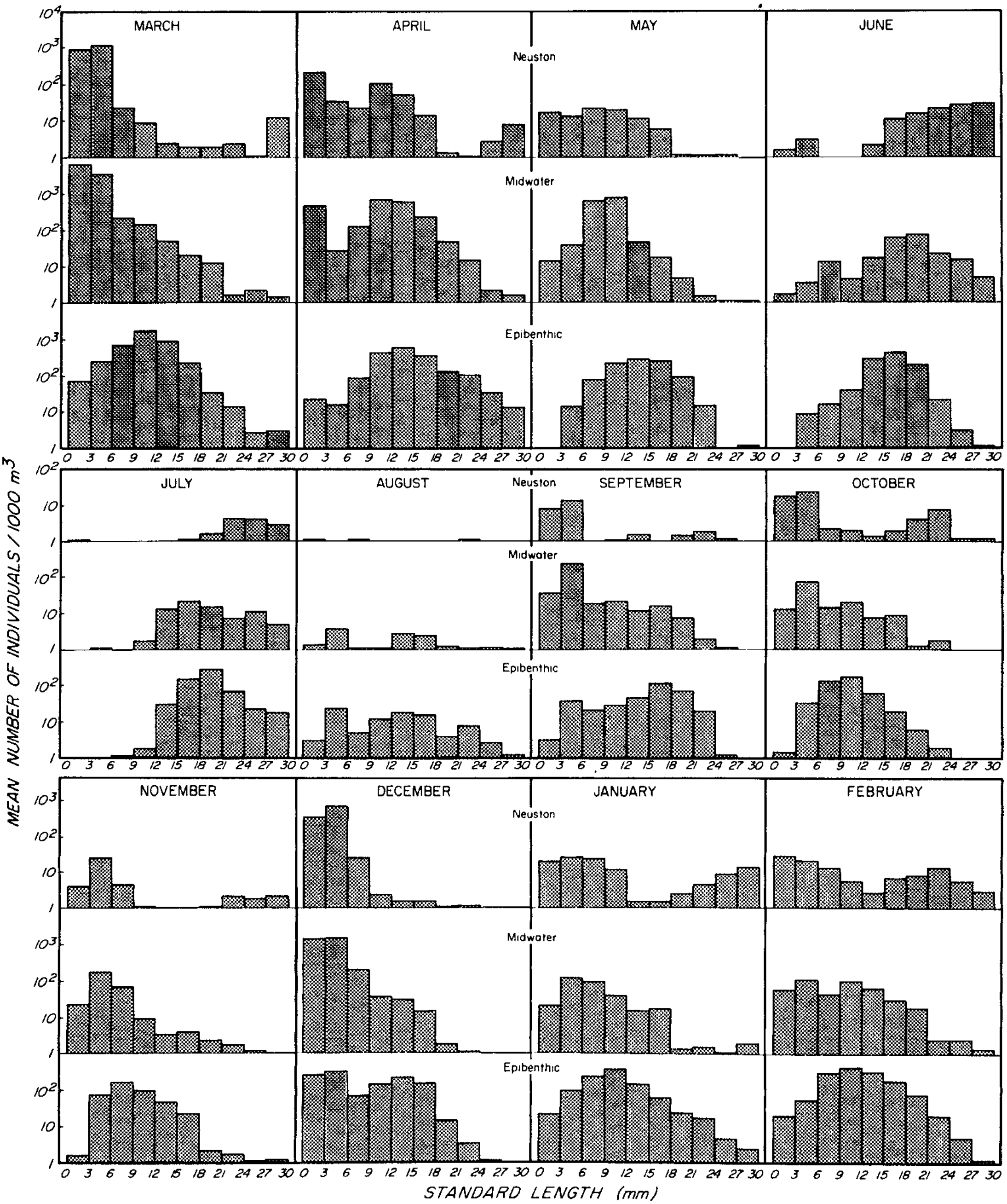

FIGURE 2.—Mean monthly concentrations of 10 larval size classes of northern anchovy, *Engraulis mordax*, in three water column levels, March 1978-February 1979. Each monthly value represents a mean of 4 replicates from each of 4 transects (total replicates = 16).

Discussion

In preliminary studies near San Onofre from August 1977 through February 1978, significantly greater numbers of larvae were observed in all three water column levels at night compared with daytime collections. Sampling was restricted to nighttime beginning in March 1978.

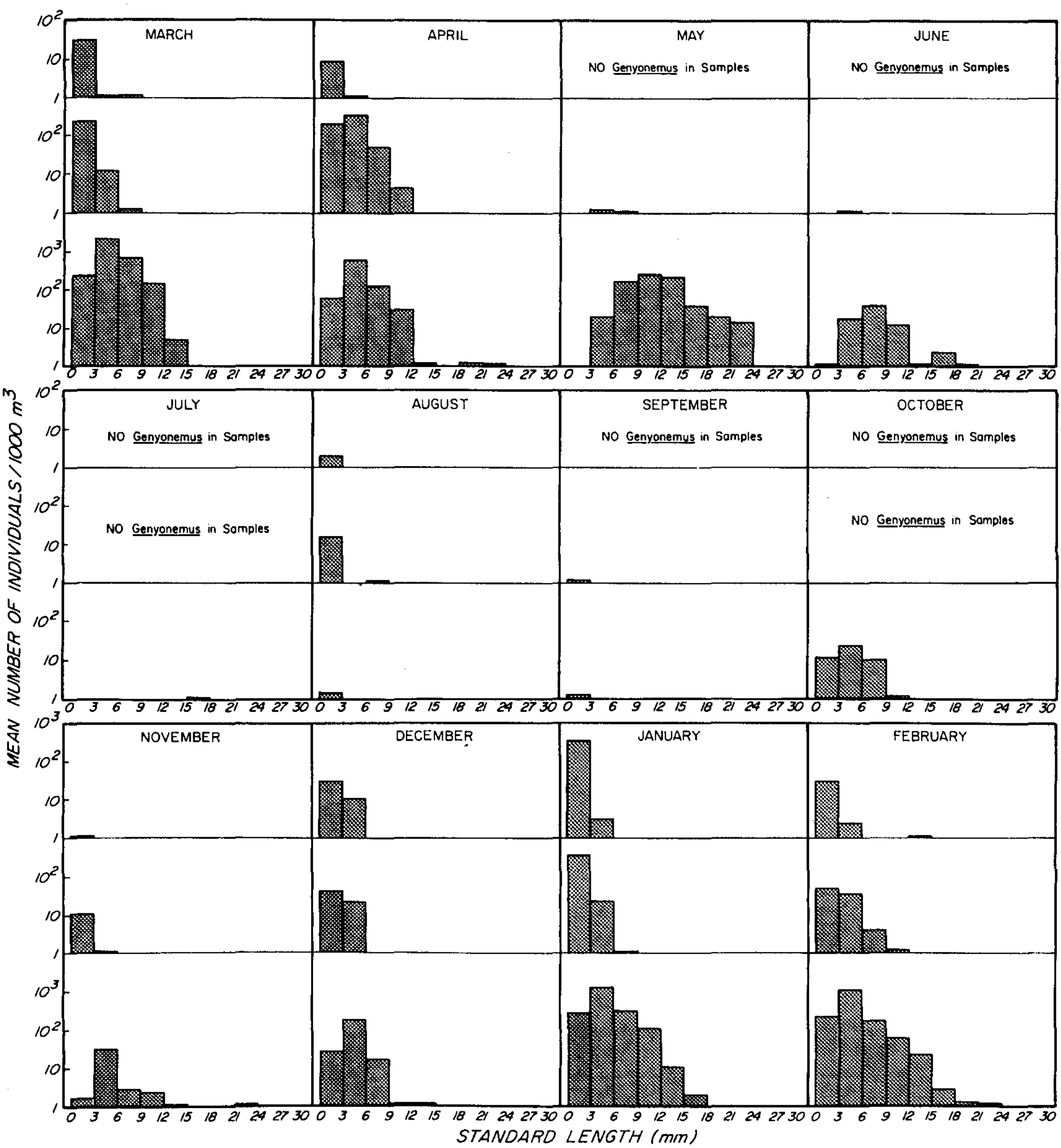

FIGURE 3.—Mean monthly concentrations of 10 larval size classes of white croaker, *Genyonemus lineatus*, in three water column levels, March 1978-February 1979. Each monthly value represents a mean of 4 replicates from each of 4 transects (total replicates = 16).

During the course of the study, no relationship between larval abundance and distribution and tidal stage, sea state, or stage of the moon was noted.

Vertical length-frequency distributions of all three species examined appear to be related to mode of feeding of each larval species, development during life history, and availability of food in the study area. The relationship between food availability and survival of larval northern anchovy is well documented. Larval anchovy require cells of 40 μm diameter in concentrations near 30 particles/ml (Lasker 1975, 1978). Lasker (1975) observed extensive feeding of anchovy larvae at the chlorophyll maximum layer, and Hunter and Thomas (1974) stated that anchovy

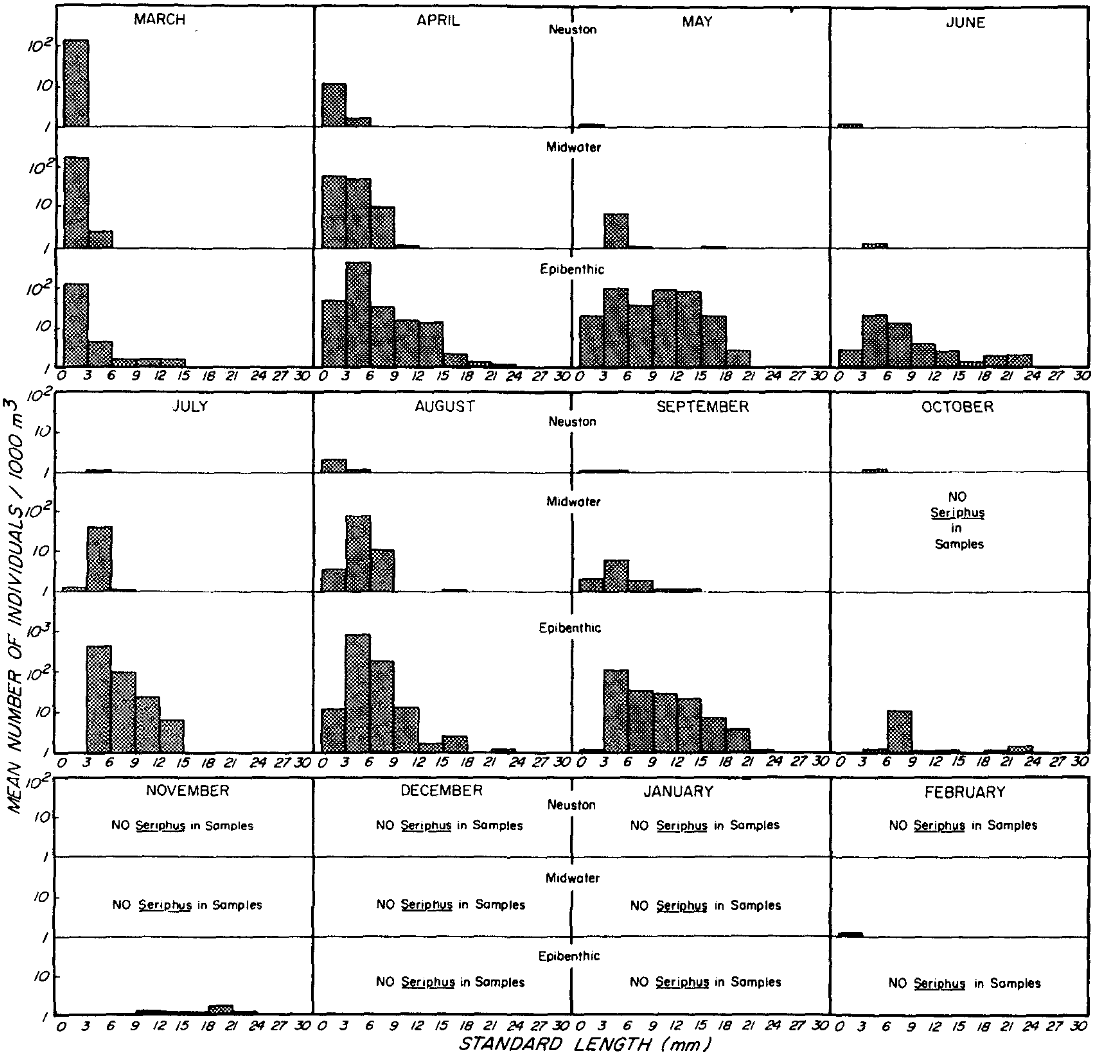

FIGURE 4.—Mean monthly concentrations of 10 larval size classes of queenfish, *Seriphus politus*, in three water column levels, March 1978-February 1979. Each monthly value represents a mean of 4 replicates from each of 4 transects (total replicates = 16).

larvae seek and remain in patches of the dinoflagellate *Gymnodinium splendens* in both day and night. Vertical differences in anchovy larval concentrations were shown by Ahlstrom (1959) to correspond to the level of the thermocline. In the San Onofre nearshore region, the maximum depths of the sampled transects were only 11 to 15 m, and the vertical zone is substantially compressed compared with offshore waters. Studies have indicated high concentrations of food in this nearshore area (Barnett and Sertic 1979). Concentrations of chlorophyll a 1 m below the surface and 1 m above the bottom were nearly equal during all times of the year from August 1976 to September 1978 at depths of 7 to 8 m and 18 to 30 m off San Onofre. Because adequate food may exist throughout the water column, a range of size classes is encountered at all depths. The apparent downward movement of larger anchovy larvae appears to be a natural behavioral response.

White croaker and queenfish larvae migrate toward the bottom after hatching. This vertical movement is associated with their adult life history, which is benthic in nature (Goldberg 1976). Additionally, larvae of 3 to 15 mm length of both these species feed primarily on zooplankton, which have been shown to be most abundant near the bottom in the nearshore San Onofre area (Barnett and Sertic 1979).

The absence of queenfish larvae in the neuston during the summer, and low concentrations in the midwater compared with the epibenthic level during the same period, may be due to the formation of the thermocline (density gradient) preventing eggs from entering the upper water column prior to hatching. Larvae of *G. lineatus* are more prevalent in these levels during the winter, when the water column is well mixed.

Length-frequency distributions of all three larval species are dependent on spawning cycles and behavioral and feeding patterns. Length-frequency distributions are reasonably accurate indicators of spawning periods, dependent on the life history of the species in question. Larvae of larger size classes are generally prevalent during periods of lowest abundance, after the main spawning period ends. During spawning periods, the distribution is dominated by smaller larvae. In distributions of northern anchovy, which apparently spawns intermittently year-round in the San Onofre region, the variability of the length-frequency median from month to month is highest in the neuston net and lowest in the epibenthos. Northern anchovy larvae apparently migrate from the neuston soon after hatching, but return upon reaching lengths of about 20 mm. Superimposed on spawning cycles, this phenomenon induces a high degree of variability to length-frequency medians of neuston samples. Larvae of the two sciaenid species, however, are benthic in nature, leading to increased variability in epibenthic samples, where the majority of these larvae are collected. At any one time, the major determining factor regulating the length-frequency distribution of these larval species near San Onofre is the reproductive state of each of the species.

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DECREASE IN LENGTH AT PREDOMINANT AGES DURING A SPAWNING MIGRATION OF THE ALEWIFE, *ALOSA PSEUDOHARENGUS*[1]

The spawning migration of the anadromous alewife, *Alosa pseudoharengus*, has been characterized by a decreasing trend in size and age. Cooper (1961) reported a trend in decreasing size in Pausacaco Pond, R.I., and Kissil (1974) found this one year in a 2-yr study at Bride Lake, Conn. A trend of decreasing size and age composition was also found in the Damariscotta River, Maine, alewife migration for the years 1977 through 1979 (Libby 1981).

Since 1977, data have been collected for length, weight, sex, age, and daily catch from the Damariscotta River commercial fishery. Analysis resulted in length-weight relationships, length, sex and age compositions, and an overall view of the annual stock changes. Further analysis of the collected data revealed that as age of the alewives decreased during migration, lengths at age also decreased with time. The analysis was applied only to 1979 and 1980 because of insufficient data in the other years.

The intent of this paper is to show the analysis and explain in greater detail this trend in decreasing length at age of an alewife migration.

The Study Area

The Damariscotta River alewife fishery is located approximately 29 km from the mouth of the river at the head of tide (Fig. 1). The river terminates at Great Salt Bay where a small outflow stream connects it with Damariscotta Lake.

Alewives are harvested with traps consisting of moveable metal bins that are set into the stream. Alewives swim into these bins which are then hoisted out of the water and the fish are dumped into a holding trough. The alewives that escape capture may pass through a fishway and

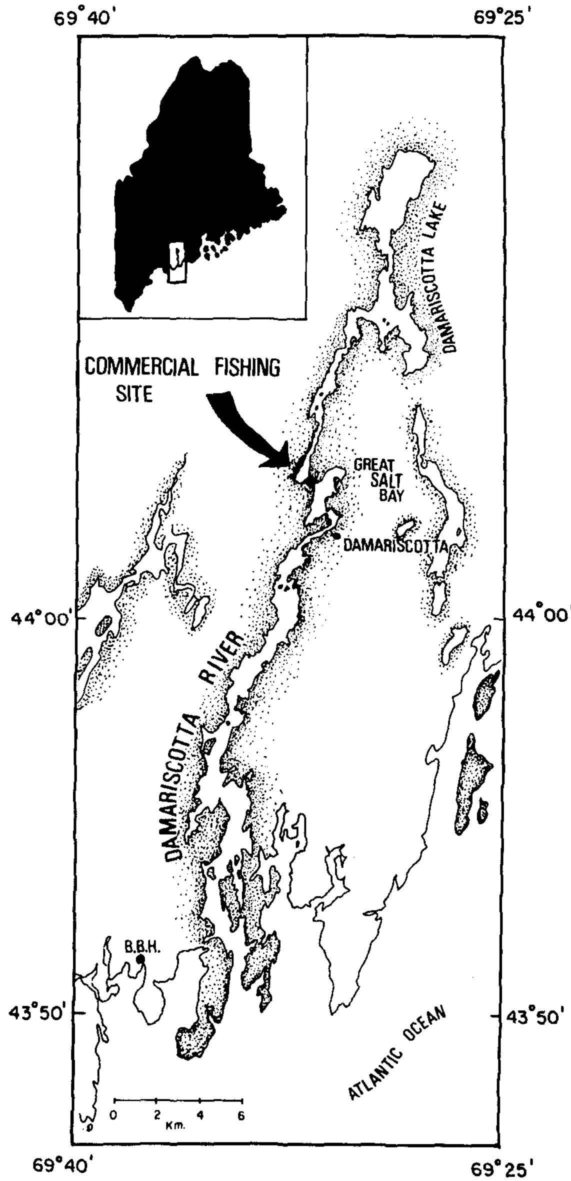

FIGURE 1.—Damariscotta River and site of the commercial alewife fishery.

[1]This study was conducted in cooperation with the U.S. Department of Commerce, National Marine Fisheries Service, under Public Law 89-304, as amended, Commercial Fisheries Research and Development Act, Projects AFC-21-1 and AFC-22-2.