# LARVAL FISHES OF YAQUINA BAY, OREGON: A NURSERY GROUND FOR MARINE FISHES?

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## ABSTRACT

Based on a survey of planktonic fish larvae, the Yaquina Bay estuary appears important as a spawning or rearing ground only for *Clupea harengus pallasi* (Pacific herring) and a variety of small cottids, gobies, and stichaeids. Other investigators, however, have found an abundance of juvenile *Parophrys vetulus* (English sole), *Citharichthys stigmaeus* (sanddab), *Hypomesus pretiosus* (surf smelt), *Platichthys stellatus* (starry flounder) and embiotocids (surf perches), indicating that the bay is an important nursery area for these species.

Of the 44 types of larval fishes found in the bay, *C. h. pallasi* and *Lepidogobius lepidus* (bay goby) were co-dominants each year, 1960-1970, comprising 90% of all larvae collected. There was no evidence of trends in abundances or species composition during the 11-yr study.

Maxima of planktonic fish eggs and *L. gobius* larvae occurred in the summer; maxima of all larvae combined and most species of larvae occurred in the winter and spring. High densities of larval herring were found in February and March, and peak numbers appeared earlier in the lower than the upper estuary.

Larvae of *C. h. pallasi*, *L. lepidus*, and *Cottus asper* were common at all stations from 0.5 to 8 nautical miles up the estuary, but not in the adjacent open ocean. Larvae of many species that were found in the estuary in small numbers were more abundant in offshore waters. Although English sole and sanddab were rare in the bay as larvae, juveniles were numerous.

This is a study of the species composition, relative abundance, seasonal and annual occurrence and distribution of larval fishes in an Oregon estuary. It was undertaken to increase the extremely limited knowledge of fish larvae in estuaries of the Pacific Northwest and to evaluate the role of these estuaries as spawning and nursery grounds.

According to Clark (1967) and McHugh (1966, 1967) the young of up to 70% of the economically important Atlantic species of fishes inhabit estuaries during part of their early life. Many species spawn offshore and young stages subsequently move into brackish estuaries. Although the Pacific coast is known for its runs of anadromous salmonids which migrate through estuaries, "There is no counterpart on the Pacific coast of the mass inshore movement of larvae and young of offshore-spawning nektonic species into brackish nursery grounds that is such a striking feature of the ecology of most Atlantic coast and Gulf of Mexico estuaries." (McHugh, 1967). Thus the number of species that are dependent on estuaries may not be as great on the Pacific as the Atlantic coast.

Oregon's estuaries are few in number and include but a small area. For this reason man's infringement on them for recreation, land development, harbors, agriculture, and waste disposal will be intense. This study evaluates some long-term trends of the relative abundance of larval fishes. Hopefully it will facilitate future comparisons of faunal changes within this estuarine habitat.

## THE ESTUARY

Yaquina Bay (Figure 1) is a small tidal estuary on the central Oregon Coast. It extends inland about 37 km and has an area of about 11.6 $km^2$. A channel is dredged to a depth of 7.9 m to McLean Point and to 3.7 m to the town of Toledo. Tides are mixed, semidiurnal with a mean tidal range of 1.7 m (Kulm and Byrne, 1967). According to Zimmerman (1972) the bay has an exchange ratio of 52% and a flushing time of 13.3 tidal cycles during the summer. The estuary is well-mixed with little vertical stratification in the summer when freshwater runoff is low, and is partially mixed (4-19‰ salinity

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Manuscript accepted June, 1973.
FISHERY BULLETIN, VOL. 72, NO. 1, 1974

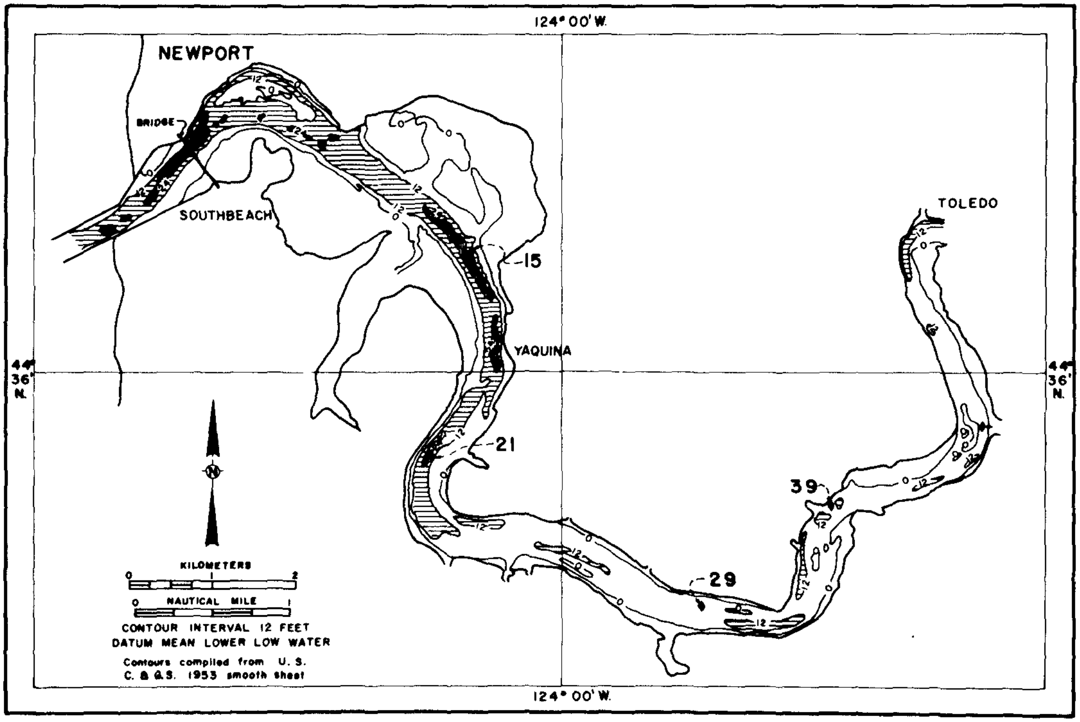


FIGURE 1.—Yaquina Bay estuary, showing location of stations: Bridge, Buoy 15, 21, 29, and 39.

difference from surface to bottom) during other seasons (Burt and McAlister, 1959; Kulm and Byrne, 1967; Zimmerman, 1972). Salinity is lowest and also most variable during the winter period of high precipitation. Temperatures, however, are most variable during the summer, owing to periodic advection of cold upwelled waters into the bay and to local heating (Frolander, 1964; Frolander et al., 1973).

## SAMPLING METHODS

A 12.5 cm diameter Clarke-Bumpus (CB) Sampler with nylon (Nitex®)[2] net of 0.233 mm mesh aperture was used to collect 393 plankton samples from January 1960 to December 1970 and to provide a long time series for analysis at one station (Buoy 21) located in Yaquina Bay about 4.3 nautical miles from the ocean (Figure 1). In addition, both the CB and a 20.2 cm diameter nonclosing Bongo Sampler were towed together at five stations (Bridge and Buoys 15, 21, 29, and 39) from June 1969 to June 1970 (223 tows). The bongo had nylon nets with 0.233 mesh on one side and a 0.571 mesh on the other and was attached 1 m below the CB on the same towing cable. The CB net was 61.6 cm long with the filtering area of the mesh to mouth area ratio of 6.2:1. The bongo nets were cylindrical-conical, 177 and 161 cm long for the 0.233 and 0.571 mesh nets respectively. Both bongo nets had a filtering area to mouth area ratio of 10.5:1.

Samples were collected from small boats, generally at weekly intervals during the sampling period. Oblique-step tows were made at 2 knots. At the three deep stations (Bridge, Buoys 15 and 21) the net was towed horizontally at each of three depths for 4 min: about 1 m above the bottom, at mid-depth and 1 m below the surface. At the two shallow stations in the upper estuary the nets were towed at each of two depths for 6 min: 1 m above the bottom and 1 m below the surface. Tows were made during daylight, in mid-channel, against tidal currents, and did not coincide with any particular tidal stage. However, several 24-h series of CB tows (123 tows) were made during the 11-yr period to assess diel and tidal variations at single stations.

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

Samples were also collected with the bongo nets (0.233 and 0.571 mm mesh) in the open ocean off Yaquina Bay from June 1969 to June 1970, often within a day of the bay sampling. A total of 113 step oblique tows was made at four stations 1, 3, 5, and 10 miles from the coast.

Volume of water filtered during each tow was estimated by flowmeters in the mouth of the nets. TSK meters were mounted on the inside wall of the bongo frames. Meters were calibrated periodically by towing them over a measured distance. Samples were preserved in the field with Formalin. In the laboratory entire samples were sorted for fish larvae with the aid of 2¼-power illuminated magnifier. Fish eggs were sorted from the 1960-1968 CB samples.

## SPECIES COMPOSITION

Larval fishes representing 17 families were found in Yaquina Bay during the 11-yr studies. These included 45 distinct types of larvae, 22 of which were identified to species (Table 1). Most families were represented by only one or two species or types. The family Cottidae, however, was represented by 14 different larval types, by far the most for any family. The family with the next largest number of types was Pleuronectidae with 6 identified species.

## THE 11-YR SERIES

### Relative Abundances

Table 2 summarizes the occurrence and average density of different fish larvae collected during the 11-yr CB series at Buoy 21. Two species, *Clupea harengus pallasi* (Pacific herring) and *Lepidogobius lepidus* (bay goby), were clearly the most abundant larvae. Combined they accounted for 90% of all the fish larvae collected in the 393 samples.

These two species were consistently the codominants during all years of the sudy (Table 3). *C. h. pallasi* ranked first in abundance during 8 yr. *L. lepidus* ranked first in 3 yr and second in the 8 yr that *C. h. pallasi* was dominant. *Cottus asper* (prickly sculpin) ranked third in abundance. *Leptocottus armatus* (Pacific staghorn sculpin), Gobiidae type 1, and *Hypomesus pretiosus* (surf smelt) alternated in the fourth, fifth, and sixth positions. Average number of these larvae per m$^3$ varied from year to year, but no obvious long-term trends in the relative abundance of these species suggested environmental changes or species succession. (Similarly, Frolander et al. [in press] found no evidence for persistent changes of zooplankton abundances in Yaquina Bay over the same time period.)

In order to learn if all six of the common species were more abundant in some years than others, rank correlations were calculated from annual abundances in Table 3. *Clupea h. pallasi* and *L. lepidus* were both caught in large numbers in 1967, but the Coefficient of Concordance, $W$, (Tate and Clelland, 1957) indicated little agreement among ranking of years ($P > 0.2$). In other words, there was no

TABLE 1.—Species composition of fish larvae from Yaquina Bay from all samples examined, 1960-1970.

Clupeidae
  *Clupea harengus pallasi*
Engraulidae
  *Engraulis mordax*
Osmeridae
  *Hypomesus pretiosus*
Gobiesocidae
  *Gobiesox meandricus*
Gadidae
  *Microgadus proximus*
Gasterosteidae
  *Aulorhynchus flavidus*
Syngnathidae
  *Syngnathus griseolineatus*
Stichaeidae
  *Lumpenus sagitta*
  *Anoplarchus* sp.
  *Chirolophis* sp.
  2 unknown types
Pholidae
  *Pholis ornata*
Ammodytidae
  *Ammodytes hexapterus*
Gobiidae
  *Lepidogobius ledpidus*
  1 unknown type
Scorpanenidae
  *Sebastes* spp.
Hexagrammidae
  *Hexagrammos* sp.
  *Ophiodon elongatus*
Cottidae
  *Leptocottus armatus*
  *Cottus asper*
  *Scorpaenichthys marmoratus*
  *Enophrys bison*
  *Hemilepidotus* spp.
  9 unknown types
Agonidae
  2 unknown types
Cyclopteridae
  3 unknown types
Bothidae
  *Citharichthys* sp.
Pleuronectidae
  *Psettichthys melanostictus*
  *Platichthys stellatus*
  *Glytocephalus zachirus*
  *Isopsetta isolepis*
  *Parophrys vetulus*
  *Lyopsetta exilis*

TABLE 2.—Fish larvae collected in Clarke-Bumpus nets during 1960-1970 at Buoy 21, ranked by abundance.

| Item | No. of Tows occurred in out of 393 | Total No. collected | Total No. larvae ÷ total volume of water filtered $m^3 x 10^3$ | Months of occurrence |
|---|---|---|---|---|
| *Clupea harengus pallasi* | 76 | 2,174 | 510 | I-V |
| *Lepidogobius lepidus* | 98 | 1,287 | 302 | IV-X |
| *Cottus asper* | 47 | 129 | 30 | I-V |
| *Leptocottus armatus* | 42 | 53 | 12 | VIII-III |
| Gobiidae type 1 | 27 | 49 | 11 | VII-III, VI |
| *Hypomesus pretiosus* | 23 | 39 | 9.1 | VIII-IX, XI-IV |
| *Lumpenus sagitta* | 8 | 29 | 6.8 | I-II |
| *Enophrys bison* | 12 | 20 | 4.7 | I-III |
| *Ammodytes hexapterus* | 10 | 15 | 3.5 | I-III |
| *Anoplarchus* sp. | 10 | 12 | 2.8 | II-III |
| Cottidae type 1 | 8 | 10 | 2.3 | II-III, VI-VII |
| *Engraulis mordax* | 6 | 7 | 1.6 | VII-IX |
| *Pholis ornata* | 7 | 7 | 1.6 | I-III |
| *Parophrys vetulus* | 4 | 6 | 1.4 | II-III |
| *Platichthys stellatus* | 3 | 3 | 0.7 | V-VI |
| Cyclopteridae type 1 | 3 | 3 | 0.7 | VI, VII, XII |
| Cottidae type 10A | 3 | 3 | 0.7 | II, XI |
| Cottidae type 5 | 3 | 3 | 0.7 | VIII, IX |
| *Citharichthys* sp. | 2 | 2 | 0.5 | II-III |
| Cyclopteridae type 2 | 2 | 2 | 0.5 | VI-VII |
| *Syngnathus griseolineatus* | 2 | 2 | 0.5 | VII-VIII |
| Cottidae type 10B | 1 | 1 | 0.2 | I |
| Cottidae type 11 | 1 | 1 | 0.2 | III |
| *Sebastes* spp. | 1 | 1 | 0.2 | I |
| Hexagrammidae | 1 | 1 | 0.2 | II |

evidence that "good" or "bad" years occurred simultaneously for different species of larvae.

## SEASONAL VARIATIONS

### Total Eggs and Larvae

The average monthly catch of pelagic fish eggs at Buoy 21 was highest in the summer, with highest values ($>2/m^3$) from July to October (Figure 2). Eggs of the northern anchovy (*Engraulis mordax*) were sometimes abundant during this season. Numbers of fish larvae, on the other hand, peaked early in the year, from February to June, and few larvae were taken after June. *C. h. pallasi* and *L. lepidus* larvae were the main contributors to these large larval catches. These two species, and many others found in the estuary, have demersal eggs.

This seasonal maximum of fish larvae in the first half of the year in Yaquina Bay is similar to the seasonality reported in the Straits of Georgia, British Columbia by Parsons, LeBrasseur, and Barraclough (1970).

### Individual Species

The seasonal occurrence of larvae collected at Buoy 21 is summarized in Table 2. The majority of the larval species were most common in the winter or spring, including *C. h. pallasi*, *Cottus asper*, *Hypomesus pretiosus*, *Parophrys vetulus*, *Ammodytes hexapterus*, *Lumpenus sagitta*, *Anoplarchus* sp., *Pholis ornata*, and *Enophrys bison*. *L. lepidus* was

TABLE 3.—Average abundance of the six most common fish larvae by year, 1960-1970, Clarke-Bumpus samples, Buoy 21.

| Item | Average number of larvae per $10^3 m^3$ water filtered | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 |
| *Clupea harengus pallasi* | 174 | 542 | 278 | 279 | 1,230 | 335 | 273 | 1,136 | 961 | 526 | 506 |
| *Lepidogobius lepidus* | 312 | 230 | 37 | 114 | 326 | 402 | 161 | 1,169 | 471 | 74 | 132 |
| *Cottus asper* | 17 | 35 | 24 | 38 | 41 | 48 | 35 | 68 | 5 | 20 | 14 |
| Gobiidae type 1 | 11 | 1 | 2 | 50 | 24 | 0 | 0 | 11 | 0 | 34 | 14 |
| *Leptocottus armatus* | 17 | 6 | 12 | 34 | 12 | 7 | 18 | 17 | 5 | 10 | 2 |
| *Hypomesus pretiosus* | 5 | 7 | 0 | 23 | 4 | 4 | 18 | 3 | 0 | 44 | 7 |

the only common species with a distinct peak of larval abundance in the summer (April-September). Several species were collected most months of the year: considering all years together, larvae of *Hypomesus pretiosus* were found every month but May, June, July and October, *L. armatus* every month except April-July, and Gobiidae type 1 every month but April, May and July.

## Pacific Herring

Catches of *C. h. pallasi* larvae during each January-June period, 1960-1970, are illustrated for Buoy 21 in Figure 3. Herring larvae were common from February-April, with peak numbers usually in February and March. Though sampling variability and the limited number of samples precluded annual comparisons of abundance, no obvious long-term trends, such as decreasing catches, are evident during this 11-yr period, nor is there good evidence for large fluctuations in larval numbers. This suggests a fairly stable population of spawning herring over this time period.

The initial occurrence of larval herring varied among years, from January to March, suggesting annual differences in time of spawning or hatching times (e.g., contrast 1969 and 1970 with 1961-1963). This variability may be related to water temperature. The surface temperature of first larval occurrence varied from 7.3°C to 10.5°C (average = 9.0°C). To estimate date of first spawning, incubation time was calculated from a curve of incubation times vs. temperature (Outram, 1955; Taylor, 1971; Steinfeld, 1972). Incubation was estimated to range between 12 and 17 days for the first herring larvae caught during these years using surface water temperatures at Buoy 21. (Because herring spawn in shallow water, often intertidally [Steinfield, 1972; Taylor, 1971; Hardwick, 1973], surface temperatures were used.) Surface temperatures averaged for the date of first herring larval occurrence and the previous 17 days (2-3 observations) were plotted against time of first larval occurrence after January 1 (Figure 4). This revealed a surprising relationship: Years of earliest occurrence of larvae (i.e., 1969 and 1970) had lowest water temperatures (< 8°C) preceding first catches, and most years of latest occurrence (i.e. 1961, 1963, 1965, 1966) had highest temperatures (>9.2°C) during

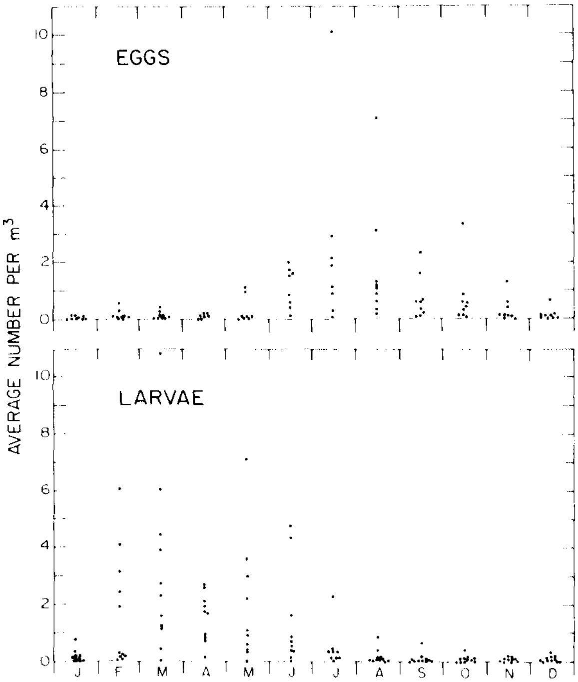


FIGURE 2.—Average monthly catches of fish eggs and larvae in Clarke-Bumpus samples at Buoy 21. Each point represents a monthly average for fish eggs each year, 1960-1968, and for fish larvae each year, 1969-1970. No samples were available from April-July 1966.

incubation of the first hatch. Thus, factors other than water temperature appear to be important in determining the time of the initial spawning of herring in Yaquina Bay.

Steinfeld (1972) observed from egg surveys in Yaquina Bay that herring had four major spawnings during February and March 1970. These occurred at about 2-wk intervals starting in early February, the most intensive spawnings coinciding with highest tides. Newly hatched larvae would therefore be expected in most of the catches throughout the larval periods. Measurements of larvae contributing to early and late peaks in 1964 and 1967 showed that recently hatched larvae (6-8 mm) were indeed present in April, but as expected, the percentage of small larvae was lower later in the year.

## HORIZONTAL VARIATIONS

The average number of larvae collected at the different stations in both the estuary and the open ocean are listed in Table 4, permitting comparison of horizontal variations of relative abundance at nine stations from 8 miles up the

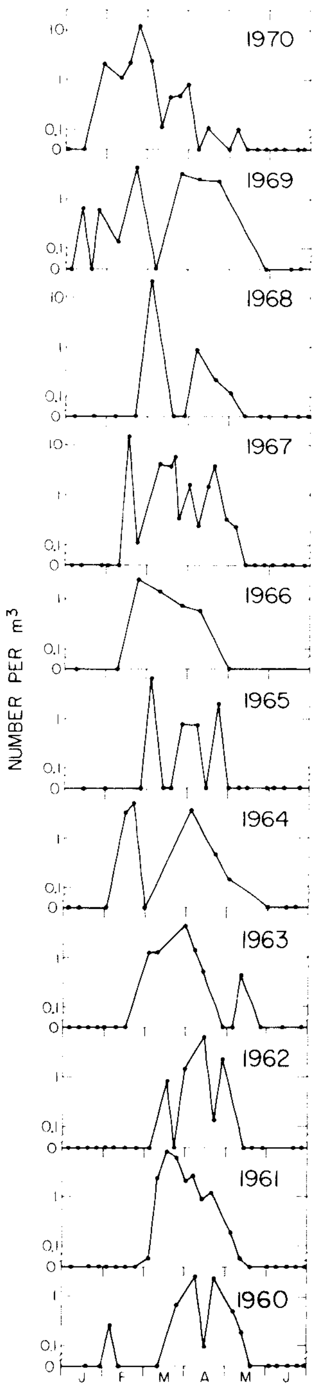


FIGURE 3.—Number of Pacific herring larvae per m³ caught in Clarke-Bumpus nets at Buoy 21 during January-June periods, 1960-1970.

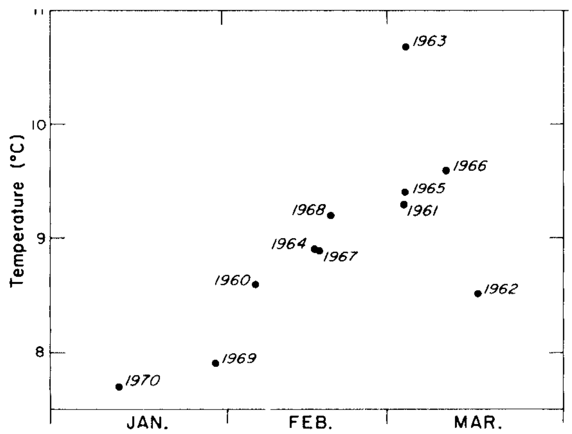


FIGURE 4.—Average surface temperature at Buoy 21 during and 14-17 days prior to first catches of herring larvae vs. date of first catches of herring larvae, 1960-1970.

estuary to 10 miles off the coast. Within the estuary, larvae of *C. h. pallasi*, *L. lepidus*, and *Cottus asper* usually ranked first, second, and third respectively in the catches at all five stations, from 0.5 to 8 nautical miles up the estuary. *L. lepidus* was the only common species restricted to the bay; it was most numerous in the upper estuary. Larvae of *C. h. pallasi* were abundant in the bay and rare outside the bay. Some of the other species that are considered to be primarily bay forms are *Cottus asper*, found in greatest numbers in the upper estuary, and *Enophrys bison*, *Leptocottus armatus* and *Pholis ornata*, found mainly in the lower estuary.

Many of the larvae found in the bay were found in greater numbers offshore. Larvae of the surf smelt, *H. pretiosus*, were sometimes abundant in the lower estuary where juvenile *H. pretiosus* were also numerous. Osmerids were most abundant 1 mile offshore. We assume that these were mainly *H. pretiosus*, a species known to spawn in the surf zone. Consequently, the surf smelt larvae found in the bay may be carried there by tidal exchange. Larvae of *A. hexapterus*, *Sebastes* spp., pleuronectids, gadids, and cyclopterids were all found in higher numbers offshore than in the bay. *Parophrys vetulus* was only found offshore.

*Engraulis mordax* larvae were found throughout the bay and to 3 miles offshore. They were not found 5 or 10 miles offshore. This larval distribution, and the large numbers of anchovy

TABLE 4.—Average number of larvae per $10^3 m^3$ filtered in bongo nets (mesh 0.233 and 0.571 mm combined) calculated from total number of specimens collected ÷ total volume filtered for entire year. Only species represented by five or more larvae are listed. June 1969-June 1970.

| | BAY | | | | | OFFSHORE (mi) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 39 | 29 | 21 | 15 | BR | 1 | 3 | 5 | 10 |
| A. BAY ONLY | | | | | | | | | |
| *Lepidogobius lepidus* | 106.0 | 340.5 | 113.4 | 92.9 | 6.4 | 0 | 0 | 0 | 0 |
| *Lumpenus sagitta* | 0 | 0 | 0.5 | 1.1 | 1.3 | 0 | 0 | 0 | 0 |
| *Anoplarchus* spp. | 0 | 0.6 | 0.7 | 1.1 | 1.0 | 0 | 0 | 0 | 0 |
| B. PRIMARILY BAY | | | | | | | | | |
| *Clupea h. pallasi* | 509.2 | 428.2 | 442.6 | 556.0 | 183.3 | 0.3 | 0.5 | 0 | 0 |
| Gobiidae type 1 | 0.5 | 0.9 | 13.7 | 5.3 | 1.3 | 0.6 | 0.3 | 0 | 0 |
| *Cottus asper* | 40.7 | 42.3 | 21.0 | 10.1 | 9.2 | 0.6 | 0 | 0 | 0 |
| *Enophrys bison* | 0 | 0 | 2.3 | 9.6 | 18.8 | 0.3 | 0 | 0 | 0 |
| *Leptocottus armatus* | 0.7 | 1.6 | 10.0 | 7.2 | 3.8 | 0.3 | 0 | 0 | 0 |
| Cottidae Type 1 | 0 | 0 | 0.5 | 1.3 | 1.3 | 0.6 | 0.5 | 1.0 | 0.3 |
| *Pholis ornata* | 0 | 0 | 0.8 | 1.3 | 1.3 | 0.3 | 0.5 | 0 | 0 |
| C. PRIMARILY OFFSHORE | | | | | | | | | |
| *Engraulis mordax* | 0.5 | 1.0 | 0.5 | 0.3 | 0.2 | 2.1 | 1.1 | 0 | 0 |
| *Hypomesus pretiosus*-Osmerids | 1.0 | 0.6 | 3.0 | 15.7 | 27.2 | 100.9 | 18.6 | 4.6 | 0.3 |
| Gadidae | 0 | 0 | 0.5 | 0 | 0.2 | 0.6 | 4.5 | 0.7 | 1.1 |
| *Ammodytes hexapterus* | 0 | 0 | 0 | 0.5 | 0.5 | 1.8 | 13.0 | 2.0 | 2.5 |
| *Sebastes* spp. | 0 | 0 | 0 | 0.5 | 0.8 | 6.9 | 4.2 | 1.5 | 19.6 |
| *Ophiodon elongatus* | 0 | 0 | 0 | 0.3 | 0 | 0.6 | 0.8 | 0.7 | 0 |
| *Hemilepidotus* | 0 | 0 | 0 | 0 | 0.2 | 1.5 | 2.9 | 0 | 1.2 |
| Cottidae type 12 | 0 | 0 | 0 | 0.3 | 0.5 | 0.9 | 0 | 0 | 0 |
| Agonidae | 0 | 0 | 0 | 0 | 1.0 | 0.3 | 0.5 | 0.2 | 0 |
| Cyclopteridae | 0 | 0 | 0.2 | 0.3 | 0.2 | 0.6 | 3.2 | 0.2 | 0.5 |
| *Psettichthys melanostictus* | 0.2 | 0 | 0.5 | 0 | 0.5 | 5.1 | 31.1 | 3.4 | 0.5 |
| *Isopsetta isolepis* | 0 | 0 | 0 | 0 | 0.2 | 0.6 | 36.1 | 5.1 | 1.1 |
| *Lyopsetta exilis* | 0.2 | 0 | 0 | 0 | 0 | 0 | 9.0 | 0 | 0.3 |
| *Citharichthys* sp. | 0 | 0 | 0 | 0.5 | 0.5 | 1.0 | 0 | 0 | 0 |
| D. OFFSHORE ONLY | | | | | | | | | |
| *Stenobrachius leucopsarus* | 0 | 0 | 0 | 0 | 0 | 0.3 | 0.5 | 1.0 | 1.6 |
| Cottidae type 16 | 0 | 0 | 0 | 0 | 0 | 0 | 2.4 | 0 | 0.3 |
| Cottidae unident. spp. | 0 | 0 | 0 | 0 | 0 | 1.8 | 9.6 | 7.1 | 0.6 |
| *Parophrys vetulus* | 0 | 0 | 0 | 0 | 0 | 1.2 | 9.0 | 11.9 | 8.9 |
| Blennoids | 0 | 0 | 0 | 0 | 0 | 3.3 | 4.5 | 0 | 0 |

eggs within the bay, is peculiar since Richardson (1973) reported that anchovy larvae were abundant well offshore, usually in Columbia River plume waters, and not near the coast.

## Pacific Herring

### Abundance

Herring larvae were abundant at all five stations during February and March 1970 (Figure 5). A peak in catches occurred in late January at the three stations closest to the ocean, and conversely, higher numbers occurred later (April and May) at the upper estuarine stations. These trends suggest earlier spawning near the mouth and later spawning in the upper estuary. Based on intertidal surveys, Steinfeld (1972) found herring eggs near the mouth from February 5 to 20, 1970, and in the upper estuary above Buoy 21 from March 8 to 24, 1970. The trend for earlier spawning near the mouth of the estuary was therefore found in both larval and egg surveys. However, the fact that Steinfeld did not find any spawn before February 5 while we collected many larvae between January 23 and February 10 indicates that intertidal surveys may miss substantial areas of eggs, perhaps from subtidal spawning.

### Comparison of Nets

Catches of herring larvae in the three types of nets (CB and bongo with 0.233 mm mesh and bongo with 0.571 mm mesh) were usually similar on a $m^3$ basis, especially at high densities of larvae (Figure 5). The type of net catching the highest or the lowest number of larvae alternated among tows. We had not expected catches by the CB to compare favorably with the bongo in view of the known avoidance capability of Atlantic herring larvae (Bridger, 1956; Tibbo et al., 1958).

The percentage of herring larvae of different sizes caught at Buoy 29 in the three nets during the 1970 larval season is shown in Figure 6. Little difference is apparent in the proportion of different sizes of larvae in the different nets. All curves show that the number of larvae caught between 6 and 8 mm was less than between 8 and 10 mm. This is probably explained by hatching of some larvae at lengths over 8 mm, and hence is a true reflection of relative abundance, rather than lack of retention of the smallest larvae by the nets. Larvae larger than 20 mm were not caught at all in the CB samples, presumably because of the capability of large larvae to avoid this gear.

## TIDAL-DIEL VARIATIONS

Figure 7 illustrates the variations in CB catches of fish eggs and larvae during several diel sampling periods at Buoy 21. In Figure 7A, peaks in both egg and larval abundance occurred during periods of low water (Mann-Whitney $U$ test, $P < 0.01$). Similarly, highest catches of herring larvae coincided with times of low water in Figure 7B ($P = 0.06$). In neither of these figures is a day-night difference evident ($P > 0.2$). In Figure 7C, however, catches of herring larvae were not correlated with tidal stage ($P > 0.2$), but highest catches coincided with darkness ($P < 0.01$); all but one of the 9 nighttime catches exceeded the 14 daytime catches.

Therefore, both tidal and diel factors may influence catches. We believe the high catches associated with low water were caused by tidal excursion of water with high density of eggs or larvae. In other words, the center of abundance of *L. lepidus* larvae and fish eggs (Figure 7A) and *C. h. pallasi* (Figure 7B) was up the estuary from Buoy 21 at high tide. The ability of larger larvae to avoid plankton nets during the daytime (see Figure 6; Tibbo et al., 1958; Bridger, 1956; and Colton, Honey, and Temple, 1961) was thought to explain the high catches after dark in Figure 7C, but this interpretation was not supported by the similar size-frequency distributions of day- and night-caught larvae.

## THE ESTUARY AS A NURSERY

The results of this study on the planktonic fish larvae tentatively support McHugh's (1966,

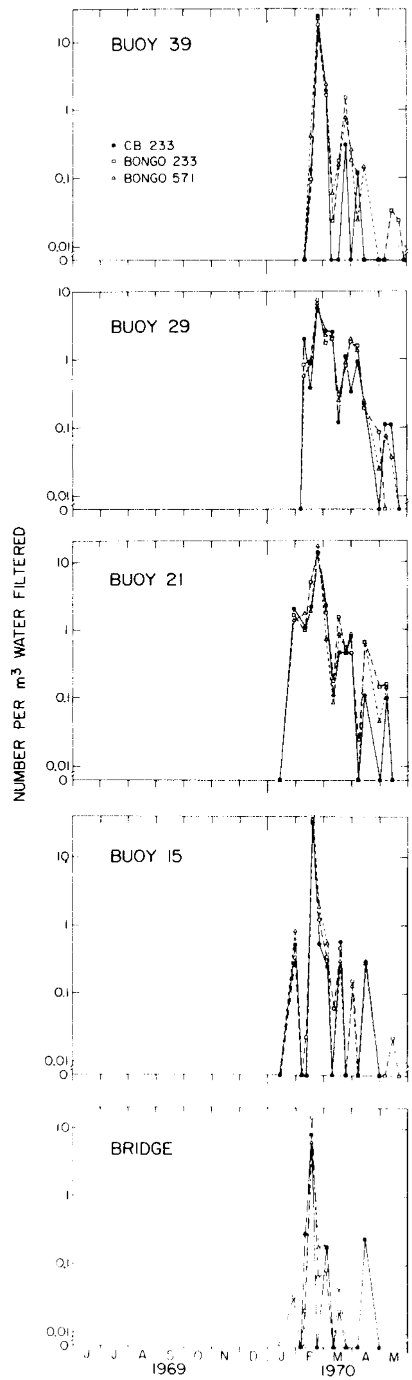


FIGURE 5.—Number of Pacific herring per m$^3$ caught in Clarke-Bumpus nets with 0.233 mm mesh, the bongo net with 0.233 mm mesh and the bongo net with 0.571 mm mesh at five stations in Yaquina Bay, June 1969-June 1970.

1967) contention that estuaries of the Pacific coast may be less important as nursery grounds than eastern seaboard estuaries. But such a conclusion is unwarranted without a comparison of larval abundances within the estuary with those in adjoining open ocean to learn if larvae are restricted to or concentrated in estuaries. High numbers of larvae within the estuary are not necessarily proof of estuarine dependance, as they may be more abundant in the ocean. Conversely, low densities of a species inside the estuary may indicate importance if it is absent elsewhere. A comparison of larval catches in Yaquina Bay with the open ocean is possible since we collected fish larvae at stations 1, 3, 5, and 10 miles off Yaquina Bay, using the same bongo nets during the same sampling period as the bay sampling. The results of this comparison (Table 4) corroborate our earlier suggestion: with the exception of the Pacific herring the estuary does not appear to be important to the pelagic larvae of commercial fishes. Most of the larvae that were restricted to or were most common in the estuary were of small, non-food species of cottids, stichaeids, and gobies. Larvae of all the pleuronectids collected were more common offshore than inside the estuary.

Thus the Pacific herring was the only species of commercial interest that appeared to use the estuary extensively as both a spawning and a nursery ground. In California, herring spawn in bays and estuaries (Hardwick, 1973). Since Pacific herring are known to comprise more or less distinct populations with adults returning to the same bay to spawn (Stevenson, 1955; Rounsefell, 1930), estuaries may be vital to the maintenance of herring along some portions of the west coast.

Feeding conditions for herring are undoubtedly related to their use of estuaries as nurseries. Russell (1964) found that Yaquina Bay is used as a feeding ground for 1 to 4 yr-old herring which fed mainly on the copepods *Acartia clausii* and *Pseudocalanus* sp., both abundant within the bay. *A. clausii*, which is thought to maintain indigenous populations in Yaquina Bay, is especially abundant in the upper estuary (Buoys 21 and 29) early in the spring when densities of adults and immatures exceed 30,000m$^3$ (Zimmerman, 1972 Frolander et al., 1973). The numbers of copepod eggs, nauplii, and copepodites, important food for Atlantic herring larvae, probably exceed this

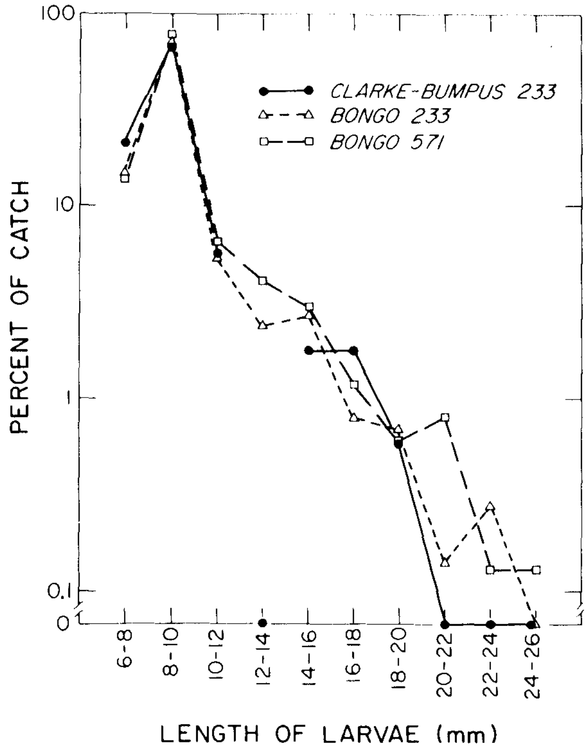


FIGURE 6.— Catches of different lengths of herring larvae at Buoy 29 expressed as a percentage of the total catch for each of the Clarke-Bumpus and bongo nets with 0.233 mm mesh and the bongo net with 0.571 mm mesh, February 10-March 13, 1970.

density during the early spring and provide adequate food for larval herring (Blaxter, 1965; Bainbridge and Forsyth, 1971; Sherman and Honey, 1971).

Our planktonic survey of fish larvae was not adequate to assess completely the estuary as a nursery ground. First, plankton nets are selective and only weakly swimming pelagic larvae were effectively sampled. Other young stages may not have been fully susceptible to capture because they actively avoid the nets. Secondly, the young of some species may have been present but simply unavailable for sampling because of their distributions. These may include young that migrate into the estuary after metamorphosis, benthic forms, or young that reside in shallow areas of the estuary.

For example, viviparous embiotocids (*Phanerodon furcatus*, *Rhacochilus vacca*, and *Embiotoca lateralis*) are common species in Yaquina Bay. Mature females of all these species are numerous in the middle and upper estuary

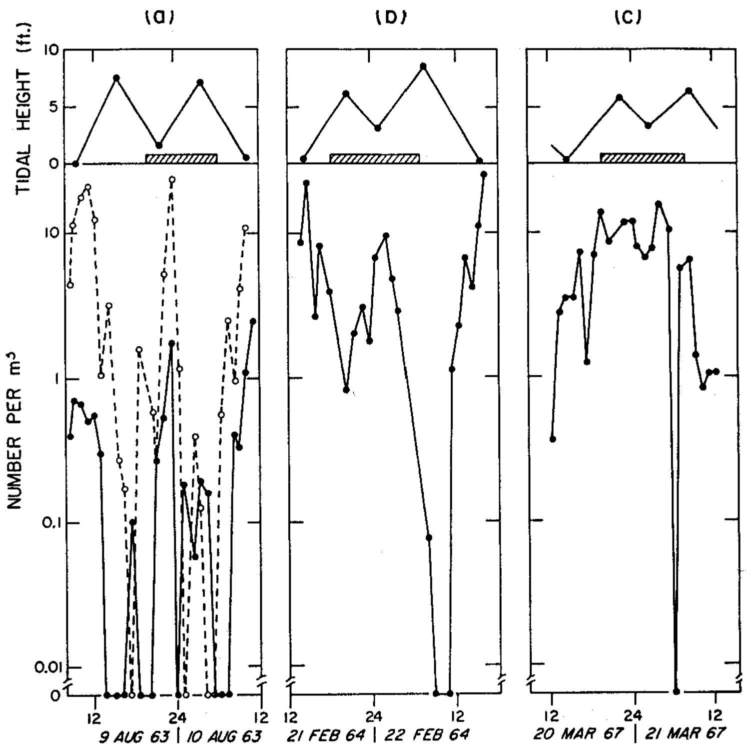


FIGURE 7.—Diel variations in the CB catches at Buoy 21: A. 9-10 August 1963; solid line = fish larvae; dashed line = fish eggs. B. 21-22 February 1964; solid line = herring larvae. C. 20-21 March 1967; solid line = herring larvae. The tidal height above mean lower-low water and period of darkness (hatched bar) are shown above each figure. Dates and noon and midnight are indicated below each figure.

during the spring when they give birth to young which use the estuary as a nursery (Beardsley, 1969; Wares, 1971). Because of their pelagic nature and swimming abilities, young embiotocids are not readily captured in small plankton nets or trawls. Beardsley (1969) and Westrheim (1955) also found many juvenile starry flounder (*Platichthys stellatus*) in Yaquina Bay, and Haertel and Osterberg (1967) concluded that the starry flounder use the upper Columbia River estuary as a nursery ground.

A trawl survey of juvenile fishes of Yaquina Bay by Wm. Johnson (pers. comm.), conducted during the same period and at the same stations as our plankton survey, provided useful information on the juvenile fishes caught in midchannel of the estuary near the bottom. Relative abundances of the young fishes caught are shown in Table 5. Three species were dominant: *Hypomesus pretiosus*, *Parophrys vetulus*, and *Citharichthys stigmaeus*. They comprised 79% of the total number of fishes collected. Of these, only the abundant *H. pretiosus* was also common in plankton collections (Tables 2, 3, and 4). *Lepidogobius lepidus*, *Cottus asper*, and *Leptocottus armatus*, though presumbly benthic as juveniles, were not abundant in the trawl collections despite their abundance as pelagic larve. Johnson (pers. comm.) caught large numbers of juvenile *L. armatus* in shoal areas of Yaquina Bay with a beach seine, indicating that juveniles of some species may reside mainly in shallow water.

Young of both *Parophrys vetulus* and *Citharichthys stigmaeus* were abundant within Yaquina Bay, indicating that the bay provides a nursery for these species. Peak numbers of *P. vetulus* (15-45 mm) were found between April and June at Buoy 21, but young were captured at all stations from Buoy 15 to 39.

*Citharichthys stigmaeus* (30-80 mm) were concentrated in the lower estuary and were rarely captured up-estuary of Buoy 21. They were most common in May and June. *Hypomesus pretiosus* (35-50 mm) were abundant at all trawling stations, but only in January and February (Johnson, pers. comm.).

The importance of estuaries as nursery grounds for flounder, and especially for *Parophrys vetulus*, has been emphasized by others. Westrheim (1955) reported appreciable numbers of small *Parophrys vetulus, Citharichthys sordidus*[3] and *Platichthys stellatus* (starry flounder) in Yaquina Bay. Sand sole (*Psettichthys melanostictus*) were also encountered frequently. Although no adults of the commercially important English sole were caught, juveniles (20-180 mm) were common until autumn when most emigrated from the bay. Olsen and Pratt (1973) also reported that juvenile English sole were abundant in lower Yaquina Bay from April to September 1971, emigrating to offshore areas in October. Based on the incidence of a parasitic infection, apparently acquired only in estuaries, they concluded that estuaries are likely to be the exclusive nursery grounds for *Parophrys vetulus* on the Oregon coast, a conclusion that is supported by the absence of 0-age English sole in Demory's (1971) ocean trawling survey off the Oregon-Washington coast. Misitano (1970) and Eldridge (1970) found large numbers of English sole in Humboldt Bay, California. Villadolid (1927, as cited in Misitano, 1970) captured 0-age English sole by trawling in San Francisco Bay but found none off the coast. Shallow protected waters along the indented British Columbia coastline also provide nursery grounds for this species (Ketchen, 1956). Bays and estuaries are therefore vital as nursery areas for *P. vetulus* in their first year of life, perhaps because the sediments in these protected waters provide an ideal feeding habitat for the young as opposed to coarse sand sediments at similar depths along the open coast.

Sexually mature (ripe) *P. vetulus* were not caught in Humboldt or Yaquina Bay but are known to spawn offshore (Westrheim, 1955; Harry, 1959; Jow, 1969). Young larvae were uncommon in plankton collections from these

[3] Probably *C. stigmaeus*, the species usually found by others in Yaquina Bay.

TABLE 5.—Relative abundance (%) of juvenile fishes collected at four stations in Yaquina Bay (Bridge to Buoy 29) in a 1.8-m beam trawl (1.5 mm stretch mesh), January-June, 1970 (courtesy Wm. Johnson).

| | |
|---|---|
| *Hypomesus pretiosus* | 36.2 |
| *Parophrys vetulus* | 24.6 |
| *Citharichthys stigmaeus* | 18.2 |
| *Enophrys bison* | 4.1 |
| *Clupea h. pallasi* | 3.6 |
| *Ammodytes hexapterus* | 2.5 |
| *Leptocottus armatus* | 2.3 |
| *Hexagrammos decagrammus* | 1.1 |
| *Pholis ornata* | 1.0 |
| *Raja binoculata* | 0.7 |
| *Platichthys stellatus* | 0.7 |
| *Hemilepidotus hemilepidotus* | 0.7 |
| *Lumpenus sagitta* | 0.7 |
| *Engraulis mordax* | 0.6 |
| *Lepidogobius lepidus* | 0.5 |
| *Cymatogaster aggregata* | 0.5 |
| *Sebastes melanops* | 0.4 |
| *Artedius fenestralis* | 0.4 |
| *Psettichthys melanostictus* | 0.4 |
| *Ophiodon elongatus* | 0.3 |
| *Sygnathus griseolineatus* | 0.3 |
| *Pallasina barbata* | 0.1 |
| *Symphurus atricauda* | $<0.1$ |
| *Artedius harringtoni* | $<0.1$ |
| *Anoplarchus purpurescens* | $<0.1$ |
| *Phanerodon furcatus* | $<0.1$ |
| *Embiotoca lateralis* | $<0.1$ |
| *Occella verrucosa* | $<0.1$ |
| *Gobiesox maeandricus* | $<0.1$ |

bays (Eldridge, 1970; Misitano, 1970). In our study *P. vetulus* larvae were common offshore but were absent or rare in Yaquina Bay (Table 4). Therefore young English sole must be transported into the bay from offshore waters as late larval stages or migrate in as juveniles. In Humboldt Bay, Misitano (1970) captured metamorphosing English sole (average length, 23 mm) by midwater trawling, especially after dark. These larvae were active swimmers in aquaria but usually resided on the bottom. As a result they would be relatively inaccessible to daytime plankton collections.

The question remains, however, how these larvae enter estuaries. Currents off the northern Pacific coast during the winter and spring are largely inshore and northerly (Burt and Wyatt, 1964; Wyatt, Burt, and Pattullo, 1972) and would transport buoyant fish eggs such as those of English sole (Budd, 1940; Ketchen, 1956; Alderdice and Forrester, 1968) toward and then along the coast. Retention in estuaries would seem to require active behaviorial responses by the larvae, such as a change in depth distribution to enhance transport into and reduce advection out of estuaries. Since a two-layered transport system prevails in Yaquina Bay during the winter (Kulm and Byrne, 1967; Burt and McAlister, 1959) and since Kulm and Byrne (1967) found that marine sand was transported by strong currents 6 miles up the Yaquina Bay estuary during the winter, the season when *P. vetulus* enter the estuary, then descent of larvae into deep water, where net transport exists up the estuary, may result in transport into and retention within estuaries of English sole and other species, as found for other larval fish (Pearcy, 1960; Pearcy and Richards, 1962; and Graham, 1972).

In conclusion, Yaquina Bay, like many east coast estuaries, is an important nursery for the young of several species of marine fishes. This was not apparent from a survey of planktonic larvae, however. Only the larvae of Pacific herring, a species that spawns in bays, were abundant in our plankton collections in Yaquina Bay. Although the pelagic larvae of flatfishes were much more common in offshore than estuarine waters, the juveniles of several species move into the estuary in large numbers.

## ACKNOWLEDGMENTS

We are indebted to H. F. Frolander who has tenaciously conducted the plankton survey of Yaquina Bay since 1960 and provided the 11-yr series of collections and to Joan Flynn who curated these collections. We are also grateful to William Johnson, University of Rhode Island, who generously supplied his data on juvenile fishes, to Peter Rothlisberg, Greg Lough, and Dean Satterlee who were essential for field sampling in 1969 and 1970, to Elbert Ahlstrom, Elaine Sandknop, Maxwell Eldridge, and James Blackburn who helped to identify fish larvae and to Sally Richardson, Charles Miller, and William McNeil for their helpful criticisms of the manuscript.

This research was supported by NOAA Institutional Sea Grant, Contract No. 2-35187.

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