Seasonal Diversity, Abundance, and Distribution of Ichthyoplankton in Tamiahua Lagoon, Western Gulf of Mexico

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Abstract
The ichthyoplanktonic community of Tamiahua Lagoon, Veracruz, Mexico, was studied throughout an annual cycle. Major concentrations of larvae occurred in the central portion of the lagoon, occasionally along the channels, but never at the inlets. The cycle of larva abundance was correlated with cycles of salinity and temperature. In spite of the greater number of species then, the spring and summer periods had low species diversity and evenness, due to the marked domination by larvae of Anchovia mitchilli. The number of larval fish species and individuals entering the lagoon from the adjacent offshore waters was minimal. The greatest portion of species diversity is generated within the lagoon itself. The community structure identified corresponds to the physically controlled type, as indicated by the poor diversity values obtained.

Coastal lagoons are ecosystems of high productivity that support important fisheries. The relationships between fishes and lagoons can not be fully understood without ichthyoplankton studies that elucidate the life cycles of the species. Knowledge of the relationships of lagoonal systems and fisheries production is important to Mexico, because lagoons occur along one-third of its coast line. According to Yañez-Arancibia (1978), 80% of the coastal ichthyofauna of Mexico is closely related to lagoons or to the areas that lagoons influence.

Our study is part of a series dealing with the composition and fluctuations of ichthyoplankton in several coastal lagoons along the Gulf of Mexico. In this paper, we report the distribution, abundance, structure, and fluctuations of the ichthyoplankton community, and factors affecting these, during an annual cycle in Tamiahua Lagoon.

Study Area
Tamiahua Lagoon is located in the state of Veracruz, Mexico, between latitudes 21°10' and 22°10'N, and at longitude 97°50'W (Fig. 1). It is long and narrow, with an approximate length of 93 km and a maximum width of 21.5 km, and shallow, with an average depth of 3 m in its central part. Its topography includes three major islands: Del Toro at the center, and Juana Ramirez and Del Idolo at opposite ends of the lagoon. The latter two islands have channels going around them that connect the lagoon with the sea. The lagoon has two inlets, Boca de Corrazones to the south, of natural origin, and Boca de Tampachichi in the north, which was artificially opened.

Along the inner margin of the lagoon, there are several small streams whose discharges vary greatly throughout the year. The most important ones are La Laja, Cucharas, Tanocochin, and Tampache.

Methods
Twenty-five sampling stations were visited approximately every 3 months during 1980: March 3–5, May 26–28, August 25–27, and November 27–29.

The ichthyoplankton samples were collected with a trapeze net having a mesh of 500 μm, a length of 1.5 m and diameters of 0.1 m at the collector and 0.5 m at the mouth. A digital flow meter, previously calibrated, was placed at the net's mouth. Five-minute tows were made along circular paths, the net being 0.1 to 0.15 m below the surface. Each sample was fixed with 4% formalin buffered with sodium borate.

Surface temperature and salinity were measured at each sampling station with a bucket thermometer and a refractometer, respectively.

Four diversity indices were calculated (Table 1): the Shannon-Weaver function and the evenness index (Pielou 1975); the Margalef (1968) index of species richness; and the Simp-
son index (Pielou 1975). Species affinities were obtained by Jaccard index. On the basis of these affinities, a dendrogram was constructed by the single-linkage clustering method (Sneath and Sokal 1973).

Results and Discussion

Hydrology

Because the lagoon lacks large inflows of freshwater and has limited marine influence via the channels, it is mainly polihaline. It is ultrahaline only in the channels and at the two inlets. Neritic waters (as measured by salinities) enter the lagoon system through the northern Tam-\pachichi Inlet and, in summer, through the Corazones Inlet (Fig. 2). The salinity is lowest in winter (15–31%), gradually increases towards spring (21–35%) and summer (25–36%), and decreases again towards fall (23–33%) as a result of the rainy season.
The distribution of temperatures (Fig. 3) is determined basically by the topography of the lagoon and by areas that are more or less protected from the winds. The lowest temperatures were recorded in the lagoon, the highest in the channels. The inflow of neritic waters did not influence the temperature, except in restricted areas near the inlets. The temperature regime was similar to that of the salinity and showed lower values in winter (15.2–18.2 °C) and fall (16.5–18.5 °C), and higher ones in spring (28.5–32.1 °C) and summer (29.6–32.2 °C). The differences between fall and winter, as well as between spring and summer were not significant. Based on these data, the year can be considered as two seasons: winter and spring, and the summer and fall.

**Ichthyoplankton**

**Abundance and Distribution**

Egg diversity was low, those of only four families being present in the plankton (Table 2). Engraulididae (72% of all eggs collected during the year) was represented by *Ctenogadus edentulus*, collected at one station during spring, and *Anchoa mitchilli*, by far the most abundant species. Eggs of Scianidae (15%), unidentified species, were distributed throughout the lagoon, but their highest concentration occurred at the inlets and the adjacent area. Soleididae eggs (12%), all from *Achirus lineatus*, had higher concentrations both in the central portion of the lagoon and in the channels around Del Idolo Island, but were absent in the areas close to the inlets. Clupeid eggs (0.2%), represented by *Brevoortia* sp., were found only at the Tamapachichi inlet.

Twenty-six species of fish larvae, representing 15 families and 18 genera, were collected (Table 2). Larvae of *Anchoa mitchilli*, *Microgobius gulosus*, *Achirus lineatus*, *Cynoscion nebulosus*, *Gobiosoma boscii*, *Baardelia chrysoura*, *Membras vagrans*, *Syngnathus lousianae*, *Gobiesox strumosus*, *Dormitator maculatus*, *Blennius* sp., *Syngnathus scovelli*, *Strongylura marina*, and *Strongylura notata*, listed in decreasing order of abundance, constitute an assemblage whose distribution shows its highest concentration in the central area of the lagoon or at the channels, but not at the inlets or stations near them. This, as well as the available literature (Reséndez 1970; Lippsone and Moran 1974; Castro 1978; Flores-Goto and Méndez 1982), indicates the presence of such species is a consequence of spawning activity within the lagoon, not of immigration by larvae from offshore waters.

The larvae of *Brevoortia* sp., *Lagodon rhomboides*, *Elops saurus*, *Hyporhamphus unifasciatus*, and *Oligoplites saurus* were scarce. Their occurrences were basically restricted to the inlets. This agrees with published records (Mansueti and Hardy 1967; Lippsone and Moran 1974; Wang and Kernehan 1979; and others), which indicate that these species spawn in the sea and their larvae then migrate towards lagoons and estuaries.

Thus, despite the incoming flow of neritic waters through the inlets, the quantities of larvae entering the lagoon were low, and the greater proportion of larvae was generated in the lagoon itself by resident species and those that entered the lagoon for spawning. Such a pattern has been reported for other areas (Sabin and Truesdale 1974; Guillen and Landry 1981).

The annual cycle of larva abundance conforms with the general pattern of fluctuations in temperature and salinity (Fig. 4). The fall–winter season is characterized by low temperatures and salinities and low abundances of larvae. The spring–summer season is characterized by high temperatures and salinities and
greater larva abundances. Despite this seasonal correspondence, a clear relationship was not observed with either environmental variable. Highest larva densities within a season always occurred in the area of lowest temperature and salinity, normally in the central area of the lagoon. At the channels, where salinity and temperatures were higher, the densities of larvae were lower.

The cycle of larva abundance may be governed more directly by temperature, due to its influence on spawning, than by salinity. Larger numbers of species, as well as of larvae, occurred during the warm period. This type of cycle has been observed in other areas such as Port Aransas, Texas (Hoese 1965), Caminada Pass, Louisiana (Sabins and Truesdale 1974), Terminos Lagoon, Campeche (Flores-Coto and
icthyoplankton dynamics in a mexican coastal lagoon

winter spring

8.2 5.1

summer fall

6.5 6.8

fit:ie 3.1 alsotherm (c) for tamiahua lagoon, 1980.

alvarez-cadena 1980), and alvarado lagoon, veracruz (flores-coto and mendez 1982), although differences in larva abundances were less obvious between the warm and cold periods.

community structure

based on their distribution, abundance, and affinity indices, four groups of species were discerned. the first is formed by anchoa mitchilli, achirus lineatus, membras vagrans, cynoscion nebulosus, microgobius gulosus, bairdiella chrysoura, and gobiosoma bosci (fig. 5). this is the only group that appears well defined, with an affinity higher than 59%; if g. bosci is excluded, the affinity level is above 74%. these species spawn wholly or predominantly in the spring–summer warm period. similar results have been ob-
Table 2.—Fish eggs and larvae netted from Tamiahua Lagoon (numbers per 100 m² of water filtered) by season, 1980. All samples were pooled by season, and values were rounded to two significant digits or to 0.1 egg or larva. Blank space means no catch; + means a taxon was caught, but in quantities less than 0.05/m².

| Taxon                        | Winter | Spring | Summer | Fall |
|------------------------------|--------|--------|--------|------|
| **Eggs**                     |        |        |        |      |
| Brevoortia sp.               | 0.2    | 1.4    |        |      |
| Centengraulis edentulus      | 1.3    |        |        |      |
| Anchoa mitchilli             | 280    | 170    | 110    | 3.3  |
| Sciaenidae                   | 2.7    | 110    | 9.3    | 0.6  |
| Achirus lineatus             | 70     | 24     |        |      |
| Undetermined                 |        | 0.1    |        |      |
| **Larvae**                   |        |        |        |      |
| Elops saurus                 | 0.2    |        |        |      |
| Brevoortia sp.               | 6.9    | 0.2    | 0.4    |      |
| Anchoa mitchilli             | 22     | 290    | 1,700  | 12   |
| Strongylura marina           |        |        | 0.1    |      |
| Strongylura notata           |        |        | 0.1    |      |
| Hyporhamphus unifasciatus    |        | +      | +      | +    |
| Syngnathus louisianae        | 0.5    | 0.3    | 0.1    | +    |
| Syngnathus scovelli          |        | +      |        |      |
| Oligoplites saurus           |        |        |        |      |
| Diaplerus olidhostomus       |        |        |        | +    |
| Eucinostomus                 |        |        |        | 0.1  |
| melenopterus                 | 0.1    |        |        |      |
| Gerreidae                    |        | 2.7    | 11     |      |
| Bairdiella chrysoura         | 0.3    | 2.1    |        |      |
| Bairdiella sp.               | 0.2    | 0.5    |        |      |
| Cynoscion nebulosus          | 1.2    | 1.3    |        |      |
| Cynoscion sp.                |        | +      |        |      |
| Sciaenidae species 1         |        | +      | 0.1    |      |
| Sciaenidae species 2         | 0.1    | +      |        |      |
| Sciaenidae species 3         |        | +      | 0.1    |      |
| Lagodon rhomboides           | 5.5    |        |        |      |
| Sparidae                     |        | +      |        |      |
| Dormitator maculatus         | 0.2    | 0.1    | +      | +    |
| Gobiosoma bosci              | 0.4    | 1.5    | 0.3    | 0.2  |
| Microustus gulaeus           | 0.4    | 1.1    | 2.7    | 0.2  |
| Gobiidae                     | 0.1    | +      | 1.0    | +    |
| Blennius sp.                 |        | 0.2    | +      | 0.1  |
| Membran vaginae              | 0.2    | 0.7    | 0.2    | 1.2  |
| Achirus lineatus             |        |        | 1.4    | 2.0  |
| Gobiesox strumosus           | 0.3    | 0.1    |        |      |

Diversity

Relationships can be seen between abundance of larvae or of species, and seasonal variation of the various indexes calculated (Fig. 4). One exception is the species richness index (D), which does not follow any trend in the number of species. The lowest D value was recorded in summer (2.68), the highest in winter (3.79) when the fewest species were present. Perhaps this is because this index gives more weight to presence than to proportion of the species involved.

The dominance index (λ) followed the tendency of larva abundance, and was opposite to the trends in H' and J'. It clearly indicates the extreme abundance of Anchoa mitchilli. This dominance was the major factor of the ichthyoplanktonic community during the fall sampling period, though it was more obvious during spring and summer. Summer dominance of this species seems to be quite common in estuaries and coastal areas, as has been shown in Texas (Bechtel and Copeland 1970; Guillen and Landry 1980).
dry 1981), South Carolina (Reis and Dean 1981), Louisiana (Sabins and Truesdale 1974), and Florida (Subrahmanyan and Coultas 1980).

With the higher number of species in spring and summer it seems that the indices of Shannon–Weaver ($H'$) and evenness ($J'$) would reach higher values then, but they seem to be inverse to the number of species and abundance of larvae. This may be because $H'$ gives more weight to proportions of the species than to their num-
The low values recorded in spring and summer only reflect the dominance of *A. mitchilli*. The importance of the proportion of species was mentioned by Dahlberg and Odum (1970), who pointed out that the Shannon–Weaver function exhibits a dampened seasonal cycle that reflects the changes in the relative abundance of species. Because $J'$ is related to $H'$, it shows the same trends.

The seasonal variation in diversity ($H'$) in the
present study (Fig. 4) seems clearer than those previously recorded for similar habitats (Dahlberg and Odum 1970; Cain and Dean 1976; Subrahmanyan and Coultas 1980; Guillen and Landry 1981; Reis and Dean 1981). In those studies, the maximum values of $H'$ are indicated for different seasons, normally in the periods with higher number of species, which is opposite to the results of the present study.

The values calculated for $H'$ and $J'$ in Tamiahua Lagoon were low when compared to those recorded by other authors in estuarine habitats (Subrahmanyan and Drake 1975; Moore 1978; Bravo-Nufiez and Yafiez-Arancibia 1979; Shenker and Dean 1979). As previously noted, the low values of $H'$ and $J'$ are consequences of dominance of A. mitchilli.

In reference to the structure of the community, the low diversity found in the lagoon seems to have two main causes. One is that the higher richness of species is generated in the lagoon itself by resident species (group 1) and by few species that enter the lagoon for spawning (groups 2 and 3). The second is that few marine larvae penetrate the lagoon.

The low values of diversity make the ichthyoplanktonic community of Tamiahua Lagoon fall within the physically controlled type, where environmental conditions fluctuate widely, and the organisms are subjected to a strong physical stress (Sanders 1968). This tends to eliminate the more sensitive species, resulting in a greater degree of unequallity (Bechtel and Copeland 1970; Adams 1976).

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