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 *Anchoa 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 Ramírez 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 Corazones 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-

FIGURE 1.—Map of Tamiagua Lagoon, with numbered sampling sites.

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 polyhaline. 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 Tampachichi 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 (15–18.2 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). Engraulidae (72% of all eggs collected during the year) was represented by *Cetengraulis 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. Soleidae 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. Clupeidae eggs (0.2%), represented by *Brevoortia* sp., were found only at the Tampachichi 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*, *Bairdiella 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; Lippson and Moran 1974; Castro 1978; Flores-

TABLE 1.—Diversity and affinity indices used for analysis of ichthyoplankton assemblages in Tamiahua Lagoon.

Shannon-Weaver: ^a	$H' = -\sum_{i=1}^S P_i \log_e P_i$
Evenness index: ^a	$J' = H' / \log_e S$
Margalef index: ^b	$D = \frac{S - 1}{\log_e N}$
Simpson index: ^a	$\lambda = \sum_{i=1}^S P_i^2$
P_i = proportion of the i th species S = number of species N = number of specimens	
Jaccard index: ^c	$J_i = 100 \left(\frac{c}{a + b - c} \right)$
a = number of occurrences of species A b = number of occurrences of species B c = number of joint occurrences of species A and B	

^a Pielou 1975.

^b Margalef 1968.

^c Margalef 1977.

Coto 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; Lippson 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 (Sabins 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

FIGURE 2.—Salinity isopleths (‰) for Tamiahua Lagoon, 1980.

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

FIGURE 3.—Isotherms (C) for Tamiahua Lagoon, 1980.

Alvarez-Cadena 1980), and Alvarado Lagoon, Veracruz (Flores-Coto and Méndez 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 dis-

cerned. The first is formed by *Anchoa mitchilli*, *Achirus lineatus*, *Membras vagrans*, *Cynoscion nebulosus*, *Microgobius gulosus*, *Bairdiella chrysoura*, and *Gobiosoma boscii* (Fig. 5). This is the only group that appears well defined, with an affinity higher than 59%; if *G. boscii* 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 m³ 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/m³.

Taxon	Winter	Spring	Summer	Fall
Eggs				
<i>Brevoortia</i> sp.	0.2	1.4		
<i>Centengraulis edentulus</i>		1.3		
<i>Anchoa mitchilli</i>	280	170	110	3.3
Sciaenidae	2.7	110	9.3	0.6
<i>Achirus lineatus</i>		70	24	
Undetermined	0.1			
Larvae				
<i>Elops saurus</i>	0.2			
<i>Brevoortia</i> sp.	6.9	0.2		0.4
<i>Anchoa mitchilli</i>	22	290	1,700	12
<i>Strongylura marina</i>			0.1	
<i>Strongylura notata</i>			0.1	
<i>Hyporhamphus unifasciatus</i>		+	+	+
<i>Syngnathus louisianae</i>	0.5	0.3	0.1	+
<i>Syngnathus scovelli</i>	+	+		
<i>Oligoplites saurus</i>			+	
<i>Diapterus olithostomus</i>				0.1
<i>Eucinostomus melanopterus</i>		0.1		
Gerreidae	+	2.7	11	
<i>Bairdiella chrysoura</i>		0.3	2.1	
<i>Bairdiella</i> sp.		0.2	0.5	
<i>Cynoscion nebulosus</i>		1.2	1.3	
<i>Cynoscion</i> sp.		+		
Sciaenidae species 1		+	0.1	
Sciaenidae species 2	0.1	+	+	
Sciaenidae species 3		+	0.1	
<i>Lagodon rhomboides</i>	5.5			
Sparidae			+	
<i>Dormitator maculatus</i>	0.2	0.1	+	+
<i>Gobiosoma boscii</i>	0.4	1.5	0.3	0.2
<i>Microgobius gulosus</i>	0.4	1.1	2.7	0.2
Gobiidae	0.1	+	1.0	+
<i>Blennius</i> sp.		0.2	+	0.1
<i>Membras vagrans</i>	0.2	0.7	0.2	1.2
<i>Achirus lineatus</i>		1.4	2.0	
<i>Gobiosox strumosus</i>	0.3	0.1		

tained in other areas of the Gulf of Mexico. Guillen and Landry (1980) in Texas and Sabins and Truesdale (1974) in Louisiana identified assemblages of species that have been included in the first group. These authors indicate that these warm-season assemblages primarily consisted of larvae belonging to resident species that spawn there, and not of immigrant larvae, as our data also indicate.

The first group can be considered the base

of the ichthyoplankton community. The rest of the species do not constitute defined groups by their affinity values, which are lower than 50%, but rather by features of their life cycles.

The second group was formed by *Syngnathus louisianae*, *Syngnathus scovelli*, *Gobiosox strumosus*, *Blennius* sp., *Strongylura marina*, and *Strongylura notata*. These species spawn in the lagoon but are less abundant than group-1 species, and perhaps less important to the structure of the community. In most estuarine ichthyoplankton studies they are reported as scarce or not present. This apparently is caused by the relatively low number of adults in the estuaries, lagoons, and coastal areas (Dahlberg and Odum 1970; Moore 1978; Naughton and Saloman 1978; Weinstein et al. 1980).

A third group consisted of the single species *Dormitator maculatus*. It was the only species of freshwater fish found that utilizes the lagoon for spawning and nursery.

The fourth group was formed by *Brevoortia* sp., *Lagodon rhomboides*, *Elops saurus*, *Hyporhamphus unifasciatus*, and *Oligoplites saurus*. These species represent marine components whose larvae migrate from spawning grounds in the Gulf of Mexico to estuarine nursery areas (Modde 1979; Shenker and Dean 1979; Weinstein 1979; Bozeman and Dean 1980).

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 Lan-

FIGURE 4.—Seasonal changes in environmental and biological variables, Tamiahua Lagoon, 1980: generalized salinity (‰) and temperature (°C); abundance of fish eggs and larvae (numbers/100 m³); number of species (S); and indexes of Margalef's species richness (D), Shannon-Weaver diversity (H'), evenness (J'), and Simpson's dominance (λ). Seasons: w = winter; sp = spring; su = summer; f = fall.

dry 1981), South Carolina (Reis and Dean 1981), Louisiana (Sabins and Truesdale 1974), and Florida (Subrahmanyam and Coultas 1980).

With the higher number of species in spring and summer it seems that the indices of Shan-

non-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-

FIGURE 5.—Cluster analysis of species assemblages in the ichthyoplankton of Tamiahua Lagoon, 1980.

ber. 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; Subrahmanyam 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 (Subrahmanyam and Drake 1975; Moore 1978; Bravo-Núñez and Yañez-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 unequalness (Bechtel and Copeland 1970; Adams 1976).

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