Abundance and Distribution of Fish Larvae in the Channel Area of the Patos Lagoon Estuary, Brazil

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ABSTRACT

Distribution and abundance of fish larvae in the channel area of the Patos Lagoon, Brazil are reported. The Patos Lagoon is a shallow coastal lagoon with a very narrow connection with the Atlantic Ocean. Its southernmost region, characterized by a very dynamic estuary, was the site of 32 ichthyoplankton surveys conducted at 5 stations from April 1981 to March 1983. Samples were taken at 3 depth levels (surface, mid-water and bottom) and results indicated that larval density and distribution were associated with temperature. Larvae occurred year round and at all stations, but were most abundant and diverse during spring and summer with mean densities of 61/100 m^3 and 189/100 m^3, respectively. However, this distribution was sometimes altered by meteorological conditions prevailing in the estuary. Twenty families of fishes were represented, including 27 taxa, 19 of which were identified to species. The three most abundant taxa overall were *Micropogonias furnieri*, *Brevoortia pectinata*, and *Lycengraulis* sp., whose larvae accounted for 22.9, 22.6, and 20% of the total, respectively. *Parapimelodus valenciennis*; Blennidae; *Trichiurus lepturus*; *Gobiesox strumosus*; *Paralonchurus brasiliensis*; *Macrodon ancylodon*; *Paralichthys* sp.; Atherinidae; *Gobiosoma parri*; and *Menticirrhus* spp. had relative abundances between 1 and 5%.

Introduction

Estuaries and coastal waters play an important role in the life cycles of various marine organisms. They provide an abundance of food and protection from predators for larval and juvenile fishes which use these areas as nursery grounds (Pearcy and Myers 1974; Chao and Musick 1977; Misitano 1977; Weinstein 1979; Weiss 1981; Castello 1986). Many marine fish species inhabit regions close to estuaries and rivers. Their eggs and larvae are transported into these areas where they develop and grow. In the North Atlantic, 70% of commercially important fish species spend part of their life cycle in or near estuaries (McHugh 1966, 1967; Clark 1967). In Mexico, Yañez-Arancibia (1978) reported that 80% of the coastal ichthyofauna was related to coastal lagoons or areas influenced by them. In addition to these marine species, there are some groups that have their entire life cycles confined to estuarine areas (Weiss 1981; Chao et al. 1982a).

According to Flores-Coto et al. (1983), the association between ichthyofauna and estuarine environments cannot be completely understood without ichthyoplankton studies which provide information about the early life histories of these organisms. Despite their importance, only a few surveys have been conducted in Brazil to study the relationship between estuarine environments and the development of fish eggs and larvae (Phonlor 1975; Castello 1976, 1977, 1978; Weiss and Krug 1977; Sinque 1980; Weiss 1981; Muelbert 1986).

The Patos Lagoon, located in the southernmost state of Brazil, is the largest coastal lagoon of South America, covering an area of 10 360 km^2. Its southern region (900 km^2) is characterized by a very dynamic estuary (Fig. 1). Its dynamic characteristics are determined by its topography and prevailing meteorological conditions, since the tidal range within the estuary is limited to a low diurnal tidal amplitude (mean of 0.47 m). Most of the estuarine area is very shallow (mean depth of 2 m), and a channel in its center (mean depth of 15 m) leads to a very narrow inlet (750 m) connecting the estuary to the Atlantic Ocean. Wind pattern and precipitation in the highlands drained by the lagoon determine the salinity regime of the estuary

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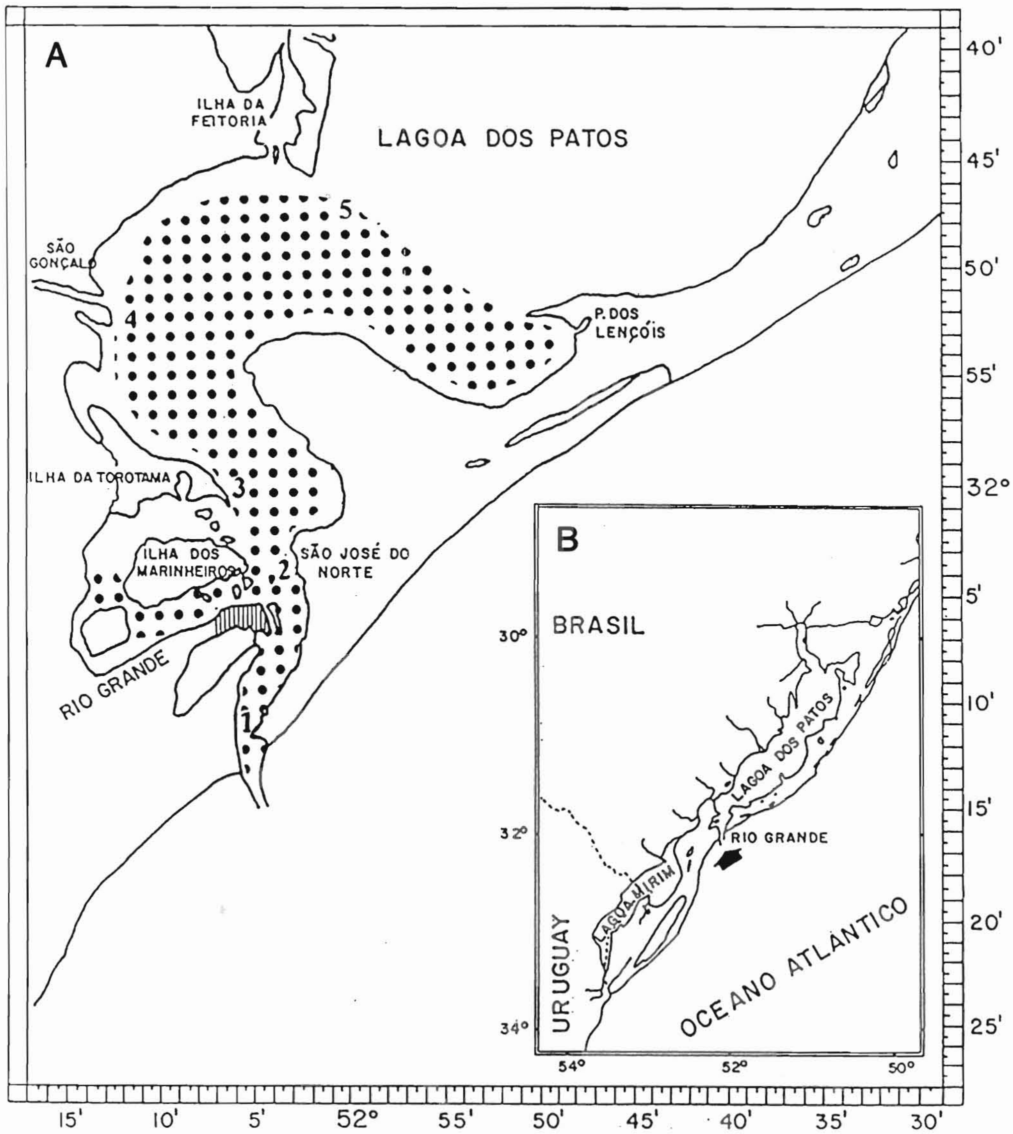

Figure 1
Study area and location of the sampling stations. Dotted area represents estuarine region of the Patos Lagoon.

(Castello and Möller 1978). Southerly winds are associated with salt water intrusion whereas northerly winds are related to oligohaline conditions (Costa et al. 1988).

Chao et al. (1982b) cited 110 estuarine and marine fish species inhabiting the estuary and the adjacent coastal waters of the Patos Lagoon. *Brevoortia pectinata*, *Micropogonias furnieri*, *Cynoscion striatus*, and *Macrodon ancylodon* are commercially important species whose larvae use the Patos Lagoon estuary as a nursery ground (Weiss 1981).

In this paper, we present results on abundance and distribution of fish larvae in the channel of the Patos Lagoon estuary. The study was restricted to the channel area of the estuary to account for the influence of salt water intrusion and freshwater run-off in the assemblage of fish larvae.

Materials and Methods

Fish eggs and larvae were collected during 32 ichthyoplankton surveys at five sampling stations in the Patos Lagoon estuary from April 1981 to March 1983 (Fig. 1; Table 1). The sampling stations were distributed along the channel area of the estuary from its connection with the ocean to its most interior limit. Stations 1, 2, and 3 were sampled at surface, mid-water and bottom depths, whereas only surface and bottom were sampled at stations 4 and 5, which were shallower. All five stations were sampled on the same day.

A 61-cm conical net without a closing system was used to take the samples. Owing to the high concentration of

Table 1

Absolute and relative density of fish larvae, temperature, and salinity (Mean ± SE) for the entire study.

Survey	Date	Season	Temperature (°C)	Salinity (ppt)	Larval density (N/100m^3)	(%)
1	06/04/81	Autumn	22.5 ± 0.3	18.9 ± 2.0	44.3 ± 9.4	1.72
2	01/06/81	Autumn	18.5 ± 0.03	8.1 ± 2.0	6.4 ± 1.0	0.25
3	19/06/81	Autumn	15.1 ± 0.4	25.2 ± 0.8	24.0 ± 10.0	0.93
4	16/07/81	Winter	15.3 ± 0.3	18.9 ± 3.0	34.0 ± 9.0	1.32
5	31/07/81	Winter	16.3 ± 0.3	2.2 ± 0.4	40.3 ± 8.9	1.57
6	20/08/81	Winter	18.4 ± 0.4	8.4 ± 2.0	18.7 ± 4.5	0.73
7	28/08/81	Winter	19.6 ± 0.5	16.3 ± 2.9	11.4 ± 2.2	0.44
8	08/09/81	Winter	19.6 ± 0.4	1.2 ± 0.5	34.0 ± 10.0	1.32
9	22/09/81	Winter	18.7 ± 1.2	3.2 ± 1.8	9.3 ± 1.7	0.36
10	16/10/81	Spring	21.7 ± 1.0	8.0 ± 3.0	8.0 ± 2.2	0.31
11	11/11/81	Spring	24.3 ± 1.5	12.6 ± 3.1	91.8 ± 39.5	3.57
12	25/11/81	Spring	24.0 ± 0.6	6.9 ± 2.0	44.5 ± 7.4	1.73
13	04/12/81	Spring	21.2 ± 0.8	19.5 ± 2.0	30.4 ± 9.6	1.18
14	23/12/81	Summer	22.6 ± 0.3	23.7 ± 2.8	202.3 ± 39.1	7.87
15	11/01/82	Summer	21.4 ± 0.4	27.2 ± 3.0	145.9 ± 19.4	5.68
16	22/01/82	Summer	23.3 ± 1.2	22.1 ± 4.0	474.4 ± 66.6	18.46
17	08/02/82	Summer	23.9 ± 1.1	31.5 ± 1.5	79.0 ± 23.8	3.08
18	02/04/82	Autumn	23.8 ± 0.2	32.2 ± 1.0	84.8 ± 16.4	3.30
19	13/05/82	Autumn	20.1 ± 0.3	27.5 ± 2.0	5.6 ± 1.4	0.22
20	01/06/82	Autumn	15.8 ± 0.4	26.4 ± 2.0	2.0 ± 0.8	0.08
21	25/06/82	Winter	13.7 ± 0.6	9.6 ± 0.5	1.1 ± 0.4	0.04
22	09/08/82	Winter	14.5 ± 0.4	1.5 ± 0.5	156.0 ± 41.9	6.07
23	30/08/82	Winter	16.5 ± 0.7	3.7 ± 1.8	118.8 ± 24.7	4.62
24	06/09/82	Winter	16.0 ± 0.0	12.2 ± 3.0	44.0 ± 17.9	1.71
25	20/09/82	Winter	16.2 ± 0.4	13.2 ± 2.8	19.0 ± 17.5	0.74
26	13/10/82	Spring	14.8 ± 0.3	21.9 ± 2.8	29.7 ± 10.8	1.16
27	17/11/82	Spring	19.1 ± 0.3	0.0 ± 0.1	72.2 ± 14.0	2.81
28	13/12/82	Spring	24.3 ± 0.3	2.0 ± 1.8	140.4 ± 22.9	5.47
29	23/12/82	Summer	24.6 ± 0.8	0.3 ± 0.7	69.5 ± 10.9	2.70
30	07/01/83	Summer	22.8 ± 0.6	1.7 ± 1.5	176.1 ± 43.1	6.85
31	21/01/83	Summer	23.9 ± 0.8	24.9 ± 3.0	169.4 ± 35.9	6.59
32	10/02/83	Summer	23.4 ± 2.1	9.7 ± 3.6	181.5 ± 51.5	7.06

suspended material, a 500-μm mesh size was used to minimize clogging of the net. Tows, lasting three minutes each, were taken during daylight hours at a speed of 1 m/s against the water current. This procedure resulted in an overestimation of the bottom and mid-water samples of approximately 10 and 5%, respectively. A self-constructed digital flowmeter (identical to General Oceanics Model 2030) was placed in the mouth of the net to estimate volume filtered. Salinity values were obtained using an American Optical refractometer and expressed as ppt (parts per thousand). Water temperature, recorded in degrees Centigrade, was obtained by thermometer. Water samples were collected with a bucket from the surface and with a modified Niskin bottle from mid-water and bottom. All sampled material was preserved with 5% buffered formalin and processed in the laboratory. Fish eggs and larvae were sorted and counted using a binocular dissecting microscope and their densities were standardized to 100 m^3 of water filtered.

Larvae and egg identification was done following Weiss (1981), and determined to the lowest taxonomic level possible. Standard length was measured for the most important species, *Brevoortia pectinata*, *Lycengraulis* sp., and *Micropogonias furnieri*, with an ocular micrometer. Seasonal designations were based on the solar calendar for the Southern Hemisphere. Only the results regarding fish larvae will be addressed in this paper.

A three-way analysis of variance (ANOVA) (Kim and Kohout 1975) was used to assess the effect of season, sampling station, depth strata, and the interactions of these factors on the distribution of temperature, salinity, and larval density. This analysis was combined with the Multiple Comparisons Test of Scheffé ($P<0.05$) to determine the significant differences observed in the spatial and temporal distribution of the dependent variables. Normality of the variables was obtained with the use of the following mathematical transformation of the raw data: salinity and

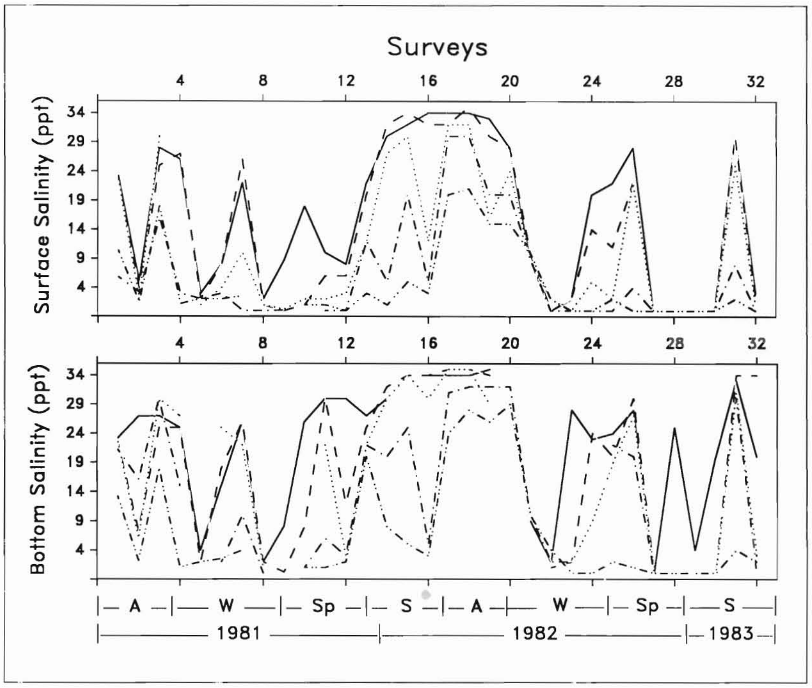

Figure 2
Distribution of salinity (ppt) at each station for the 32 surveys. (——) station 1; (- - -) station 2; (·····) station 3; (- · - · -) station 4; and (- · · - · · -) station 5. A = Autumn; W = Winter; Sp = Spring; S = Summer.

fish larval density were transformed with the expression $y = \ln(x \pm 1)$. Normality was confirmed with the use of Student's t test ($t<0.025$) for the values of asymmetry and kurtosis of the transformed variable, and homogeneity of variance was tested using Bartlett-Box F statistics ($P<0.05$) (Sokal and Rohlf 1981).

Results and Discussion

Salinity and Temperature

During the study period the mean ($\bar{x}$) salinity (for all sample stations and depths combined) ranged from 0.0 to almost 35.0 ppt and exhibited a seasonal trend (Fig. 2; Table 1). An increase in salinity values was observed from spring to autumn, the period of maximum salinity. After autumn, the values began to decrease and reached minimal levels in winter (Table 1). However, this pattern was not constant, as shown by sudden changes in salinity at surveys 4 and 5, 7, and 8, and 30 and 31 (Fig. 2; Table 1).

Salinity decreased significantly from station 1 to station 5 (Fig. 3; Tables 2 and 3). Mean values changed from 19.2 ± 1.26 to 5.9 ± 1.06 ppt. Stations 2 and 3 were intermediate or transitional between stations 1, 4, and 5 (Table 3).

Salinity was significantly different with respect to depth strata (Table 2). The mean salinity increased from 10.6 ± 0.94 to 15.8 ± 1.07 ppt from surface to bottom, and surface values were significantly different from mid-water and bottom salinities.

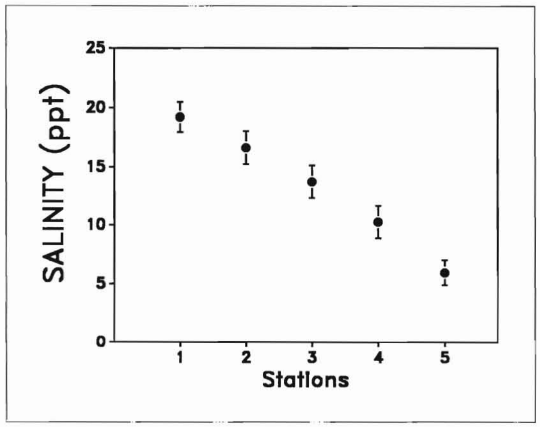

Figure 3
Distribution of mean salinity (ppt) over all surveys and depth levels along the 5 sampling stations. The vertical lines indicate ± 1 standard error.

Three vertical distribution patterns were observed for salinity: vertically homogeneous, with high or low salinity values in the entire water column; slightly stratified; and highly stratified (Fig. 2). Any one station, independent of its position in the estuary, could present any one of these patterns. Station 3, for example, was vertically homogeneous with low salinity during survey 32 (Summer/83) and with high salinity in survey 17 (Summer/82); it was slightly stratified during survey 13 (Spring/81); and it was highly stratified in survey 6 (Winter/81; Fig. 2).

Changes from one pattern to another could occur very rapidly, depending on the dominant meteorological con-

Table 2

Results of the three-way analysis of variance on temperature, salinity, and larval density. df = degrees of freedom; * = variances were significantly different ($P<0.05$); ** = variances were highly significantly different ($P<0.01$).

Source of variation	df	Dependent variables (Mean squares) Temperature	Salinity	Larval density
Within – Temperature	296	7.50		
Within – Salinity	340		1.36	
Within – Larval density	347			1.89
Season	3	259.75*	15.07*	43.49*
Station	4	5.23	7.68**	2.51
Depth	2	6.42	9.40**	1.11
Season by station	12	1.49	0.41	3.16
Season by depth	6	4.24	0.31	0.81
Station by depth	6	0.66	0.41	0.80
Season by station by depth	18	0.54	0.24	0.52

Table 3

Distance of the sampling stations from the ocean; temperature, salinity, and larval density at each station (Mean ± SE). ns = means are not significantly different between stations; a = mean salinities between stations 1, 2, and 3 are not significantly different; b = salinities between stations 2, 3, and 4 are not significantly different; c = mean salinities between stations 4 and 5 are not significantly different. (Multiple comparison test of Scheffé [$P<0.05$].)

Station	Distance from ocean (km)	Temperature (°C)	Salinity (ppt)	Larval density ($N/100m^3$)
1	3.7	19.6 ± 0.37(ns)	19.2 ± 1.26(a)	94.4 ± 12.92(ns)
2	17.6	20.1 ± 0.38(ns)	16.6 ± 1.40(ab)	68.5 ± 10.90(ns)
3	30.5	20.4 ± 0.42(ns)	13.7 ± 1.40(ab)	97.4 ± 18.00(ns)
4	44.4	20.2 ± 0.52(ns)	10.2 ± 1.40(bc)	66.7 ± 13.26(ns)
5	62.0	20.8 ± 0.53(ns)	5.9 ± 1.06(c)	83.4 ± 14.86(ns)

ditions. The large Patos Lagoon basin is drained exclusively through the narrow access channel. During winter and spring, high precipitation levels (Castello and Möller 1978) combined with moderate northerly winds (Costa et al. 1988) result in intense freshwater discharge. During these seasons, only sporadic strong southerly winds may intrude seawater into the channel area (Fig. 2). An increase in the estuarine salinity results from a decrease in freshwater run-off during summer and fall (Castello and Möller 1978) combined with either weak or moderate southerly winds (Costa et al. 1988), or with an increased tidal action on the estuary which is dampened during winter and spring by high freshwater run-off (Abreu 1987). However, the pattern of the salinity distribution depends on the interaction of all these forces. During survey 4 and 5, for example, the velocity of the southerly wind changed from approximately 36 to 4.5 km/h (Costa et al. 1988). This caused the mean salinity of the channel to decrease from 18.9 ± 3.0 to 2.2 ± 0.4 ppt (Table 1; Fig. 2).

Temperature also followed a seasonal pattern (Fig. 4). Mean values ranged from 24.3 ± 1.5 °C during spring to 13.7 ± 0.6 °C during winter (Table 1; Fig. 4). The horizontal distribution of temperature was relatively constant along the stations sampled (Fig. 5) and no significant differences were found among the station means (Table 2; Table 3). Temperature remained relatively constant over depth and no significant differences were found (Table 2). The fact that the estuary is shallow and well mixed prevents the development of thermal stratification.

Larval Abundance and Seasonal Distribution

Twenty families of fishes were represented in samples that included 27 taxa, 19 of which were identified to species

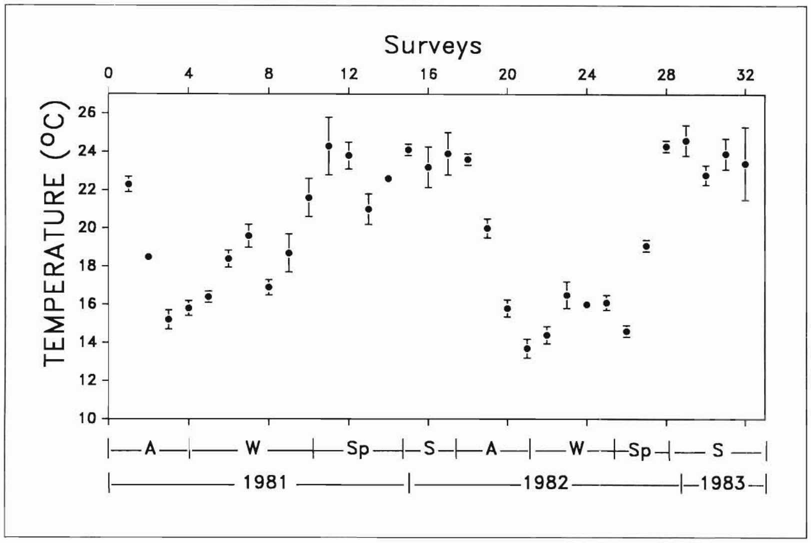

Figure 4
Distribution of mean temperature (°C) over all sample stations and depth levels for the 32 surveys. The vertical lines indicate ± 1 standard error. A = Autumn; W = Winter; Sp = Spring; S = Summer.

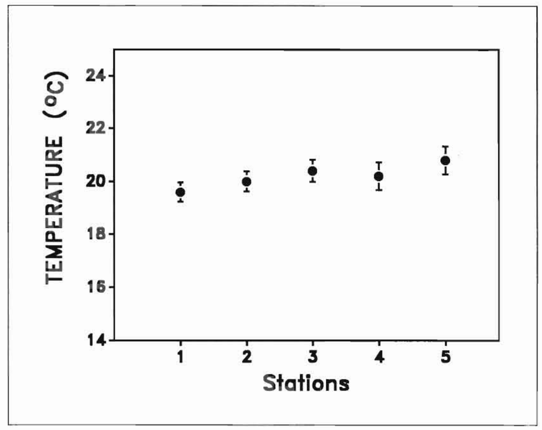

Figure 5
Distribution of mean temperature (°C) over all surveys and depth levels along the 5 sampling stations. The vertical lines indicate ± 1 standard error.

(Table 4). About 8.8% (primarily damaged clupeiform larvae) were unidentifiable. *Micropogonias furnieri*, *Brevoortia pectinata*, and *Lycengraulis* sp. were the most abundant species. Together they represented 65.4% of the total larval fish density, and their length distribution was between 1.8 and 12.0 mm SL, 2.9 and 21.0 mm SL, and 1.3 and 34.0 mm SL, respectively. The second group of taxa was less abundant and accounted for 23.4% of the total. These included *Parapimelodus valenciennis*; Blenniidae; *Trichiurus lepturus*; *Gobiesox strumosus*[1]; *Paralonchurus brasiliensis*; *Macrodon ancylodon*; *Paralichthys* sp.; Atherinidae; *Gobiosoma parri*; and *Menticirrhus* spp. A third group was composed of taxa whose relative abundance was less than 1% each and included *Achirus garmani*; *Syngnathus folletti*; *Gobionellus* spp.; *Peprilus paru*; *Cynoscion striatus*; *Umbrina canosai*; *Hyporhamphus kronei*; *Parona signata*; *Symphurus jenynsi*; *Anchoa marinii*; *Prionotus punctatus*; *Synagrops* sp.; *Mugil* spp.; and *Porichthys porosissimus*.

In general, the highest mean density of larvae was observed during the summer (Fig. 6; Table 1), during which time every species identified in the study, with the exception of *Prionotus punctatus* and *Porichthys porosissimus*, was present (Fig. 7). This was particularly evident during the summers of 1981 and 1982. Autumn showed the lowest mean larval density (Table 1). During this season *Brevoortia pectinata*, *Lycengraulis* sp., and Atherinidae were the dominant taxa, while *Anchoa marinii*, *Parapimelodus valenciennis*, *Hyporhamphus kronei*, *Syngnathus folletti*, *Mugil* spp., *Micropogonias furnieri*, *Paralonchurus brasiliensis*, and *Gobiosoma parri* were present, but not in large numbers (Fig. 7). During the period studied, winter and spring had a relatively higher density than autumn (Table 1). However, during winter, fewer species were present in the estuary (Fig. 7). An increase in the number of species and density was observed in spring, and the maximum density was reached in summer (Figs. 6 and 7).

The increase in larval fish density and composition, which occurred during spring and summer months, was associated with an increase in temperature (Figs. 4 and 7). Owing to its influence on spawning, temperature, rather than salinity, may influence the cycle of larval density (Flores-Coto et al. 1983; Houde and Alpern Lovdal 1984).

Two different patterns of seasonal distribution occurred in the Patos Lagoon estuary: one group of larvae occurred

[1] Johnson and Greenfield (1983) (Northeast Gulf Science 6(1):33–49) consider *Gobiesox barbatulus* rather than *G. strumosus* to be the form ocurring in Brazil. Based on the fact that there is only one species of *Gobiesox* in the Patos Lagoon, we decided to use *G. strumosus* following Chao et al. (1982b). Further investigation to determine which form is present in the southern coast of Brazil is necessary, but it is beyond the scope of this study.

Table 4

Absolute and relative mean density of fish larvae collected per cruise in the Patos Lagoon estuary. All stations and depth levels were combined.

Family	Species	Larval density [(*N*/100 m^3)/cruise]	Larval density (%)
CLUPEIDAE	*Brevoortia pectinata*	225.9	22.56
ENGRAULIDAE	*Anchoa marinii*	0.2	00.2
	Lycengraulis sp.	200.2	20.00
PIMELODIDAE	*Parapimelodus valencienis*	43.5	4.34
BATRACHOIDIDAE	*Porichthys porosissimus*	0.02	0.002
EXOCOETIDAE	*Hyporhampus kronei*	0.9	0.09
ATHERINIDAE	Atherinidae spp.	13.9	1.39
SYNGNATHIDAE	*Syngnathus folletti*	4.8	0.48
TRIGLIDAE	*Prionotus punctatus*	0.1	0.01
PERCICHTHYIDAE	*Synagrops* sp.	0.1	0.01
CARANGIDAE	*Parona signata*	0.6	0.06
SCIAENIDAE	*Cynoscion striatus*	2.3	0.23
	Macrodon ancylodon	18.4	1.84
	Menticirrhus spp.	11.0	1.10
	Micropogonias furnieri	229.2	22.89
	Paralonchurus brasiliensis	21.4	2.14
	Umbrina canosai	1.7	0.17
MUGILIDAE	*Mugil* spp.	0.1	0.01
BLENNIIDAE	Blenniidae spp.	36.1	3.61
GOBIIDAE	*Gobiosoma parri*	11.2	1.12
	Gobionellus spp.	3.3	0.33
TRICHIURIDAE	*Trichiurus lepturus*	34.3	3.43
STROMATEIDAE	*Peprilus paru*	2.6	0.26
GOBIESOCIDAE	*Gobiesox strumosus*	29.0	2.90
BOTHIDAE	*Paralichthys* sp.	14.9	1.49
SOLEIDAE	*Achirus garmani*	6.8	0.68
CYNOGLOSSIDAE	*Symphurus jenynsi*	0.2	0.02
Others		88.4	8.83

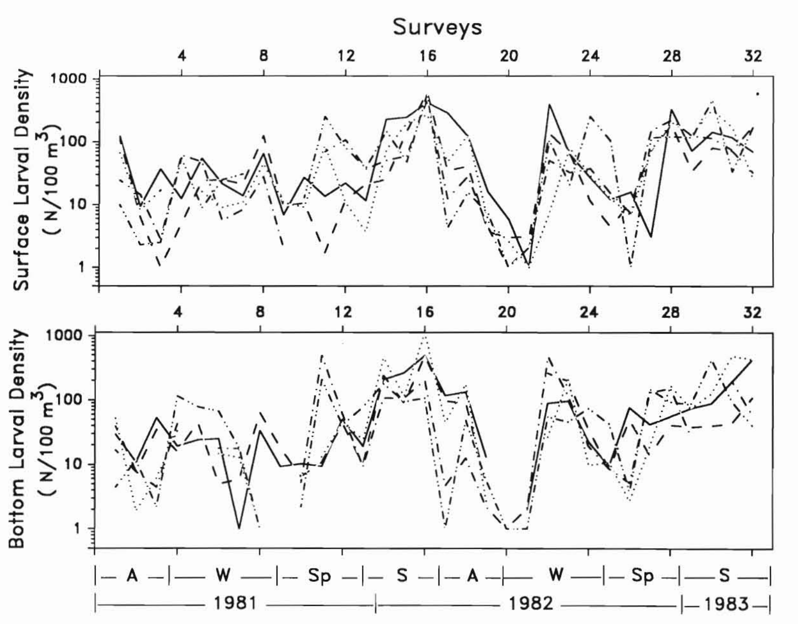

Figure 6

Distribution of larval density (*N*/100 m^3) at each station for the 32 surveys. (——) station 1; (- - -) station 2; (· · · · ·) station 3; (- · - · -) station 4; and (- · · - · · -) station 5. A = Autumn; W = Winter; Sp = Spring; S = Summer.

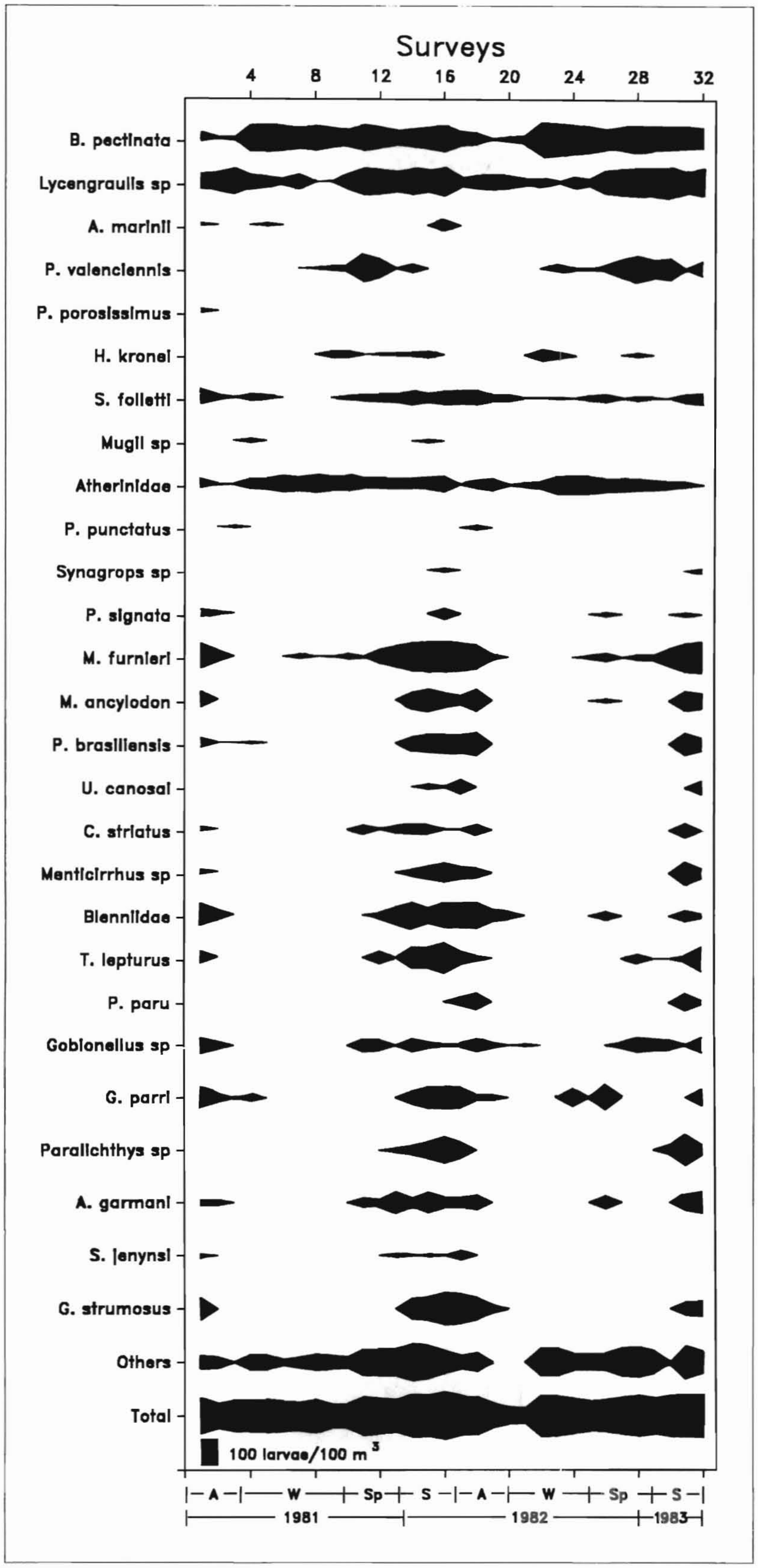

Figure 7
Distribution of total larval density ($N/100\text{m}^3$) expressed as $\ln(x + 1)$ for each identified species along the 32 surveys. A = Autumn; W = Winter; Sp = Spring; S = Summer.

continuously throughout the year, and another exhibited a discontinuous seasonal cycle (Fig. 7). *Brevoortia pectinata*, *Lycengraulis* sp., and Atherinidae represented the first group and their presence in the estuary suggested that these species reproduce during the entire year. The second group predominated during early spring and late summer and included *Micropogonias furnieri*, *Macrodon ancylodon*, *Paralonchurus brasiliensis*, Blenniidae, *Gobionellus* spp., *Peprilus paru*, *Trichiurus lepturus*, *Paralichthys* sp., and *Achirus garmani*.

Horizontal Distribution

Most of the species sampled showed a decrease in their density towards the interior of the estuary, whereas others, such as *Parapimelodus valenciennis*, increased. *Brevoortia pectinata*, *Lycengraulis* sp., Atherinidae, *Micropogonias furnieri*, and *Achirus garmani* were abundant throughout the entire estuary. *Hyporhamphus kronei* was most abundant in the central region of the estuary (stn. 3; Fig. 8).

The individual patterns of horizontal distribution and abundance reflected the origins of the species and the degree to which the estuary is used by them. Species with an oceanic origin, such as *Anchoa marinii*, *Porichthys porosissimus*, *Prionotus punctatus*, *Synagrops* sp., *Parona signata*, *Cynoscion striatus*, *Umbrina canosai*, *Mugil* spp., *Trichiurus lepturus*, *Peprilus paru*, and *Symphurus jenynsi*, occurred in the estuary during periods of strong salt water intrusion. This increase in salinity was the result of an increase in the frequency of southerly winds (Costa et al. 1988) which favor their transport into the estuary. They were generally restricted to regions influenced by the ocean (stns. 1 to 3), occurring only in low densities in the interior of the estuary (stns. 4 and 5; Fig. 8).

Species whose eggs and larvae originated in the adjacent coastal region were distributed along the entire estuary with a small decrease in abundance in the most interior waters. These species use the estuary as a nursery area for their larvae and juveniles, and include *Brevoortia pectinata*, *Lycengraulis* sp., *Macrodon ancylodon*, *Menticirrhus* spp., *Micropogonias furnieri*, and *Paralonchurus brasiliensis* (Fig. 8).

Atherinidae, *Syngnathus folletti*, Blenniidae, *Gobionellus* spp., and *Achirus garmani* are taxa that reside in the Patos Lagoon estuary and show a uniform density distribution throughout the entire channel (Fig. 8). However, the presence of more than one species in each of the above families could mask their individual distributional patterns.

Parapimelodus valenciennis is a freshwater species and showed a decrease in its density towards the ocean (Fig. 8). It is an uncommon species in the estuary and its presence is associated with periods of strong freshwater run-off. These larvae apparently cannot withstand increases in salinity, and they do not use the estuary as a nursery area.

Vertical Distribution

While most of the species showed a homogeneous vertical distribution, a few were selectively distributed with depth (Fig. 9). *Parapimelodus valenciennis*, *Umbrina canosai*, *Gobionellus* spp., *Trichiurus lepturus*, and *Achirus garmani* were most abundant at the bottom, whereas *Brevoortia pectinata*, *Lycengraulis* sp., *Parona signata*, *Gobiesox strumosus*, and *Symphurus jenynsi* showed highest densities at the surface. *Anchoa marinii* was found at the surface and bottom, *Porichthys porosissimus* was present only at the bottom, and *Mugil* spp. occurred at surface and mid-water levels.

The vertical distribution of fish larvae in estuaries is generally related to tidal flow (Graham 1972; Weinstein et al. 1980; Fortier and Leggett 1982). In the Patos Lagoon estuary, astronomic tides have a very small amplitude and their flow can be amplified or reduced by the action of either wind (Costa et al. 1988) or precipitation in the drainage basin (Castello and Möller 1978). Consequently, the vertical distribution of fish larvae probably does not reflect a well-defined circulation pattern.

Different groups of larvae presented different patterns of vertical distribution (Fig. 9). Weiss (1981) found this selective distribution to be related to the salinity structure of the water column. According to her, *Brevoortia pectinata*, *Lycengraulis* sp., *Parapimelodus valenciennis*, and Atherinidae are abundant in less saline surface waters, while *Micropogonias furnieris* and *Trichiurus lepturus* are frequently found near the more saline bottom waters. In this study, however, *Parapimelodus valenciennis* and Atherinidae did not exhibit this pattern. *Parapimelodus valenciennis* was found to be more abundant at the bottom than near the surface (Fig. 9). This may have been the result of a large number of larvae being captured during an anomalous period of freshwater run-off in the spring of 1982 (Fig. 2). At this time, this species dominated the entire estuary (Fig. 7). The abundance of Atherinidae was high at the surface and at the bottom with a decrease in mid-water levels (Fig. 9). Three atherinid species occur in the Patos Lagoon estuary (Chao et al. 1982b) and their individual distributions could be associated with different depths.

Conclusion

Micropogonias furnieri, *Brevoortia pectinata*, and *Lycengraulis* sp. are the most abundant fish larvae in the channel area of the Patos Lagoon estuary. Fish larvae are present throughout the year in the estuary, and abundance and diversity increases during the months of spring and summer, with an increase in temperature. The larvae are distributed along the entire estuary and in the entire water column. This general picture of seasonal, horizontal, and vertical distribution can be altered by the meteorological conditions prevailing in the estuary. Further studies should be con-

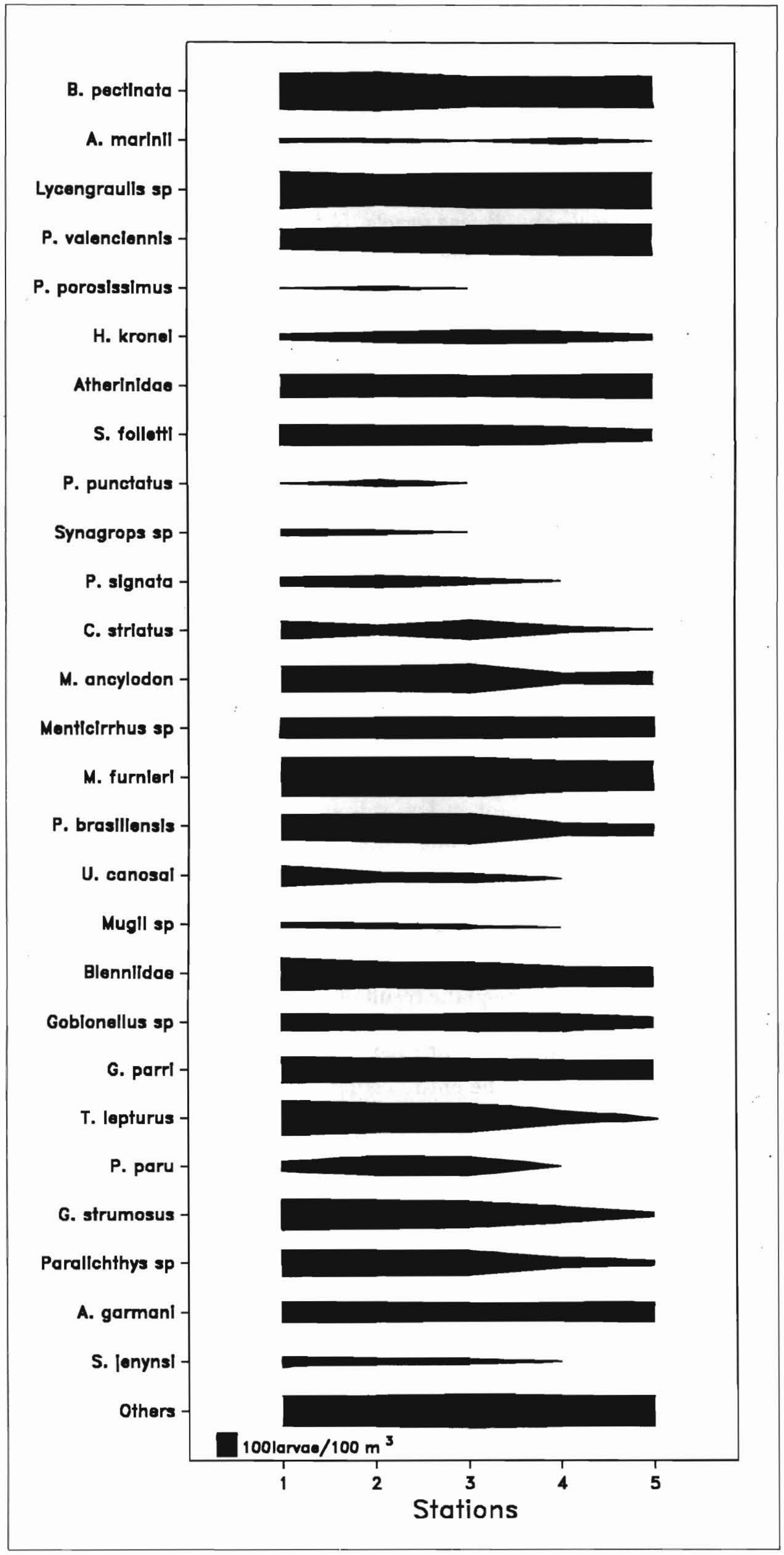

Figure 8
Distribution of total larval density (N/100m^3) expressed as $\ln(x + 1)$ for each identified species at the 5 sampling stations.

ducted to understand specific distribution patterns better. These studies should take into account the biology and ecology of individual species and the dynamic character of the Patos Lagoon estuary.

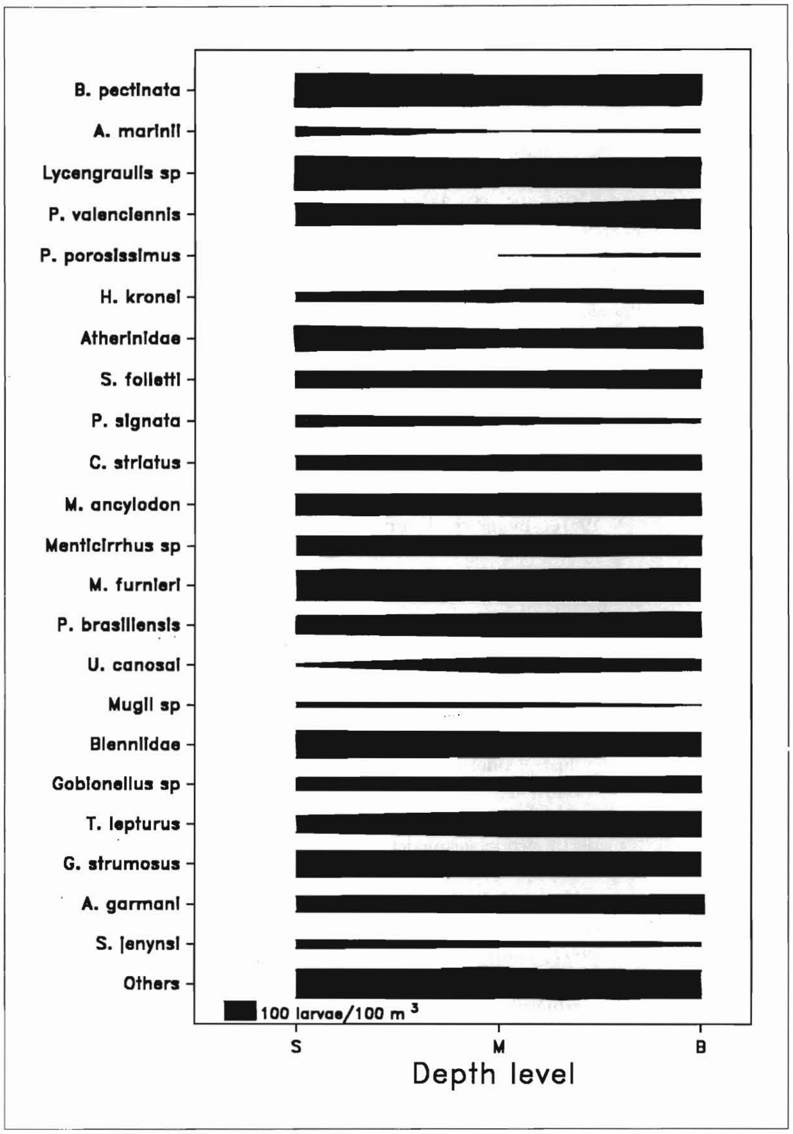

Figure 9
Distribution of total larval density ($N/100m^3$) expressed as $\ln(x + 1)$ for each identified species at the 3 depth levels. S = surface waters; M = mid-water; B = bottom-waters.

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Citations

Abreu, P.C.O.V.
1987. Variações temporais de biomassa fitoplanctônica (clorofila) e relações com fatores abióticos no canal de acesso ao estuário da lagoa dos Patos (RS-Brasil). M.S. thesis, Universidade do Rio Grande, Rio Grande, RS, Brasil, 107 p.

Castello, J.P.
1976. Projeto Lagoa. Relatórios. Rio Grande. FURG, BOA, ser. rel. 1-4.
1977. Projeto Lagoa. Relatórios. Rio Grande. FURG, BOA, ser. rel. 5-6.
1978. Projeto Lagoa. Relatórios. Rio Grande. FURG, BOA, ser. rel. 8-9.
1986. Distribuición, crecimiento e maduración sexual de la corvina juvenil (*Micropogonias furnieri*) en el estuario de la "Lagoa dos Patos", Brasil. Physis (B. Aires) 44(106):21-36.

Castello, J.P., and O.O. Möller Jr.
1978. On the relationship between rainfall and shrimp production in the estuary of the Patos Lagoon (Rio Grande do Sul, Brazil).

Atlântica (Rio Grande) 3:67–74.

Chao, L.N., and J.A. Musick.
1977. Life history, feeding habits and functional morphology of juvenile sciaenid fishes in the York River estuary, Virginia. Fish. Bull., U.S. 75(4):657–702.

Chao, L.N., L.E. Pereira, J.P. Vieira, M.A. Benvenuti, and L.P.R. Cunha.
1982a. Bio-ecology of fishes in the estuary and the adjacent coastal region of the Lagoa dos Patos, Brazil. Atlântica (Rio Grande) (Resumos) 5(2):27.
1982b. Relação preliminar dos peixes estuarinos e marinhos da Lagoa dos Patos e região costeira adjacente, Rio Grande do Sul, Brasil. Atlântica (Rio Grande) 5(1):67–75.

Clark, J.
1967. Fish and man. Conflict in the Atlantic estuaries. Am. Littoral Soc. Spec. Publ. 5, 78 p.

Costa, C.S.B., U. Seeliger, and P.G. Kinas.
1988. The effect of wind velocity and direction on the salinity regime in the Lower Patos Lagoon estuary. Cienc. Cult. (São Paulo) 40(9):909–912.

Flores-Coto, C., F. Barba-Torres, and J. Sanchez-Robles.
1983. Seasonal diversity, abundance, and distribution of ichthyoplankton in Tamiahua Lagoon, Western Gulf of Mexico. Trans. Am. Fish. Soc. 112:247–256.

Fortier, L., and W.C. Leggett.
1982. Fickian transport and the dispersal of fish larvae in estuaries. Can. J. Fish. Aquat. Sci. 39:1150–1163.

Graham, J.J.
1972. Retention of larval herring within the Sheepscot Estuary of Maine. Fish. Bull., U.S. 70(2):299–305.

Houde, E.D., and J. Alpern Lovdal.
1984. Seasonality of occurrence, foods and food preferences of ichthyoplankton in Biscayne Bay, Florida. Est. Coast. Shelf Sci. 18:403–419.

Kim, J., and F.J. Kohout.
1975. Analysis of Variance and Covariance: Subprograms Anova and Oneway. *In* Statistical package for the social sciences (N.H. Nie, C.H. Hull, J.G. Jenkins, K. Steinbrenner, and D.H. Brent, eds.), p. 398–433. McGraw-Hill, NY.

McHugh, J.L.
1966. Management of estuarine fisheries. Am. Fish. Soc. Spec. Publ. 3:133–154.
1967. Estuarine nekton. *In* Estuaries (G.H. Lauff, ed.), p. 581–620. Am. Assoc. Adv. Sci. Publ. 83.

Misitano, D.A.
1977. Species composition and relative abundance of the Columbia River Estuary, 1973. Fish. Bull., U.S. 75(1):218–222.

Muelbert, J.H.
1986. Estrutura e dinâmica do ictioplâncton da área de canal, no estuário da Lagoa dos Patos, RS, no período outono/81 à verão/83. M.A. thesis, Universidade do Rio Grande, Rio Grande, RS, Brasil, 88 p.

Pearcy, W.G., and S.S. Myers.
1974. Larval fishes of Yaquina Bay, Oregon: A nursery ground for marine fishes? Fish. Bull., U.S. 72:201–213.

Phonlor, G.
1975. Ictioplâncton da região de Tramandaí e adjacências. GEDIP-Projeto Tramandaí Documentos Ocasionais, 2: 1–45.

Sinque, C.
1980. Larvas de Sciaenidae (Teleostei) identificadas na região estuarino-lagunar de Cananéia. Bolm. Zool. (Univ. S. Paulo) 5:39–77.

Sokal, R.R., and F.J. Rohlf.
1981. Biometry: the principles and practice of statistics in biological research. W.H. Freeman and Co., San Francisco, (2nd edition), 776 p.

Weinstein, M.P.
1979. Shallow marsh habitats as primary nurseries for fishes and shellfishes, Cape Fear River, North Carolina. Mar. Biol. (Berl.) 58:227–243.

Weinstein, M.P., S.L. Weiss, R.G. Hodson, and L.R. Gerry.
1980. Retention of three taxa of postlarval fishes in an intensively flushed tidal estuary, Cape Fear River, North Carolina. Fish. Bull., U.S. 78:419–436.

Weiss, G.
1981. Ictioplancton del Estuario de Lagoa dos Patos, Brasil. Ph.D. thesis, Faculatad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, 164 p.

Weiss, G., and L.C. Krug.
1977. Características do desenvolvimento e metarmorfose de *Lycengraulis olidus* (Engraulidae) e *Brevoortia pectinata* (Clupeidae) no estuário da Lagoa dos Patos, Brasil. Atlântica (Rio Grande) 2(1):83–117.

Yañez-Arancibia, A.
1978. Taxonomía, ecología y estructura de las comunidades de peces en las lagunas costeras con bocas efímeras del Pacífico de México. Instituto de Ciencias del Mar y Limnología, Univ. Nal. Auton. de México, Publ. Esp. 2, México, Distrito Federal.