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Juvenile Mullet (Pisces: Mugilidae) in the Estuary of Lagoa dos Patos, RS, Brazil

JOÃO P. VIEIRA

Juvenile mugilids collected during a 5 yr monthly beach seine survey in the shallow waters of the Lagoa dos Patos estuary, Brazil were examined in order to describe spatial and temporal patterns of species abundance. Species occurrence and abundance could be classified into two seasonal periods related to changes in water temperature and salinity. One period, associated with warmer and more saline waters and typified by a mixture of the three species (*Mugil platanus*, *M. curema*, and *M. gaimardianus*), occurred during the first 5–6 mo of each year. From mid-winter through early summer *M. curema* and *M. gaimardianus* were scarce or absent, resulting in a second period associated with cold and less saline waters and typified by *M. platanus*. A life history model for *M. platanus* in southern Brazil is proposed.

Cinco anos de amostragem, com arrasto de praia, nas águas rasas do estuário da Lagoa dos Patos, RS, Brasil, são analisados com o objetivo de descrever a variação sazonal e espacial dos padrões de ocorrência e abundância de três mugilídeos juvenis. O padrão geral, no estuário da Lagoa dos Patos, pode ser classificado em dois períodos relacionados com variações na temperatura e salinidade das águas. O primeiro período, associado com águas quentes e mais salinas, se caracteriza pela presença de três espécies (*Mugil platanus*, *M. curema*, e *M. gaimardianus*), e ocorre durante os cinco a seis primeiros meses de cada ano. Da metade do inverno ao início do verão *M. curema* e *M. gaimardianus* estão ausentes ou pobremente representadas nas capturas resultando no segundo período, o qual está associado à água mais fria e menos salinas, e representado apenas por *M. platanus*. Um modelo hipotético do ciclo de vida de *M. platanus* para a região sul do Brasil é proposto.

THE Lagoa dos Patos is a lagoon-type, bar-built estuary in the state of Rio Grande do Sul, southern Brazil (Fig. 1). With its adjacent coastal lagoons, it forms the largest and most complex coastal lagoon system in South America. The Lagoa dos Patos estuarine system communicates with the ocean via a narrow channel between a pair of jetties, about 4 km long and only 740 m apart at the mouth. All estuarine organisms enter and leave the estuary through this channel for nursery, reproductive, and feeding purposes (Chao et al., 1985). Descriptions of the Lagoa dos Patos fish community are detailed in Chao et al. (1982, 1985, 1986).

Juveniles (usually less than 50 mm TL) of three species of mullets (*Mugil platanus* Günther, 1880, *M. curema* Valenciennes, 1836, and *M. gaimardianus* Desmarest, 1831) are recruited from northern offshore spawning grounds and utilize shallow water habitats of the Lagoa dos Patos estuary (<1.5 m depth) as a nursery

ground (Vieira and Scalabrin, in press). These species numerically dominate shallow shore catches making up over 35–42% of the total number of individuals (Chao et al., 1982, 1985).

Prior to recruitment of juvenile mullets into the estuary, their diet changes from zooplankton to iliophagous—a combination of benthic microorganisms, detrital material and inorganic sediment (Pillay, 1953). According to Blaber (1987) it is probable that the iliophagous feeding habit can only occur in shallow sheltered areas and the feeding habits transition takes place gradually with the ingestion of increasing quantities of substrate. Juvenile mullets less than 30 mm TL are often more abundant in coastal waters than in the estuary of Lagoa dos Patos (Vieira, 1985), and recruitment to estuaries apparently provides the necessary conditions for growth and survival of juveniles.

Adults of *M. curema* and *M. gaimardianus* are not found in estuaries and offshore coasts of the Rio Grande do Sul state (Chao et al., 1985; Vieira

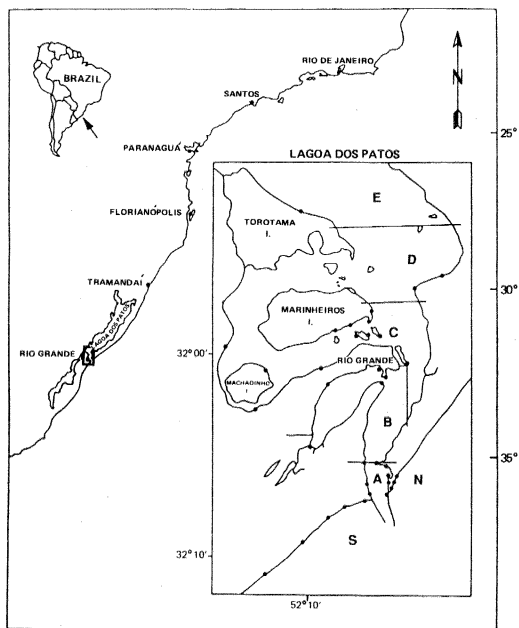


Fig. 1. The southern Brazilian coast and the area of the Lagoa dos Patos estuary studied (inset). Strata (N, S and A to E) and fixed beach seine stations (●).

and Scalabrin, in press), whereas, adults of *M. platanus* are one of the most important food fishes of southern Brazil with about 6000 metric tons of *M. platanus* caught annually (Vieira and Scalabrin, in press). More than 95% of the total catch of *M. platanus* is harvested in the states of Rio Grande do Sul and Santa Catarina (Vieira and Scalabrin, in press).

This paper describes recruitment patterns and seasonal variation in abundance of the juvenile stages (less than 100 mm TL) of three mugilid species in the Lagoa dos Patos estuary.

MATERIALS AND METHODS

Fish were sampled from Jan. 1979–Dec. 1983 during 55 monthly collecting trips. Six to 10 of 35 selected beach seine stations were sampled monthly (Fig. 1). Each station was located at an accessible fixed point in different habitats (sandy, muddy, and vegetated bottoms) along the margin of the embayments and shoals of the estuary and on the open oceanic beach. Five longitudinal strata, from the mouth of the lagoon (oceanic end of the jetties) to about 40 km northward in the estuary (A–E) and one marine, south (S) and north (N) of the jetties on the outer

coast beach were designated (Fig. 1). Each estuarine stratum was delimited by a longitudinal distance of 7–9 km. Three hauls were made at each station with a 10 m seine (1.8 m deep at the middle, 1.3 cm bar mesh in the wings and 0.5 m in the center 3 m section), covering approx. 100 m². Seine catches were pooled to produce a single sample at each station (CPUE = Catch Per Unit Effort = number of individuals per station). Specimens were preserved in 10% formalin and later identified, enumerated and measured to the nearest millimeter.

Specimens used to describe food habits were from beach seine collections (strata A–B, and S) taken from Dec. 1980–May 1981 (Summer to Fall) in which each of the three species occurred together. The stomach contents were pooled for each species in each sample in quantities of approx. 2 ml (one pooled sample represents 1–5 individuals). The pooled sample was shaken to loosen aggregates and mix the contents. Before it settled, a sub-sample was dropped onto a slide and the number of each food category was determined using a counting cell grid. Mineral particles found in the gut of the species were considered as a food category because of the organic material associated with the particles (Odum, 1968). Stomach contents were described by a frequency-of-occurrence method, where the number of samples containing one or more of each food category was expressed as a percentage of all samples (Hyslop, 1980).

Depending upon the subject to be studied, a series of data matrices were constructed. The first matrix classified the mugilids collected by month, area of collection, salinity, temperature, frequency of occurrence (FO) and CPUE for each species for each beach seine station. To assess patterns of dominance among species, another matrix consisted of a dominance index, calculated as the ratio of individual species CPUE to CPUE for all mullets per month for each area sampled. To assess patterns of spatial distribution within species, a third matrix consisted of a distribution index, calculated as the ratio of CPUE per area over total CPUE per month. The fourth matrix included the number measured of individuals per size class (5 mm TL) and CPUE for each species per month. Relative abundance per size class was based on the proportion of the monthly CPUE. Data in this data set were grouped into seasons as summer (Dec.–Feb.), fall (March–May), winter (June–Aug.), and spring (Sept.–Nov.).

The analysis of covariance (ANCOVA) mod-

TABLE 1. SEASONAL MEAN CPUE, MEAN FO OF *Mugil platanus* (M.P), *M. curema* (M.C), AND *M. gaimardianus* (M.G), MEAN WATER TEMPERATURE (TEMP.), AND MEAN SALINITY (SAL.) IN THE ESTUARY OF LAGOA DOS PATOS (1979–83). n = number of observations.

		Summer	Fall	Winter	Spring
M. P	CPUE (SD)	25.0 (71.5)	31.3 (151.7)	87.4 (385.8)	70.7 (211.3)
	FO (SD)	88.2 (32.4)	82.9 (37.7)	91.2 (28.4)	87.4 (33.3)
M.C	CPUE (SD)	11.9 (70.4)	17.0 (55.9)	0.6 (3.0)	0.0 (0.1)
	FO (SD)	25.2 (43.6)	57.3 (49.6)	15.3 (36.2)	5.9 (23.6)
M.G	CPUE (SD)	4.4 (24.7)	8.0 (20.3)	0.1 (0.4)	0.2 (2.1)
	FO (SD)	23.5 (42.6)	55.5 (49.9)	5.1 (22.1)	2.5 (15.7)
	n	119	164	137	119
	TEMP. (SD)	25.9 (2.5)	22.2 (4.0)	14.7 (2.5)	19.6 (3.7)
	n	103	151	130	110
	SAL. (SD)	12.1 (11.5)	16.2 (9.8)	7.0 (7.3)	10.4 (9.9)
	n	97	128	118	95

el used to describe temporal and spatial variation of juvenile mullets employed mean abundance (CPUE) per species as the dependent variable, season and area as independent factors, and water temperature and salinity as covariates. The unbalanced design of the ANCOVA model required the Type III sum of squares and associated F-value to be used in the analysis (Milliken and Johnson, 1984; SAS, 1986). When necessary, logarithmic, or square-root transformations, and weighted least-squares analyses were used to meet statistical assumptions (Draper and Smith, 1981). Data analysis was carried out using SAS (1985) and SPSS (1986) software on a PRIME computer. The nomenclature used in the study followed Menezes (1983) and Menezes and Figueiredo (1985).

A simplified key for identification of the juvenile species (less than 100 mm TL) of mullets occurring in the Lagoa dos Patos estuary is given below.

1. Anal fin with 11 elements (II,9; III,8); base of anal fin almost entirely scaleless *M. platanus*.
1. Anal fin with 12 elements (II,10; III,9); base of anal fin almost entirely scaled 2
2. Body scales—ctenoid; the vertical line with origin at the second dorsal fin reaches one-half to three-quarters of the length of the anal fin *M. gaimardianus*.
2. Body scales—cycloid; the vertical line with origin at the second dorsal fin reaches one-quarter to one-third of the length of the anal fin *M. curema*.

RESULTS

Temporal occurrence and dominance patterns.—Juveniles of *M. curema* and *M. gaimardianus* were most abundant from mid-summer to early winter (Table 1; Fig. 2A). *Mugil gaimardianus* frequency of occurrence peaked in Feb. (70.8%) and *M. curema* in April (58.3%). During the winter, when the mean water temperature drops below 20 C (Fig. 2B), *M. curema* and *M. gaimardianus* were scarce in the estuary or absent (Table 1; Fig. 2A). In contrast, juveniles of *M. platanus* were caught year-round, with peak abundance occurring during winter and early spring when temperatures were low (Table 1; Fig. 2). In general, over the 5 yr period studied, the monthly CPUE and FO of *M. platanus* was bigger than that of the other two species. In selected months in the summer or fall of 1979, 1981 and 1982 the CPUE or FO of *M. curema* or *M. gaimardianus* exceeded *M. platanus*.

A bidimensional plot of dominance index (X-axis) and distribution index (Y-axis) by season is shown in Figure 3. In general, species with dominance index values larger than 33% can be classified as dominant. Species with distribution index values close to 16% were evenly distributed in the system, whereas values close to 100% indicate that the species was restricted to one particular area during a particular month. The pair (0;0) represents absence in the sample.

Mugil platanus (Fig. 3) was dominant in summer, winter, and spring, when the majority of dominance index values were greater than 33%.

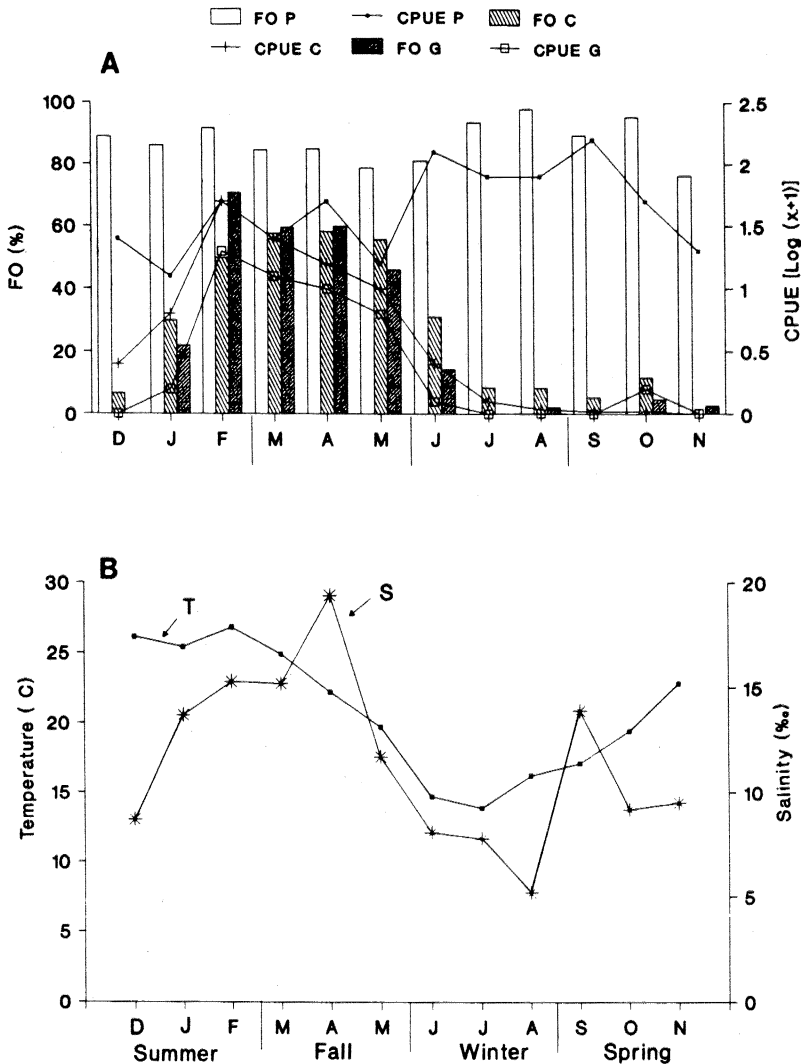


Fig. 2. (A) Monthly mean values of FO and CPUE of juvenile mullets (P = *Mugil platanus*; C = *M. curema*; G = *M. gaimardianus*), in the estuary of the Lagoa dos Patos. (B) Monthly mean values of salinity (S) and temperature (T) in the estuary of the Lagoa dos Patos. Data are pooled over a 5 yr period (1979–83).

In fall, when the other two species were abundant, *M. platanus* remained dominant, but less extensively so. Throughout all seasons the majority of the distribution index values of *M. platanus* were less than or equal to 50%, suggesting spatial distribution is even rather than clumped in the estuary and adjacent areas.

Mugil curema and *M. gaimardianus* displayed similar patterns of distribution and dominance but different from *M. platanus* (Fig. 3). During the winter and spring, *M. curema* and *M. gai-*

mardianus were virtually absent from the system, showing sporadic occurrence. In the summer and fall, during their peak abundance, both species were dominant in some samples. Over all seasons the majority of distribution index values were less than 50%, suggesting a more even rather than clumped distribution in the system.

The ANCOVA model used to describe temporal and spatial variation of juvenile mullets employed mean abundance (CPUE) per species

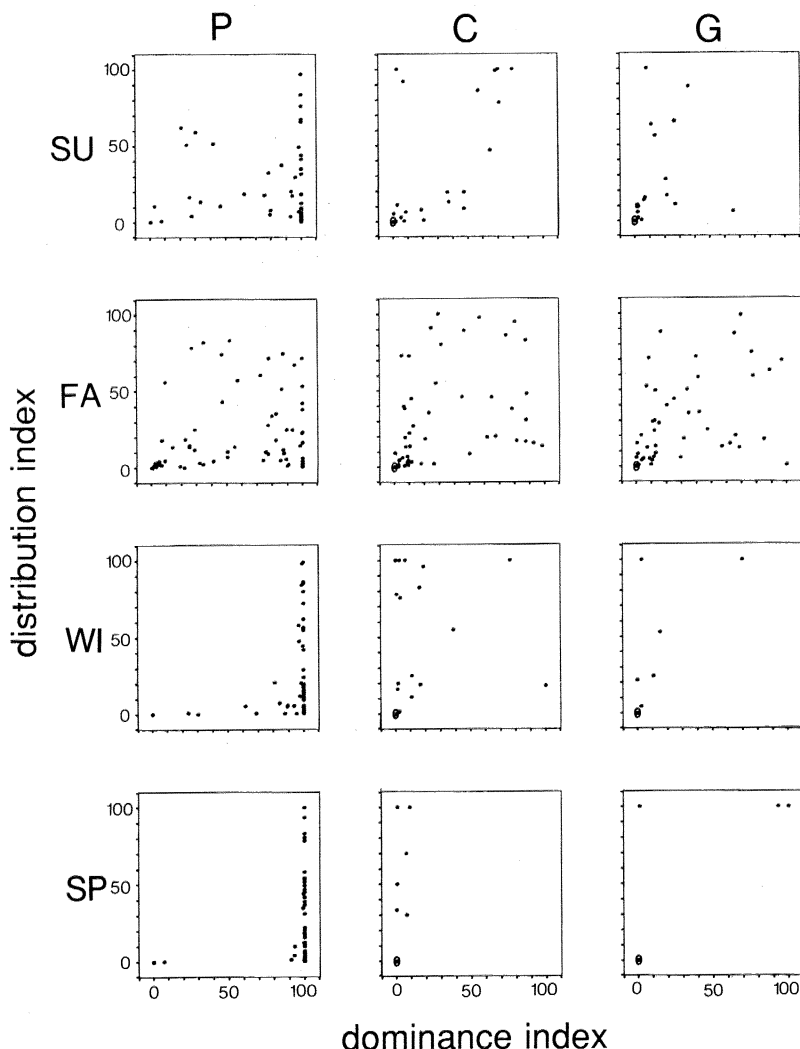


Fig. 3. Seasonal variation of dominance index (% of total CPUE; X-axis) and distribution index (% of total CPUE; Y-axis) of *Mugil platanus* (P), *M. curema* (C), and *M. gaimardianus* (G). SU = summer (n = 119); FA = fall (n = 164); WI = winter (n = 137); SP = spring (n = 119). Data are pooled over a 5 yr period (1979–83).

as the dependent variable, season and area as independent factors, and water temperature and salinity as covariates. When applied to *M. platanus*, the ANCOVA model was significant ($P < 0.02$), but explained just 16.2% (R-squared) of the variation in the abundance of the species. No single variables or interaction effects were significant. The low overall R-squared suggests that most of the variation is explained by some other factor(s) which were not measured in this analysis. When applied to *M. curema* and *M. gaimardianus*, the ANCOVA models were non-significant ($P > 0.05$), suggesting that either the

abundance patterns of *M. curema* and *M. gaimardianus* cannot be explained adequately by the indicated variables, or a simple linear model cannot describe the relationship.

Size-specific abundance and recruitment.—Juvenile *M. gaimardianus* began recruiting to the estuary in Jan., with the most abundant size classes between 35–40 mm TL (Fig. 4). When abundance peaked in Feb., the most numerically dominant size class was 45–50 mm TL; individuals less than 45 mm TL continued to arrive through May. During the summer and fall they grew,

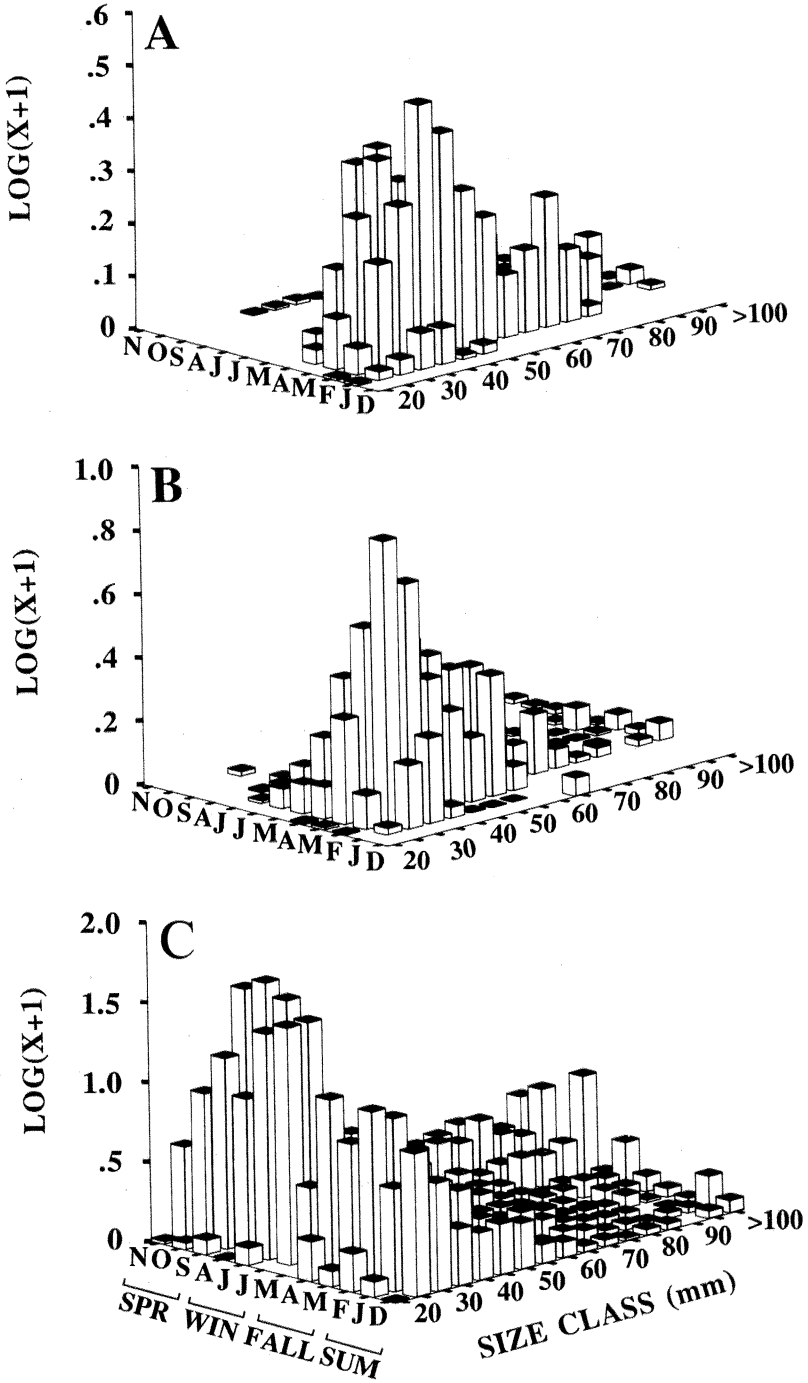


Fig. 4. Monthly mean abundance per length class (5 mm TL) of *Mugil gaimardianus* (A), *M. curema* (B), and *M. platanus* (C). Data are pooled over a 4 yr period (1979-82).

with a subsequent decrease in abundance in winter.

Mugil curema also began to recruit in Jan., with individuals less than 35 mm TL arriving through June–July (Fig. 4). The most abundant size class was 35 mm TL in Feb. Like *M. gaimardianus*, *M. curema* grew during the warm seasons and subsequently disappeared from the Patos Lagoon in the winter.

Mugil platanus recruited in the Lagoa dos Patos throughout the year (Fig. 4). Individuals less than 35 mm TL showed peak abundance in mid-winter (July) through mid-spring (Oct.). Juveniles larger than 60 mm TL were more abundant from mid-spring through early summer (Dec.). Difficulty in following monthly growth increments was probably due to the effects of continued recruitment. The decreasing abundance of juvenile mullets larger than 50 mm TL (Fig. 4) is probably due to mortality, seine avoidance, or emigration from shallow areas, although the low frequency of occurrence and CPUE of *M. curema* and *M. gaimardianus* of all sizes in winter and spring (Table 1; Fig. 2A; Fig. 3) is probably due to winter mortality, or immigration to warmer northern waters.

Diet.—The frequency of occurrence of food items in stomach contents of juvenile *M. platanus*, *M. curema*, and *M. gaimardianus* indicates a constant presence of inorganic material (sand and silt) in all species and that feeding occurred on or near the substrate (Table 2).

DISCUSSION

Seasonal patterns of occurrence of three species of juvenile mullets in the Lagoa dos Patos were classified into two periods related to changes in water temperature and salinity (Fig. 2). One period, associated with warmer and more saline waters and typified by a mixture of three species (*M. platanus*, *M. curema*, and *M. gaimardianus*), occurred from mid-summer months to early winter months. The second period, associated with cold and less saline waters and the sole occurrence of *M. platanus*, occurred from mid-winter months through mid-spring months.

Distribution and abundance patterns of estuarine fish are influenced by various biotic and environmental factors such as salinity and temperature (Weinstein, 1982). Biological processes in marine and estuarine systems display large variability in time and space (Underwood, 1981)

TABLE 2. TOTAL LENGTHS (TL; IN MM), AND FO OF FOOD ITEMS IN THE DIET OF MULLET (<65 MM TL) CAPTURED IN THE LAGOA DOS PATOS ESTUARY. (n1 = number of individuals measured; n2 = number of samples analyzed).

Species TL (SD; n1)		<i>M. platanus</i> 38.3 (13.7; 32)	<i>M. curema</i> 40.2 (10.8; 18)	<i>M. gai- mardianus</i> 58.1 (7.3; 9)
Food items	n2	11	7	5
Diatoms		100	100	100
Cyanophyta		67	29	40
Dinoflagellates		50	57	0
Chlorophyceae		25	14	20
Silicoflagellates		17	29	40
Foraminifera		8	0	0
Crustaceans		58	29	0
Mineral particles		100	100	100

and analysis of such factors requires investigation across each dimension (Lipcius and Subrahmanyam, 1986) and their interactions.

In an attempt to quantify the temporal and spatial relationships of organisms in marine and estuarine habitats complex statistical models have been used (Underwood, 1981). Such models are often misinterpreted due to incorrect sampling designs or violations of statistical assumptions (Underwood, 1981), low explicability (Livingston, 1988), and difficult interpretation of the results (Lipcius and Subrahmanyam, 1986). In our study, ANCOVA models for each species of mullet did not explain much of the variation in abundance over time and space. Thus, a graphical approach was used to discern the temporal and spatial relationships of juvenile mullets in the Lagoa dos Patos estuarine habitats.

Mugil gaimardianus is common in the West Indies and southward (Rivas, 1980) and has a similar distribution to *M. curema* in the eastern Atlantic (Menezes, 1983). Few ecological studies have been done with *M. gaimardianus* due to its negligible importance in the fishery and the modest abundance of juveniles in estuaries of the eastern Atlantic (Rivas, 1980; Vieira, 1985).

In this study, juvenile *M. curema* and *M. gaimardianus* were most abundant at temperatures above 20 C (Fig. 2; Table 1). Temperature data do not necessarily predict where a species will occur as much as indicate areas from which it will be excluded because of physiological or behavioral thermal limits (Olla et al., 1985). Previous studies of *M. curema*, which are in agree-

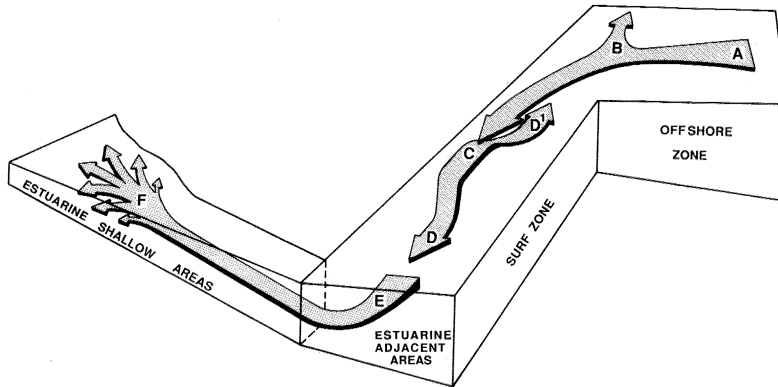


Fig. 5. Movements of *Mugil platanus* into Lagoa dos Patos estuary. (A) Offshore northern spawning pelagic area. (B) Dispersal of neustonic eggs and larvae towards coastal shallow areas. (C) Surf zone pelagic recruitment. (D and D') Surf zone demersal recruitment. (E) Estuarine recruitment. (F) Dispersal in shallow estuarine areas.

ment with the results from this study, suggest that juveniles and adults are most often found at temperatures above 20 C (Anderson, 1957; Moore, 1974) and at high salinities (Moore, 1974; Weinstein, 1979; Weinstein et al., 1980). According to Moore (1974), it is not a simple physiological inability to tolerate high or low salinities that restricts the distribution of *M. curema*. Higher temperatures may allow the species to penetrate a wider range of salinities. These observations may also be valid for *M. gaimardianus*.

Juveniles of *M. platanus* occur year-round in estuarine and adjacent marine habitats of the Lagoa dos Patos, and show peak recruitment during mid-winter months through early spring, 2–4 mo after the northward reproductive migration of maturing adults from the Lagoa dos Patos estuary in April and May (Vieira and Scalabrin, in press). The mean monthly abundance is consistently greater than that of *M. curema* and *M. gaimardianus* and the species seems to be well adjusted to the strong variations of water temperature and salinity of the Lagoa dos Patos estuarine system.

Adult *M. platanus* represent approx. 9% of the average artisanal fishery landings at Rio Grande do Sul (Chao et al., 1986). This species occurs only from Rio de Janeiro (Brazil) to Argentina and is rare in its northern limit of distribution (Menezes, 1983; Vieira and Scalabrin, in press). The importance of *M. platanus* in the fishery of southern Brazil (Vieira and Scalabrin, in press) and the dominance of juveniles over the two other mullet species in shallow waters

of the Lagoa dos Patos (Table 1; Fig. 2) suggests that southern Brazilian estuaries, especially the shallow waters of Lagoa dos Patos, are their principal nursery ground.

The gut of larval and early juvenile mullets, which are zooplanktivorous (Thompson, 1966; Albertini-Berhaut, 1979), is a simple loop with the ratio between intestine length and fish length close to 1:1. With growth, the gut becomes increasingly convoluted in adults. This is correlated with a shift to an iliophagous diet and ingestion of food which contains a large quantity of indigestible minerals. The transition in the diet of mullets is closely linked with the migration into estuaries and a change from a pelagic to a benthic mode of life (Blaber, 1987). Mineral particles are often found in the diets of juvenile mullets collected outside and inside of the estuary. This suggests that changes of feeding behavior occur early (probably at less than 25 mm TL), and before juveniles migrate into the estuaries.

The survival of juvenile mullet recruiting to the Lagoa dos Patos estuary depends in part upon ontogenetic changes in feeding behaviors and diet. With regard to recruitment success and survival, there are "critical periods" in the early life history of young mullets (Blaber, 1987). Larvae of mullets are small and predominantly neustonic and the size of larvae is inversely related to distance from shore (Powles, 1981). The abundance of juvenile mullets larger than 25 mm TL is greater inside than outside of the Lagoa dos Patos estuary (Vieira, 1985). These facts are consistent with a life-cycle involving

spawning in saline offshore waters and subsequent movement of juveniles to less saline coastal waters and estuaries.

The following model describes the early-life movements of *M. platanus*. Spawning occurs in off-shore waters between northern Rio Grande do Sul and northern Santa Catarina (Vieira and Scalabrin, in press; Fig. 5A). Eggs and larvae drift towards the surf zone by wind generated surface currents (Vieira and Scalabrin, in press; Fig. 5B). After they reach approx. 20 mm TL, early juveniles gradually migrate to the bottom and begin to feed on benthic organisms and mineral particles (Fig. 5D–D'). In the surf zone, they move with longshore currents that run southward most of the year (Gianuca, 1985), resulting in passive transport toward the mouth of the Lagoa dos Patos estuary. Once close to the estuary the bottom net upstream estuarine circulation moves recruits into estuaries (Vieira and Scalabrin, in press; Fig. 5E), after which they actively spread throughout shallow water areas (Fig. 5F).

The prolonged recruitment of *M. platanus* into the Lagoa dos Patos estuary probably results primarily from both a long spawning period (March–Aug.) and retention of juveniles in the more saline surf-zone environment. Extended retention in oceanic waters may reduce growth rates due to temperature or salinity stress (De Silva and Perera, 1976; Martin and Drewry, 1978; Vieira and Scalabrin, in press). Distinctive latitudinal distribution of adults of *M. platanus*, *M. curema*, and *M. gaimardianus*, as well as the temperature preferences of juveniles, favor a distinct seasonal pattern of juvenile recruitment among these three species in the Lagoa dos Patos estuary.

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