

ICHTHYOPLANKTON VARIATIONS IN TWO MANGROVE CREEKS OF THE CURUÇÁ ESTUARY, PARÁ, BRAZIL

VARIACIÓN DE ICTIOPLANTON EN DOS ARROYOS DE AMBIENTES DE MANGLE DEL ESTUARIO DE CURUÇÁ, PARÁ, BRAZIL

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ABSTRACT

Fish larvae diversity and abundance were compared between two mangrove creeks (C1 and C2) of the Curuçá Estuary, state of Pará, Brazil, from November 2003 to September 2004. Both habitats exhibited similar taxa composition, with 14 families and 32 identified species. The engraulids were the most abundant, representing 60% and 79% of the individuals in C1 and C2, respectively, while the carangids exhibited the highest diversity, with seven species. Monthly larval abundance in C1 followed the same variation pattern as salinity, with significantly more individuals at the beginning of the rainy season (November to January) and a minimum at the end of the rainy period (MAY). Larvae in C1 were predominant at night and during flood tides. Ichthyoplankton abundance was lower in C2 than C1, but remained constant over time, except for the month of July, when larvae were statistically more abundant. Larvae were more numerous in the daytime and during ebb tides. Differences in the nycthemeral and monthly abundances between the two creeks were related to the ontogenic stages of the larvae, with a predominance of pre-flexion/flexion stages in C1 and the post-flexion stage in C2.

Key words: fish larvae, mangrove creeks, North Brazil, habitat complexity, diversity

RESUMEN

Se comparó la diversidad y la abundancia de larvas de peces de dos quebradas de manglares (C1 y C2) del Estuario Curuçá, estado de Pará, Brasil, desde noviembre de 2003 hasta septiembre de 2004. Los dos hábitat presentaron una composición similar de taxa con 14 familias y 32 especies identificadas. Los engraulidos fueron los más abundantes representando 60% y 79% de los individuos en C1 y C2 respectivamente; en tanto que los carángidos presentaron la mayor biodiversidad con siete especies. La abundancia mensual de las larvas en C1 siguió el mismo patrón de variación de la salinidad, con un número significativamente mayor de individuos al inicio de la estación de lluvias (noviembre a enero) y el mínimo al final del mismo periodo (mayo). Las larvas en C1 predominaron durante la noche y en los periodos de inundación. La abundancia de ictioplanton fue menor en C1 que en C2 aunque permaneció constante en el tiempo, excepto en el mes de julio cuando las larvas fueron estadísticamente más abundantes. Las larvas fueron más numerosas durante el día y en la marea baja. Las diferencias en las abundancias nictimeral y mensual entre las dos quebradas se asociaron con los estados ontogénicos de las larvas, con una predominancia de los estados de pre-flexion/flexion en C1 y el estado de post-flexion en C2.

Palabras clave: larvas de peces, quebradas de ambientes de mangle, norte de Brasil, complejidad del hábitat, diversidad

INTRODUCTION

Mangrove ecosystems, with shallow waters, high turbidity, high habitat complexity and abundant planktonic food, provide auspicious conditions for fish larva growth and survival (Ikejima *et al.* 2003, Islam and Wahab 2005). In recent decades, a better understanding of the interactions between ichthyoplankton and its nursery ground has become a necessity to preserve the endangered fish stocks and provide insights on the impact of coastal degradation (Beck *et al.* 2001). Thus in this objective, ichthyoplankton surveys must be intensive and take into consideration as many parameters as possible, such as water column stratification, tides, photoperiod and climatic variations, in all habitats that characterize mangrove ecosystems (Hartill *et al.* 2003). The main difficulty hampering proper mangrove ecosystem studies probably resides in site accessibility, resulting in the restriction of most study sites to the main mangrove channels, in detriment to small creeks, where motorized craft cannot enter. However, the habitat complexity characterizing these inner forest areas and their isolation from direct anthropogenic disturbances make them preferential grounds for larval development (Mérigoux and Ponton 1999, Rönnbäck *et al.* 1999). A second factor limiting most fish larva ecology studies is the specificity of the individual behavior throughout the life cycle, requiring proper taxonomic knowledge of the local taxa and the assessment of development stages (Sone *et al.* 2006).

Studies on ichthyoplankton in the inter-tidal Amazonian region of Brazil are relatively scarce and, to our knowledge, limited to a single international article published by Barletta-Bergan *et al.* (2002). Despite being a part of the Amazonian basin, the natural richness of the coastal region of the state of Pará (Northern Brazil), where the largest mangrove ecosystems in Brazil are found, remains poorly understood, which makes management rather hazardous. As a contribution to the understanding of this unique environment, a sub-project was initiated within the scope of the “Milênio - RECOS” project, “Use and Appropriation of Coastal Resources” (www.mileniodomar.org.br) in 2003, with the objective of studying the ichthyoplankton community in two mangrove creeks of the Curuçá Estuary. The aim of the present study was to describe fish larvae abundance and diversity in two estuarine creeks, 8Km apart, and determine the tidal and

nycthemeral effects on the ichthyoplankton assemblage.

MATERIALS AND METHODS

Study area

The ichthyoplankton of two mangrove creeks (C1 and C2) of the Curuçá estuary - eastern tip of the southern channel of the Amazon delta (0° 10' S, 47° 50' W) - was studied on a bimonthly basis and at neap tide from November 2003 to September 2004. The two creeks are located 8Km apart and exhibit similar topography characteristics, with a 10-m wide, 2m deep mouth and 200m in total length. *Rhizophora mangle* fringes both creeks edges, whereas *Avicennia germinans* is more abundant at the end of the creeks. The semi-diurnal tidal variations dry the creeks at low tide, whereas the water rises to an average of 2m at high tide. The rainy season extends from December/January to May, resulting in high salinity yearly variations. Surface water temperatures do not vary over time and have a monthly mean of 28°C. The water quality study (pH, DO, salinity, temperature and chlorophyll a) did not reveal any significant difference between the two creeks throughout the study period (Pereira *et al.* 2007).

Samples collection and analysis

A passive trap net was manufactured following the design of Barletta-Bergan (1999). It consisted of a 12m long and 2m wide, with a 1mm mesh size. There was with an opening in the center, where a conical plankton net was inserted (0,6 m in diameter and 1,8m, with a 0,5 mm mesh size). The net was attached to both edges of the creek mouth and set in a “V” position in such a way that the plankton population was stopped by the wings of the net and guided toward the cone collector. During tide movements, the net height was constantly adjusted (lifted up or lowered down) to keep the top rope at the water surface, thereby maintaining the conical plankton net 30 cm below the surface, always trapping larvae at the same depth. In each creek, three consecutive 20minute pseudo-replicates were taken in the daytime during flood (DF) and ebb (DE) tides and at night during the ebb tide (NE). Samplings were initiated when the water current was at a maximum, approximately 2h 30 after the tide turn. The time taken for a small float to travel a 3m stretch was measured three times consecutively and averaged to calculate the water velocity. As the net was positioned in a “V” shape,

all individuals situated at the depth of the conical net were considered to be captured. Hence, the water volume filtered was calculated based on water velocity, conical plankton net diameter and transversal distance of the flooded creek. Samples were kept in a 4% formalin solution buffered with borax. In the laboratory, larvae were sorted from the plankton sample, identified to the family level and, when possible, to the species level based on descriptions available in the literature (Barletta-Bergan 1999) and by tracing back meristic and morphometric characters from the largest to the smallest larva. Larval development stages were

assessed based on the presence/absence of the yolk-sac and the flexion of the notochord, as summarized in Leis & Trnski (1989). Total length of individuals was measured using a calibrated ocular micrometer fitted on a binocular microscope.

Data treatment

Mean abundance of individuals (ind.100m⁻³) and standard error were calculated in order to compare fish larva populations within and between creeks, taking into consideration bimonthly variations as well as tidal and nycthemeral effects. Analyses were conducted at the family level, as the engraulids

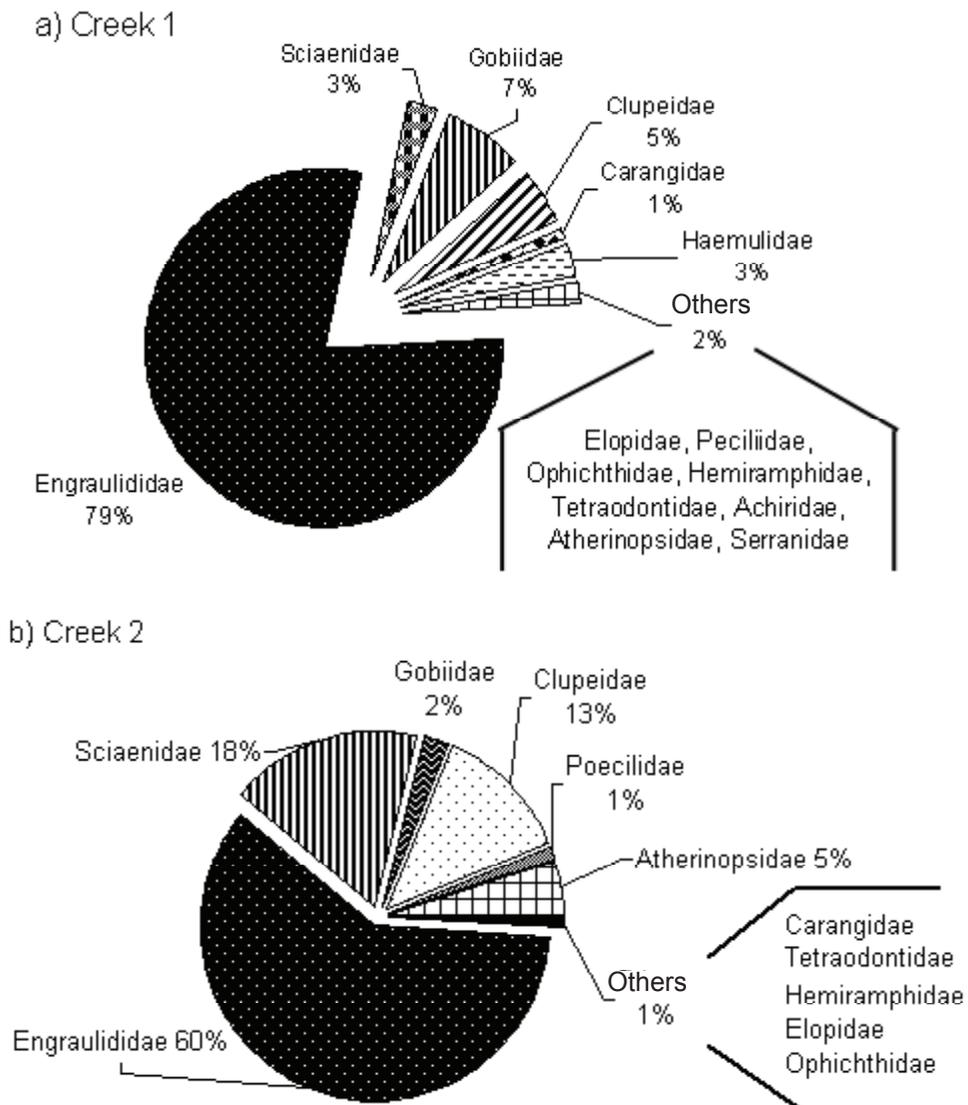


Figure 1. Overall relative abundance (%) of larva families encountered in C1 (a) and C2 (b) between November 2003 and September 2004.

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Table 1. Presence/absence of each family per month and creek from November 2003 to September 2004.

Family	CREEK C1						CREEK C2					
	Month						Month					
	Nov	Jan	Mar	May	Jul	Sep	Nov	Jan	Mar	May	Jul	Sep
Achiridae		X				X						
Atherinopsidae		X						X	X			
Carangidae	X	X	X	X	X	X	X		X	X	X	X
Clupeidae	X	X	X	X	X	X	X	X	X	X	X	X
Elopidae		X			X			X			X	X
Engraulididae	X	X	X	X	X	X	X	X	X	X	X	X
Gobiidae	X	X	X		X	X	X	X	X	X	X	X
Haemulidae	X											
Hemiranphidae	X							X	X		X	
Ophichthidae			X				X		X			
Poeciliidae	X	X					X	X		X		X
Sciaenidae		X		X	X		X	X	X		X	X
Serranidae	X	X										
Tetraodontidae	X	X				X	X					X

(representing more than 50% of the individuals) could not be identified to the species level. In order to fulfill the criteria for use of parametric tests (Sokal and Rohlf 1998), abundances were standardized and transformed into square roots, upon which the analysis of variance (ANOVA) test was run to assess differences between two sets of values. Equitability was calculated using the Pielou index. Differences in larval development stages and abundance differences between creeks were tested using a paired student's t-test ($p = 0,05$). All

larvae were combined for this analysis, regardless of taxa and month of the year. Subsequently, temporal abundance and diversity variations combining bimonthly, tidal and nychehrmeral data were studied through cluster analysis (complete linkage), based on the Bray-Curtis similarity index matrix (Ludwig and Reynolds 1998). The similarity of the groups defined by the cluster analysis was tested using the SIMPER (similarity of percentage) routine, whereas similarity between populations captured at night, in the daytime and

Table 2. Similarity (%) in family contribution for daytime/flood tide (DF), daytime/ebb tide (DE) and nighttime/ebb tide (NE) catches in Creeks 1 and 2. Maximum values are indicated in bold.

	CREEK 1			CREEK 2		
	DF	DE	NE	DF	DE	NE
Avarage similarity (%)	57,96	82,52	58,84	41,60	63,81	58,25
Fam. Contribution (%)						
Engraulididae	93,59	81,76	63,23	60,04	85,65	36,34
Clupeidae		12,57		8,70	10,44	9,00
Gobiidae			16,44	16,40		10,29
Sciaenidae			11,51	10,30		15,57
Haemulidae						
Atherinopsidae						22,95

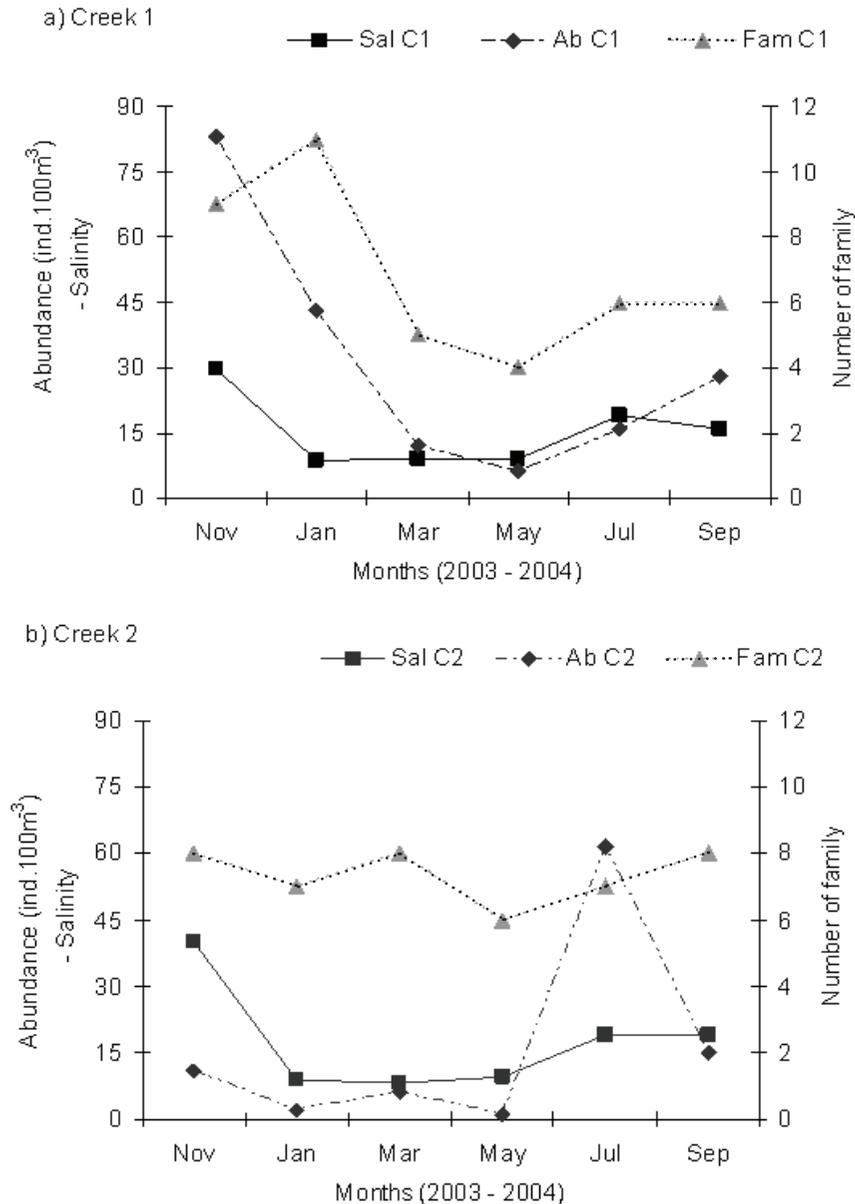


Figure 2. Variations in salinity, larval abundance (individual $.100m^{-3}$) and number of families in Creek 1 (a) and Creek 2 (b) between November 2003 and September 2004.

during flood and ebb tides were compared using the ANOSIM (analysis of similarity) routine (Clarke and Warwick 1994). The similarity between C1 and C2 matrices was compared using the similarity matrix 2-stage routine.

RESULTS

Diversity and development stages

The family Engraulididae dominated the

ichthyoplankton community in both creeks, representing 79% and 60% of the individuals in C1 and C2, respectively. The families Sciaenidae, Gobiidae, Clupeidae, Carangidae, Poeciliidae, Tetraodontidae, Hemiramphidae, Elopidae, Atherinopsidae and Ophichthidae were found at both sites, while three families, namely Serranidae, Haemulidae and Achiridae, were only encountered in C1 (Figures 1a and 1b). In terms of species composition, the carangids were

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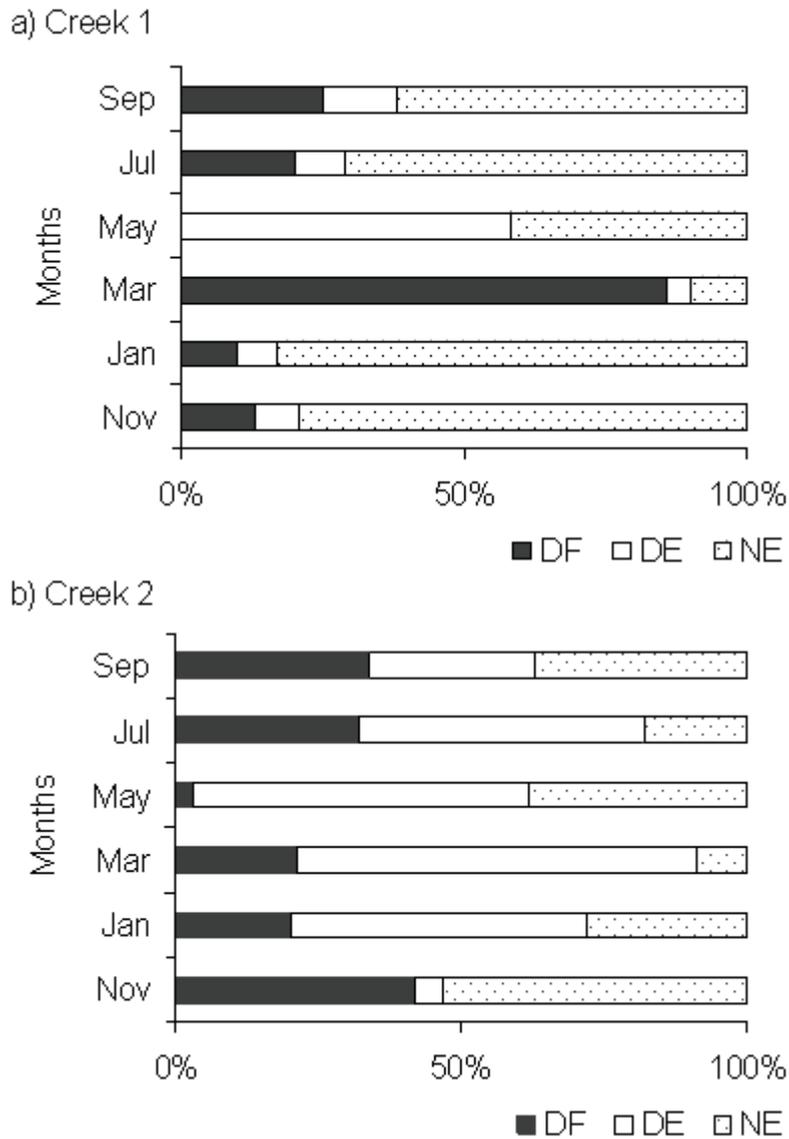


Figure 3. Relative abundance (%) of larvae during daytime/flood tide (DF), daytime/ebb tide (DE) and nighttime/ebb tide (NE) between November 2003 and September 2004 in Creek 1 (a) and Creek 2 (b)

represented by seven species: *Oligoplites saurus*, *O. palometa*, *Caranx latus*, *Uraspis secunda*, *Selar crumenophthalmus*, *Trachinotus carolinus* and *Hemirax amblyrhynchus*; the gobiids were represented by six species: *Ctenogobius smaragdus*, *Gobionellus oceanicus*, *G. stigmaticus*, *Gobioides broussoneti*, *Gobiosoma hemigymnum* and *Microgobius mekki*; the sciaenids were represented by four species: *Cynoscion acoupa*, *C. leiarchus*, *C. microlepidotus* and *Macrodon ancylodon*, the tetraodontids by two species: *Sphaeroides testudineus* and *Colomosus psittacus*;

the hemiramphids were represented by two species: *Hemiramphus roberti* and *H. unifasciatus*; the poeciliids were represented by two species: *Tomeurus gracilis* and an unidentified species; the achirids were represented by two species: *Achirus lineatus* and *Apionichthys dumerilli*; the ophichthids were represented by a single species: *Ophichthus parilus*; the serranids were represented by a single species: *Epinephelus itajara*; the haemulids were represented by the species *Genyatremus luteus*; the clupeids were represented by the species *Rizosardinia amazonica*; and the

Table 3. Percentage of family contribution to the dissimilarity between daytime/flood tide (DF), daytime/ebb flood (DE) and nighttime/ebb tide catches in Creeks 1 and 2.

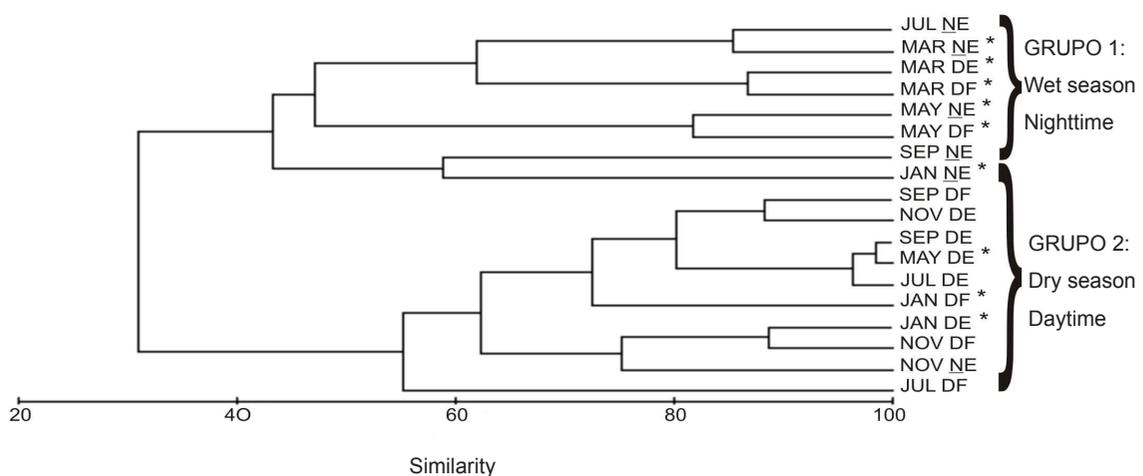
	CREEK 1			CREEK 2		
	DF*DE	DF*NE	DE*NE	DF*DE	DF*NE	DE*NE
Average similarity (%)	57,96	82,52	58,84	41,60	63,81	58,25
Fam. Contribution (%)						
Engraulididae	93,59	81,76	63,23	60,04	85,65	36,34
Clupeidae		12,57		8,70	10,44	9,00
Gobiidae			16,44	16,40		10,29
Sciaenidae			11,51	10,30		15,57
Atherinopsidae						22,95

atherinopsids were represented by two unidentified species. None of the engraulids were identified, but large specimens of *Anchovia clupeioides* and *Cetengraulis edentulus* were recognized. Table 1 displays data on the presence/absence of each family per month and creek.

ANOSIM results (Table 2) indicate that the Engraulididae family contributed most to catch homogeneity in both creeks, regardless of the tidal or nycthemeral cycle. Three other families contributed to catch similarity in C1, namely, Clupeidae, Gobiidae and Sciaenidae. These

families were also important in C2, along with the Haemulidae and Atherinopsidae families.

In terms of individual size and development stages, larvae in C1 were smaller ($p < 0,05$) than in C2, averaging a standard length (SL) of 6,5mm SL vs 10.1 mm SL in C2. Statistical differences ($p < 0,05$) were also observed between individual development stages, with a dominance of pre-flexion and flexion stages in C1 and the post-flexion stage in C2. Size range was similar within creeks ($p > 0,05$) over a 24hour period.

**Figure 4.** Cluster analysis (complete linkage) based on the Bray-Curtis index of similarity applied to bimonthly fish larva abundance during the night/ebb tide (NE), day/ebb tide (DE) and day/flood tide (DF) in Creek 1 (Asterisk indicates wet months).

Annual variations

In C1, family number, larval abundance, larval diversity and salinity followed a similar annual pattern, characterized by maximum values at the beginning of the rainy season (November – January) and minimum values at the end of the rainy season (May) (Figure 2a). Maximum and minimum abundances of 82,99 ind. 100m⁻³ and 6,31 ind. 100m⁻³ were recorded in November and May, respectively, whereas the highest (11) and lowest (4) number of families occurred in January and May, respectively (Figure 2a). Equitability revealed an opposite pattern, with a minimum of 0,17 in November and a maximum of 0,65 in July. Salinity ranged from 8,6 in January to 29,7 in November.

In C2, the yearly mean abundance (16,1 ind. 100m⁻³) was lower than in C1 (29,4 ind. 100m⁻³); monthly values were constant over time and lower than 20,0 ind. 100m⁻³, except for the month of July, when abundance was statistically higher (61,6 ind. 100m⁻³) (Figure 2b). The number of families remained stable over time and totaled between 6 and 8 families (Figure 2b). Equitability was higher than in C1 in all months except July, with a minimum of 0,39 in January and a maximum of 0,69 in May. Salinity variations were the same as in C1, although a higher value of 40,0 was recorded in November (Figures 2a and 2b).

Tidal and nichthemeral variations

Relative abundance of larvae for the three daily periods assessed revealed different patterns between C1 and C2, with more individuals in the former (p<0,05) at night than in the day and at flood tide (day) than at ebb tide (day) (Figure 3a), whereas, in the latter, larvae predominated (p<0,05) in the day and at ebb tide (Figure 3b). ANOSIM applied to day/flood and day/ebb catches indicated that, in C1, catch differences between tides were primarily attributable to the Clupeidae and secondarily attributed to the Sciaenidae families, both relatively abundant during the ebb tide, but rare during the flood tide. In C2, the engraulids were more numerous at ebb tide (Table 3). With regard to nichthemeral variations (day/ebb vs night/ebb), divergences were mainly associated to the Gobiidae and Sciaenidae families in C1 and to the Atherinopsidae family in C2, which were all mainly present at night (Table 3).

Cluster analysis

In Creek 1, the cluster analysis based on bimonthly larval abundance and diversity at NE, DE and DF tides allowed the separation of two larval groups: one gathering most of the samples taken at night during the wet season; and a second including the remaining samples taken in the day during the dry season (Figure 4). SIMPER analysis revealed that

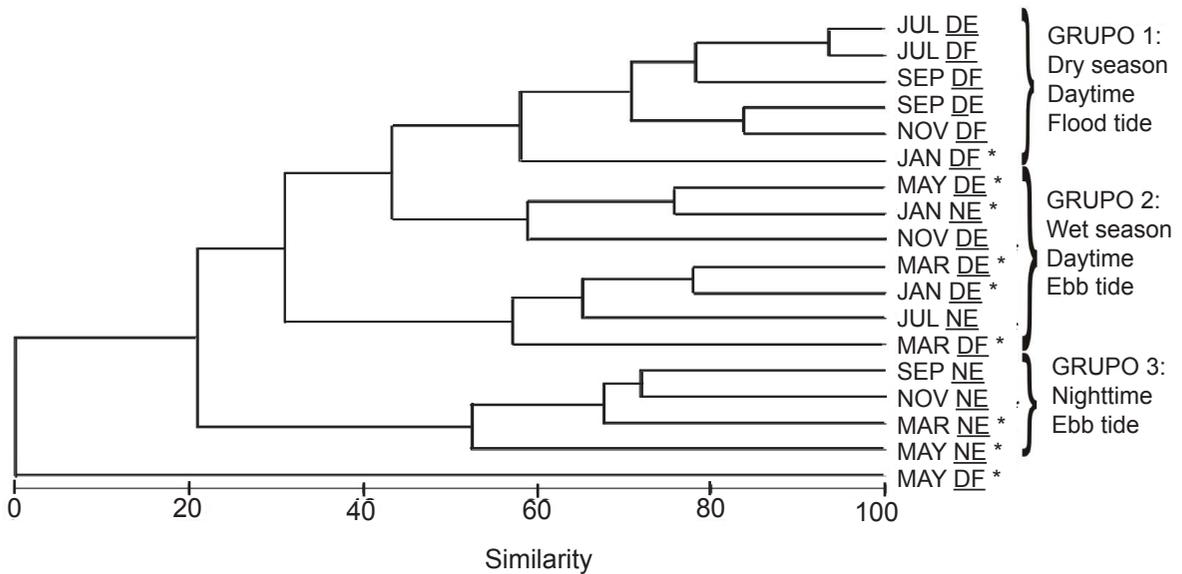


Figure 5. Cluster analysis (complete linkage) based on the Bray-Curtis index of similarity applied to the bimonthly fish larva abundance during the night/ebb tide (NE), day/ebb tide (DE) and day/flood tide (DF) in Creek 2 (Asterisk indicates wet months).

Table 4. Percentage of family contribution to the similarity (a) and dissimilarity (b) between larval groups in Creeks 1 and 2 as defined by cluster analysis. Maximum values are indicated in bold.

a)	CREEK 1		CREEK 2		
	I	II	I	II	III
Average similarity (%)	61,03	74,96	72,32	57,84	62,99
Fam. Contribution (%)					
Engraulidae	64,55	89,49	67,03	71,97	26,32
Carangidae		4,73			
Clupeidae	15,01			12,89	9,12
Gobiidae					16,43
Sciaenidae	11,84		24,38		12,11
Poeciliidae					5,45
Atherinopsidae				11,97	24,38

b)	CREEK 1		CREEK 2	
	I*II	I*II	I*III	II*III
Average similarity (%)	45,26	41,46	49,26	50,74
Fam. Contribution (%)				
Engraulidae	15,31	11,45	16,19	14,97
Clupeidae	20,34	22,52	9,65	14,83
Gobiidae	15,41		16,41	14,05
Sciaenidae	20,65	24,06		
Atherinopsidae		18,89	20,91	15,15

both groups were characterized by the dominance of engraulids, but differed mainly in the relative abundance of sciaenids and clupeids in the first group and by the predominance of carangids in the second group (Table 3).

In Creek 2, three larval groups were identified: the first referred to the populations present during the dry season and flood tides, whereas the second united larvae from the wet season and ebb tides (both groups were predominant during the day). The third group included all nighttime samples (ebb tide), regardless of the season. A single sample (May DF) formed a fourth group with no larvae (Figure 5). Results from the SIMPER analysis on family contribution within groups indicated a majority of engraulids in all three groups, although their contribution to catch similarity was much lower in Group III (26,32%) than in Groups I (67,03%) and II (71,97%). The dissimilarity between Groups I and II was mainly due to the dominance of sciaenids in the former and clupeids in the latter. Dissimilarity between Groups I and III was attributed to the dominance of engraulids

in Group I and atherinopsids, gobiids and clupeids in Group III. Dissimilarity between Groups II and III was attributed to the fact that atherinopsids and gobiids were more frequent in Group III and engraulids and clupeids were more frequent in Group II (Table 4). The 2-stage similarity matrix conducted on the two creeks indicated a similarity level of 38%.

DISCUSSION

Researchers dealing with ichthyoplankton studies are continuously faced with the problem of sampling design in order to combine data representativity and pertinence with work load and financial restrictions. Ideally, studies on fish larvae in tropical countries would imply a minimum of two replicates per sampling area to minimize bias attributable to patchy distribution (Janekarn and Kiørboe 1991), a minimum of one survey per month to catch fast growing species (Ekau 1998) and sampling efforts covering all tides and light cycles (Schlotterbeck and Connally 1982;

Chiappa-Carrara *et al.* 2003). When carried out, this intensive coverage often achieves a very high level of specificity between individuals and their surrounding environment, including both biotic and abiotic factors, which usually prevents the generalization of findings from one microsystem to another (Mérigoux *et al.* 1998). Such was the case in the present study, as larval abundance and diversity on a daily and annual basis differed between two creeks of approximately similar size, morphometry and water quality.

The predominance of engraulids observed in this study is in agreement with the results of numerous other studies conducted in mangrove and estuarine environments (Hayase 1984). Besides stressing the ecological importance of anchovies, these results also contribute toward improving taxonomic knowledge on this group. Due to their high external similarity, anchovy species are hardly differentiable based only on meristic and morphometric parameters and the use of molecular biology or genetic tools is required (Brierley *et al.* 1993, Borsa 2002) to ascertain larva taxonomic identification. When such methods cannot be undertaken, anchovy larvae are united on the family level (Joyeux *et al.* 2004), resulting in the loss of specific information on taxa biology and ecology, as was the case in the present study, in which taxonomic limitation led to the uniting of 60% and 79% of the larvae from C1 and C2, respectively. Thus, it is hoped that more detailed studies will be carried out in the near future for anchovy taxonomic identification and enabling proper ecological and biological studies on young individuals.

The yearly diversity was similar in both mangrove creeks, with 14 families and 32 identified species. This is considered low compared to the results of other studies, which commonly report 20 to 30 families in this part of the world (Barletta-Bergan *et al.* 2002). The low diversity is attributed to 1) the specificity of the microsystem studied (mangrove creeks); 2) the restriction to two sampling sites; 3) small creek small; and 4) bimonthly samples. The highest species diversity observed for the carangids contrasted with their low abundance. As adults from this family spawn offshore, it is suggested that larva scarcity might be the result of a high larval mortality rate and dispersal during the larval drift from the offshore spawning group to the costal/estuarine nursery ground. The high level of diversity observed for the gobiids has been reported in mangrove environments and correlated

to the morphological and physiological adaptations of these individuals to life in inter-tidal habitats (Barletta *et al.* 2000). Larvae from freshwater fishes, such as *Tomeurus gracilis* (Poeciliidae), were found throughout the year in the brackish waters of the Curuçá, at salinity ranging from 5 to 20 ppt. Their presence over both a long time period and a 24-hour cycle suggest that the larvae are residents of the area and are able to withstand a wide range of salinity.

The correlation between abundance, diversity and rainfall (as observed in C1) is common in tropical countries and is associated to an increase in plankton availability at the onset of the rainy season, when storms are not yet strong or frequent enough to disperse larvae and their food patches (Cury and Roy 1989, Cushing 1990; Vásquez-Yeomans 2000). The reduced number of species at the peak of the rainy season, when salinity is at its lowest, could be due to the death of larvae and natural selection for tolerant freshwater species. However, the completely different patterns of daily and yearly abundances and diversity observed in C2 (although the two creeks are inhabited by the same species of fish), suggest that factors other than climatic conditions and subsequent water quality variations control larval populations. Hence, it is suggested that the discrepancies observed between creeks are due to their respective occupation by fish larvae at a different developmental stage. Segregation of fish larvae in function of their biological and morphological characteristics has been observed in other areas (Sarpedonti 2005) and is explained by sudden changes in body segments and organ growth (Fuiman 1983; Sarpedonti *et al.* 2000) that govern individual ecological preferences (Simonovic *et al.* 1999; Gonçalves *et al.* 2002). Based on these findings, a subsequent closer observation of the larvae from both creeks indicated a significant difference between the body size of larvae in C1 and C2, thereby sustaining the hypothesis on ontogenical control of fish behavior and distribution. Overall, larvae in C1 were smaller ($p < 0,05$) than in C2, averaging a standard length (SL) of 6,5mm CL vs 10.1 mm SL in C2. Statistical differences were also observed between individual development stages, with a dominance of pre-flexion and flexion stages in C1 and the post-flexion stage in C2. As both creeks exhibited similar topography and water quality, it is suggested that habitat complexity resulting from the number and characteristics of mangrove tree roots might account for habitat selection by

younger and older larvae, as has been reported for juveniles and adults (Mérigoux *et al.* 1998, Rönnbäck *et al.* 1999, Gratwicke and Speight 2005). Therefore, it is proposed that abundance and diversity variations observed in C1 essentially reflect the annual spawning seasons and mortality rate of the youngest individuals, whereas C2 experiences minor population variations, as it is inhabited by larvae and juveniles of a wider age-class range and less vulnerable to environmental factors. These divergences in larval development stages would also explain the different abundances obtained between day and night as well as during tidal movement in both creeks (Gonçalves *et al.* 2002). Studies on habitat complexity, fish species and developmental stages in mangrove creeks are currently being conducted by the authors of the present study to provide further information on the interactions of these variables.

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Recibido 25 de enero de 2007; revisado 18 de octubre de 2007; aceptado 31 de julio de 2008