Spatio-temporal distribution of fish larvae in relation to ontogeny and water quality in the oligohaline zone of a North Brazilian estuary

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Abstract: Larval fish assemblage in Guajará Bay was studied through four quarterly field campaigns and discussed in relation to individuals' development stages and exposure to contaminants poured out by the Pará State Capital City, Belém. Larval densities were low and diversity extremely poor with a strong dominance of clupeids, engraulids and, to a lower extent, sciaenids. The main spawning season was registered at the onset of the rainy period. Pre-flexion and flexion clupeiforms remained in the farmost stations from the city while post-flexion larvae were found near urban activity centres. Unlikely, pre-flexion and flexion sciaenids were scattered along the city waterfront. Post-flexion larvae were rare; it is suggested that sciaenids use the bay as a transitory route between their spawning grounds and more distant nursery grounds. The waters around the city of Belém showed signs of contamination. However, based on the literature, Guajará Bay environmental quality at the time of the study was suitable for fish larvae life. Nitrate with pH best explained larval distribution.
Keywords: *Ichthyoplankton, Amazon, urban impact, Belém.*

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Resumo: O padrão de distribuição das larvas de peixes na Baía do Guajará foi estudado através de coletas trimestrais e discutido em relação aos estágios de desenvolvimento dos indivíduos e a exposição dos mesmos aos contaminantes despejados pela Capital do Estado do Pará, Belém. A densidade e a diversidade larval foram baixas com forte dominância dos clupeídeos, engraulídeos e, em menor grau, os cianídeos. O principal período de reprodução foi definido no início do período chuvoso. Larvas de Clupeiformes em pré-flexão e flexão foram encontradas nos pontos de coletas mais afastados da cidade, enquanto aquelas em pós-flexão prevaleceram nas margens da cidade. Por outro lado, os cianídeos em pré-flexão e flexão foram capturados perto dos centros de atividade urbana, enquanto aqueles em pós-flexão foram pouco abundantes. É sugerido que a baía se encontra na rota migratória dos cianídeos entre a área de desova e os berçários mais distantes. Apesar das águas no entorno da cidade de Belém mostraram sinais de contaminação, a qualidade ambiental na Baía do Guajará no momento do estudo estava apropriada para a vida das larvas de peixes. Nitrato com pH foram as variáveis que melhor explicaram a distribuição larval.
Palavras-chave: *Ictioplâncton, Amazônia, impacto urbano, Belém.*

Introduction

Scientific approaches to assess environmental impacts in water bodies are various; characterization of water quality, use of biomarkers and bioindicators like fish or benthic species, are among the most common practices (http://www.epa.gov/bioiweb1/html/indicator.html). Fish larvae also allow depiction of anthropogenic disturbances through variations in abundance, distribution and incidence of malformations in embryos or larvae (Schulz & Martins-Junior 2001, Strand et al. 2004). In all cases, environmental sanity assessment requires baseline values in order to detect eventual alterations. Such data, however, are not always available, especially in emerging countries or vast ecosystems poorly explored such as the Amazon (Weiland et al. 2005, Vinod 2006). As one of many consequences, improper monitoring can prevent sustainable development and implementation of environmental mitigations for the safeguard of environmental resources and human quality of life (Walsh 2000, Maranhão 2011). Such could be the case of the Amazon basin; difficulties of access, large distances, high diversity of habitats or yet lack of professionals turn this region into one of the most complex but undiscovered of the world. Nevertheless, it is also a region passing through a quick expansion of its urban centres, a change that can be viewed as a national welfare improvement but also a threat to the ecological balance (Carvalho 2006, Vinod 2006).

The city of Belém, capital of the State of Pará in Northern Brazil and twelfth largest city of the nation, is situated in Guajará Bay, at the confluence of the Guamá and Maguarí Rivers. Like many other Brazilian metropolises, the city is experiencing both a vertical and horizontal expansion through the construction of high standard condominiums and multiplication of poor districts. In both cases, the lack of urban planning is responsible for a continuous pouring of untreated waste waters into the bay (Ribeiro 2004, Cabral 2007). Recent statistical surveys indicated that in 2011 less than 7% of the population was benefitted by the urban sanitation network and less than 20% of the sewage was treated (http://ambientes.ambientebrasil.com.br). As a consequence, the ecosystem is slowly turning into a harmful environment to human beings who use the water to drink, fish, bathe or play (Ribeiro & Marin 2002). The aquatic life is equally at risk, especially the young stages which, due to their precarious biological system, are more vulnerable to environmental disturbances (Costello & Gamble 1992, Costello & Read 1994).

Despite its ecological and social importance, the aquatic environment of Guajará Bay has been poorly monitored and receives little attention. The main objective of this study was to investigate larval fish communities as indicators of ecosystem health status. Larval fish composition and spatio-temporal variations are presented and discussed in relation to larval development stages and environmental aspects. It is hope that this research will establish a baseline for future monitoring of water quality changes along Belem city waterfront.

Material and Methods

1. *Study area*

The city of Belém, capital of the Pará State, is located at the entrance gate to the Amazon Region, 120 km away from the Atlantic Ocean. In 2010, the city counted more than 1.3 million of inhabitants scattered in a total area of 1,065 km^2. It includes a continental area and 39 islands. Guajará Bay, located at the frontal estuarine zone, between 01°22'S-01°30'S parallels and 48°25'W-48°35'W meridians, is at the city waterfront; its surface salinity usually varies between 0 and 0.5, never exceeding 1.5. The Guamá and Maguarí Rivers debouch on the Southern and Northern ends of the bay, respectively (Figure 1). The Western side includes various islands poorly populated and characterized by a very basic urban infrastructure.

Tidal amplitude ranges between 2.3 m and 3.8 m. Water direction is uniform throughout the water column, going southwards at ebb tide and northwards at flood tide, although a wind-induced north-northwest current is omnipresent at the water surface (Gregório & Mendes 2009). Velocity usually does not exceed 2.5 m.s^{-1}. The deepest areas and stronger currents are encountered at the Onça Island Channel, on the left margin of the Guajará Bay (Figure 1) and at the Guamá River main channel, on the right-hand side of the river bed. In comparison, water currents at the city waterfront are weaker, preventing large dispersion of contaminants poured in the bay (Barros et al. 2011). Further data on the hydrodynamic of the Guajará Bay and Guamá River are available in Barros et al. (2011) and Bezerra et al. (2011).

Seven sampling stations (S1 to S7) were established. Five of them (S2, S3, S4, S6 and S7) were scattered along the city margin, under direct influence of anthropogenic activities (Figure 1). All five were impacted by sewage and domestic wastes poured indiscriminately in the bay. Sources of pollution are as illustrated in Figure 1. The two remaining stations, S1 and S5 were located in areas more distant from the city and free of direct pollution sources.

2. *Field work and laboratory procedures*

Field trips took place in December 2004 (period of climatic transition from 'Dry to Wet' – 'D/W'), March 2005 (Wet season – 'W'), June 2005 (period of climatic transition from 'Wet to Dry' – 'W/D') and September 2005 (Dry season – 'D'). Seasons were set according to the rainfall index presented by Moraes et al. (2005).

Fish larvae were sampled with a conical plankton net of 330 µm mesh size positioned at about two meters from the side of the boat. Superficial, horizontal towings were conducted crosscurrent during four minutes after which plankton samples were immediately preserved in neutralized formalin 4 %. The volume of water passing through was estimated by a flowmeter placed at the mouth of the net. Three pseudo-replicates were taken per station. All cruises took place during the first quarter moon; stations were always sampled following the same order (from S1 to S7). Water quality at the time and place of larval sampling was assessed through the measurement of nine parameters: Temperature (°C), pH, conductivity (Cnd – µS.cm^{-1}), turbidity (Tb – NTU), suspended particulate matters (MS – mg.l^{-1}), chemical oxygen demand (COD – mg.l^{-1}), orthophosphate (OP – mg.l^{-1}), nitrate (NTA – mg.l^{-1}) and un-ionized ammonia (Ama – mg.l^{-1}). Water was sampled from the uppermost water layer and stored in the ice. Analyses were either conducted *in situ* using a multi-parameter 340 i/SET WTW (WTW Wissenschaftlich-Technische Werkstatten GmBH) or by spectro-photometry (HACH DR-2010).

In the laboratory, larvae were sorted under a stereomicroscope, identified to the lowest taxonomic level possible and stored in alcohol 90 %. Larval development stage was assessed based on the presence/absence of the yolk-sac and the flexion of the notochord, defining four groups, namely: yolk-sac larvae, pre-flexion, flexion and post-flexion larvae (Moser 1984).

3. *Data analysis*

Densities (number of larvae.100m^{-3}) were calculated discriminating seasons, stations, families (or species) and development stages. Seasonal variation in fish larval density was tested using the non-parametric two way crossed Analysis of Similarities (ANOSIM) pairwise test with replicates (3) considering the two factors 'season' and 'station'. For this test and the following ones, densities were square-root transformed and standardized prior

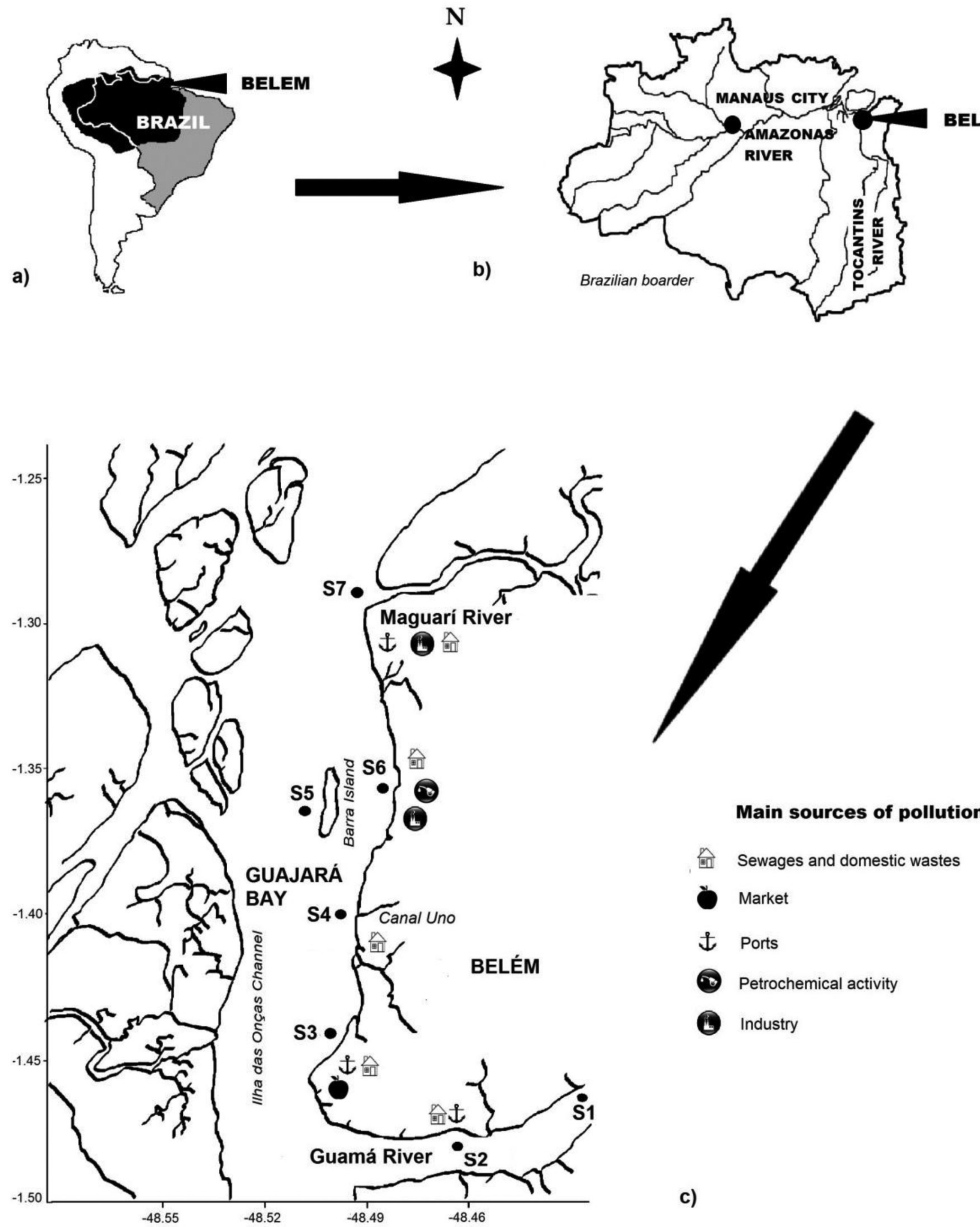

Figure 1. a) South America, Brazil and the Amazon Basin (in black); b) The Amazon basin in Brazil, with the main tributaries and State capital cities; c) Location of the seven sampling stations (S1 to S7) and pollution sources in Guajará Bay.

conducting the analysis. Larval spatial distribution was investigated through a complete linkage analysis using the Bray Curtis Similarity Measure. The Similarity Percentages test (SIMPER) was run to determine the contribution of each larval group to the average Bray-Curtis dissimilarity index, following a 75% similarity cut. Shannon's diversity index (H') and Pielou's equitability index (J) were used on spatio-temporal data. The BIOENV routine based on the Spearman rank correlation analysis was run to assess environmental variables that best explained communities' pattern during the study period. The above mentioned analyses and indices calculation were performed using the routine of the Plymouth Routine Multivariate Ecological Research – PRIMER - package, version 6.0 (Clarke & Aindworth 1993, Clarke & Gorley 2006).

To verify the existence of an ordination between species and abiotic samples at each station, the larval density matrix was first submitted to Detrended Correspondence Analysis (DCA; Ter Braak 1988) with detrending by segments. As the gradient length was short (<2.0), indicating a linear response, Redundancy Analysis (RDA) was used. The analysis was performed separately on the September and December data to assess the existence of a pattern in larval distribution. The analysis was not repeated on the March and June data as they counted very few larvae.

Cluster and RD analyses were performed only on the three most abundant families (Engraulidae, Clupeidae, Sciaenidae) with discrimination of larval development stages, resulting in a total of nine groups. Yolk-sac larvae were very few and included in the pre-flexion group.

Results

A total of 4,663 fish larvae were collected, corresponding to a mean density of 132 individuals.100m^{-3}. A total of nine families and eight species were identified. Those are: Clupeidae (76.100m^{-3}), Engraulidae (42.100m^{-3}), Sciaenidae - *Cynoscion acoupa* (Lacepède, 1801), *Plagioscion squamosissimus* (Heckel, 1840), *Stellifer rastrifer* (Jordan, 1889), Sciaenidae sp. 1, Sciaenidae sp. 2 - (10.100m^{-3}), Ariidae (2.100m^{-3}), Tetraodontidae - *Colomesus psittacus* (Bloch & Schneider, 1801) - (0.3.100m^{-3}), Achiriidae - *Achirus lineatus* (Linnaeus, 1758) - (0.3.100m^{-3}), Hemiramphidae - *Hyporhamphus roberti* (Valenciennes, 1847) - (0.3.100m^{-3}), Syngnathidae - *Oostethus lineatus* (Kaup, 1856) - (0.1.100m^{-3}) and Carangidae - *Oligoplites palometa* (Cuvier,1833) - (0.02.100m^{-3}). The values in brackets indicate the overall family mean density (.100m^{-3}). Among these nine families, only engraulids, clupeids and sciaenids were encountered at all cruises (Table 1). All three families presented individuals at all development stages. The non-identified larvae counted for 1.8% of the total population.

Table 1. Larval density (.100m^{-3}) discriminating family, development stage and season. For clarity purpose, decimals were mentioned only for values < 1. Pre-F = Pre-flexion stage, F = flexion stage, Pos-F = post-flexion stage; D/W, W, W/D and D = dry/wet, wet, wet/dry and dry seasons, respectively.

Family	Development stage	Density (.100m^{-3})			
		D/W	W	W/D	D
Clupeidae	Pre-F	89	15	10	89
	F	30	5	4	27
	Pos-F	15	4	3	13
	Total	134	24	17	129
Engraulidae	Pre-F	69	2	0.4	8
	F	13	4	2	9
	Pos-F	10	9	4	39
	Total	92	15	6.4	56
Carangidae	Pos-F		0.1		
	Total		0.1		
Sciaenidae	Pre-F	16	0.2	3	16
	F	1			1
	Pos-F	0.2		0.1	4
	Total	17.2	0.2	3.1	21
Hemiramphidae	Pos-F		0.1		1
	Total		0.1		1
Tetraodontidae	Pre-F	0.1			0.5
	F	0.1			
	Pos-F		0.1		0.4
	Total	0.2	0.1		0.9
Ariidae	Pre-F				0.5
	F			0.1	4
	Pos-F				3
	Total			0.1	7.5
Achiriidae	Pre-F	0.1			
	F				
	Pos-F	0.2			1
	Total	0.3			1
Syngnathidae	Pos-F	0.1			0.3
	Total	0.1			0.3
Entire population	Pre-F	174	17	14	114
	F	44	9	6	41
	Pos-F	26	13	7	62
	Total density	244	39	27	217

The Wet and W/D seasons presented low densities, averaging 33.100m^{-3}, while the Dry and D/W seasons showed values about eight times higher (Table 1). ANOSIM (global R=0.343) indicated no differences between larval assemblages during the Wet and W/D seasons and during the Dry and D/W seasons. All other combinations were statistically different. The rainy season was characterized by a predominance of pre-flexion larvae while the opposite was observed during the Dryer period (Table 1). Equitability and diversity were highest during the W/D season (H' = 1,26; J = 0,61) and lowest during the Wet season (H' = 0,78; J = 0,40).

The density-based clustering applied on density per station separated two groupings with a similarity index of 68.6% (Figure 2), one including both stations distant from the city (S1 and S5 – 88% similarity) and another one gathering the areas in direct contact with the urban area (S2, S3, S4, S6 and S7 – 80% similarity). Within this second group, two subsets were differentiated; one comprising the two River mouth stations (S2 and S7) and a second one with all three stations scattered along the waterfront (S3, S4 and S6). The SIMPER analysis indicated that the predominance of young clupeiforms, especially engraulids, at S1 and S5, contributed more to the dissimilarity between the two main groupings. On the other hand, stations at the river mouths and city frontline were separated based on the abundance of engraulid and sciaenid post-flexion larvae. The former were more numerous along the city shoreline while the sciaenids predominated at S2 and S7.

Station S4 presented the highest equitability (H' = 1.36) and diversity (J = 0.59) indices while the lowest values were obtained at S1 (H' = 0.81; J = 0.37).

The BIOENV analysis indicated that nitrate with pH best explained the larval assemblage (0.6).

Physicochemical properties of water at each station are summarized in Table 2 and presented through the mean of the March, June, September and December values. Data obtained in September and December and used for the RDAs are presented separately.

The first two axes generated by the RDAs explained 88.5% of the cumulative percentage of the species-environment relation in September and 93.5% in December (Table 3). The plots of RDA samples and species scores illustrate their dispersion pattern, and the plots of environmental variables vectors illustrate the directions and strengths of environmental relationships within the first two dimensions of the RDA ordination (Figure 3). Clupeiforms prevailed at both stations located in areas free of direct human activities, S5 in September and S1 in December. In December the pre-flexion and flexion clupeid and engraulid larvae sheltered at those stations were positively correlated to the suspended matter concentrations and, to a lower extent, to the orthophosphate; in September results were similar, but with a better participation of the orthophosphate. Distribution of the older clupeiforms (especially CPo) showed no reproducibility between months. Thus, in September the larvae

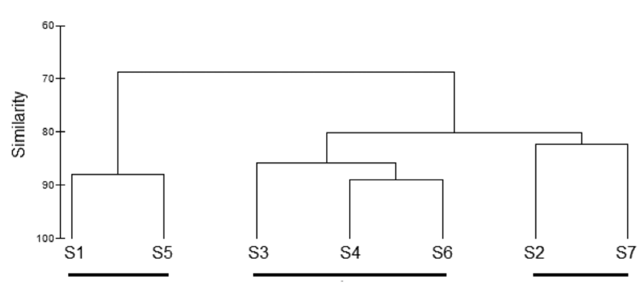

Figure 2. Cluster analysis showing the spatial repartition of all seven stations based on the densities of nine larval groups.

Table 2. Temporal mean and standard deviation of water parameters data by station. September and December data are mentioned separately. T = temperature (°C), Cnd = conductivity (µS.cm^{-1}), Tb = turbidity (NTU), MS = suspended particulate matters (mg.l^{-1}), COD = chemical oxygen demand (mg.l^{-1}), Nta = nitrate (mg.l^{-1}), Ama = ammonia (mg.l^{-1}) and OP = orthophosphate (mg.l^{-1}).

	ANNUAL MEAN ± SD September / December						
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
T	31.8±1.0 31/31	32.5±2.4 32/31	31.3±0.5 31/31	31.5±0.6 31/31	31.3±0.5 32/31	31.6±1.1 31/31	31.4±0.7 31/31
pH	5.9±0.3	6 .4±0.4	6.1±0.5	5.9±0.4	5.5±0.3	5.8±0.5	5.8±0.4
Cnd	6.1/5.9 177.3±175 243/395	6.7/6.6 427.0±716 140/1498	6.2/6.3 267.3±397 152/856	6.4/6.0 189.3±241 132/544	5.7/5.8 98.3±126 56/286	6.4/6.0 174.6±233 132/515	6.4/5.9 130.9±208 13/442
Turb	42.8±30 34/25	29.8±23 21/22	35.8±20 20/40	40.1±21 38/30	50.6±22 41/46	44.6±17 50/37	50.9±27 39/47
MS	34.1±32 39/12	17.5±12 23/3	26.2±17 39/4	22.3±17 37/4	36.9±33 39/4	16.1±20 45/3	28.2±35 77/2
COD	13.1±4.9 17/9	11.5±9.1 1/8	15.7±9.0 8/28	15.2±8.0 25/9	19.7±4.5 17/18	17.6±7.3 17/18	26.3±12.3 34/28
NTa	0.68±0.13 0.5/0.7	0.70±0.34 0.3/0.6	0.98±0.25 0.7/0.9	1.00±0.22 0.8/1.0	0.95±1.03 0.1/1.2	1.10±0.27 1.5/1.0	2.08±1.58 1.3/0.9
Ama	0.10±0.08 0.1/0.1	0.24±0.05 0.3/0.2	0.12±0.28 0.2/0.5	0.36±0.23 0.6/0.7	0.09±0.13 0/0.31	0.20±0.18 0.24/0.6	0.27±0.33 0.23/0.5
OP	0.05±0.03 0.01/0.05	0.02±0.02 0.01/0.01	0.04±0.03 0.06/0.01	0.04±0.04 0.01/0.09	0.08±0.07 0.03/0.16	0.06±0.03 0.02/0.06	0.05±0.03 0.02/0.04

Table 3. a) Results from Redundancy Analysis of the nine larval groups captured in September and December of 2005 in Guajará Bay; b) Intraset correlations of water quality parameters on the two first axes of the RDA for the months of September and December 2005.

RDA	**AXES**			
SEPTEMBER	**1**	**2**	**3**	**4**
Eigenvalues	0.674	0.211	0.065	0.028
Cumulative percentage variance of species-environment relation	67.4	88.5	95.1	97.9
Sum of all eigenvalues		1.000		
DECEMBER				
Eigenvalues	0.839	0.097	0.051	0.009
Cumulative percentage variance of species-environment relation	83.9	93.5	98.6	99.5
Sum of all eigenvalues		1.000		

b)

	SEPTEMBER		**DECEMBER**	
	Axis 1	**Axis 2**	**Axis 1**	**Axis 2**
pH	–0.5359	0.5451	–0.7670	–0.0751
Cnd	–0.4940	0.6182	–0.5799	0.2869
Tb	–0.1429	–0.8080	0.2666	0.3136
MS	0.7961	0.1986	0.1431	–0.2991
COD	–0.5114	–0.2463	0.0877	–0.1185
Nta	–0.0604	–0.8386	–0.2992	0.3335
Ama	–0.7288	–0.3275	–0.2555	0.2669
OP	0.3862	–0.6127	0.4603	0.3010

were present all along the city frontline and positively correlated to the nutrient concentrations, while in December they were found predominantly in the Guamá River and at S6, near the Maguarí River, where nutrients were less.

Pre-flexion and flexion sciaenid larvae were found mostly along the city frontline, especially at S3 and S4. Both in September and December their presence was best explained by the orthophosphate concentrations. The post-flexion individuals were more numerous at the Guamá and Maguarí Rivers without any special affinities towards the water parameters assessed.

Discussion

Oligohaline areas are important nursery grounds for both estuarine and freshwater fishes although they are often characterized by fish assemblages of low diversity (Rozas & Hackney 1984, Campfield & Houde 2011). Such is the case of Guajará Bay. Densities and diversity registered in this study are considered average to low compared to those in the lower estuary and freshwaters of the Amazon basin (Araújo-Lima et al. 2001, Costa et al. 2011). Clupeiforms strongly dominated the assemblages, as it is the case in many Brazilian and

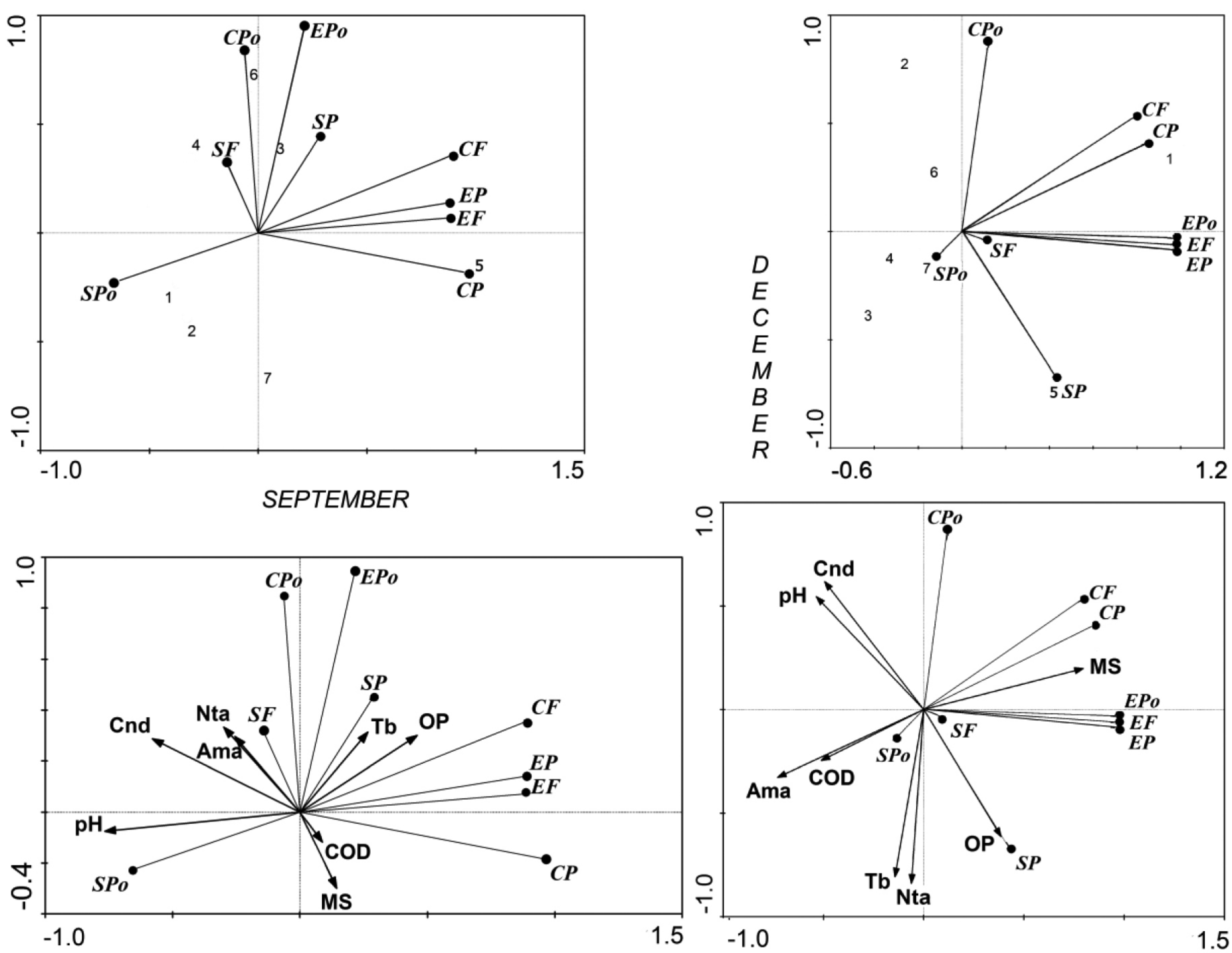

Figure 3. Ordination diagram of the Redundancy Analysis of water parameters and fish larvae in Guajará Bay showing the sampling stations in September and December of 2005. EP, EF, EPo = engraulids in pre-flexion, flexion and post-flexion; CP, CF, CPo = clupeids in pre-flexion, flexion and post-flexion; SP, SF, SPo = sciaenids in pre-flexion, flexion and post-flexion. Cnd = conductivity, Tb = turbidity, MS = suspended matter, COD = chemical oxygen demand, Nta = nitrate, Ama = ammonia and OP = orthophosphate.

worldwide estuaries (Barletta-Bergan et al. 2002a, Bonecker et al. 2007). Studies on the adults' gonad maturation stages indicated that the widely distributed euryhaline engraulid *Anchoa spinifer* (Valenciennes, 1848) predominantly used Guajará Bay as a breeding ground (Viana et al. 2010). However, difficulties faced to identify clupeiform larvae up to the species level as it is often the case (e.g. Coser et al. 2007), did not allow cross-checking this information with the ichthyoplanktonic data. The absence of Pristigasteridae larvae contrasted with the relatively strong abundance of the adults individuals (Viana et al. 2010), suggesting that their main spawning ground is not in the area of study. It is however noted that a few larvae of this family were encountered in small, highly contaminated creeks of the capital city during the months of September and January (V. Sarpedonti, unpublished data).

Discrepancies between adults (Viana et al. 2010) and larvae (this study) encounters in the bay were also registered among non-clupeiforms and attributed to habitat specificity or reproduction strategy. For example, adults *Colomesus asellus* (Müller & Troschel, 1849 - Tetraodontidae) and *Curimata inornata* (Vari, 1989 - Curimatidae) used the bay as a breeding ground; however, as they occupy essentially small channels, their larvae were absent from the bay samples (this study) but were found in nearby mangrove environments (Sarpedonti et al. 2008) and small creeks of Belém's Islands (V. Sarpedonti, unpublished data). The practice of parental care, as it is the case for *Anableps anableps* (Linnaeus, 1758 - Anablepidae) and *Hoplia* gr. *malabaricus* (Bloch, 1794 - Erythrinidae), justify the scarcity of their larvae in the planktonic catches (Prado et al. 2006, Oliveira et al. 2011). The opposite scenario, when only larvae were present, was also observed. This was the case of the sciaenid *Stellifer rastrifer*. According to Camargo & Isaac (2005) the adults' spawning ground is located in the lower estuary; yet, eggs and newly hatched larvae would not remain there but drift towards the upper estuary where salinity is much lower. Similar behaviour applies to *Cynoscion acoupa* (Barletta & Barletta-Bergan 2009), although the presence of their larvae in oligohaline waters like in Guajará Bay, is unusual. *Plagioscion squamosissimus* is the only identified sciaenid species that use Guajará Bay both at the larval and adult stage. This pelagic species, originally from the Amazonian basin, is commonly found in the freshwaters of Northern South America. The relative abundance of young larvae and concentration of the elderly at the river mouth corroborated the migration pattern documented for this species. Indeed, studies conducted in South Brazil indicated that adults spawn in calm areas where the young larvae would remain. As they reach a more advanced development stage, the individuals move towards areas of stronger water flow and use the currents to reach other nursery grounds (Baumgartner et al. 2003, Bialetzki et al. 2004). All the remaining larval species that were absent from the juvenile/adult catches (Viana et al. 2010) counted very few individuals suggesting that their presence was accidental or that Guajará Bay was on their migration route.

The time frame for fish reproduction in tropical countries matches either a peak in natural food production (Cushing 1990) or propitious weather conditions that enhance recruitment success (Sinclair & Tremblay 1984). The main reproduction period at the onset of the rainy season (Viana et al. 2010, present study) when levels of primary production are high (Paiva et al. 2006), supports the first affirmation. According to Paiva et al. (2006), the high quantity of sediment load transported by the Guamá River during the rainy season increases water turbidity which, in return, inhibits phytoplankton growth. On the contrary, the greater water transparency during the dry season favours primary production and therefore larval survival through an increase of aliments availability (Cushing 1990, Mertz & Myers 1994). Besides food availability, floodplains that form with rising water level are crucial to the survival of many species that use these temporary environments as nursery grounds (Sousa & Freitas 2008, Sarpedonti et al. 2008, Barletta-Bergan et al. 2002b).

Fish larvae distribution is highly variable and depends essentially on hydrogeographical processes and meteorological events (Munk et al. 2003). The RDAs conducted on the September and December data showed similar patterns of larval distribution, indicating constancy in the use of Guajará Bay. For both months, assemblages' structure was controlled by the interactions between larval biological characteristics at the ontogenetic and taxonomic levels, and water components. Segregation between development stages is usually explained by a gain, or change, in biological abilities that enables the older larvae to use a wider - or new - range of environments (Simonović et al. 1999, Sarpedonti et al. 2000, Pinder et al. 2005). In this study growing Clupeiforms moved from the farmost stations, S1 and S5, to the stations closer to the waterfront. The higher levels of conductivity and concentrations of N-compounds at stations S3, S4, S6 and S7 were related to the organic matter and domestic wastes poured into the bay. It is suggested that the higher concentrations of NO_3 (compatible with the ichthyoplankton life) in a stretch where currents are weaker (Barros et al. 2011) contributed to the higher larval diversity and to the approximation to the city of post-flexion clupeiforms. Ammonia levels of toxicity for fish vary considerably with pH, temperature, dissolved oxygen, taxa and development stages (Vosylienë & Kazlauskienë 2004, Eddy 2005). Previous studies indicated that concentrations registered at station S4 both in September and December can be unsuitable for the younger stages of some species. However, it was not possible to verify whether this observation also applied to the species present in the bay, although a negative correlation between young clupeiforms and NH_3 was observed, corroborating the findings of Mafalda Junior et al. (2008). Orthophosphate ions correspond to the aqueous form of phosphates; they are readily used by plants, or stored when present in excess. Their level of concentration is crucial for the ecosystem, especially freshwater environments where eutrophication is essentially controlled by P and not N (Howarth et al. 2000). Unlike nitrate, the higher amounts of OP were not necessarily associated to the waterfront stations and city pollution. Both N and P are directly related to sewage pouring; however P is also highly correlated to agricultural activities and erosion in the watershed. Phosphate concentrations loaded by the Guamá and Maguarí Rivers along their courses are high; once in the bay, particles are dispersed by the strong currents to form peaks of concentration randomly distributed in the bay. The amounts of OP registered occasionally indicated quantities that could affect the environment through eutrophication. However, these cases were rare and taking into consideration the continuous mixing of waters in the bay, it is believed that, at the time of the study, concentrations were harmless to fish larvae.

The remaining water parameters, temperature, suspended matter and pH were within ranges of compatibility for aquatic life (www.mma.gov.br/conama/; www.water.epa.gov, http://ceqg-rcqe.ccme.ca/). It is noted that the occasional peaks (>500 NTU) of turbidity were related to the rainy season when water flow increases drastically. The pH, slightly acid in reason of the high concentrations of humic acid in the soil, is within range of normality for the Amazon Basin and should not be a limiting factor for larval growth and survival.

Although this study associated some larval distribution patterns to water parameters, it is unlikely that water quality governs larval assemblage. The water showed signs of contamination but, in the overall, parameters remained within the ranges of tolerance for fish. However, as little is known about larvae tolerance to water quality, histological analysis were subsequently performed on tissues of 28 clupeiforms measuring 1.0 mm total length. Their digestive tract cells showed no alterations sustaining the hypothesis that, to date, the environment is suitable for the ichthyoplankton. Complementary analysis on water microbiology indicated intensive amounts of bacteria, essentially coliforms, which make the environment inappropriate for Human use (Dilva 2006). However, their impact on the fish community of the Bay of Guajará is yet to be demonstrated. Instead, it is more probable that the hydrodynamic features around the insular system controls larval distribution.

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