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ICHTHYOFAUNA IN AN ESTUARY OF THE MATARIPE AREA, TODOS OS SANTOS BAY, BAHIA, BRAZIL

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ABSTRACT

The community structure and dynamics as well as some biological parameters of selected species of the ichthyofauna of the Mataripe estuarine region affected by the Landulfo Alves Oil Refinery (RLAM) were analyzed. Twenty stations were sampled with a gillnet in five different periods: August and December 2003, March and July/August 2004 and January 2005. Thirty-five actinopterygian species and one elasmobranch species were recorded, *Oligoplites saurus*, *Diapterus rhombeus*, *Lutjanus synagris* and *Scomberomorus brasiliensis* among them, on all the campaigns. A total of 1368 specimens, weighing 36.10 kg, were caught. The ichthyofauna total biomass was greater, in weight, on the eastern side of the study region, especially at the stations close to the shoals/reefs and the rocky bottom. A similar pattern was also observed for the diversity values. In general, low evenness and diversity were observed in the area studied, possibly as a result of the fishing gear used. *D. rhombeus* juveniles dominated in all but one of the samplings (July 2004), in which latter *Cyclichthys spinosus* was dominant. Carangids and species associated with consolidated bottoms were observed, although in small numbers, throughout the study period. In spite of the limitations imposed by the gear used for sampling, the estuarine area influenced by the RLAM was seen to play a role as a growth area for the great majority of species, especially the mojarra (*D. rhombeus*), but it offers no fishing potential due to the prevalence of young and small individuals. Evidence of imminent spawning was recorded for *Pomadasys corvinaeformis* in August 2003, and recent spawning in March 2004 for *Oligoplites saurus*. Further, mature individuals occurred in insufficient numbers to permit population level evaluation.

RESUMO

A estrutura e dinâmica da ictiofauna amostrada na região estuarina de Mataripe sob a influência da Refinaria Landulpho Alves-Mataripe (RLAM) foi analisada. Vinte estações foram amostradas com rede-de-abalo em cinco períodos: agosto e dezembro de 2003, março e julho/agosto de 2004 e em janeiro de 2005. Foi verificada a ocorrência de 35 espécies de actinopterígios e uma de elasmobrânquio, sendo que *Oligoplites saurus*, *Diapterus rhombeus*, *Lutjanus synagris* e *Scomberomorus brasiliensis* ocorreram em todas as campanhas. Um total de 1368 espécimes, pesando 36,10 kg, foram capturados. A biomassa total da ictiofauna foi maior no lado leste da região estudada, especialmente nas estações próximas de coroas/recifes e fundos consolidados. Um padrão similar foi também observado para os valores de diversidade. De maneira geral, baixa equitatividade e diversidade foram observadas na área de estudo, possivelmente como o resultado da rede utilizada. Ocorreu a dominância de formas juvenis de *Diapterus rhombeus* em todas as campanhas exceto uma (julho de 2004), quando *Cyclichthys spinosus* foi a espécie dominante. Embora em pequeno número, a presença de carangídeos e espécies associadas a fundos consolidados foi observada durante todo o período de estudo. Apesar das limitações impostas pelo aparelho de coleta, o papel da região estuarina sob a influência da RLAM, durante os períodos amostrados, foi classificado como área de crescimento para a maioria das espécies, principalmente a carapeba (*D. rhombeus*), não oferecendo potencial pesqueiro, dada a ocorrência de indivíduos jovens e de pequeno porte. Evidência de desova iminente foi relatada para *Pomadasys corvinaeformis* em agosto de 2003, e de desova recente em março de 2004 para *Oligoplites saurus*, somando-se a indivíduos maduros ocorrendo em números não-representativos para uma avaliação em nível populacional.

Descriptors: Estuarine fish, Community structure, Todos os Santos Bay, Brazil.
Descritores: Peixes estuarinos, Estrutura da comunidade, Baía de Todos os Santos, Brasil.

INTRODUCTION

It is well know that estuarine and coastal habitats are subject to the impact of human activities. Biological components of coastal ecosystems may, therefore, be directly or indirectly influenced by these activities. As it is intimately related to coastal habitats, the ichthyofauna constitutes the interface between man and the aquatic environment, particularly as it is the source of direct (protein source) and indirect (commercial) resources. Beyond that, the specific, genetic and habitat biodiversities of coastal areas are being increasingly valued, and the ichthyofauna is now thus being recognized as an indicator of environmental health (Kennish, 1997). Specific biodiversity is also a key element for the understanding of ecosystems, in view of their contribution to the composition of the total biomass.

Todos os Santos Bay – TSB (coordinates 12°35’30’’-13°07’30’’S and 038°29’00’’-038°48’00’’W), situated in the state of Bahia, is the largest Brazilian bay, having an area of about 1,200 km^2. This area suffers the impact of a large metropolitan area (Salvador, the capital of Bahia) as well as of an important petrochemical pole. One of the biggest Brazilian oil refineries, the Landulfo Alves Refinery (RLAM - Mataripe, Bahia), lies on this bay.

Our knowledge of the ichthyofaunal biodiversity and composition of the TSB is still slight and requires fuller investigation. The data available in the literature is restricted to the coast of Bahia. For instance, several studies concerning juvenile or adult feeding have been carried out for various species such as *Albula vulpes, Atherinella blackburni, Bathygobius soporator, Chloroscombrus chrysurus, Diplectrum radiale, Larimus breviceps, Lutjanus sinagris, Lycengraulis grossidens, Ogcocephalus vespertilio, Serranus flaviventris, Thalassophryne sp., Trichiurus lepturus* and *Umbrina coroides* (Lopes and Miranda, 1995; Lopes and Oliveira-Silva, 1998, 1999a; Lopes and Silva, 2000; Lopes et al., 2001a, 2001b, 2003, 2004a, 2004b; Oliveira-Silva et al., 2002, 2003; Oliveira-Silva and Lopes, 2002a, 2002b, 2005; Chagas et al., 2004, and Moraes et al., 2004).

The diversity of fish in the TSB is relatively high (Lopes and Oliveira-Silva, 1999b, 2001a, 2001b, 2002; Lopes et al., 1998, 2000a, 2000b, 2001a, 2001b, 2003a, 2003b; 2003c, 2003d, 2003e; Lopes and Sampaio, 2002). Eighty-five species have been recorded in the mangrove region of Itaparica Island further south (Lopes et al., 1998), 70 species in the Itapema region (Lopes et al., 1999) and 107 species in the northern region of the TSB (Almeida, 1996). Moreover, studies on the fish larvae assemblages in the innermost region of TSB indicate that this region is used as a spawning and/or growth area for some species of at least 12 families (Mafalda Jr. *et al*., 2008). However, no investigation of the juvenile and adult fauna is as yet available. The data available in the literature, although significant, have not provided accurate knowledge regarding the number and diversity of the species in this region. This is due principally to the lack of surveys and systematic studies. Further, taxonomic problems such as misidentifications, inadequate descriptions and lack of accuracy as to the origin of the material, make any precise, complete knowledge of the TBS ichthyofauna difficult to attain. In Brazil, our knowledge of the estuarine and coastal ichthyofauna is particularly limited.

The objective of this study is to describe, within this context, the fish community structure and biological parameters of the populations of the estuarine area affected by the Landulpho Alves Oil Refinery - Mataripe (RLAM) in the various seasons, based on the data of the catches made with the gillnet, and to detect spatial and temporal patterns in the distribution of fish species.

MATERIAL AND METHODS

Sampling was undertaken on five dates: 05/06 August 2003; 06 December 2003; 17 March 2004; 31 July/01 August 2004, and 16 January 2005 (Fig. 1), at 20 selected stations. The stations were 500 m apart.

The gear used for the collection was a gillnet, 400 m long, 3 m in height and of 25 mm mesh size. The netting operation involved a vessel that towed a boat from which the fishermen mounted a drifting gillnet. After setting up the net, the fishermen hit the water surface with their oars, driving the fish into the net. The duration of the permanence of the net in the water depended on meteorological and sea conditions and lasted from 30 to 40 minutes. This prospection resulted in 7-10 fishing CPUEs (catches per unit effort) per campaign, excluding the time taken to remove enmeshed organisms. Each fish caught was considered as one CPUE (specimens/haul).

The specific composition of the catches was determined using the species identification guides of Figueiredo and Menezes (1978; 1980; 2000) and Menezes and Figueiredo (1980; 1985). All the specimens were counted and weighed for estimation of the biomass. Non-parametric ANOVA (Kruskal–Wallis, KW) were used to test for any significant differences in spatio-temporal variation in the abundance and biomass of the species.

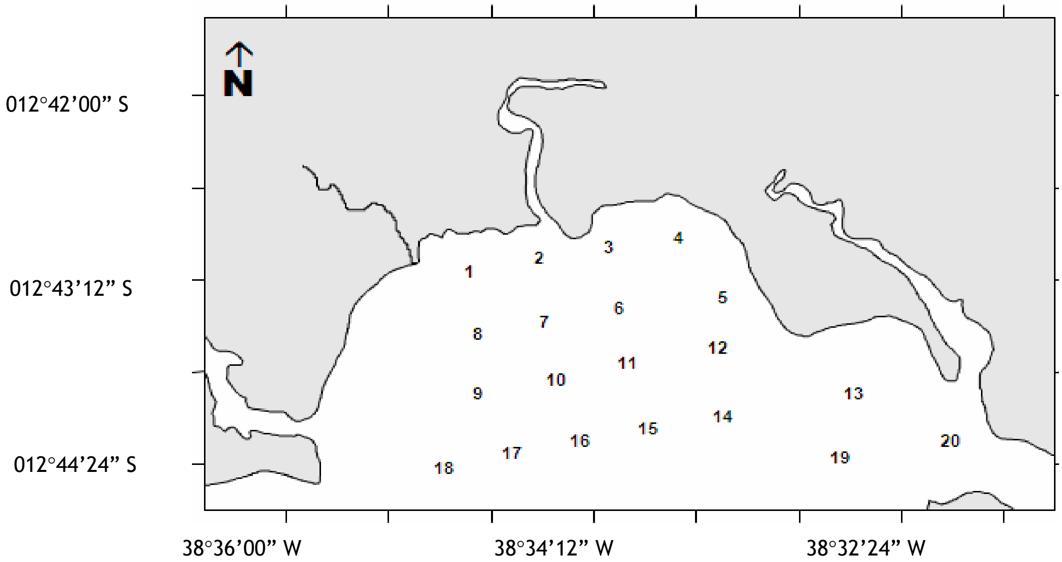

Fig. 1. Study area of 5 sampling campaigns undertaken in the Mataripe estuarine region, between August 2003 and January 2005.

The ichthyofauna structure was described in terms of the following indicators: Simpson's dominance index (λ); Shannon and Weaver's diversity index; Margalef's richness index (R); and Pielou's evenness index (J) (Begon et al., 1996). Fish assemblage structure was evaluated using the non-metric multi-dimensional scale – MDS based on CPUE values and Bray-Curtis´s coefficient. Logarithmic transformation of the variables was also performed prior to the analyses in order to reduce the influence of rare species. The abundance-biomass comparison (ABC) or k-dominance curves and the W statistics were used to evaluate community structure to identify possible environmental influences on the diversity and dominance patterns of fish species without the interference of rare ones.

Estimates of weight-length relationships were calculated for the most abundant species. The potential equation, adjusted by the least-squares method, is $Tw=aTl^b$, where Tw is the total weight (g), Tl is the total length (mm), a the correlation and b the curvature parameter estimates.

The condition factor (K) was calculated as the relationship between the individual's weight and its length (Vazzoler, 1996). In this study both Fulton's and the allometric condition factor were estimated, the latter being a more realistic reflection of the sites where the individuals occur (Braga, 1986). Significant differences between female and male proportions, in those species for which it was possible to differentiate between the sexes, were checked by a chi-squared (χ^2) test.

The stages of gonadal maturation were classified macroscopically, on a 5 stages female scale (Dias *et al*., 1998). Although the sex of both males and females was verified, only data pertaining to females were used for the frequency estimates because ovaries are better than testicles for providing information, such as spawning period and location, relating to degree of maturation as well as to the possible number of descendants (Lara, 1951; West, 1990). Maturity stage frequencies were grouped into life cycle phases and reproductive activity: juveniles (stage A); adults (stages B and C), and spawners (stages D and E).

The temporal variation of the gonadosomatic index (GSI) was estimated in accordance with $GSI=(Gw/Bw)*100$, where Gw corresponds to the gonad weight and Bw to the fish´s body weight (Tw-Gw). Estimates were also made by maturation stage. A temporal evaluation was not feasible, since no sampling of the same species was available in sufficient and significant individual numbers.

Of the total material collected, 89 ovaries from different species were processed by routine methods for microscopic tissue examination. The ovary samples of 5 µm-thick slices were prepared by dehydration, paraffin embedding, and staining with hematoxylin and eosin. The ovaries were classified microscopically, on a 5 stages female scale (Dias *et al*., 1998). The number of atretic oocytes was also determined.

RESULTS

Ichthyofauna Structure

Positive stations per period varied as follows: 7 stations (35 %) on 05 and 06 August 2003 (stations 1, 5, 7, 9, 12, 17 and 20); 7 stations (35 %) on 06 December 2003 (stations 5, 7, 9, 12, 17, 19 and 20); 10 stations (50 %) on 17 March 2004 (stations 5, 6, 7, 11, 12, 14, 16, 17, 19 and 20); 7 stations (35 %) on 31 July and 01 August 2004 (stations 5, 7, 9, 12, 14, 16 and 20); and 6 stations (30 %) on 16 January 2005 (stations 5, 7, 9, 12, 14, 16 and 20).

The ichthyofauna of the area studied was represented by Actinopterygii fishes comprising 5 orders, 15 families, 29 genera and 35 species (Table 1). Only one elasmobranch species (*Rhinobatos percellens* - Elasmobranchii, Rajiformes, Rhinobatidae) was caught - in July 2004.

As shown in Table 1, *Oligoplites saurus*, *Diapterus rhombeus*, *Lutjanus synagris* and *Scomberomorus brasiliensis* species occurred on all the campaigns. Further, the highest number of species (19) was caught on the 2004 winter campaign (Table 2). On all the campaigns *D. rhombeus* represented between 71.2 % and 88.3 % of the total catch, except on the July/August 2004 campaign when *C. spinosus* accounted for 57 % of the total catch, *D. rhombeus* being the second most abundant fish (34 %). Only in March 2004, was 90% of the total catch represented by more than two species. Some species appeared exclusively on the 2003, 2004 or 2005 campaigns (Table 2).

Table 1. Occurrence of species, by sampling campaign, caught in the Mataripe estuarine region. The table is organized according to species phylogeny and the shaded lines indicate species that occurred on all the campaigns.

		Winter		**Summer**		
		1^{rst} year	**2nd year**	**1^{rst} year**	**2nd year**	
SPECIES	**Brazilian regional name**	**August 2003**	**July/ August 2004**	**December 2003**	**March 2004**	**January 2005**
Opisthonema oglinum	sardinha-faca	X			X	X
Cetengraulis edentulus	sardinha	X				
Anchoa tricolor	pititinga	X			X	
Lycengraulis grossidens	manjuba/ manjubão		X			
Bagre marinus	bagre		X		X	X
Mugil curema	parati		X			
Mugil sp.	parati olho-de-fogo		X			
Dactylopterus volitans	coió		X			
Carangoides crysos	solteira	X	X		X	
Chloroscombrus chrysurus	carapau	X			X	X
Oligoplites saurus	riate	X	X	X	X	X
Caranx latus	xarelete				X	X
Caranx hippos	xaréu					X
Diapterus rhombeus	carapeba	X	X	X	X	X
Eucinostomus gula	carapicu	X				
Eucinostomus melanopterus	carapicu		X	X		X
Conodon nobilis	roncador	X				
Pomadasys corvinaeformis	coró	X				X
Haemulon steindachneri	corcoroca		X	X		X
Anisotremus virginicus	salema				X	
Haemulon aurolineatum	corcoroca		X			
Orthopristis ruber	corcoroca		X			
Lutjanus synagris	vermelho	X	X	X	X	X
Lutjanus analis	cioba		X	X		
Polydactylus virginicus	barbudo		X		X	
Cynoscion leiarchus	pescada branca	X				X
Cynoscion jamaiscensis	pescada			X	X	
Micropogonias furnieri	corvina			X	X	
Larimus breviceps	roncador			X		
Ctenosciaena gracilicirrhus	chumberga				X	
Scomberomorus brasiliensis	sororoca	X	X	X	X	X
Archosargus rhomboidalis	sambuia		X	X	X	
Calamus pennatula	pena				X	
Sphyraena guachancho	bicuda	X				
Cyclichthys spinosus	baiacu		X			

Table 2. Summary of the main aspects considered for the fish community of the Mataripe estuarine region in August and December 2003, March and July/August 2004 and January 2005: (a) winter and (b) summer.

(a)

Variable	Winter August 2003	 July/August 2004
Number of species	14	19
Much abundant species	*Diapterus rhombeus* (79.1%) *Pomadasys corvinaeformis* (7.4%)	*Cyclichthys spinosus* (57.1%) *Diapterus rhombeus* (34.3%)
Species that occurred in one campaign	*Cetengraulis edentulus* *Conodon nobilis* *Eucinostomus gula* *Sphyraena guachancho*	*Cyclichthys spinosus* *Dactylopterus volitans* *Haemulon aurolineatum* *Lycengraulis grossidens* *Mugil curema* *Mugil sp.* *Orthopristis ruber* *Polydactylus virginicus* *Rhinobatos percellens*

(b)

Variable	 December 2003	Summer March 2004	 January 2005
Number of species	11	17	13
More abundant species	*Diapterus rhombeus* (88.3%) *Oligoplites saurus* (2.3%)	*Diapterus rhombeus* (71.2%) *Lutjanus synagris* (5.4%) *Caranx latus* (4.5%) *Scomberomorus brasiliensis* (4.5%)	*Diapterus rhombeus* (86.8%) *Lutjanus synagris* (4.0%)
Species that occurred in one campaign	*Larimus breviceps*	*Anisotremus virginicus* *Calamus pennatula* *Ctenosciaena gracilicirrhus* *Polydactylus oligodon*	*Caranx hippos*

A total of 1368 specimens were caught, giving a total biomass of 46,594.32 g. The lowest catch rate (both in numbers and in weight) was observed in December 2003 and was equivalent to approximately half or less than half of the total catch observed in the other sampling periods (Table 3). Despite the fact that the area is restricted, the number of specimens caught and the sample's total biomass were largest in January 2005, with 403 individuals totalizing 12,661.44 g.

The catches at the stations were heterogeneous, both in numbers and in biomass. Only stations 5, 7, 12 and 20 featured individuals on all the campaigns. These were also the stations at which the highest total numbers of specimens were caught. Although a high number of individuals was also found at stations 14 and 16, these stations were not sampled on all the campaigns (Fig. 2).

Table 3. Frequency of ichthyofauna occurrence, by numbers and by biomass, on the different sampling campaigns undertaken in the Mataripe estuarine region.

	Winter		**Summer**		
	1rst year	**2nd year**	**1rst year**		**2nd year**
	August 2003	July/August 2004	December 2003	March 2004	January 2005
number of specimens	230	364	128	243	403
catch biomass	8,760.14 g	11,655.48 g	4,313.33 g	9,203.93 g	12,661.44 g

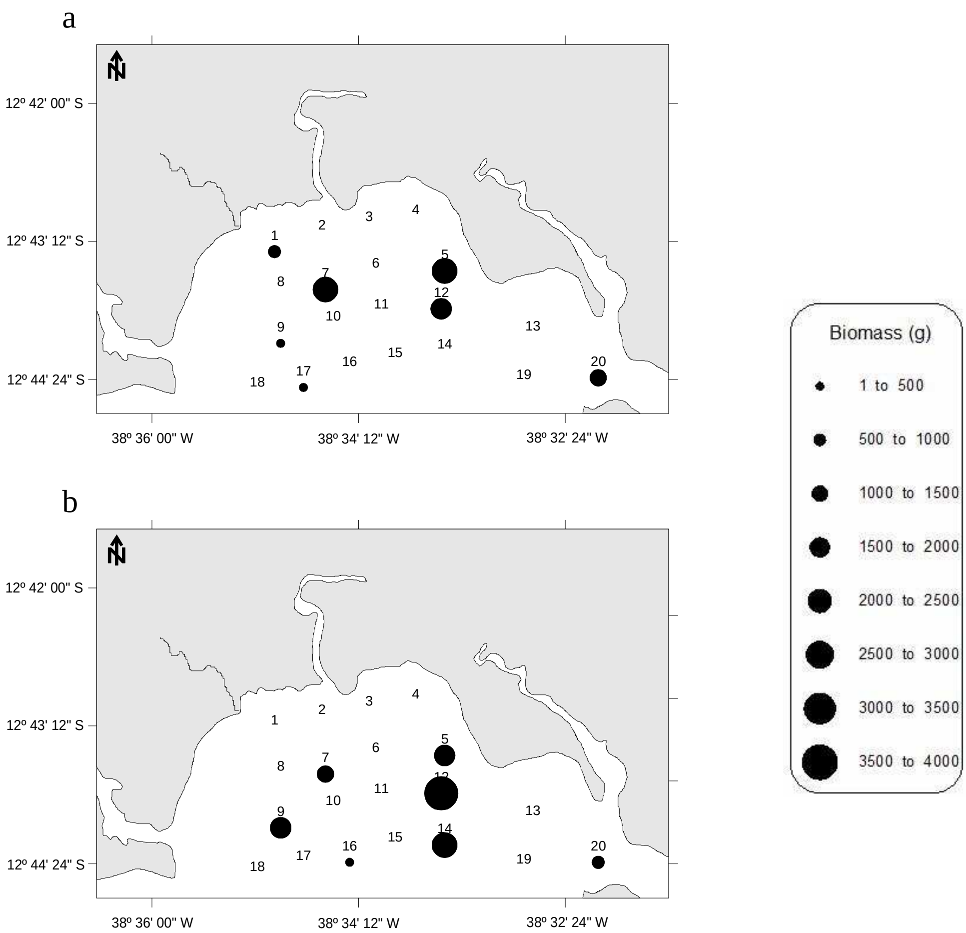

Fig. 2. Ichthyofauna biomass per sampling station on the campaigns of (a) August 2003 and (b) July/August 2004, in the Mataripe estuarine region.

Overall, the spatio-temporal patterns in the distribution of ichthyofauna were similar across the seasons: the highest biomasses in numbers and weight were associated with the same stations, though with slightly variable abundances. The Kruskal-Wallis results calculated for stations by distance from the outflow zone and numbers and biomass yielded no significant result ($p=0.2919$ and 0.3506, respectively) and the same was found as regards numbers and biomass by month ($p=0.1000$). In the winters of both the first and second years (Fig. 3a and b), the highest biomass values were recorded on the eastern side of the estuarine region. Stations 5, 7 and 12 were those with the largest biomass, with some contribution, in the second year, from stations 9 and 14. In the winter of the first year, the biomass was more homogeneously distributed among the stations with the highest abundance; in the second year, higher biomass values were observed at stations 12 and 14.

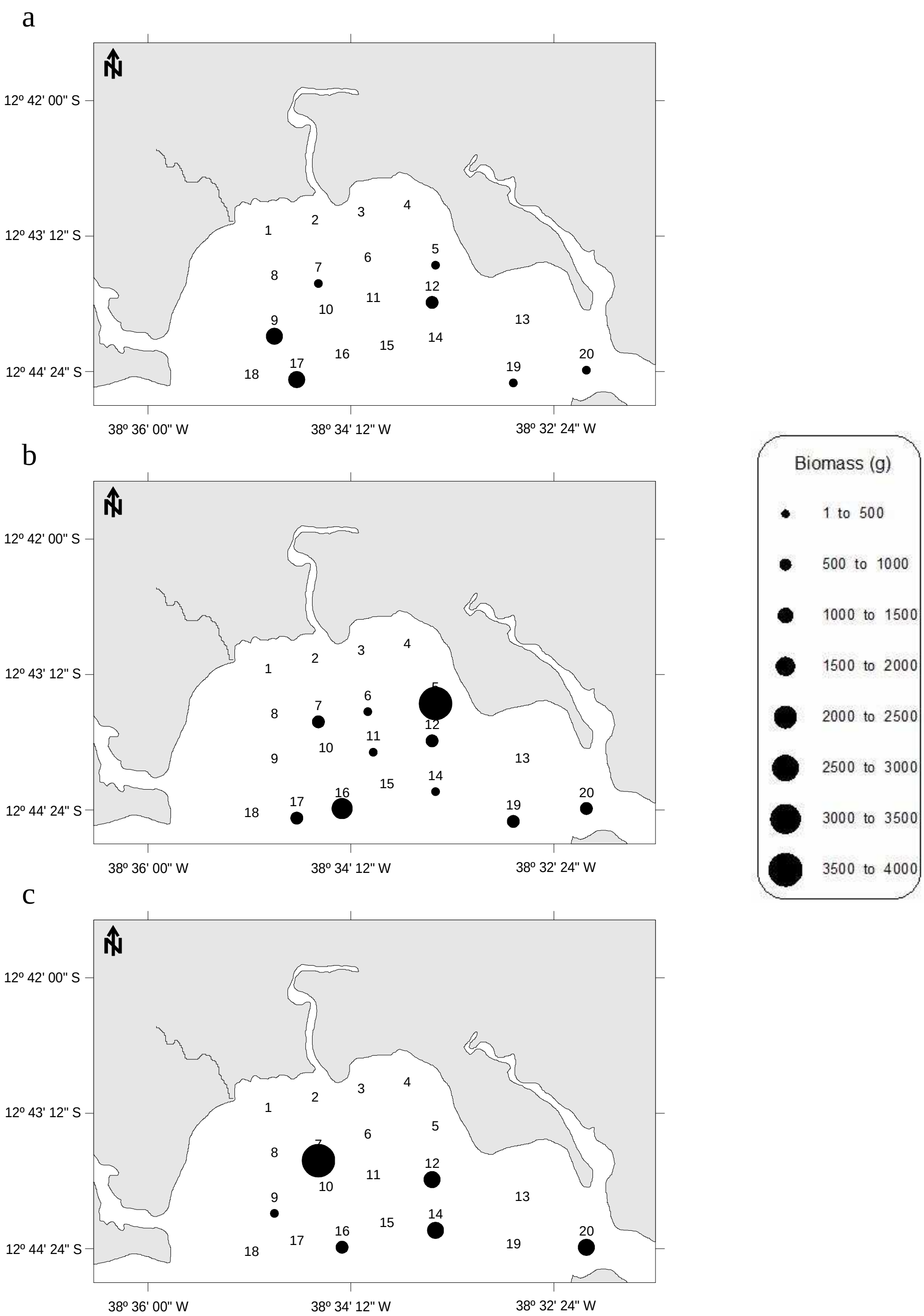

Fig. 3. Ichthyofauna biomass per sampling station on the campaigns of (a) December 2003, (b) March 2004 and (c) January 2005 in the Mataripe estuarine region.

In the summer of the first year (December 2003), very low biomass values, evenly distributed throughout the area, were observed (Fig. 4a). On the other hand, in March 2004, higher biomass values were observed at station 5, where the catch was also more numerous (Fig. 4b). In the January 2005 campaign higher biomass was found, mainly concentrated at stations 5 and 7 (Fig. 4c).

The most striking difference observed between the winter campaigns related to the richness index, which presented a much higher value in the winter of 2004 than in that of 2003 (Tables 4a-b). In addition, the dominance index varied over time, decreasing from the first to the second year, due to the occurrence of *Cyclichthys spinosus* as the most abundant species. However, the evenness values were found to be quite similar for both winter campaigns.

On the other hand, when considering the summer alone, the highest richness index was observed in March 2004. The highest diversity values were also found in March, almost double the values estimated for the two other summer samples. The dominance value in March was the lowest among those of the summer campaigns.

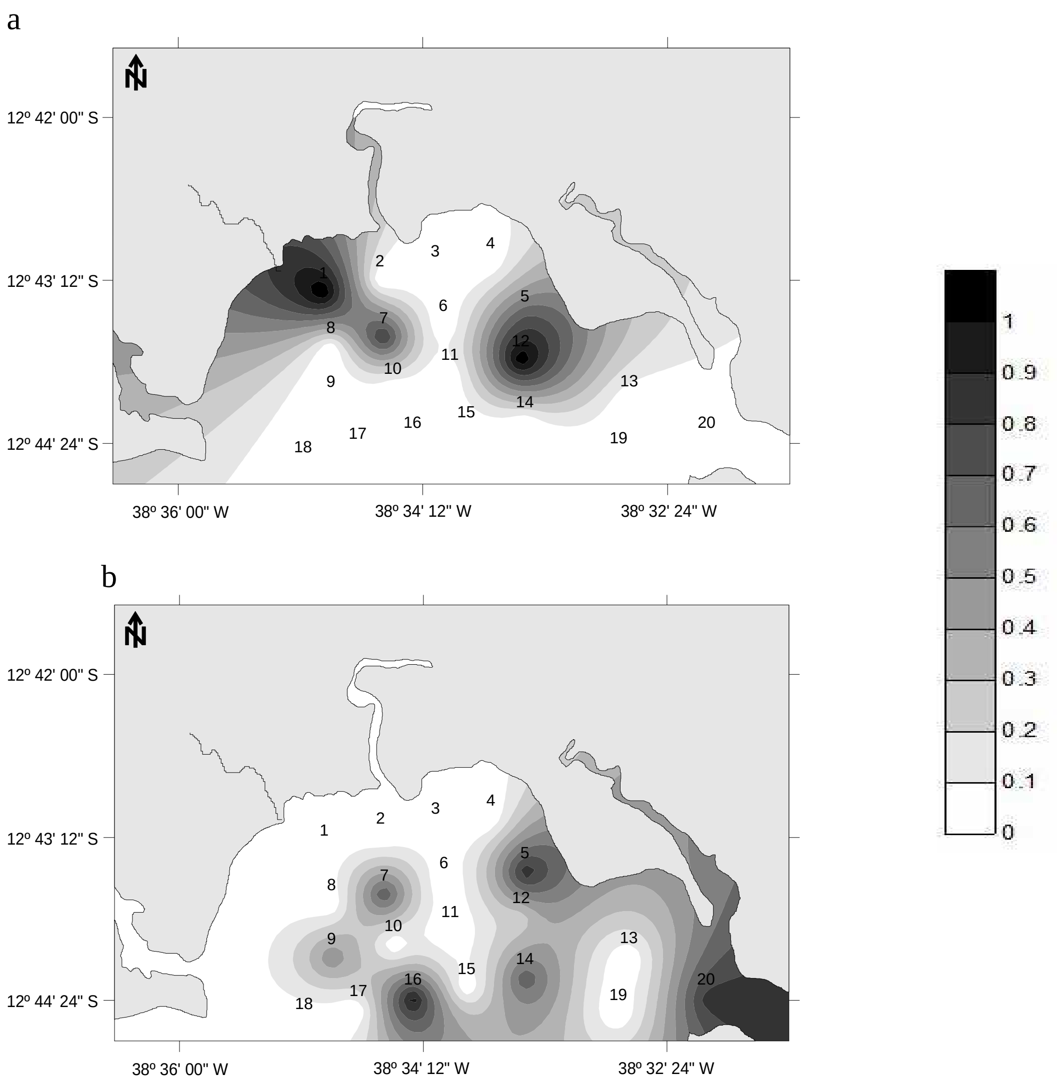

Fig. 4. Species diversity estimated for the Mataripe estuarine region in the winters of (a) July 2003 and (b) July/August 2004.

Table 4. Summary of the main fish community structure indicators for the Mataripe estuarine region in August and December 2003, March and July/August 2004 and January 2005: (a) winter and (b) summer.

(a)	**Winter**	
Index	**August 2003**	**July/August 2004**
Richness	2.39 high values in stations 12 and 7	7.03 high values in stations 5 and 7
Dominance	0.6518 high (*Diapterus rhombeus*)	0.4436 high (*Cyclichthys spinosus*)
Diversity	0.96 high values in stations 1 and 17	1.11 high values in stations 5 and 20
Evenness	0.367 low	0.378 low, except in stations 16 and 20

(b)	**Summer**		
Index	**December 2003**	**March 2004**	**January 2005**
Richness	4.74 low values in stations 12 and 5	6.71 high values in stations numbers 16 and 5	4.60 high values in stations 14 and 16
Dominance	0.7793 high (*D. rhombeus*)	0.5147 high (*D. rhombeus*)	0.7564 high (*D. rhombeus*)
Diversity	0,62 high values in stations 12 and 17	1,28 high values in stations 5 and 20	0,66 high values in stations 16 and 14
Evenness	0.258 low	0.452 low, except in stations 20 and 5	0.259 low, except in station 16

The stations closer to the shoals (5 and 12), were responsible for the highest species diversity values during the winter campaigns. In the summers, a great diversity pattern was also observed on the eastern side of the study area with a contribution from the stations on the transect farthest from the shore (16 and 17) (Fig. 5).

The MDS ordination analysis using CPUE values recorded at different stations on all the campaigns revealed two clear groups of stations in the two- dimensional ordination space (Fig. 6a). Stations 17, 16 and 9 showed intermediate abundance values at similar depths, whereas stations 14, 12, 5 (located on the eastern side of the area sampled), 20 and 7 showed higher abundances and dominance of *D. rhombeus*. Station 19 was isolated from the others. Stations 14, 12 and 5 are physically characterized by shoals and rocky bottoms, and by species such as *Pomadasys corvinaeformis*, *Lutjanus synagris* and *L. analis*. The stress values were low (0.05) and the groups well defined. The temporal analysis of the MDS results identified one consistent group, with intermediary stress value (0.13) (Fig. 6b).

ABC curves showed that k-dominance analysis for numerical abundance extended above biomass at all the stations except station 19 (W=0.311). These inversions cannot be related solely to environmental degradation but must be due to several factors, including geomorphological characteristics, and distance from the shore (Fig 7).

Population Dynamics

The mojarra *D.rhombeus* was the most abundant species on all the campaigns (n=943 or 68.9%). The number of individuals in the area was much higher in January 2005 than in the other sampling periods (Table 5). Higher values of the b coefficient in the weight-length relationship suggest greater individual weight during winter.

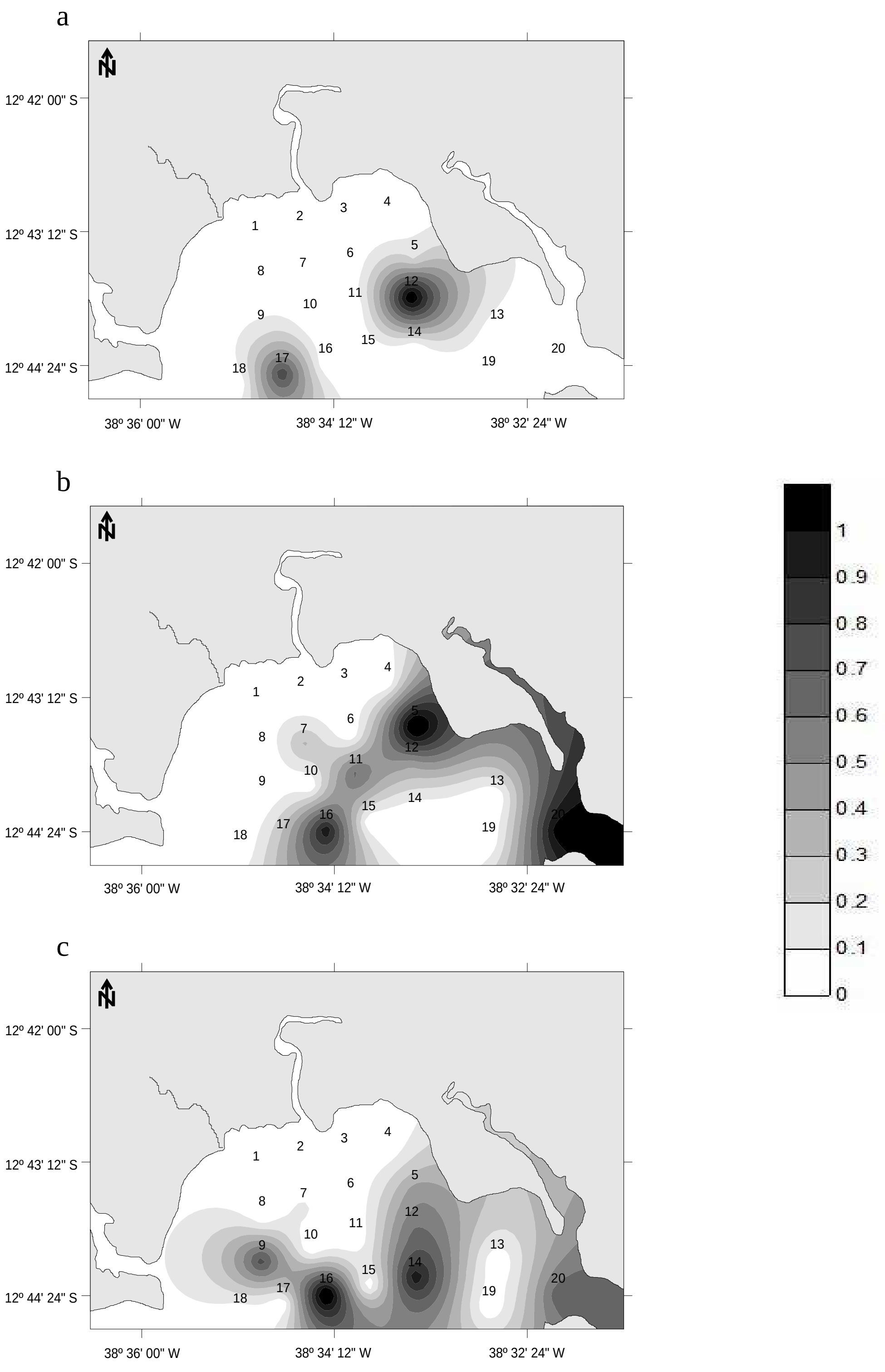

Fig. 5. Species diversity estimated for the Mataripe estuarine region in (a) December 2003; (b) March 2004, and (c) January 2005.

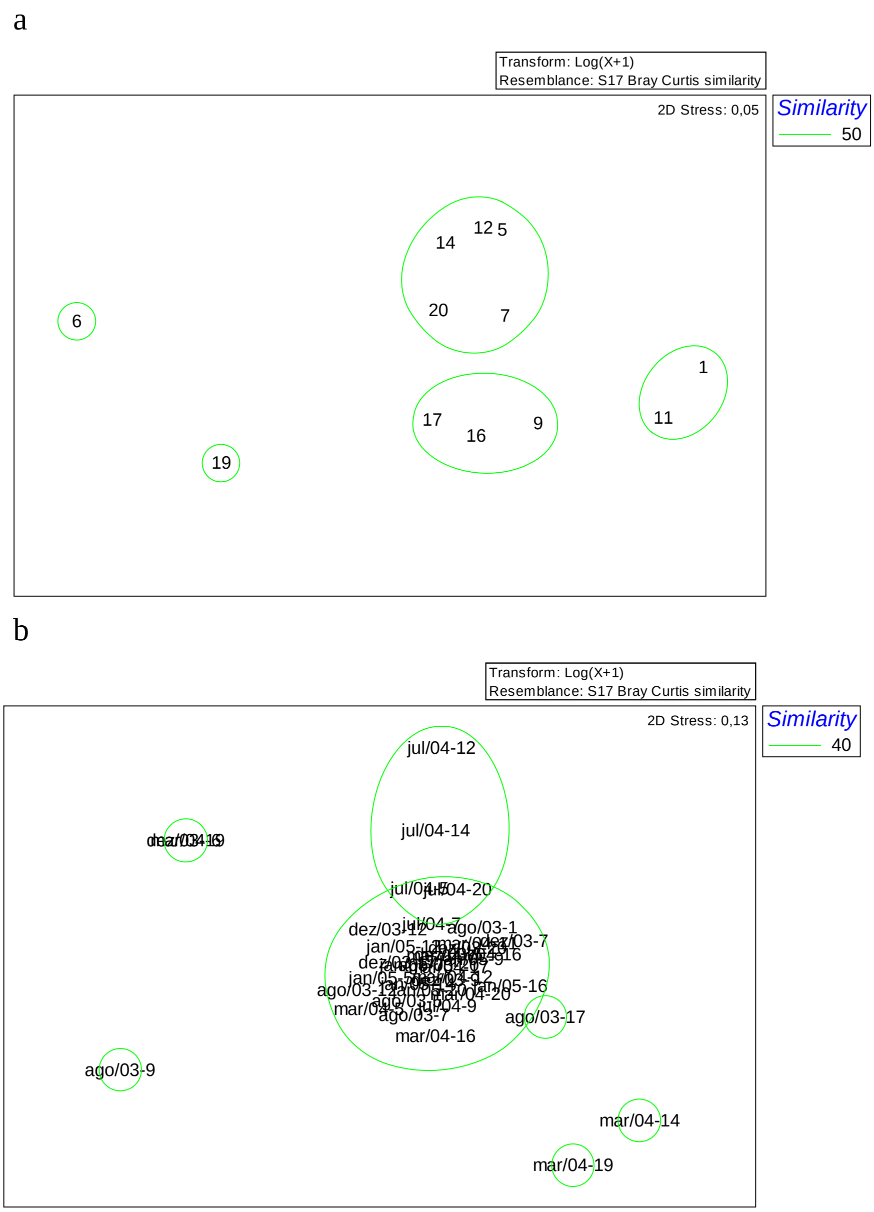

Fig. 6. The MDS ordination analysis based on CPUE and classified by station (a) and sampling period (b) of the ichthyofauna in the Mataripe estuarine region.

As shown in Table 5a, the average $K_{allometric}$ factor indicates an improvement in the condition of the specimens caught in winter 2004 as compared to those of the previous winter sampling. Moreover, on the summer campaigns, a great increase in the condition factor was observed as from December 2003 to March 2004, followed by a fall in values on the next summer campaign (January 2005). The values obtained in March suggest that the mojarras caught then presented the best condition found on any of the sampling campaigns.

Adult mojarras did not occur in the samples. In spite of the low numbers of specimens of other species, the relative frequency of these females by life cycle phase indicates that in August 2003 and March 2004 there occurred spawning individuals, which clearly suggests that the area in question is used by the species for spawning (Fig. 8).

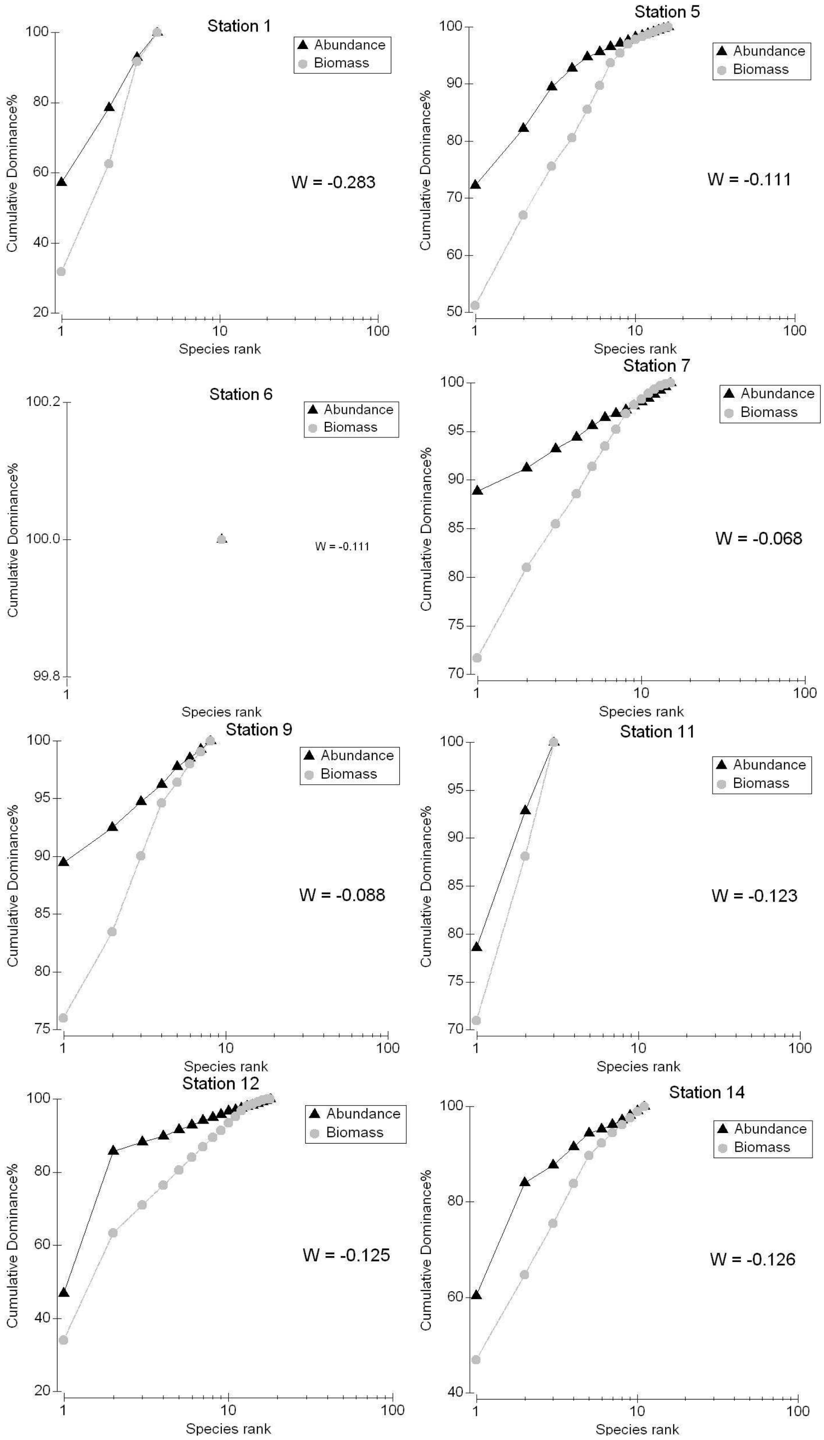

Fig. 7. ABC curves and W statistics for ichthyofauna per station in an estuary of the Mataripe Area, Todos os Santos Bay, Brazil.

Table 5. Comparison of population variables parameters estimated for the sampling campaigns of August and December 2003, March and July/August 2004 and January 2005, for *Diapterus rhombeus* caught in the Mataripe estuarine region, Todos os Santos Bay: (a) winter and (b) summer.

(a)		Winter	
		August 2003	**July/August 2004**
Number of specimens		182	124 (2 damaged)
length classes	lenght range	95 to 155 mm	102 to 152 mm
	Major occurrence	105├110 mm and 125├130 mm	111├115 mm and 116├120 mm
	Menor occurrence	95├100 mm and 100├105 mm 130├135 mm and 150├155 mm	101├105 mm and 106├110 mm 121├125 mm and 151├155 mm
Weight x length relationship		b = 2.979	b = 2.828
Allometric condition factor ($K_{allometric}$)		0.1672	0.3989
Foulton condition factor ($K_{Foulton}$)		0.1520	0.1540
Maturity stage		stage A - immature	stage A – immature
Life cicle phase		only juveniles	only juveniles

(b)		Summer		
		December 2003	**March 2004**	**January 2005**
Number of specimens		110 (3 damaged)	173	343 (7 damaged)
length classes	length range	95 to 150 mm	95 to 140 mm	92 to 167 mm
	Major occurrence	106├110 mm and 131├135 mm	106├110 mm and 131├135 mm	106├110 mm and 126├130 mm
	Minor occurrence	95├100 mm; 101├105 mm; 136├140 mm and 156├150 mm	95├100 mm; 101├105 mm and 136├140 mm	91├95 mm and 101├105 mm; 131├135 mm and 166├170 mm
weight X length relationship		b = 2.676	b = 2.4092	b = 2.785
Allometric condition factor ($K_{allometric}$)		0.6737	2.6258	0.3851
Foulton condition factor ($K_{Foulton}$)		0.1621	0.1502	0.1484
Maturity stage		stage A - immature	stage A – immature	stage A – immature
Life cicle phase		only juveniles	only juveniles	only juveniles

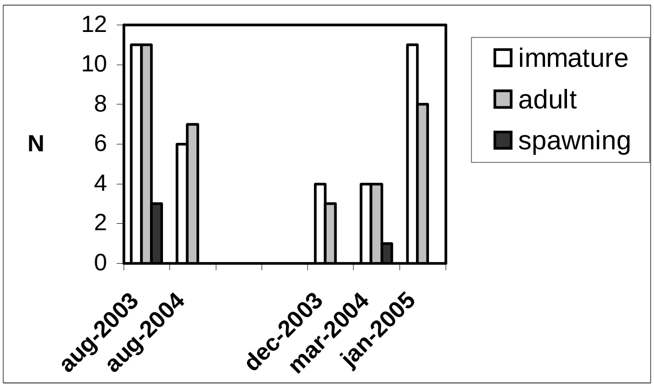

Fig. 8. Absolute frequency of females classified macroscopically and grouped by life cycle phase, caught on the sampling campaigns in the Mataripe estuarine region.

In August, 3 specimens of *Pomadasys corvinaeformis* in final maturation (stage D) were identified. This number, though small, is significant, because only some individuals in the population spawn at any one time and stage D is very short (a matter of hours). In March 2004, an individual, which had not been identified by macroscopic analysis, was identified as stage E (spawned) through microscopic analysis of the ovaries (Fig. 9).

The numbers of young and adult females of the other species remained practically the same, except in January 2005, when young females predominated. The microscopic analysis of the gonads revealed that 85 % of the total of individuals examined had been correctly classified. The misidentification was easy to explain because many specimens were too small for correct macroscopic sexing. Regarding the stages of gonadal maturation, misclassification was higher between stages A and B, when the gonads present hyperplasia and thus some growth in weight and size. But their oocytes showed no yolk deposition. However, the presence of post-ovulatory follicles in a gonad macroscopically identified as mature (C), indicates that the specimen should have been classified as stage E (Fig. 9).

Nor did microscopic study of the ovaries give any evidence of stress, represented by abundant atresia and melanomacrophage centers, on the female gonads, on any of the five campaigns. Recorded occurrence of atresic oocytes in *Pomadasys corvinaeformis* and *Oligoplites saurus* was under 5% on two of the campaigns.

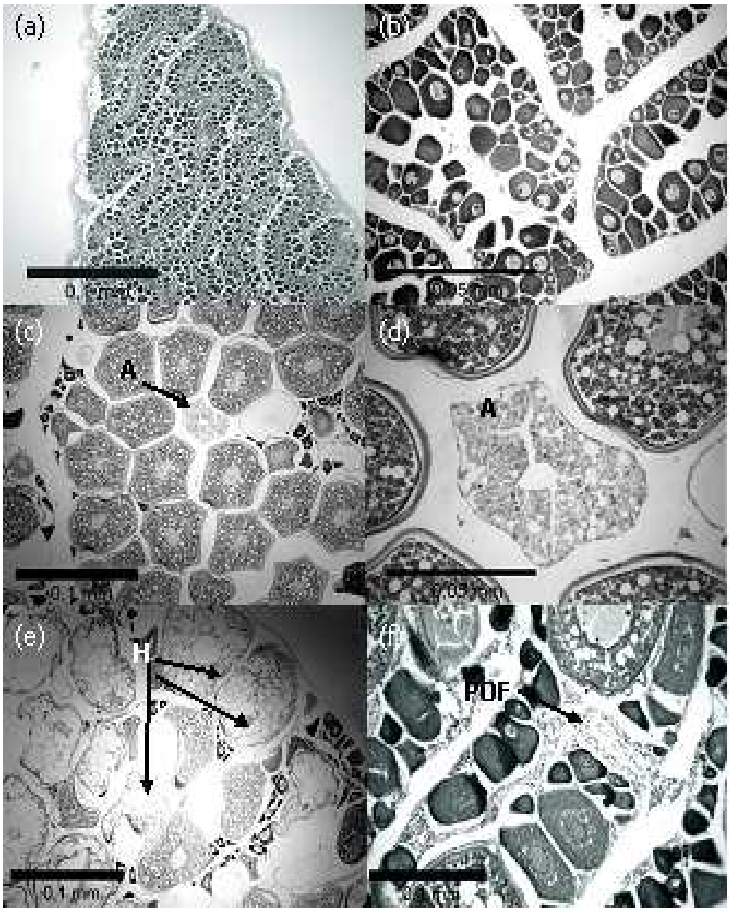

Fig. 9. Sections of ovaries processed by histological routine. (a) *Lutjanus synagris*, HE, 40X; (b) *Diapterus rhombeus*, HE, 100X; (c) and (d) *Eucinostomus gula*, HE, 40X and 100X, respectively; (e) *Pomadasys corvinaeformis*, HE, 40X; (f) *Oligoplites saurus*, HE, 40X. A=follicular atresia oocyte; H=hydrated oocytes; POF=post-ovulatory follicle.

The ovary sections revealed the occurrence of maturation stage A, with avitellogenic oocytes (Fig. 9 (a) and (b)); of stage C, with avitellogenic, vitellogenic and atresic oocytes (Fig. 9 (c) and (d)); stage D, with avitellogenic, vitellogenic and hydrated oocytes, the latter being a typical indicator of imminent spawning (Fig. 9 (e)); and stage E of gonadal maturation, with the presence of post-ovulatory follicles, a clear indication of recent spawning (Fig. 9 (f)). Thus, at an individual level, signs of spawning were observed for the species *Pomadasys corvinaeformis* and *Oligoplites saurus*. *O. saurus* was able to spawn in areas close to the Mataripe estuarine region, since the post-ovulatory follicles were found to be at least 48 hours old.

A descriptive ecological evaluation summary of the ichthyofauna of the Mataripe area, of three groups and 10 functional attributes, based on fish species composition and population data from this study and trophic guilds determined in accordance with information available in Figueiredo and Menezes (1978; 1980; 2000), Menezes and Figueiredo (1980; 1985) and Fröese and Pauly (2006), is presented in Table 6.

Discussion

A total of 35 species (34 actinopterygians and 1 elasmobranch) were identified during the sampling undertaken in the estuarine area prospected. The composition by species and by families points to the occurrence of groups that spend at least part of their life cycle in coastal and estuarine regions.

The total number of individuals caught on each campaign may be considered low (N=230 and 364 for the winter of the first and second year, and 128, 243 and 403 for the summer of the first and second year, respectively). It is not possible to compare these results with those from other bays, due to the local physical, chemical and biological particularities, but also because these numbers may be related to the sampling gear used on this project, the gillnet. The operation of the net was hampered by tide dynamics and sea conditions resulting from an increase in the strength of the wind during samplings and its dependence on the fishermen´s ability to position the nets in relation to winds and currents. Furthermore, the net selects individuals that, during the day, stay in the shallow water column and may avoid or escape from the net due to the transparency of the water in some places. The net did not, thus, catch many of the individuals of species that live close to the bottom, such as catfish, flatfish and some scienids, but rather individuals of those species, such as *D. rhombeus* and the mackerels, that remain in the water column a great deal of the time. Besides, a greater diversity of the fishing gear used might have been able to exploit the biological particularities, such as body shape, behavior and habits, of the fish thus permitting an increase in the number of species and individuals caught.

Table 6. Description of the community structure and population dynamics of ichthyofauna from the Mataripe estuarine region organized by group and functional attribute.

groups	attributes	relative values
richness and specific composition	richness	low
	resident species	high
	elasmobranch species	low
	dominance	high
guilds of throphic integrity	proportion of demersal generalist-invertivore species	high
	proportion of pelagic generalist-invertivore species	medium
	proportion of carnivorous-piscivorous species	low
abundance and condition	total number of specimens	medium
	proportion of young specimens	high
	proportion of specimens in reproduction	very low

The local salinity exhibits wide variation, from typically estuarine/coastal values, reflecting the influence of the discharge of 3 rivers (Caípe, Mataripe and São Paulo) and of the effluents of the Landulpho Alves Oil Refinery, to oceanic water values, conditioning the occupation of the region to those species that tolerate great variation in salinity (Miranda et al., 2011).

Diapterus rhombeus was the predominant and the most abundant species on practically all the campaigns, both when considering the total biomass in terms of the number of individuals caught on the campaign itself or at the stations where it occurred. This species inhabits the water column but is a bottom feeder. The exception was the winter of the second sampling year, when the area was dominated by *Cyclichthys spinosus* at 6 out of 7 stations.

D. rhombeus is the dominant species in estuarine coastal ecosystems, capable of tolerating the environmental variations typical of such habitats (Menezes and Figueiredo, 1980). In this study, the individuals caught were all juveniles, and this species was found to occur at moderate to medium abundance level. High frequency occurrence of this species in the coastal and estuarine zone has already been observed in other areas of the country (Menezes and Figueiredo, 1980). The occurrence of other species caught in this study has already been recorded in coastal and estuarine zones, both in juvenile and adult phases, at low abundances, both on the southeastern and northeastern coasts of Brazil (Oliveira, 1972, 1974, 1976; Zani Teixeira, 1983; Vasconcelos Filho et al., 1994; Bernardes, 1995; Diniz Filho, 1997; Araújo et al., 2000; Maciel, 2001; Neta and Castro, 2008; Paiva et al., 2008). Only 26 species had so far been identified as occurring in the northern region of the TSB (Almeida, 1996). Nevertheless, 11 of the species identified in this study: *Stephanoleps hispidus*, *Cyclichthys spinosus*, *Sphyraena guachancho*, *Calamus pennatula*, *Cynoscion jamaiscensis*, *Micropogonias furnieri*, *Larimus breviceps*, *Ctenosciaena gracilicirrhus*, *Orthopristis ruber*, *Conodon nobilis* and *Anchoa tricolor* had not been collected by Almeida (1996).

The occurrence of some species may be related to local physiographical and hydrographical particularities. Species such as *Archosargus rhomboidalis*, *Calamus pennatula* and *Anisotremus virginicus* are associated with coastal regions with rocky bottoms, shoals or coral reefs, which explains their occurrence at stations 5, 12 and 14. On the other hand, the occurrence of carangids such as *Carangoides crysos*, *Caranx latus*, *Chloroscombrus chrysurus* and *Oligoplites saurus* is related to areas of low salinity at some phase in their life cycle. *Cyclichthys spinosus* occurs in estuarine and marine waters, and all the individuals caught were small.

The stations with the largest biomass both in numbers and weight were 5, 7 and 12. Stations 5 and 12 are located on the eastern side of the study region, a more enclosed area closer to the shoals, exposed at low tide, and closer to the RLAM effluent outflow zone.

Besides the low number of individuals caught during the five sampling periods, the abundance of *D. rhombeus* lowers the evenness indices and increases the dominance values for the area as a whole. As has already been mentioned, the only exception was the winter of the second year, when a large number of *C. spinosus* individuals was observed in the area, thus changing the dominance values.

It is neither possible nor appropriate to compare the results of the indices found here with those from other areas, due to the selectivity imposed by the sampling gear, in addition to the local particularities. A temporal analysis of the community structure shows that, for the entire area, diversity increased from the first winter to the second, as a result of the increase in richness, and in March 2004 by the drop in dominance, which caused an increase in evenness. Since the shoal regions are characterized by higher productivity as well as by greater availability of food and shelter, the higher diversity values found for these regions can thus be explained (Stal et al., 2007).

Further, the ABC-index showed that 11 stations are under moderate stress concerning community structure in the area. The inversions of abundance and biomass, with abundance curves above those of biomass cannot be due only to environmental degradation because aggregation and dominance may be associated with biological and ecological processes, such as recruitment, as well as water quality (Bervoets et al., 2005; Queiroz et al., 2007; Falcão et al., 2008).

The biomass results obtained from the analysis of the ichthyofauna collected on the five sampling campaigns were compared with those of the Caípe, Cação Suape and Madre de Deus fishery data (Soares et al., 2011). Despite the fact that the fishery studies have much higher sampling frequency and contemplate various kinds of sampling gear, the results for the actinopterygians caught with gillnets partially agree with those found by the scientific prospection of the ichthyofauna: *D. rhombeus* is an important commercial fishing species, as also are *Scomberomorus brasiliensis* and *Lutjanus sinagris*. Other species such as *Archosargus rhomboidalis*, *Pomadasys corvinaeformis*, *Sphyraena guachancho*, *Rhinobatos percellens* and *Cynoscion jamaiscensis* also figure among those with the highest biomasses landed at different times. However, some commercially important species such as the mullet and the snook were not observed in the samplings carried out in the study area affected by the RLAM. Other species, such as *Carangoides crysos*, *Bagre marinus*, *Chloroscombrus chrysurus*, *Cynoscion leiarchus* and *Cetengraulis edentulus*, also important in commercial fishing, were present, though with low biomass.

The population dynamics indicators could not properly be applied: for some species the limitation was the low number of individuals caught, while only immature juveniles of others occurred, which rendered estimates related to sex and gonadal development impossible.

One of the indicators, the condition factor, which reveals recent feeding conditions, could be estimated for *D. rhombeus*, and there were differences in the results obtained for K calculated in each of two distinct ways. When K is estimated for species with $b<3$ (b = curvature value of the weight-length relationship) there occurs a reduction in the values of K with an increase in length. Therefore, the predominance of individuals in larger or smaller size classes may affect the value of K. At any rate, the $K_{allometric}$ results for the averages over time indicate an increase in weight by length of individuals collected in the winter of the first to that of the second year. In the summers, by contrast, there was a great improvement in condition between December 2003 and March 2004, with a drop in values for the second year. The values obtained for $K_{allometric}$ for the month of March suggest that the specimens were in the best comparative weight condition of all the sampling campaigns.

The low number of specimens in certain size classes precludes more conclusive statements. It is important to emphasize that the estimates were made considering the total weights of individuals, which might have their stomachs and digestive tracts full of food, thus leading in some cases to an overestimation of the condition factor.

Sex structure could only be assessed for the *P. corvinaeformis*, in August 2003, and for *L. synagris*, in January 2005. The structure normally found in populations, i.e., predominance of larger females, occurred in both cases.

The few individuals of other species caught in "maturing" and "mature" stages, which compose the adult phase of the life cycle, occurred in extremely low numbers, making the extrapolation of individual results to population levels impossible. Some spawning individuals were identified macroscopically in August 2003, as in the case of *Pomadasys corvinaeformis*. Microscopic analysis of ovaries detected the presence of an *Oligoplites saurus* spawned female in March 2004 among those classified as "mature". This is a relatively common event, especially in the case of a species with batch spawning and low batch fecundity (Dias et al., 1998), as seems to be the case for this species. On the whole, the estuarine region studied is an area of growth for the great majority of the species caught, and of spawning for *P. corvinaeformis*. Individuals of *Oligoplites saurus* may spawn in the region or in nearby areas. These results are in disagreement with those on actinopterygian eggs and larvae obtained from the ichthyoplankton survey (Katsuragawa et al., 2011; Mafalda et al., 2008). Some explanations may be proposed: a) spawning might not have occurred when the samples were caught; b) adults might have left the area; c) the selectivity of the gillnet; d) the difficulty in identifying eggs and larvae at the species level. In the RLAM area many engraulid eggs were found, but only one mature *C. edentulus* female was caught.

Gobiid larvae, the adults of which are not caught by the fishing gear used, were also observed among the ichthyoplankton (Katsuragawa op. cit.). Larvae of gerreids, which occur abundantly in young stages, were also found. In addition, carangid larvae, which occurred in almost all the collections in low numbers (Katsuragawa, op. cit.), could be the larvae of *Caranx hippos*, *Carangoides chrysos* or *Oligoplites saurus*.

In the specific case of *D. rhombeus*, more frequent samplings would be necessary to draw more precise conclusions. Small individuals appear on all the sampling campaigns undertaken, suggesting continuous reproductive activity of the population and recruitment or arrival of juveniles in the area. Adults may not be occupying the area affected by the RLAM, at least they may not have been occupying it during the period of the five sampling campaigns. In addition, reproduction in the area could not be more conclusively confirmed by the occurrence of mojarra larvae or eggs among the ichthyoplankton (Katsuragawa et al., subm.), for the reasons given above. Therefore, the occurrence of a great number of young, and the absence of adults, spawning adults or larvae in the plankton suggest that the species does not spawn in the area, which is used rather as a growth area by the juveniles.

Considering that the gillnet is commonly used in the region, the results obtained indicate that the area under the influence of the RLAM does not present any fishery potential, since the site is used for the growth of most species, with the occurrence of small individuals that often do not compensate for the outlay necessary to catch them. It must be emphasized that the individuals caught were not only small but also immature, never ever having reproduced, especially in the cases of *Diapterus rhombeus* and *Scomberomorus brasiliensis*, caught in nearby areas with different fishing gear (Soares et al., 2011).

Fish community structure and population dynamics have been used to assess the effects of pollution in rivers and coastal ecosystems such as estuaries, but there are no multimetric indices available for application to marine waters using only fish as biological indicators (Henriques et al., 2008). Considering the difficulties involved in the application of these indices in a poorly studied area, the evaluation of the ecological status of the community calls for caution in ecological interpretation.

The conclusions to be drawn from the ichthyofauna studied here may be summarized as follows: 1) the estuarine area affected by the RLAM, during the samplings carried out in August and December 2003, March and July 2004 and January 2005, was occupied and dominated by *Diapterus rhombeus* juveniles on 4 out of 5 campaigns; the area in question is a site for the growth of individuals of this species, since the whole catch was represented by small, immature individuals; 2) this area is characterized by low evenness and species diversity, with a recorded occurrence of 35 species; 3) the variation in the number of individuals observed at the sampling stations may be related to changes in environmental variables, to the sites chosen for sampling, and also to the specimens' swimming capabilities and their ability to escape from the net; in addition, higher densities and diversity were found in the bay's eastern area, close to the rocky bottom or shoals and deeper sites which offer a favorable habitat for some fish species; 4) spawning individuals were identified in the area, but the numbers, from a population standpoint, were not significant.

In summary, interesting results relating to the population and community structure patterns of the TSB ichthyofauna affected by the RLAM were brought to light by the ecological and biological indicators used in this study. However, further investigation on this issue is called for in order to corroborate our results. Further, the selectivity of the fishing gear used should also be viewed as a limiting factor for the interpretation of the data collected and the conclusions that may be drawn from them.

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