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Evidence of seasonal changes in community structure for a coastal ecosystem in the central coast of Brazil, south-west Atlantic

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This study reports on the seasonal variations of the community structure of a coastal ecosystem, off the central coast of Brazil. Samples were collected on a monthly basis on board a bottom otter trawl vessel from October 2003 to September 2004. A total of 57 species belonging to 26 families and 10 orders were collected. Resident species, which presented a high proportion of juveniles throughout the year, were the most abundant. Among these, benthonic fish of the Sciaenidae family were the dominant species, followed by Tetraodontiformes, nektonic Sciaenidae and Clupeiformes. Benthonic fish were more abundant during the spring/summer months (October to February) and pelagic species dominated the autumn/winter months (May to September). However, these differences were not statistically significant. The spring/summer months were also characterized by reproduction activity, while the autumn/winter months saw high proportions of juveniles. Indicator species analyses showed that 5 species presented significant differences in their occurrence and abundance throughout the seasons of the year. This study shows that the coastal area is an important place for reproduction and a nursing ground of many species. It also shows evidence of community-level reproductive patterns for a tropical ecosystem. Future studies are necessary to identify the likely ecosystem forcings underlying these patterns.

Keywords: community structure, coastal zone, south-west Atlantic

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INTRODUCTION

Coastal ecosystems provide important habitats for different life stages of many fish species (Amara, 2003). Coastal areas are of special importance for juveniles of many commercial species that use these places as a feeding ground and refuge (Paterson & Whitfield, 2000). However, the recent impact of the intense human development in coastal areas (Lassari *et al*., 2003), along with increased effort and competition for natural resources (McClanahan & Mangi, 2004), have modified the functioning of coastal ecosystems and have led to a worldwide decrease in fish abundance.

There is a great interest in research to increase the knowledge about vulnerable species and habitats of coastal ecosystems. This knowledge is an important part of the scientific basis for implementing protection regulations against anthropic impacts and for creating the conditions for long-term and continued productivity of natural resources (Lange, 2003). Places with great species diversity, as well as areas where the important processes of reproduction and recruitment are concentrated could be the priority for conservation programmes. However, it is important to know the seasonality of abiotic factors and their influence on the fish community (Nero & Sealey, 2005).

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Information on the ecology and fish community structure of Brazilian soft bottom coastal ecosystems is lacking at present. Research on the central coast of Brazil has been focused mainly on the composition and the community structure of coral reefs and estuarine areas (Chagas *et al*., 2006; Floeter *et al*., 2007). This study shows that the seasonal composition of the fish community in a tropical–subtropical transition area of the west South Atlantic seems to be related to the seasonal pattern of reproduction at the community level, as well as to seasonal migration of individuals that use the area as a feeding ground.

MATERIALS AND METHODS

Study area

The study area is located in the Benevente Bight (21° 57′S 40° 47′W), in the Central Brazil Shelf ecosystem (Figure 1), and is part of a region that is the subject of a proposal that aims to create a Marine Protection Area. The sampled area was located between 500 and 1000 m from the coast. The average depth in this area is 4 m and the bottom is composed of sand, mud and gravel. The region is located in a transition zone between tropical and subtropical environments and is characterized by northerly inflows of oligotrophic tropical waters from the Brazil Current and southerly inflows from the South Atlantic Central Waters (Schmid *et al*., 1995).

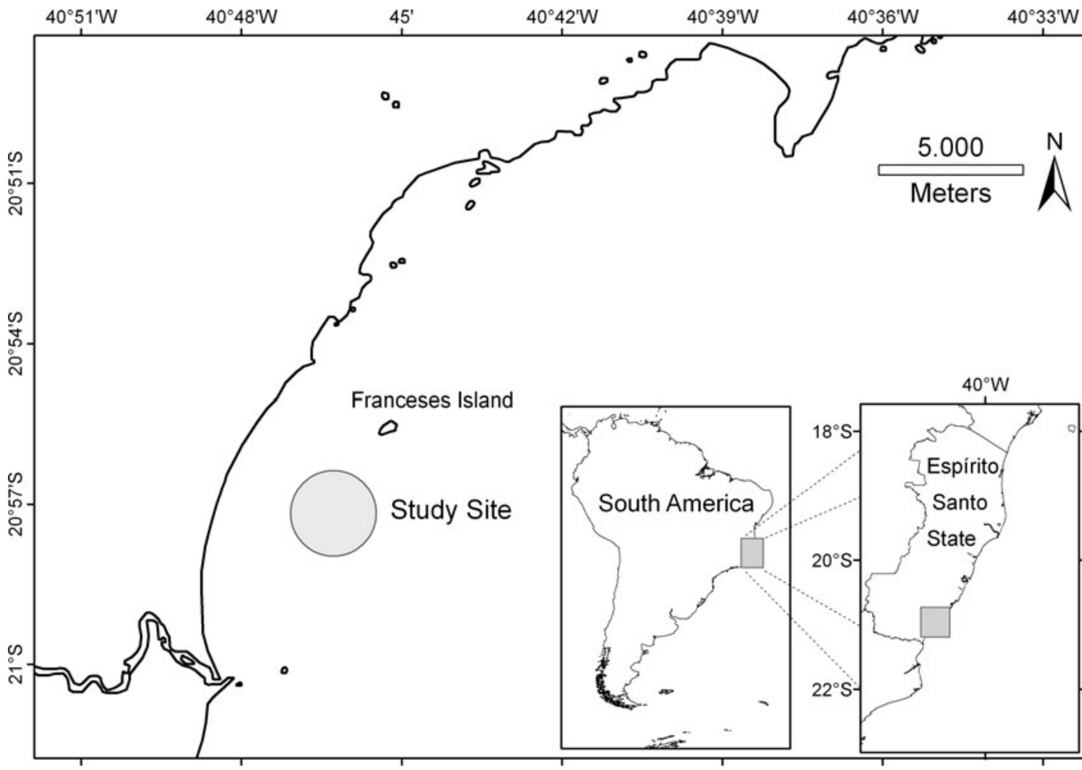

Fig. 1. Study area on the central coast of Brazil.

The predominant winds in the coastal zone come from the north-east, north and east quadrants. However, south and south-east winds are common during winter due to the passage of cold fronts. There is also seasonal variability in wave heights. In summer, when waters are calmer, small waves (Hs = 1.5 m) predominate. The sea then becomes rough throughout the autumn months with increased wave sizes (Hs = 1.8 m), which achieve their maximum in winter (Hs > 2 m) to decrease again in spring (Hs = 1.8 m) (CCAR, 2001).

The place is the fishing ground of bottom trawlers that are based at fishing communities located along the coast (communities of Itaoca, Barra and Pontal do Itapemirim). The region is home to approximately 80 fishermen who work on 38 boats, with sizes varying from 6 to 12 m. The main activity is the prawn *Xiphopenaeus kroyeri* trawl fishery. Landings for this species are estimated to be about 150 t per year but there is a great deal of uncertainty related to this figure.

Sampling protocol

Data collection was performed on a monthly basis, from October 2003 to September 2004, on board a bottom otter trawl boat similar to the commercial ones used in the region. A total of 10 monthly samplings were carried out, since the prawn fishery is closed every year in March and April as a measure of effort control. The boat used was a commercial artisanal shrimp vessel hired for this study, including its experienced fishermen crew. It was 6 m long powered by an 18 cc engine and equipped with a 10 m long net with an opening of 5 × 3.5 m. The mesh size of the net was 2 cm in the main body and 1 cm in the codend.

One to three hauls performed with a towing speed of 2.5 km/h and lasting between 60 and 90 minutes were sampled in the region of the prawn fishery. The total catch was separated onboard and stored in ice to be transported to the laboratory. A sub-sample of 50 or 25% of the total weight of each haul was collected when the catches were too large.

Laboratory analysis

Fish species were identified following Figueiredo (1977), Figueiredo & Menezes (1978, 1980, 2000), Fischer (1978) and Menezes & Figueiredo (1980, 1985). For each individual sampled the following data were recorded: total length (TL) measured to the nearest millimetre; total weight (TW) measured to the nearest tenth of gram; sex and maturity stage. Maturity stages of males and females of the teleost fish were classified according to Martins & Haimovici (2000) in: I, juveniles/immature; II, resting; III, ripening; IV, ripening 2 (advanced); V, running; VI, spent; and VII, recovering. These stages were grouped into adults (II–VII) and juveniles (I) for general comparison purposes. Adults were divided into 'reproductive group' (III–VI) and 'recovering group' (II and VII). In this study we used the term recruitment to refer to juveniles that become vulnerable to being caught by the bottom trawl fishing.

Data analyses

Numbers and weight data for each species were converted to numbers and weight caught per hour to be used in subsequent analyses. In cases of large catches, when just a fraction was sampled, total numbers and weight were estimated using a

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multiplying factor estimated as the whole catch weight divided by the total weight of the sample taken. The community structure was analysed using the species grouped into taxonomic/functional unities.

To determine the temporal (monthly) pattern, catch rates (numbers/h) expressed as ln(x + 1) were analysed with the detrended correspondence analysis (DCA; Hill & Gauch, 1980), a method developed specifically for ecological analysis and indicated for situations when the data to be analysed are restricted to species abundance of different samples. Mann–Whitney *U*-tests (hereafter *U*-test) were used to determine whether there were significant differences between CPUEs of different seasons.

The UPGMA (unweighted pair group method with arithmetic mean) clustering method was used to examine the consistency of the classification system obtained with the DCA. The clustering was performed with the Sørensen's relative distance measure. The Sørensen's relative distance measure is a modified version of the Sørensen's distance measure ('relativized Manhattan' in Faith *et al.*, 1987), and is based on the standardized summation of each sampling unit. As a result, each unity contributes equally to the distance measure. The advantage of using this coefficient, when compared with the Euclidian distance for example, is that it retains more sensitivity in heterogeneous matrices and gives less weight to outliers (McCune & Mefford, 1999).

Discriminating species for each assemblage determined by the ordination and clustering analyses were identified with the indicator species analysis (Dufrene & Legendre, 1997). The method combines information on abundance and occurrence and produces indicator values for each species in a group. These values were statistically tested with the Monte Carlo resampling methodology (McCune & Mefford, 1999).

RESULTS

Species composition

A total of 4625 fish were caught. These fish comprised 57 species, 26 families and 10 orders. The Perciformes presented the largest numbers of families (8), followed by Rajiformes (3), Scorpeaniformes (3) and Pleuronectiformes (3). The Sciaenidae had the largest number of species (13), followed by Carangidae (5) and Tetraodontidae (4) (Table 1). The catches comprised demersal, pelagic and benthonic species. Eighteen species represented 95% of the total numbers, the remaining 39 just 5%. Seventeen species were considered rare since they occurred just in one month.

The benthonic Sciaenidae were the most important group caught, representing 33.9% of the sampled weight, followed by Tetraodontiformes species with 15.4%, nektonic Sciaenidae with 14.9% and Clupeiformes with 9.6% (Figure 2).

The main species caught, their relative abundances (CPUE) in weight and numbers, size-ranges, mean weights and occurrence in the sampled months are shown in Table 2.

Seasonal variation of species composition

Overall, there was a monthly variation in catches for adults and juveniles and in average fish length. Figure 3 shows the largest catches of adult individuals, with largest sizes, during the spring/summer months (October–February) (*U*-test, $P < 0.01$), while small juvenile individuals were abundant in all months (*U*-test, $P = 0.545$), but were relatively more important than the adults in the autumn/winter months (May–September).

Some species that are more typical of the bottom realm had their largest catches in the spring/summer months (benthonic Sciaenidae, Pleuronectiformes and Anguiliformes), while the ones more typical of the nektonic realm (nektonic Sciaenidae and Clupeiformes) along with the Tetraodontiformes species had their largest catches in the autumn/winter months (Figure 4). However, none of these differences between spring/summer and autumn/winter catches were statistically significant (*U*-test, $P > 0.05$).

Only Clupeiformes and benthonic Sciaenidae presented a considerable proportion of adults (reproductive or non-reproductive stages), which represented more than 36 and 42% of these groups respectively. In other groups adults represented always less than 9% of the total catch.

Seasonal variation in community structure

The DCA and cluster analyses discriminated two main groups of months related to the occurrence and abundance of the most important species. One group comprised samples collected from October to February (spring and summer) and another from May to September (autumn and winter) (Figure 5).

The occurrence and abundance of the indicator species, *Cyclichthys spinosus*, *Isopisthus parvipinnis*, *Cynoscion jamaicens* and *Achirus lineatus* in the autumn/winter months and *Conodon nobilis* in the spring/summer months explained the difference between these two periods ($P < 0.05$; Table 3). Other abundant species were well represented in all months and so did not play an important role in discriminating between the two groups (Table 3).

Isopisthus parvipinnis, *Cyclichthys spinosus* and *Achirus lineatus* occurred in almost every month, but had higher abundance in the autumn/winter months. *Cynoscion jamaicensis* occurred only in the autumn/winter months and had a large catch of juvenile individuals. *Conodon nobilis* was the only discriminating species for the spring/summer months. It had a large catch of juvenile individuals in this period (Figure 6).

DISCUSSION

The studied area is located in a transition region between the tropical and subtropical fish fauna of the south-east Atlantic (Gomes *et al.*, 2001). As a result of the tropical and subtropical features it is possible to find a relatively rich ichthyofauna in the area, with species from all parts of the Brazilian coast. However, the main high taxa found in the studied area are the dominant ones throughout the Brazilian coast and are closed related to the influence of estuaries and fishing ground of Penaeidae species (Santos, 2000; Bail & Branco, 2003). Many Sciaenidae and Clupeiformes species are important fishery resources in shallow waters and estuarine environments around the world.

The fish community sampled is characterized by a group of resident species that are observed throughout the year and composed mainly of juveniles and small individuals.

Table 1. Species caught in 10 bottom trawl surveys carried out off the central coast of Brazil between October 2003 and September 2004.

Order/family/species
Rajiformes
Rhinobatidae
Rhinobatos horkelii Müller & Henle, 1841
Rhinobatos percellens (Walbaum, 1792)
Zapteryx brevirostris (Müller & Henle, 1841)
Dasyatidae
Dasyatis guttata (Bloch & Schneider, 1801)
Gymnuridae
Gymnura altavela (Linnaeus, 1758)
Anguilliformes
Muraenidae
Gymnothorax ocellatus Agassiz, 1831
Ophichthidae
Ophichthus gomesii (Castelnau, 1855)
Clupeiformes
Engraulidae
Anchoa filifera (Fowler, 1915)
Anchoa spinifera (Valenciennes, 1848)
Cetengraulis edentulus (Cuvier, 1829)
Pristigasteridae
Chirocentrodon bleekerianus (Poey, 1867)
Pellona harroweri (Fowler, 1917)
Odontognathus mucronatus Lacepède, 1800
Clupeidae
Harengula clupeola (Cuvier, 1829)
Siluriformes
Ariidae
Cathorops spixii (Agassiz, 1829)
Aspistor luniscutis (Valenciennes, 1840)
Lophiiformes
Ogcocephalidae
Ogcocephalus vespertilio (Linnaeus, 1758)
Syngnathiformes
Syngnathidae
Microphis brachyurus lineatus (Kaup, 1856)
Scorpaeniformes
Scorpaenidae
Scorpaena isthmensis Meek & Hildebrand, 1928
Dactylopteridae
Dactylopterus volitans (Linnaeus, 1758)
Triglidae
Prionotus punctatus (Bloch, 1793)
Perciformes
Serranidae
Diplectrum formosum (Linnaeus, 1766)
Carangidae
Caranx crysos (Mitchill, 1815)
Caranx latus Agassiz, 1831
Chloroscombrus chrysurus (Linnaeus, 1766)
Selene setapinnis (Mitchill, 1815)
Haemulidae
Conodon nobilis (Linnaeus, 1758)
Orthopristis ruber (Cuvier, 1830)
Sciaenidae
Ctenosciaena gracilicirrhus (Metzelaar, 1919)
Cynoscion jamaicensis (Vaillant & Bocourt, 1883)
Cynoscion leiarchus (Cuvier, 1830)
Cynoscion virescens (Cuvier, 1830)
Isopisthus parvipinnis (Cuvier, 1830)
Larimus breviceps (Cuvier, 1830)
Menticirrhus americanus (Linnaeus, 1758)
Nebris microps Cuvier, 1830
Paralonchurus brasiliensis (Steindachner, 1875)
Stellifer brasiliensis (Schultz, 1945)
Stellifer naso (Jordan, 1889)
Stellifer rastrifer (Jordan, 1889)
Umbrina coroides Cuvier, 1830
Polynemidae
Polydactylus virginicus (Linnaeus, 1758)
Ephippidae
Chaetodipterus faber (Broussonet, 1782)
Trichiuridae
Trichiurus lepturus Linnaeus, 1758
Stromateidae
Peprilus paru (Linnaeus, 1758)
Pleuronectiformes
Bothidae
Bothus ocellatus (Agassiz, 1831)
Bothus robinsi Topp & Hoff, 1972
Achiridae
Achirus declivis Chabanaud, 1940
Achirus lineatus (Linnaeus, 1758)
Cynoglossidae
Symphurus plagusia (Block & Schneider, 1801)
Symphurus tessellatus (Quoy & Gaimard, 1824)
Tetraodontiformes
Tetraodontidae
Lagocephalus laevigatus (Linnaeus, 1766)
Sphoeroides greeleyi Gilbert, 1900
Sphoeroides pachygaster (Müller & Troschel, 1848)
Sphoeroides testudineus (Linnaeus, 1758)
Diodontidae
Cyclichthys spinosus (Linnaeus, 1758)

However, important differences regarding the frequency of juveniles and adults and in a lesser degree the catch composition were observed. These differences discriminated the samples in two main groups related to the seasons of the year. The spring/summer months were characterized by a higher proportion of the spawning biomass, largely related to the contribution of the benthonic Sciaenidae and the Clupeiformes species. These groups were also abundant in the autumn/winter months but were dominated by juveniles. This pattern characterized by reproduction of some species in the spring/summer months, with the dominance of young individuals in the autumn/winter months seems to be common in coastal waters of the south-east region of Brazil and has been observed previously (Araújo *et al.*, 1998).

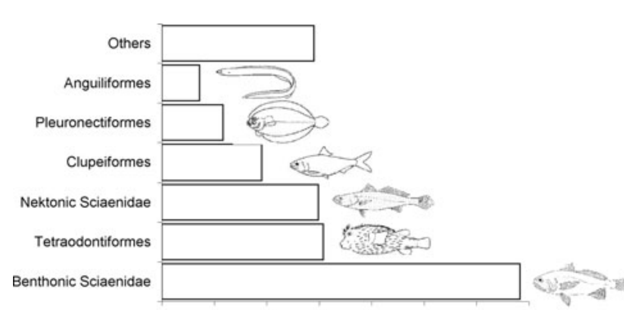

Fig. 2. Relative catch rates (Kg/h) of taxonomic groups in the catches of 10 bottom trawl surveys carried out off the central coast of Brazil from October 2003 to September 2004.

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Table 2. Taxonomy, catch rates (n/h and kg/h), average weight, size-range, sampling month and life stage of the 18 most abundant species. The species presented made up 95% of the catches of 10 bottom trawl surveys carried out off the central coast of Brazil between October 2003 and September 2004. SE = standard error.

Group/species	Average catch rate		Average weight	Total length range (cm)													Life stage
	n/h (SE)	g/h (SE)	(g) (SE)		O	N	D	J	F	M	A	M	J	J	A	S	
Tetraodontiformes																	
Cyclichthys spinosus	23 (9)	685 (209.9)	32.2 (2.4)	4–21	■	■	■	■	■			■	■	■	■	■	Juveniles
Clupeiformes																	
Chirocentrodon bleekerianus	30 (10)	172 (59.2)	5.8 (0.09)	6–13	■	■	■	■	■			■	■	■	■	■	Adult/juvenile
Odontognathus mucronatus	10 (4)	56 (20.2)	10.0 (0.71)	7–17	■			■				■	■	■	■	■	Adult/juvenile
Pellona harroweri	83 (27)	347 (86.7)	3.6 (0.09)	4–14	■	■	■	■	■			■	■	■	■	■	Adult/juvenile
Pleuronectiformes																	
Achirus declivis	10 (4)	154 (84.4)	11.6 (1.9)	4–12		■							■	■		■	Adult/juvenile
Achirus lineatus	5 (1)	127 (17.2)	27.5 (1.95)	7–16	■		■	■	■			■	■	■	■	■	Adult/juvenile
Symphurus tessellatus	5 (1)	104 (23.9)	19.9 (1.69)	10–18	■	■	■	■	■					■	■	■	Adult/juvenile
Anguiliformes																	
Gymnothorax ocellatus	3 (1)	243 (87.1)	78.3 (7.92)	29–44		■	■	■	■			■		■	■	■	Juveniles
Others																	
Anchoa filifera	3 (0,5)	84 (38.5)	6.7 (4.82)	9–13				■	■			■	■	■	■	■	Adult/juvenile
Conodon nobilis	6 (2)	117 (29.2)	26.8 (3.0)	9–17	■	■	■	■	■				■	■		■	Juveniles
Nektonic Sciaenidae																	
Cynoscion jamaicensis	28 (4)	336.3 (97.9)	12.0 (0.48)	4–15									■	■	■	■	Juveniles
Isopisthus parvipinnis	25 (8)	344.0 (89.9)	13.8 (0.69)	3–22	■	■	■	■	■				■	■	■	■	Adult/juvenile
Benthonic Sciaenidae																	
Ctenosciaena gracilicirrhus	22 (6)	258 (60.1)	10.7 (0.4)	8–14	■		■	■					■				Juveniles
Larimus breviceps	14 (3)	382 (137.1)	24.2 (1.56)	4–18	■	■	■	■	■			■	■	■	■	■	Adult/juvenile
Menticirrhus americanus	3 (1)	136 (31.3)	35.5 (7.58)	6–26	■				■			■	■	■	■	■	Adult/juvenile
Paralonchurus brasiliensis	18 (3)	437 (125.5)	24.0 (1.65)	2–23	■	■	■	■	■			■	■	■	■	■	Adult/juvenile
Stellifer brasiliensis	35 (7)	415 (100.7)	12.8 (0.42)	4–16	■	■	■	■	■			■	■	■	■	■	Adult/juvenile
Stellifer rastrifer	42 (6)	390 (109.4)	8.7 (0.65)	3–19	■	■	■	■	■			■	■	■	■	■	Adult/juvenile

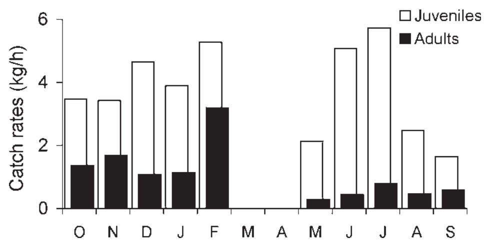

Fig. 3. Catch rates of adults and juveniles of fish species caught in 10 bottom trawl surveys carried out off the central coast of Brazil between October 2003 and September 2004.

However, shown here is the existence of community structure variation related to seasonal presence of juveniles and reproductive adults, suggesting the existence of environment forcings that lead to similar biological rhythms in species-groups that have totally distinct ecological niches. Despite the observed marked biological seasonality, there is no detailed information on variations of environmental conditions that could be used to identify the main forcings related to the observed community patterns. It can be suggested as a possible cause for the high reproduction activity in the spring/summer months, the reduction in water turbulence, which is related to the lower frequency of storms and high energy waves in the coastal area (CCAR, 2001). These conditions could act as a mechanism that retains the larval and prejuvenile stages in shallow areas, which tend to be more productive and protected from access of predators due to their shallow depths and availability of refuges. In autumn/winter, when the turbidity and turbulence is higher due to higher frequency of storms and waves entering the bight (CCAR, 2001), it is possible that the region continues to play an important role as refuge from predators due to the reduction of visibility. This hypothesis has been suggested previously as an explanation for the variation of fish abundance in other ecosystems (Maes *et al.*, 1998; Lassari *et al.*, 2003). As the young individuals have already left the planktonic phase, the water turbulence does not seem to influence their permanence in the shallow areas and in this way the environment acts as a nursing ground.

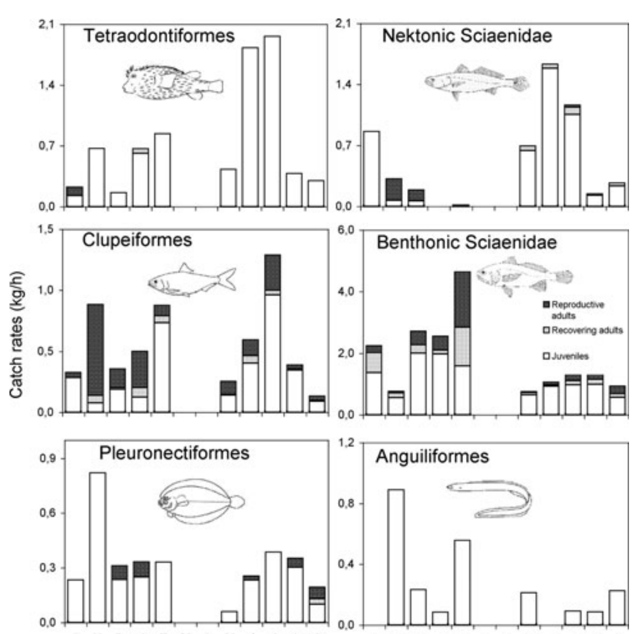

Fig. 4. Catch rates (Kg/h) of dominant groups in the catches of 10 bottom trawl surveys carried out off the central coast of Brazil between October 2003 and September 2004.

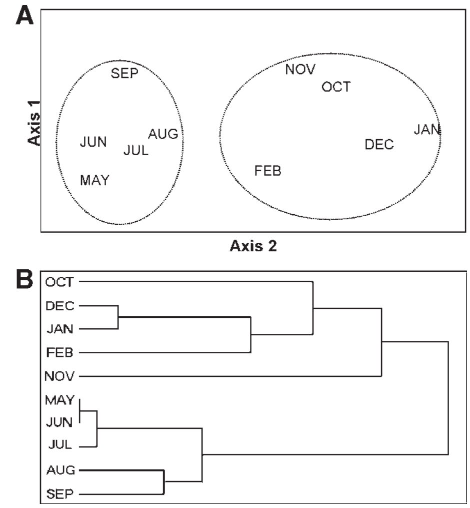

Fig. 5. (A) Detrended correspondence analysis (DCA) showing the distribution of sampling months in the main axis; (B) dendrogram showing the Sørensen's index of similarity between months. Both analyses were performed using fish catch rates (n/h) of 10 bottom trawl surveys carried out off the central coast of Brazil between October 2003 and September 2004.

The seasons of the year presented community differences not only related to the process of reproduction, but also in the occurrence of some species. Similar patterns of variation in the abundance of adults and juveniles have been observed in other studies (Nash & Santos, 1998). Some species presented large seasonal abundance variation and seem to explore the shallow waters of the studied area in an opportunistic way. The high abundance of juveniles of many species could be an attracting factor for predatory fish (Maes *et al.*, 1998), such as *Cynoscion jamaicensis* and *Isopisthus parvipinnis*, common species in estuarine/coastal zones (Froese & Pauly, 2006). The studied area seems to be an important nursery ground of many species, including the commercial ones. Several authors (Potter *et al.*, 1986; Akin *et al.*, 2003) have suggested reproductive biology as a potential factor driving seasonal changes in estuarine assemblages. Akin *et al.* (2003) and Nero & Sealey (2005) suggested that distribution and abundance of fish in a temperate estuary and tropical near-shore coastal habitats, respectively, seem to result from the combined effects of endogenous, seasonal patterns of reproduction and migration operating on large spatial scales, and species-specific response to local environmental variation. This study shows evidence of community-level reproductive patterns for a tropical ecosystem and future studies are necessary to identify the likely ecosystem forcings underlying these patterns.

The permanent local use of the bottom trawl fishery, which acts upon the adult and juvenile stages of many fish species, raises the issue of the sustainability of this activity. This kind of fishing can be even more predatory when developed in places of great diversity as in the studied area. When considering the local ichthyofauna in the management of the shrimp fishery, some areas could be closed to fishing due to their nursery function (Hall *et al.*, 2000). Also, due to its

Table 3. Groups determined by DCA and cluster analysis of the 18 most abundant species in 10 bottom trawl surveys carried out off the central coast of Brazil from October 2003 to September 2004. Discriminating species are in bold. *P*, probability that the discriminating species value could be obtained by chance.

Species	DCA group	Relative abundance %		Frequency of occurrence %		*P*
		Winter	Summer	Winter	Summer	
Pellona harroweri	Cold months	75	25	100	100	0.121
Stellifer rastrifer		64	36	100	100	0.085
Paralonchurus brasiliensis		56	44	100	100	0.452
Larimus breviceps		53	47	100	100	0.891
Achirus declivis		28	72	60	20	1.000
Odontognathus mucronatus		59	41	100	40	0.319
Anchoa filifera		35	65	100	40	0.964
Menticirrhus americanus		75	25	100	40	0.103
Cyclichthys spinosus		91	9	100	100	0.015
Isopisthus parvipinnis		87	13	100	80	0.042
Cynoscion jamaicensis		100	0	100	0	0.007
Achirus lineatus		79	21	100	80	0.015
Stellifer brasiliensis	Hot months	36	64	100	100	0.209
Chirocentrodon bleckerianus		42	58	100	100	0.835
Ctenosciaena gracilicirrhus		1	99	20	60	0.153
Symphurus tesselatus		29	71	60	100	0.167
Gymnothorax oscellatus		24	76	80	80	0.274
Conodon nobilis		10	90	60	100	0.017

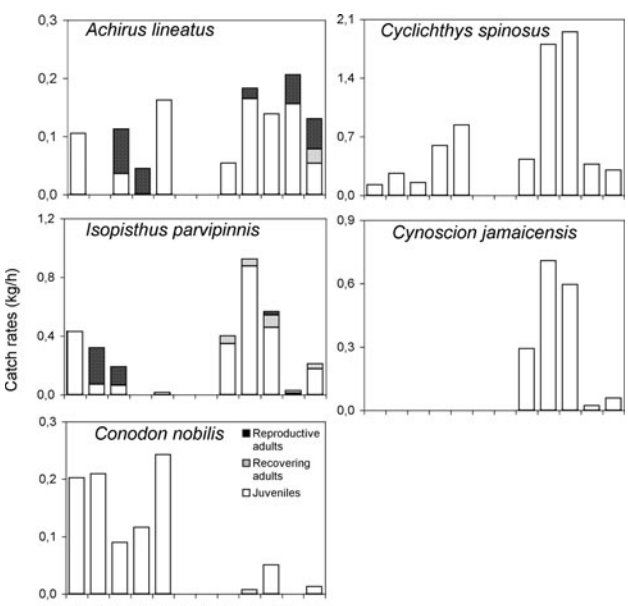

Fig. 6. Catch rates (Kg/h) of discriminating species of spring/summer months and autumn/winter months. Analysis performed using the fish catches of 10 bottom trawl surveys carried out off the central coast of Brazil between October 2003 and September 2004.

high species richness and to the process of reproduction, the study area could be a priority in conservation programmes.

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