MANGROVE OYSTER (*CRASSOSTREA RHIZOPHORAE)* (GUILDING, 1928) FARMING AREAS AS ARTIFICIAL REEFS FOR FISH: A CASE STUDY IN THE STATE OF CEARÁ, BRAZIL

Luiz Eduardo Lima de Freitas[1]*; Caroline Vieira Feitosa*[2] *& Maria Elisabeth de Araújo*[2,3]

[1]Secretaria Especial de Aqüicultura e Pesca – SEAP/PR
Esplanada dos Ministérios
(Bloco D, 2º andar, sala 246, 70043-900, Brasília, DF, Brasil)
luiz_elfreitas@hotmail.com

[2]Universidade Federal de Pernambuco
Departamento de Oceanografia – Grupo de Ictiologia Marinha Tropical
(Av. Arquitetura s/n, 50740-550, Cidade Universitária, PE, Brasil)
carol_feitosa@hotmail.com

[3]betharau@terra.com.br

ABSTRACT

A type of platform, known as a table, is now being used for mangrove oyster farming. In Fortim, Ceará, Brazil, this activity was begun in June 2000 and covers an area of 50 m² overlying a sand-clay substrate. The present study has the following main objectives: to identify and catalogue the ichthyofauna colonizing the *Crassostrea rhizophorae* farming platforms; to evaluate ecological aspects, such as the possible correlation between the physical and chemical variables for water quality and the occurrence of the ichthyofauna; and to observe the differences in the fish species found during tidal variations. Specimens were identified and quantified using the linear-transect, visual census methodology. The ichthyofauna observed comprised 3,030 individuals belonging to 28 species and 20 families. Of the 28 species found in the area studied, 14 were marine transients, 12 marine dependent, and only 2 permanent residents. A significant association was observed between the abundance of 11 species and the physical and chemical variables studied. Based on these results, it may be concluded that the platforms act as artificial reefs for the ichthyofauna, being colonized by at least 28 species, and providing protection from predators as well as a source of food and a reproductive substrate.

RESUMO

Um tipo de plataforma, conhecido como mesas, estão sendo utilizadas para o cultivo de ostras. Em Fortim, Ceará, este cultivo teve início em junho de 2000 e abrange uma área total de 50m² sobre um substrato argilo-arenoso. A presente pesquisa tem como objetivo identificar e catalogar a ictiofauna colonizadora das mesas de cultivo de ostras do mangue (*Crassostrea rhizophorae*), avaliar aspectos ecológicos tais como as possíveis correlações de parâmetros físico-químicos da água com a ocorrência da ictiofauna, além de observar as diferenças na composição da mesma durante as variações de marés. Os exemplares foram identificados visualmente e quantificados empregando-se a técnica de censo visual por transecto de faixa. A ictiofauna avistada compreendeu 3.030 indivíduos pertencentes 28 espécies e 20 famílias. Das 28 espécies encontradas na área estudada, 14 são marinhas visitantes, 12 marinhas dependentes e apenas duas aparecem como residentes. Apenas 11 espécies apresentaram correlação com os parâmetros fisico-químicos estudados. Com base nestes resultados, pode-se afirmar que as estruturas de cultivo da ostra do mangue funcionam como um recife artificial para a ictiofauna, sendo colonizadas por, no mínimo, 28 espécies de peixes, podendo fornecer abrigo, proteção contra predadores, alimento e área de reprodução.

Descriptors: Oyster farming, Ichthyofauna, Colonization, Ecology, Ceará.
Descritores: Cultivo de ostra, Ictiofauna, Colonização, Ecologia, Ceará.

Introduction

Oyster farming has been on the increase worldwide, mainly in the last few decades. In Brazil, the first commercial farming methods appeared in 1980. In Ceará, this activity was begun in late 1999, with the implementation of the *Crassostrea rhizophorae* Mangrove Oyster Cultivation Project in the district of Fortim.

The platforms used for oyster farming serve as artificial reefs (oyster reefs), which may be defined as structures intentionally deployed on the seabed to influence biological or physical processes (Seaman, 2000). The oyster reefs provide numerous and important ecosystem features which have only recently been documented and quantified, in part because of the short history of the recognition of these reefs as important habitats for fish (Peterson *et al*., 2003), as well as benthic invertebrates (Zimmerman *et al*., 1989) and mobile crustaceans (Lenihan *et al*., 2001).

Fish represent the most important group colonizing the oyster farm platform area. These animals have adapted to the peculiar conditions of the estuary environment (Haedrich, 1983; Day *et al.* 1989), once the nature of the fish communities in the estuary are largely determined by salinity, temperature, and substrate (Henderson, 1989). Over 90% of the species of fish that live in the estuaries of Ceará come from the open sea (Oliveira, 1972) and many are associated with a reef environment. Knowledge of the ichthyofauna of the oyster reefs is needed, as this ecosystem has only recently been recognized as a fish habitat. Furthermore, information about estuary ichthyofauna in the State of Ceará in general is scant, with most of the information available relating to the distribution of fish (Araújo *et al*., 2000). Some 102 species, belonging to 74 classes and 41 families, are known to have been observed in the estuaries of the rivers Cocó, Pacoti and Jaguaribe (Araújo *et al*., 2000).

This study has several main objectives: to identify and catalogue the ichthyofauna colonizing the *Crassostrea rhizophorae* mangrove oyster farm platforms; to classify the species according to period of residence in the estuary; to evaluate ecological aspects, such as possible associations between the physical and chemical variables of water quality with the occurrence of the ichthyofauna during tidal variations; and to determine the vertical distribution of the species inhabiting the oyster farm platforms.

Materials and Methods

The Study Area

The district of Fortim is situated on the eastern stretch of the Ceará coastline, 140 km from the State capital, Fortaleza. This region includes the estuary of the Jaguaribe River, whose clay soil substrate makes it more suitable for farming oysters on the platforms known as tables (Quayle, 1973). The oyster farming areas, which were installed in June 2000, are to be found near Canto da Barra, 6.5 km from Fortim (04°25'41.1"S and 37°46'32.7"W), and occupy a total area of 50 m² at a distance of 1 km from the mouth of the Jaguaribe River Estuary. Recently, there has been an increase in the human presence of this area, especially during the summer, and on weekends and holidays (Fig. 1), when intense pleasure boating activities invade the traditional site for fishing boats to cast anchor in the harbor.

The Species Catalogue

The specimens were identified and quantified *in situ* using the linear transect visual census methodology (Bortone *et al*., 1986; 1989). This technique requires a diver to swins parallel to and on one side of a transect line (50 m length) and at a distance of one meter from it, while identifying and counting the number of individual specimens per species encountered within this one-meter-wide zone parallel to the transect.

The censuses were conducted by a single diver in the course of 15 dives per day (using a snorkel), each dive lasting 15 minutes, during both flood and ebb tidal periods between June 2002 and January 2003, corresponding to the dry season in Ceará. Voucher specimens of some species were collected with the aid of a harpoon, fishing-tackle or nylon fishing net for subsequent positive identification in the laboratory, using specific identification keys (Cervigón, 1996). The specimens collected were fixed in a solution of 10% Formalin, then transferred to 70% ethyl alcohol and deposited in the ichthyological collection of the Federal University of Ceará (UFC). Samples whose species could not be identified in the field (e.g., *Centropomus* spp., *Hemirhamphus* sp. and *Strongylura* sp.) were grouped by genus to minimize possible identification error. The species were listed according to Nelson (1994), based on their evolutionary relationships.

The species were classified according to their habitats as follows: resident species that spend their entire life cycle in the estuary waters; marine visitors, species of marine origin that spend the greater part of their life cycle at sea, including the egg-laying phase, entering the estuary waters regularly or occasionally, without any apparent dependence on the estuary; and marine dependent species that need to make use of the estuary waters occasionally for feeding, or as part of their reproductive cycle (Vasconcelos-Filho & Oliveira, 2000).

Foto: Caroline Vieira Feitosa

Fig. 1. Photograph of 'summer resort' houses located next to cultivation areas.

The Measurement of Physical and Chemical Water Quality Variables

Before each dive, the following physical and chemical water quality variables were measured: salinity (ppt), transparency (m), temperature (°C) and dissolved oxygen (mg/L). For the measurement of salinity, a portable manual sodium-chloride refractometer (model SR1 Aquatic Ecosystems Inc., Apopka, Florida, USA) with temperature compensation and a scale of 0 to 100 with an accuracy of ± 1 was used. Water transparency in the estuary was measured twice, using Secchi discs tied to a bathymetric cable at 10 cm intervals. The temperature was measured using a thermometer with a mercury column and bulb, readings being taken from the moment of the immersion of the thermometer in the water until the temperature measured became stable. Dissolved oxygen levels were measured using a YSI oxymeter model F-1055 (Yellow Springs Instrument Company, Yellow Springs, Ohio, USA).

Statistical Analysis

The following values were calculated: the absolute abundance (AA), which is the number of individuals of a species present; the relative abundance (RA) corresponds to the quotient of the absolute abundance of each species and the total abundance (sum of all individuals), multiplied by 100; the absolute frequency (AF) relates to the number of visits on which a certain species was encountered; and the relative frequency (RF) which is the quotient of the absolute frequency and the number of visits, multiplied by 100.

Diversity measures, using Diversity software, were employed. to characterize the structure of the community during flood and ebb tide. The following indices were applied: the Shannon diversity index (H') and the Pielou evenness index (J). A Canonical Correspondence Analysis (CCA), utilizing MVSP 3.1 software, was used to evaluate the association between the physical and chemical variables and the abundance for each species at different tidal levels. Only species that attained a relative frequency of more than 50% were used in this analysis.

Results

The ichthyofauna observed comprised 3,030 individuals belonging to 28 species, 24 genera and 20 families. Of these, 13 are of commercial value as fish for human consumption and 3 as ornamental fish (Table 1). The vertical distribution of some species of fish inhabiting the oyster farming platform area is illustrated in Figure 2.

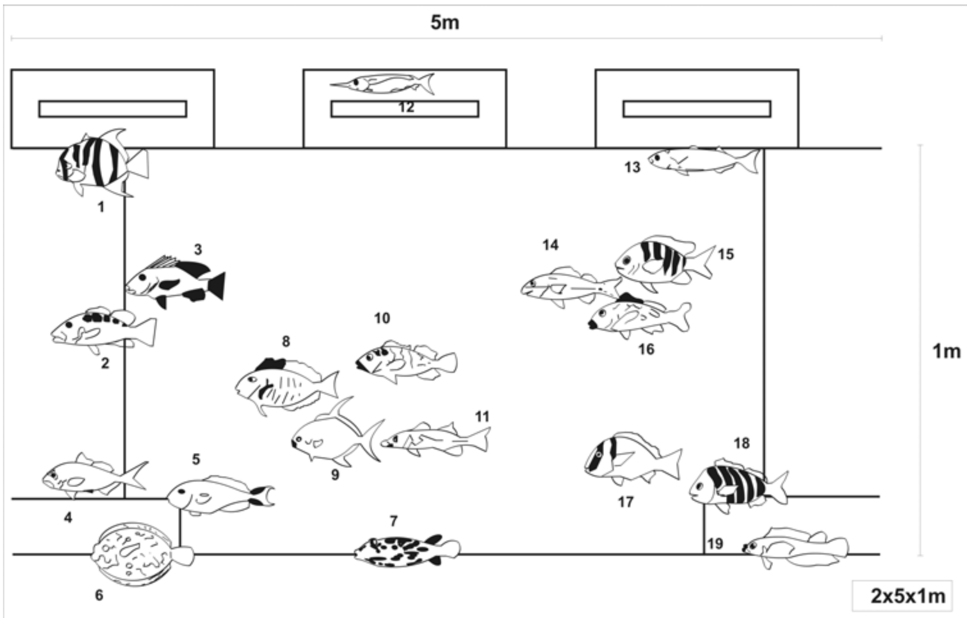
Table 1. List of families, species, popular names, economic importance and ecological classification of the fish observed in the areas of (*Crassostrea rhizophorae)* mangrove oyster cultivation, Fortim-CE, between June 2002 and January 2003.

Family	Species	Common name	Ecological classification
Engraulidae	*Cetengraulius edentulus* (Cuvier, 1829)*	Atlantic anchoveta	Marine visitor [1]
Ariidae	*Bagre marinus* (Mitchill, 1815)*	Gafftopsail sea catfish	Marine visitor [1]
Atherinidae	*Atherinella brasiliensis* (Quoy & Gaimard, 1825)	Brazilian silversides	Resident [1]
Mugilidae	*Mugil curema* Valenciennes, 1836*	White mullet	Marine dependent [1]
Belonidae	*Strongylura* sp.*	Timucu	Marine dependent [1]
Hemirhamphidae	*Hemirhamphus* sp.*	Ballyhoo	Marine dependent [1]
	Hyporhamphus sp.*	Halfbeaks	Marine dependent [1]
Centropomidae	*Centropomus* spp. *	Snook	Marine dependent [1]
Serranidae	*Mycteroperca bonaci* (Poey, 1861)*	Black grouper	Marine visitor [2]
Carangidae	*Trachinotus falcatus* (Linnaeus, 1758)	Permit	Marine visitor [1]
Lutjanidae	*Lutjanus apodus* (Walbaum, 1792)*	Schoolmaster	Marine visitor [1]
	Lutjanus cyanopterus (Cuvier, 1828)*	Cubera snapper	Marine dependent [3]
Gerreidae	*Eucinostomus melanopterus* (Bleeker, 1863)	Flagfin mojarra	Marine dependent [1]
	Eugerres brasilianus (Cuvier, 1830)*	Brazilian mojarra	Marine dependent [1]
Haemulidae	*Anisotremus virginicus* (Linnaeus, 1758)	Porkfish	Marine visitor [1]
	Haemulon aurolineatum Cuvier, 1829	Tomtate	Marine visitor [1]
	Haemulon parra (Desmarest, 1823)	Sailor's choice	Marine visitor [1]
	Pomadasys corvinaeformis (Steindachner,1868)	Roughneck grunt	Marine visitor [1]
Sparidae	*Archosargus probatocephalus* (Walbaum, 1792)	Sheepshead	Marine visitor [1]
Pomacentridae	*Abudefduf saxatilis* (Linnaeus, 1758)**	Sergeant major	Marine visitor [1]
Scaridae	*Sparisoma axillare* (Steindachner, 1878)	Gray parrotfish	Marine visitor [4]
Labrisomidae	*Labrisomus nuchipinnis* (Quoy & Gaimard, 1824)	Hairy blenny	Marine visitor [2]
Ephippidae	*Chaetodipterus faber* Broussonet, 1792**	Atlantic spadefish	Marine dependent [1]
Acanthuridae	*Acanthurus chirurgus* (Block, 1787)**	Doctorfish	Marine visitor [1]
Bothidae	*Bothus* sp.*	Flounder	Marine dependent [1]
Tetraodontidae	*Sphoeroides testudineus* (Linnaeus, 1758)	Checkered puffer	Resident [1]

* Species consumed by humans, ** sold for ornamental purposes, 1 – Vasconcelos-Filho; Oliveira (2000); 2 – Randall, 1967; 3 – Allen, 1985; Moura *et al.,* 2001.

A total of 913 individuals were observed during the flood tide (Table 2), when *Lutjanus apodus*, *Sphoeroides testudineus*, *Eugerres brasilianus* and *Abudefduf saxatilis* were the most abundant and frequent. Apart from these species, *Labrisomus nuchipinnis*, *Eucinostomus melanopterus* and *Haemulon aurolineatum* registered a frequency of occurrence of more than 60 %. The most abundant families were the Lutjanidae, Tetraodontidae, Gerreidae and Pomacentridae, in that order. A larger number of specimens (2,117) were observed during the ebb tide (Table 2), there being great abundance of the following species: *Atherinella brasiliensis*, *Cetengraulius edentulus*, *Sphoeroides testudineus* and *Lutjanus apodus*. However, the most frequent species were *Lutjanus apodus* and *Sphoeroides testudineus* (100 % each), followed by *Abudefduf saxatilis*, *Eucinostomus melanopterus, Eugerres brasilianus* and *Labrisomus nuchipinnis* with a frequency higher than 66 %. The most abundant families were the Atherinidae, Engraulidae, Tetraodontidae and Lutjanidae.

The ecological classification of the species according to the literature (Moura *et al*., 2001; Vasconcelos-Filho & Oliveira, 2000; Allen, 1985; Randall, 1967) is given in Table 1. Of the 28 species recorded in the area, fourteen are marine visitors, corresponding to 50% of all the species; twelve (42.86 %) are marine dependent, and only two (7.14 %) are resident. During the ebb tide, 48.15 % of the species observed were classified as marine visitors, 44.44 % as marine dependent, and 7.41 % as resident. During the flood tide, 50 % of the species were marine visitors, 45.45 % were marine dependent, and 4.55 % resident.



Desenho: Luiz Eduardo Lima de Freitas

Fig. 2. Vertical distribution of some species of fish in the tables of mangrove oyster cultivation.

Legend: 1- *Chaetodipterus faber*; 2- *Lutjanus cyanopterus*; 3- *Lutjanus apodus*; 4- *Eucinostomus melanopterus*; 5- *Sparisoma axillare*; 6- *Bothus* sp.; 7- *Sphoeroides testudineus;* 8- *Acanthurus chirurgus*; 9- *Trachinotus falcatus*; 10- *Mycteroperca bonaci*; 11- *Centropomus* spp.; 12- *Hemiramphus* spp.; 13- *Mugil curema*; 14- *Haemulon aurolineatum*; 15- *Abudefduf saxatilis*; 16- *Haemulon parra*; 17- *Anisotremus virginicus*; 18- *Archosargus probatocephalus*; 19- *Labrisomus nuchipinnis*

The water quality variables (salinity, transparency, temperature and dissolved oxygen) were measured at a distance of 1 m from the oyster farm area. The values for salinity varied, when the tide was in flood, from 35 to 42 ppt, and, when the tide was ebb, from 31 to 38; the temperature during the flood tide varied from 26.6°C to 31°C and during the ebb tide from 28°C to 30°C, while transparency (Secchi depth) during the flood tide ranged from 0.8 m to 1.8 m, and during the ebb tide from 0.6 m to 1 m. Dissolved oxygen during the flood tide varied from 4.81 mg/L to 7.9 mg/L and during the ebb tide from 5.66 mg/L to 7.54 mg/L.

The diversity indices obtained for the ichthyofauna colonizing the oyster reefs during the flood tide were, for the Shannon diversity index (H'), 2.31 and for the Pielou evenness index (J), 0.79, while during the ebb tide these values were H' = 2.13; J = 0.68.

Of the 28 species registered, only 9 and *Centropomus* spp (probably 02) were used in a Canonical Correspondence Analysis (CCA) (Fig. 3). It was observed in the ebb tide that the salinity and temperature were the parameters that presented the greatest variations. The species *Abudefduf saxatilis, Labrisomus nuchipinnis, Eucinostomus melanopterus* and *Chaetodipterus faber* presented a positive association with the variable salinity, while Needles (*Hemirhamphus* sp., *Hyporhamphus* sp. and *Strongylura* sp.) had an indirect correlation with this parameter and a direct one with dissolved oxygen. *Haemulon aurolineatum* showed a high correlation with temperature, while marine dependent species (*Centropomus* spp.) showed an inverse relationship to this parameter.

In the flood tide, the salinity and transparency were the parameters that presented the greatest changes. Nevertheless, the majority of species showed some correlation with temperature (*Eucinostomus melanopterus, Labrisomus nuchipinnis* and *Lutjanus apodus*). The marine dependent species, *Chaetodipterus faber* and *Centropomus* spp., presented the same ecological pattern, showing a close association with salinity. The marine dependent needles (*Hemirhamphus* sp., *Hyporhamphus* sp. and *Strongylura* sp.) were influenced by the dissolved oxygen. *Eugerres brasilianus* was the only species that presented a correlation with transparency. *Abudefduf saxatilis, Haemulon aurolineatum* and *Sphoeroides testudineus* did not show any close relationship with the water parameters during the flood tide.

Table 2. Abundance and frequency of the species observed in the areas of *Crassostrea rhizophorae* cultivation. at Canto da Barra, Fortim – CE, between June 2002 and January 2003, at flood and ebb tides.

SPECIES	Flood tide				Ebb tide			
	AA	RA(%)	AF	RF(%)	AA	RA(%)	AF	RF(%)
Abudefduf saxatilis	81	8.87	10	66.67	81	3.83	11	73.33
Acanthurus chirurgus	5	0.55	2	13.33	4	0.19	3	20
Needles*	45	4.93	6	40	46	2.17	8	53.33
Anisotremus virginicus	5	0.55	3	20	2	0.09	2	13.33
Archosargus probatocephalus	21	2.30	4	26.67	21	0.99	4	26.67
Atherinella brasiliensis	0	0	0	0	620	29.29	7	46.67
Bagre marinus	0	0	0	0	1	0.05	1	6.67
Bothus sp	0	0	0	0	1	0.05	1	6.67
Centropomus spp.	47	5.15	8	53.33	15	0.71	3	20
Cetengraulis edentulus	0	0	0	0	350	16.53	3	20
Chaetodipterus faber	35	3.83	8	53.33	23	1.09	8	53.33
Eucinostomus melanopterus	78	8.54	10	66.67	168	7.93	11	73.33
Eugerres brasilianus	136	14.90	9	60	101	4.77	11	73.33
Haemulon aurolineatum	42	4.60	9	60	20	0.94	8	53.33
Haemulon parra	3	0.33	2	13.33	1	0.05	1	6.67
Labrisomus nuchipinnis	27	2.96	11	73.33	27	1.27	10	66.67
Lutjanus apodus	213	23.34	14	93.33	273	12.89	15	100
Lutjanus cyanopterus	0	0	0	0	3	0.14	3	20
Mugil curema	24	2.63	1	6.67	62	2.93	2	13.33
Mycteroperca bonaci	4	0.44	4	26.67	1	0.05	1	6.67
Pomadasys corvinaeformis	0	0	0	0	1	0.05	1	6.67
Sparisoma axillare	1	0.11	1	6.67	1	0.05	1	6.67
Sphoeroides testudineus	145	15.88	14	93.33	295	13.93	15	100
Trachinotus falcatus	1	0.11	1	6.67	0	0	0	0
Total	**913**	**100**	**15**	**100**	**2117**	**100**	**15**	**100**

Legend: AA – absolute abundance, RA – relative abundance, AF – absolute frequency and RF – relative frequency.
Needles* = *Hemirhamphus* sp., *Hyporhamphus* sp., *Strongylura* sp.

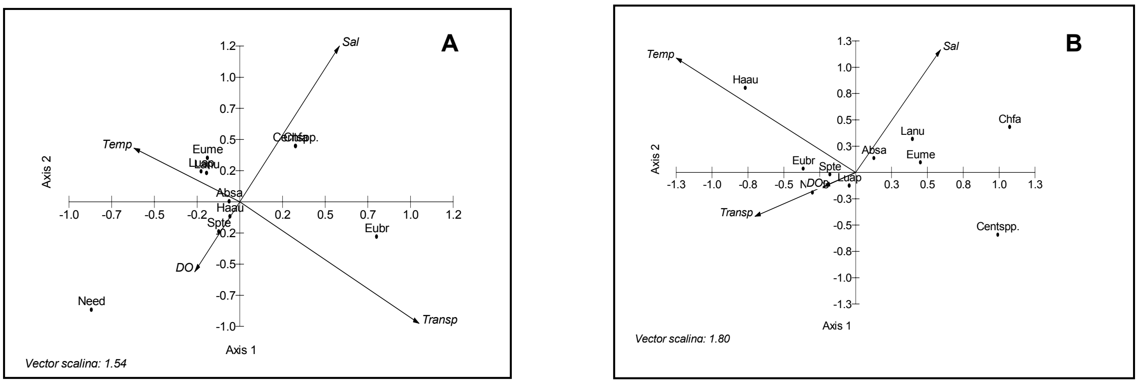


Fig. 3. Representation of the Canonical Correspondence Analysis (CCA), in the flood (A) and ebb tide (B), giving the species that attained relative frequencies higher than 50 %.
Legend: DO – dissolved oxygen, Trans – transparency, Temp – temperature, Sal – salinity, Need – needles, Spte – *Sphoeroides testudineus*, Haau – *Haemulon aurolineatum*, Luap – *Lutjanus apodus*, Absa – *Abudefduf saxatilis*, Eubr – *Eugerres brasilianus*, Eume – *Eucinostomus melanopterus*, Chfa – *Chaetodipterus faber*, Centspp – *Centropomus* spp., Lanu – *Labrisomus nuchipinnis*.

Discussion

The present study suggests that two years is a sufficient period of time to transform a simple structure, like an oyster farming platform, into an artificial reef. These structures were capable of attracting at least 3,030 individuals belonging to 28 different species of fish, despite the low visibility of the Jaguaribe estuary. A total of 450 minutes of diving time was required to obtain these results.

The diversity indices have been used by ecologists in studies of the structure of fish communities to facilitate the description of ecological characteristics and allow for comparison between different areas (Moring, 1986). Batista & Rêgo (2001) assert that diversity increases when the tide rises and this is corroborated by our results for both diversity and evenness. Overall, the diversity indices observed on the oyster reefs are similar to those calculated for the Rio Grande do Norte State Reefs: Maracajaú (Feitosa *et al*., 2002) and Risca do Zumbi (Feitoza, 2001), considered to constitute one of the richest marine ecosystems in the world (Lowe-McConnel, 1999).

In terms of the size of the specimens, it appears that these are young fish, which, when fully developed, will be of commercial value, as Vasconcelos-Filho & Oliveira (2000), Mullin (1995), and Sheridan (1992) have shown in their studies of tropical and sub-tropical estuary regions. It is also believed that the oyster farming platforms are being used by some species as a nursery area (Peterson, 2003), given the abundance of fingerlings found, *Abudefduf saxatilis* and *Haemulon aurolineatum*; specimens of some species were found of less than 2 cm in length. The oyster reef also functions as a feeding ground. The especially high abundance of the estuary resident species *Sphoeroides testudineus* in the present results may be explained by the fact that it is a potential oyster predator (Pauly, 1991).

The presence of species that commonly inhabit rocky beds (*e.g., Abudefduf saxatilis, Acanthurus chirurgus, Haemulon aurolineatum, Haemulon parra Lutjanus apodus* and *Mycteroperca bonaci*), showing a similar vertical distribution to that found on natural reefs, is noteworthy. According to Chapman & Kramer (2000), the movement of reef fish species can be extremely limited, although some species are able regularly to migrate thousands of meters when fully grown. This would certainly not be the case for the species mentioned above, because the specimens used as samples were small (between about 10 and 15 cm), or at least, young. However, fish of the Lutjanidae and Haemulidae families, for example, have been reported as undertaking feeding migrations on a daily basis, using established routes and having a fixed schedule (in terms of time of day), traveling distances of more than 1 km (Nagelkerken *et al*., 2000).

More marine visitor species (*e.g.*, *Abudefduf saxatilis, Haemulon aurolineatum, Lutjanus apodus*) were recorded in the flood tide, while resident species were more abundant during the ebb tide. Oliveira (1976) argued that marine visitors are capable of tolerating a great variation in salinity and represent a majority of the species. Several marine and estuary species have demonstrated tolerance towards variations in salinity (Griffiths, 2001), although this may vary according to life cycle phase (Poxton & Allouse, 1982). Contrary to common belief (Griffiths, 2001), marine visitors were usually found in smaller numbers in the estuaries, when the salinity was relatively high (flood tide). According to Griffiths (2001), the present study showed that four non-resident species utilized in CCA, *Abudefduf saxatilis, Labrisomus nuchipinnis, Eucinostomus melanopterus* and *Chaetodipterus faber*, were associated with salinity in the ebb tide, when this parameter is higher than it is in the flood tide.

Taking into consideration the number of species and the abundance of species of fish encountered, in addition to the different tide levels, it may be concluded that the values obtained during the ebb tide are greater than those for the flood tide. This may be attributed to the fact that, at lower tide levels, a large number of fish congregate in a smaller volume of water, increasing the probability of their being encountered. This corroborates the suggestion of Morrison *et al*. (2002) who observed that, during the flood tide, species are scattered across a wider ecosystem and this may lead to misleading conclusions regarding the overall relative abundance of the species under study.

The species *Atherinella brasiliensis*, *Bagre marinus*, *Bothus* sp., *Cetengraulius edentulus*, *Lutjanus cyanopterus* and *Pomadasys corvinaeformis* were observed only during the ebb tide, whereas *Trachinotus falcatus* was found only during the flood tide. During the ebb tide, unpredictable changes in the environmental variables occur: salinity decreases as temperature increases several degrees, owing to the smaller volume of sea water, when the tide is low and the surface of the water is nearer the bed (Levinton, 1995). It is known that abiotic variations, such as those in temperature, affect the physiology of fish, although this varies from species to species (Poxton & Allouse, 1982; Methven *et al*., 2001; Griffiths, 2001). Only species that tolerate such environmental conditions are able to make permanent use of the estuaries, and their abundance is generally high (Griffiths & West, 1999). For this reason, resident species such as *Atherinella brasiliensis* and *Sphoeroides testudineus* are the most highly "adapted" (euryhaline and eurythermic) to these adverse conditions. *Lutjanus apodus* may be considered a resident or marine dependent species, because of its presence during 100% of the dives carried out as part of this study; despite its having shown an association with high temperature in the flood tide.

With regard to water transparency (visibility) and dissolved oxygen, the needles species (*Hemirhamphus* sp., *Hyporhamphus* sp., *Strongylura* sp.), classified as marine dependent (Vasconcelos-Filho & Oliveira, 2000), were more closely associated with these parameters in the ebb tide. Given that these species come into the estuary for a specific reason (feeding, reproduction, shelter, or even to spend a part of their life cycle), transparency plays an important role in their species the distribution, since estuaries provide visual protection from predators, besides providing significant additional food supplies (Blaber & Blaber, 1980). This is the case of the marine dependent *Eugerres brasilianus*, that is influenced by this parameter in the flood tide. The levels of dissolved oxygen are important for the distribution of species, although only needles (*Hemirhamphus* sp., *Hyporhamphus* sp. and *Strongylura* sp.) were sensitive to the changes in this variable. Some marine species suffer stress when levels of dissolved oxygen fall to less than or equal to 4.5 mg/L (Poxton & Allouse, 1982). Such a low value, however, was not encountered in the course of this research project, suggesting that the fish were inhabiting an environment with a satisfactory saturation level (4.81 to 7.9 mg/L).

Even though the time period covered by this research project was insufficient to evaluate the degree of dependence of the fish on this oyster reef, more than 3,000 specimens, belonging to almost 30 species were registered, 7.14% of them being resident species, 42.86% marine dependent, and 50% marine visitors. It may be suggested that the majority of the species registered, although classified as marine visitors, are adapted to the estuarine conditions. It was discovered that the species had a tendency to adapt to the variations in the parameters of the water whitin the tidal range. On the basis of these results obtained over seven months, it may be concluded that *Crassostrea rhizophorae* oyster farm platforms act as an artificial reef for colonizing ichthyofauna, providing shelter, protection from predators, and a supply of food, as well as a safe place to reproduce.

Acknowledgements

We are grateful to the Bivalve Mollusks Study Group (LABOMAR- Federal University of Ceará - UFC), especially to Dr[a]. Tereza Cristina Gesteira and Max Dantas, for their cooperation with this research, as well as to, Dr[a] Szigrid Neumann Leitão (Federal University of Pernambuco) and Dr. Joseph Nelson (University of Alberta, Canada) for their invaluable suggestions.

References

Allen, G. R. 1985. FAO species catalogue. Vol. 6. Snappers of the world. An annotated and illustrated catalogue of lutjanid species known to date. FAO Fish Synop. 6(125):208p. 1985.

Araújo, M. E.; Teixeira, J. M. & Oliveira, A. M. E. 2000. Ictiofauna marinha do Estado do Ceará, Brasil: III. Actinopterygii de estuários. Arq. Cienc. Mar, Bras., 33:139-142.

Batista, V. S. & Rêgo, F. N. 2001. A influência da maré no sistema de amostragem de peixes no estuário do Rio Tibiri, São Luis, Estado do Maranhão, Brasil. Arq. Cienc. Mar, Bras., 34:131-136.

Blaber, S. J. M. & Blaber, T. G. 1980. Factors affecting the distribution of juvenile estuarine and inshore fish. J.Fish Biol.**,** 17:143-162.

Bortone, S. A.; Hastings, R. W. & Oglesby, J. L. 1986. Quantification of reef fish assemblages: A comparison of several *in situ* methods. Northeast Gulf Sci., 1(1):1-22.

Bortone, S. A.; Kimel, J. J. & Bundrick, C. M. 1989. A comparison of tree methods for visually assessing reef fish communities: time and area compensated. Northeast Gulf Sci., 10(2):85-96.

Cervigón, F. M. 1996. Los peces marinos de Venezuela**.** Caracas, Fondo de Cultura Científica. 951p.

Chapman, M. R. & Kramer, D. L. 2000. Movements of fishes within and among fringing coral reefs in Barbados. Environ. Biol. Fish., 57:11-24.

Day Jr, J. W.; Hall, C. A. S.; Kemp, W. H. & Yañez-Aracibia, A. 1989. Estuarine ecology. New York, Wiley and Sons. 588p.

Feitosa, C. V.; Pimenta, D. A. S. & Araújo, M. E. 2002. Ictiofauna recifal dos Parrachos de Maracajaú (RN) na área dos flutuantes: inventário e estrutura da comunidade. Arq. Cienc. Mar, Bras., 35:39-50.

Griffiths, S. P. 2001. Factors influencing fish composition in an Australian intermittently open estuary. Is stability salinity-dependent? Estuar. coast. Shelf Sci., 52:739-751.

Griffiths, S. P. & West, R. J. 1999. Preliminary assessment of shallow water fish in three small intermittently open estuaries in southeastern Australia. Fish. Manag. Ecol. 6:311-322.

Haedrich, R. L. 1983. Estuarine fishes**.** In: Ketchum B. H. ed. Estuaries and enclosed seas. Ecosystems of the world 26. New York, Elsevier Scientific. p. 183-207.

Henderson, P. A. 1989. On the structure of the inshore fish community of England and Wales. J. mar. biol. Ass. UK, 69:145-163.

Lenihan, H. S.; Peterson, C. H.; Byers, J. E.; Grabowski, J. H.; Thayer, G. W. & Colby, D. 2001. Cascading of habitat degradation: oyster reefs invaded by refugee fishes escaping stress. Ecol. Appl., 11:746-782.

Levinton, J. S. 1995. Marine Biology. Function, Biodiversity and Ecology**.** New York, Oxford University Press. 420p.

Lowe-McConnell, R. H. 1999. Estudos ecológicos de comunidades de peixes tropicais. Tradução Vazzoler A. E. A., Agostinho, A. A., Cunnhigham, P. T. M. São Paulo, EDUSP. 382p.

Methven, D. A.; Haedrich, R. L. & Rose, G. A. 2001. The fish assemblage of a Newfoundland estuary: diel, monthly and annual variation. Estuar. coast. Shelf Sci., 52:669-687.

Moring, J. R. 1986. Seasonal presence of toadpool fish species in a rock intertidal zone of northern California, USA. Hydrobiology, v. 16, p. 21-27.

Morrison, M. A.; Francis, M. P.; Hartill, B. W. & Parkinson, D. M. 2002. Diurnal and tidal variation in the abundance of the fish fauna of a temperate tidal mudflat. Estuar. coast. Shelf Sci., 54:793-807.

Moura, R. L.; Figueiredo, J. L. & Sazima, I. 2001. A new parrotfish (Scaridae) from Brazil, and revalidation of *Sparisoma amplum* (Ranzani, 1842), *Sparisoma frondosum* (Agassiz, 1831), *Sparisoma axillare* (Steindachner, 1878) and *Scarus trispinosus* (Valenciennes, 1840). Bull. mar. Sci., 68(3):505-524.

Mullin, S. J. 1995. Estuarine fish populations among red mangrove prop roots of small over wash islands. Wetlands, 15:567-573.

Nagelkerken, I.; Dorenbosch, M.; Verberk, W. C.; De La Moriniere, C. E. & Van Der Velde, G. 2000. Day-night shifts of fishes between shallow-water biotopes of a Caribbean bay, with emphasis on the nocturnal feeding of Haemulidae e Lutjanidae. Mar. Ecol. Prog. Ser., 194:55-64.

Nelson, J. S. 1994. Fishes of the world. 3rd ed. New York, John Wiley & Sons Inc. 600p.

Oliveira, A. M. E. 1972. Peixes estuarinos do Nordeste oriental brasileiro. Arq. Cienc. Mar, Bras., 12(1):35-41.

Oliveira, A. M. E. 1976. Composição e distribuição da ictiofuna, nas águas estuarinas do rio Jaguaribe (Ceará-Brasil) Arq. Cienc. Mar, Bras., 1(16):9-18.

Pauly, D. 1991. Growth of the checkered puffer *Sphoeroides testudineus*: postscript to papers by Targett and Pauly & Ingles. Fishbyte, 9(1):19-22.

Peterson, C. H.; Grabowski, J. H. & Powers, S. P. 2003. Estimated enhancement of fish production resulting from restoring oyster reef habitat: quantitative valuation. Mar. Ecol. Prog. Ser., 264:249-264.

Poxton, M. G. & Allouse, S. B. 1982. Water quality criteria for marine fisheries. Aquacult. Eng., 1:153-191.

Quayle, D. B. 1973. Possibilidades para o cultivo de ostras em algumas áreas estuarinas do Estado do Ceará (Brasil). CESO do Brasil, 12p.

Randall, J. E. 1967. Food habits of reef fishes of the West Indies. Stud. Trop. Oceanogr., 5:665-847.

Seaman Jr, W. S. 2000. Artificial reef evaluation with aplication to natural marine habitats., Boca Raton, CRC Press. 246 p.

Sheridan, P. F. 1992. Comparative habitat utilization by estuarine macro fauna within the mangrove ecosystem of Rookery Bay, Florida. Bull. mar. Sci., 50:21-39.

Vasconcelos-Filho, A. L. & Oliveira, A. M. E. 2000. Ictiofauna. In: Gerenciamento participativo de estuários e manguezais. Recife, Editora UFPE. p. 143-153.

Zimmerman, R. J.; Minello, T. J.; Baumer, T. & Castiglione, M. 1989. Oyster reef as habitat for estuarine macrofauna. Tech Memm NMFS-SEFC-249, NOAA.

Source of Unpublished Material

Feitoza, B. M. 2001. Composição e estrutura da comunidade de peixes recifais da Risca do Zumbi, Rio Grande do Norte. 156p. Msc. Dissertation (Master in Zoology) Federal University of Paraíba, João Pessoa.

(Manuscript received 20 April 2005; revised 06 June 2005; accepted 15 December 2005)