

Comparative analysis of tidepool fish species composition on tropical coastal rocky reefs at State of Ceará, Brazil

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ABSTRACT. This study compared tidepool fish assemblages within and among habitats at Iparana and Pecém beaches, State of Ceará, Northeast Brazil, using visual census techniques. A total of 8,914 fishes, representing 25 families and 43 species were recorded. The most abundant taxon was *Sparisoma* spp, followed by *Haemulon parra* (Desmarest, 1823), *Acanthurus chirurgus* (Bloch, 1787) and *Abudefduf saxatilis* (Linnaeus, 1758). Haemulidae was the most abundant family in number of individuals, followed by Scaridae, Acanthuridae and Pomacentridae. Within- and between- site differences in species assemblages probably reflected environmental discontinuities and more localized features, such as pool isolation episodes, or environmental complexity, both acting isolated or interactively. The locality of Iparana was probably subjected to a greater fishing pressure and tourism than Pecém, a potential cause for the observed lowest fish abundance and biodiversity. We conclude that tidepool ichthyofauna may be quite variable between and within reef sites. Thus, observations taken from or damages caused on one area may not be generalized to or mitigated by the protection of adjacent sites.

KEYWORDS. Visual census, fish assemblages, abundance, biodiversity.

RESUMO. Análise comparativa da composição das espécies de peixes em poças de maré em recifes costeiros no estado do Ceará, Brasil. Este estudo comparou assembléias de peixe em poças de maré dentro e entre habitats nas praias de Iparana e Pecém, estado do Ceará, nordeste do Brasil, usando técnicas de censo visual. Um total de 8.914 peixes, representando 25 famílias e 43 espécies foi registrado. *Sparisoma* spp. formaram o *taxon* mais abundante, seguido por *Haemulon parra* (Desmarest, 1823), *Acanthurus chirurgus* (Bloch, 1787) e *Abudefduf saxatilis* (Linnaeus, 1758). Haemulidae foi a família mais abundante em número de indivíduos, seguida por Scaridae, Acanthuridae e Pomacentridae. Diferenças encontradas nas assembléias de espécies provavelmente refletiram descontinuidades ambientais e aspectos mais localizados, como a ocorrência de isolamento das poças, ou complexidade ambiental atuando de forma isolada ou interativamente. A localidade de Iparana provavelmente foi submetida a uma maior pressão de pesca e turismo que Pecém, uma causa potencial para a menor abundância e biodiversidade de peixes observada. Concluímos que a ictiofauna de poça de maré pode ser variável dentro dos recifes e entre localidades diferentes. Assim, observações tomadas ou os danos causados em uma dada área não podem ser generalizados ou mitigados para a proteção de locais adjacentes.

PALAVRAS-CHAVE. Censo visual, assembléias de peixe, abundância, biodiversidade.

Tropical reef fish communities are rich and complex, and comprise species of different ecological strategies, at several life history stages. Coastal intertidal reefs and their associated tidepools are important habitats, especially for young-of-the-year of both coastal and oceanic fish species, some of which of special economic interest (CADDY & SHARP, 1986; GRIFFITHS *et al.*, 2003).

MORING (1986) studied the use of tidepools as breeding areas by many fish species, whereas UNDERWOOD & CHAPMAN (1996) observed that rock pools might provide refuges for many intertidal and subtidal invertebrates. In fact, ROSA *et al.* (1997) stressed the importance of tidepools for both coastal and marine fish populations, as these habitats maybe part of the home ranges for some species.

Tidepools are often used by swimmers, artisanal fishers, and may be impacted by development in the coastal zone. In the state of Ceará, artisanal fishers and seaweed collectors harvest on coastal reefs and tidepools, and have reduced considerably the abundance of some taxon (Dárlío A. Teixeira, pers. comm.). Uncontrolled fish and live rock (reef rocks containing

sponges, corals, crabs, shrimps, algae and natural bacteria) collection for the aquarium trade have also negatively impacted fish communities of these habitats (WOOD & WELLS, 1988; MONTEIRO-NETO *et al.*, 2003). Finally, reefs and tidepools have been impacted at several scales due to coastal development, resulting in coastal erosion, habitat loss and reduction of biodiversity (CAMPOS *et al.*, 2003). Therefore, reef fish studies are essential for a precise evaluation of the damages caused by those activities and the elaboration of environmental management plans.

Few studies have addressed reef fishes in Northeast Brazil. Early studies on tidepool fishes were limited to species inventory (ARAÚJO *et al.*, 2000). More recently, research focused on the distribution, abundance and diversity of reef fish fauna (FERREIRA *et al.*, 1995; ROSA & MOURA, 1997; ROCHA *et al.*, 1998; ROCHA & ROSA, 2001a and FEITOSA *et al.*, 2002). ROSA *et al.* (1997) studied the abundance and diversity patterns of tidepool fishes at State of Paraíba and concluded, among other findings, that Gobiidae, Pomacentridae and Labrisomidae were the most abundant families, in terms of number of individuals.

Reef topography usually limits the array of sampling techniques to highly selective fishing strategies such as hook and line and spearfishing (FERREIRA *et al.*, 1995). Therefore, several complimentary techniques are needed to fully assess reef fish communities (ZAPATA, 1992). Alternatively, underwater visual census broadens the limits of reef fish community studies, allowing the simultaneous data collection on species composition and abundance, ecology and behavior (FERREIRA *et al.*, 1995).

One pitfall of visual census may be the underestimation of cryptic species. ACKERMAN & BELLWOOD (2000) observed that a significant proportion of the total number and biomass of fishes on the reef were not accounted for by visual census. Nevertheless, non-destructive techniques should be recommended whenever reef ecosystem conservation is at stake, due to their little environmental interference and the possibility of fish observation in their natural habitat (ROSA *et al.*, 1997).

The aim of this study was to investigate aspects of the tidepool fish assemblages structure to: (i) provide information on the composition of species found in tidepools of tropical coastal rock reefs at state of Ceará, Northeast Brazil; (ii) quantitatively document the patterns of variation in fish assemblages' structure within and between reef localities; (iii) discuss which environmental variables may be important in influencing the structure of tidepool fish assemblages.

MATERIALS AND METHODS

Underwater censuses were performed in four tidepools located along intertidal reefs at the beaches of Iparana (3°41'21"S, 38°36'36"W) and Pecém (3°32'40"S, 38°48'52"W), situated nearly 40 km apart from each other in the coast of State of Ceará, NE Brazil (Fig. 1). Sandstone, Calcium Carbonate and Iron Oxide reefs extended from the beach face to nearly two hundred meters seaward, and were exposed at spring low tides (MORAIS, 1968).

Tidepools selected for this study were characterized by a sand-rubble bottom with sparsely distributed small boulders, and walls partially covered with macroalgae. The pools became isolated from the sea at 0.3 m low tides.

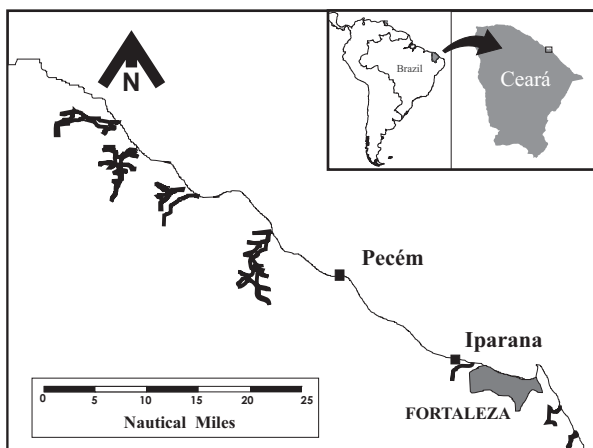


Fig. 1. Map of Brazil within South America, the State of Ceará within Brazil, and both studied localities within the coastal zone of the state, showing their distance relation between each other and among the state Capital Fortaleza.

Pools 1 and 2 were located at Iparana, and 3 and 4 at Pecém reefs (Fig. 1). Each pool was visually examined for the percent cover of the substrate (sand-rubble, bare rock, rock covered with algae). The structural complexity was assessed based on frequency of occurrence of each of the three dimensions (presence of pebbles, crevices and holes) and put into one of the categories (high, medium, low). The surface area (A) of each tidepool was estimated by adding up the triangular areas to match the approximate surface area of the tidepool. Average depth (D) was estimated from three measurements taken at random locations along a longitudinal transect in order to estimate the volume ($V = A \times D$).

Visual census methodology was adapted from CHRISTENSEN & WINTERBOTTOM (1981) in respect to observation time, and consisted of an intensive species search, by snorkeling around the internal rim of the tidepool. Each full search lasted less than 25 minutes to avoid repetitive counts. Species were identified and counted by trained divers, and data recorded on PVC boards. Visual censuses were conducted monthly during daytime, at tides lower than or equal 0.3 m (pools became isolated). A total of 96 censuses were conducted from June 1998 to June 2000. When species determination was uncertain in the field, specimens were captured for laboratory identification. These specimens were not included in the statistical analysis. Taxonomic identification was based on BURGESS *et al.* (1990), CERVIGÓN (1991, 1993, 1994, 1996), FIGUEIREDO & MENEZES (1978, 1980, 2000), HUMANN (1995), MENEZES & FIGUEIREDO (1980, 1985), RANDALL (1996) and ROBINS (1986). The revisions of *Anisotremus moricandi* (Ranzani, 1842), *Halichoeres brasiliensis* (Bloch, 1791) and *Halichoeres penrosei* Starcks, 1913 were based on ACERO & GARZÓN (1982), ROCHA & ROSA (2001b) and ROCHA (2004) respectively, and were aided by specialists and visits to University and Museum Collections. *Sparisoma* spp. (*S. axillare* (Steindachner, 1878) or *S. frondosum* (Agassiz, 1831), following MOURA *et al.*, 2001)) were left at the genus level due to the subtle visual identification of small individuals in waters of low visibility. The collected material was identified, photographed, preserved and deposited at the Collection of Aquatic Biology, Department of Engenharia de Pesca, Universidade Federal do Ceará.

Occurrence and abundance patterns and species associations were studied through cluster analysis and PCA ordination. Abundance data was distributed on a species (rows) by sample (columns) data matrix. Species representing less than or equal to 10% of the hypothetical abundance of 44 individuals (one individual per sample) were discarded to reduce bias and contagion as other authors have suggested (BOESCH, 1977; MONTEIRO-NETO *et al.*, 2003). Thirty-two species were included in the analysis.

The Hellinger's Distance was used as a similarity measure for both cluster and ordination analyses. This distance reduces the effects of null abundances inherent of biological surveys and better resolves the proportional similarities between less common species and abundant ones (LEGENDRE & GALLAGHER, 2001; LEGENDRE & LEGENDRE, 1998). The distance was calculated by

applying the Euclidean Distance to transformed abundance data, following LEGENDRE & GALLAGHER (2001), for both Q-mode and R-mode analysis. A Ward clustering strategy was used to form species and sample groups (MILLIGAN & COOPER, 1987). Analyses were conducted on Statistica for Windows (v.5.5) and Fitopac (developed by George Shepperd, Departamento de Botânica, UNICAMP - Brazil).

Differences between species and sample groups defined in cluster analysis were statistically tested using a Monte Carlo permutation model. The Hellinger's distance between all group centroids was calculated using the objects (species or samples) within group mean abundances, and set as benchmarks. Ten thousand permutations on the original abundance values were performed, and the proportion of null centroid distances (p) higher than or equal to the correspondent benchmarks was calculated. Groups were considered significantly different from each other if $p \leq 0.05$. This test was performed on Excel's add in Resampling (Resampling Stats 1999).

To facilitate cluster interpretation, Q- and R-mode classifications were related to each other using nodal analysis, which determines species-collections coincidences (BOESCH, 1977). Nodal analysis related dendrograms to each other, by calculating the frequency of occurrence and transformed average abundance of species within sample groups, providing a near tridimensional space to interpret species-habitat relationships (ROSSI-WONGTCHOWSKI & PAES, 1993).

Indicator Values (IndVal) were calculated for all 32 species, in order to identify indicator species for typologies of ecological samples obtained by Q-mode classification. Species presenting significant IndVal lower than or equal to 0.5 ($p \leq 0.05$) were considered as indicators of the sample groups. Calculations used sample groups derived from cluster analysis and followed DUFRENE & LEGENDRE (1997). All values were tested with 10,000 Monte Carlo permutations. IndVal calculations and statistical tests were performed on PCOrd for Windows, version 3.0 (McCUNNE & MEFFORD, 1997).

The transformed data matrix was also submitted to Principal Component Analysis where both sample and species gradients were analyzed along the resulting Canonical Axes. Analyses were carried on CANOCO for Windows v.4.0 (TER BRAAK & SMILAUER, 1998).

Shannon-Wiener (H) and Simpson (D) diversity (SIMPSON, 1949) were compared among classification groups and tidepools using the averaged species abundances within classification groups or pools. Renyi's graphic ordination method was used to check whether groups or pools were comparable (RENYI, 1961). If the resulting diversity patterns are parallel to each other, species diversity may be compared, whereas when lines cross each other, no comparisons are possible. Differences among average diversity were statistically tested with bootstrapping following the model proposed by SOLOW (1993). For all procedures the Species Diversity and Richness v.2.3 software was used (Henderson and Seaby, Pisces Conservation, ltd., 1998).

RESULTS

The physical descriptors of each of the examined tidepools are presented in table I. All pools had nearly the same area, ranging between 185 to 194 m², but pool volume differed considerably, especially between pool 1 (deepest) and 3 (shallowest). With respect to substrate cover, Iparana pools tended to present a greater proportion of bare rock and rock covered with algae, whereas Pecém pools had a greater proportion of rock covered with algae (pool 3) and sand (pool 4). Pools 1 and 4 apparently showed a greater habitat complexity represented by a greater frequency of occurrence of crevices and holes as compared to the other pools examined (Tab. I).

A total of 8,914 fishes, from 25 families, 32 genera and 43 species, were recorded through visual censuses. *Sparisoma* spp. (*S. axillare* (Steindachner, 1878) or *S. frondosum* (Agassiz, 1831), following MOURA *et al.*, 2001) was the most abundant taxon, followed by *Haemulon parra*, *Acanthurus chirurgus* and *Abudefduf saxatilis*. Together, they comprised 74.53% of the total fish recorded. In terms of number of individuals, Haemulidae was the most abundant family, comprising 34% of the total abundance followed by Scaridae (26%), Acanthuridae (16%) and Pomacentridae (10%). Haemulidae was also the most speciose family with 7 species, followed by Lutjanidae (5 species) (Tab. II).

Iparana pools 1 and 2 showed lowest fish abundance (1,480 and 1,356 respectively) as compared to Pecém pools 3 and 4 (2,912 and 3,179 fishes recorded respectively). On the average, fish densities were three times greater at Pecém than at Iparana. Pecém pools also attained the highest species richness with 34 and 29 species, respectively (Tab. II).

Q-mode cluster analysis identified two major sample groups showing significant locality (Pecém vs. Iparana) related differences at similarities lower than 1.5. For exploratory purposes, these groups were subdivided into two groups each, as shown in the nodal diagram (Fig. 2). Groups A and B were formed by samples from Pecém Pools 3 and 4, respectively. Group C included nearly all Iparana samples, whereas group D was composed by

Table I. Descriptive physical characteristics of tidepools at Iparana and Pecém beaches, State of Ceará, Brazil, from June 1998 to June 2000.

Descriptive Characters	IPARANA		PECÉM	
	Pool 1	Pool 2	Pool 3	Pool 4
Distance from Shore (m)	160	150	75	100
Area (m ²)	190	185	194	194
Volume (m ³)	133	102	68	95
Maximum Depth (m)	1.4	1.1	0.7	1.0
Percent Coverage				
Sand-rubble	7	6	15	56
Bare Rock	58	37	10	26
Rock covered with algae	35	57	75	18
Complexity				
Pebbles	low	moderate	moderate	low
Caves	high	low	low	high
Holes	high	low	low	moderate

samples from June, August and September in Pool 3 and June in Pool 4, showing less evident temporal patterns (Fig. 2).

Species Groups (R-mode cluster analysis) were not statistically different from each other (Tab. III). However, distinct dominance could be detected among the surveyed pools (Fig. 2). For descriptive purposes we refer to the four species Groups discriminated in table II and figure 2, in spite of their apparent lack of ecological significance.

Groups 1 and 3 gathered species that were found almost exclusively in Pecém pools, with the exception of *Acanthurus coeruleus* Bloch & Schneider, 1801 and *Mugil curema* Valenciennes, 1836 from group 3, and *Haemulon plumierii* (Lacepède, 1801) and *Sphoeroides testudineus* (Linnaeus, 1758), from Group 1, which occurred only occasionally at Iparana. The occurrence of species from group 3 was sparse among both sampling sites. *Acanthurus coeruleus* Bloch & Schneider, 1801, *Halichoeres brasiliensis*, *Haemulon plumierii*, *Haemulon steindachneri* (Jordan & Gilbert, 1882), *Holocentrus adscencionis* (Osbeck, 1765), *Eucinostomus lefroyi* (Goode, 1874), *Anisotremus surinamensis*, *Sphoeroides testudineus* and *Serranus flaviventris* (Cuvier,

1829), from Group 1, were recorded in both pools in Pecém (groups A and B).

Group 2, composed by *Eucinostomus* spp., *Engraulidae*, *Lutjanus jocu* (Bloch & Schneider, 1801) and *Gymnothorax vicinus* (Castelnau, 1855) was observed mainly at Iparana Pools, with *G. vicinus* and *Eucinostomus* spp. being sporadically found at Pecém. The presence of these species at Iparana was more pronounced in June, August and September (samples from Group D).

Species clustered at Group 4 could be divided in central (widely distributed) and periferic (with a more restricted distribution) components (*sensu* HANSKI, 1982). *Abudefduf saxatilis*, *Sparisoma* spp., *Lutjanus apodus* (Walbaum, 1792), *Haemulon parra* and *Acanthurus chirurgus* were frequently recorded on both localities, constituting a sub-group of ubiquitous species. *Pomacanthus paru* (Bloch, 1787) and *Labrisomus nuchipinnis* (Quoy & Gaimard, 1824) were also found in all pools at lower abundances, whereas *Anisotremus* species, *Pareques acuminatus* (Bloch & Schneider, 1801), *Acanthurus coeruleus* and *Haemulon steindachneri* occurred almost exclusively at Pecém (Fig. 2).

Although intra-site differences regarding species occurrence were not significant, some discrepancies could

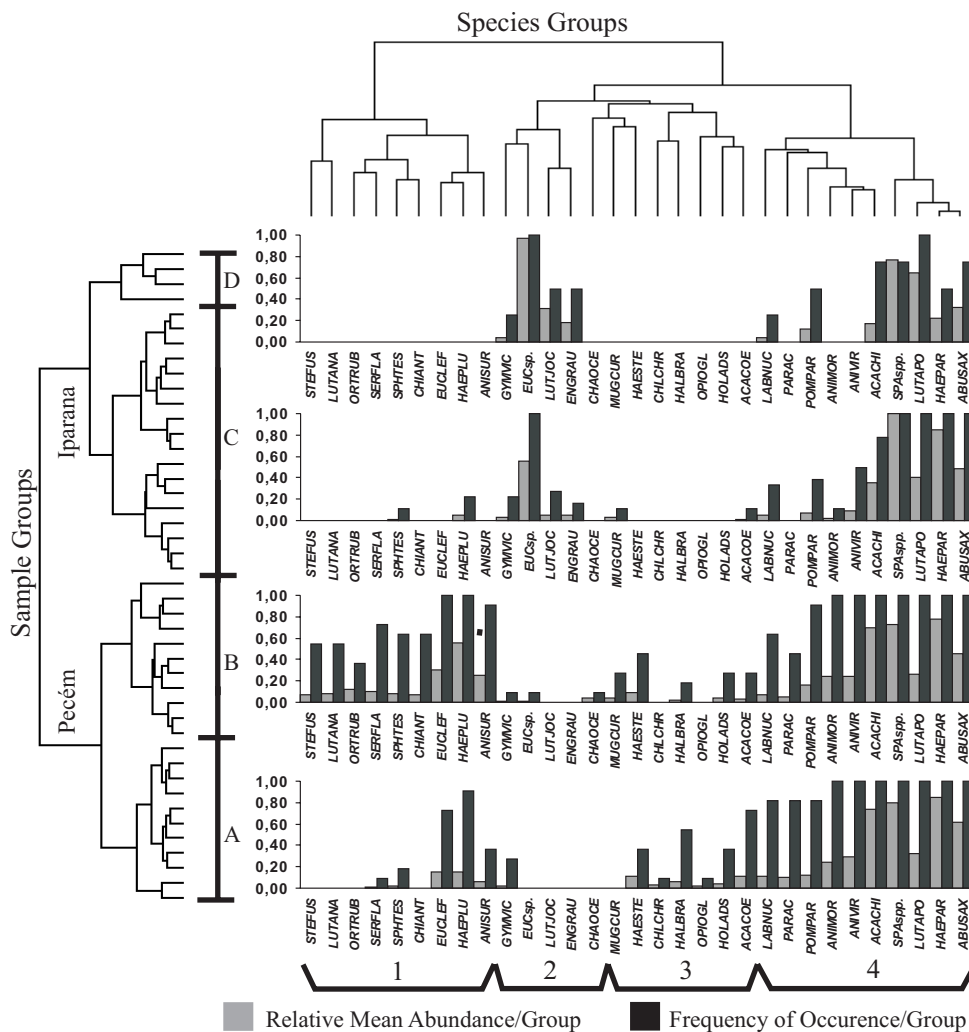


Fig. 2. Nodal diagram showing species and sample groups and relative mean abundance and frequency of occurrence of species per sample groups at Iparana and Pecém beaches, State of Ceará, Brazil, from June 1998 to June 2000.

Table II. List of family/taxon and their respective codes and numerical abundance per tidepool, location and pooled total numerical (N) and percent (%) abundance. Bottom shows total abundance and total number of species at Iparana and Pecém beaches, State of Ceará, Brazil, from June 1998 to June 2000.

FAMILY/TAXON	IPARANA					PECÉM				Pooled Total	
	Group	P1	P2	Total	%	P3	P4	Total	%	N	%
HAEMULIDAE		334	349	683	7.65	1266	1091	2357	26.40	3040	34.06
<i>Haemulon parra</i> (Desmarest, 1823)	4	323	327	650	7.28	634	804	1438	16.11	2088	23.39
<i>Haemulon plumieri</i> (Lacepède, 1801)	1	1	11	12	0.13	333	32	365	4.09	377	4.22
<i>Anisotremus virginicus</i> (Linnaeus, 1758)	4	9	9	18	0.20	68	102	170	1.90	188	2.11
<i>Anisotremus moricandi</i> (Ranzani, 1842)	4	1	2	3	0.03	57	70	127	1.42	130	1.46
<i>Haemulon steindachneri</i> (Jordan & Gilbert, 1882)	3	0	0	0	0.00	36	70	106	1.19	106	1.19
<i>Anisotremus surinamensis</i> (Bloch, 1791)	1	0	0	0	0.00	78	13	91	1.02	91	1.02
<i>Orthopristis ruber</i> (Cuvier, 1830)	1	0	0	0	0.00	60	0	60	0.67	60	0.67
SCARIDAE		531	498	1029	11.53	558	723	1281	14.35	2310	25.88
<i>Sparisoma</i> spp.	4	531	498	1029	11.53	558	723	1281	14.35	2310	25.88
ACANTHURIDAE		123	83	206	2.31	523	664	1187	13.30	1393	15.60
<i>Acanthurus chirurgus</i> (Bloch, 1787)	4	121	82	203	2.27	519	642	1161	13.01	1364	15.28
<i>Acanthurus coeruleus</i> Bloch & Schneider, 1801	3	2	1	3	0.03	4	22	26	0.29	29	0.32
POMACENTRIDAE		127	118	245	2.74	225	431	656	7.35	901	10.09
<i>Abudefduf saxatilis</i> (Linnaeus, 1758)	4	126	118	244	2.73	216	431	647	7.25	891	9.98
<i>Stegastes fuscus</i> (Cuvier, 1830)	1	0	0	0	0.00	8	0	8	0.09	8	0.09
<i>Stegastes variabilis</i> (Castelnaud, 1855)		1	0	1	0.01	1	0	1	0.01	2	0.02
LUTJANIDAE		109	129	238	2.67	107	127	234	2.62	472	5.28
<i>Lutjanus apodus</i> (Walbaum, 1792)	4	93	116	209	2.34	89	127	216	2.42	425	4.76
<i>Lutjanus jocu</i> (Bloch & Schneider, 1801)	2	16	13	29	0.32	0	0	0	0.00	29	0.32
<i>Lutjanus analis</i> (Cuvier, 1828)	1	0	0	0	0.00	15	0	15	0.17	15	0.17
<i>Lutjanus griseus</i> (Linnaeus, 1758)		0	0	0	0.00	2	0	2	0.02	2	0.02
<i>Ocyurus chrysurus</i> (Bloch, 1791)		0	0	0	0.00	1	0	1	0.01	1	0.01
GERREIDAE		206	155	361	4.04	109	33	142	1.59	503	5.63
<i>Eucinostomus</i> spp.		206	155	361	4.04	1	0	1	0.01	362	4.05
<i>Eucinostomus lefroyi</i> (Goode, 1874)	1	0	0	0	0.00	108	33	141	1.58	141	1.58
POMACANTHIDAE		12	4	16	0.18	31	24	55	0.62	71	0.79
<i>Pomacanthus paru</i> (Bloch, 1787)	4	12	4	16	0.18	31	24	55	0.62	71	0.79
LABRISOMIDAE		5	4	9	0.10	7	20	27	0.30	36	0.40
<i>Labrisomus nuchipinnis</i> (Quoy & Gaimard, 1824)	4	5	4	9	0.10	7	20	27	0.30	36	0.40
ENGRAULIDAE	2	23	2	25	0.28	0	0	0	0.00	25	0.28
SCIANIDAE		0	0	0	0.00	9	16	25	0.28	25	0.28
<i>Pareques accuminatus</i> (Bloch & Schneider, 1801)	4	0	0	0	0.00	9	16	25	0.28	25	0.28
MUGILIDAE		0	11	11	0.12	10	0	10	0.11	21	0.23
<i>Mugil curema</i> Valenciennes, 1836	3	0	11	11	0.12	10	0	10	0.11	21	0.23
SERRANIDAE		2	0	2	0.02	20	2	22	0.25	24	0.26
<i>Serranus flaviventris</i> (Cuvier, 1829)	1	0	0	0	0.00	19	1	20	0.22	20	0.22
<i>Mycteroperca bonaci</i> (Poey, 1860)		0	0	0	0.00	1	1	2	0.02	2	0.02
<i>Epinephelus adscensionis</i> (Osbeck, 1765)		2	0	2	0.02	0	0	0	0.00	2	0.02
TETRAODONTIDAE		1	1	2	0.02	14	2	16	0.18	18	0.20
<i>Sphoeroides testudineus</i> (Linnaeus, 1758)	1	1	1	2	0.02	12	2	14	0.16	16	0.18
<i>Sphoeroides tyleri</i> Shipp, 1972		0	0	0	0.00	2	0	2	0.02	2	0.02
CARANGIDAE		0	0	0	0.00	0	14	14	0.16	14	0.16
<i>Chloroscombrus crysurus</i> (Linnaeus, 1766)	3	0	0	0	0.00	0	14	14	0.16	14	0.16
CHAETODONTIDAE		0	0	0	0.00	13	1	14	0.16	14	0.16
<i>Chaetodon ocellatus</i> Bloch, 1787	2	0	0	0	0.00	9	0	9	0.10	9	0.10
<i>Chaetodon striatus</i> Linnaeus, 1758		0	0	0	0.00	4	1	5	0.06	5	0.06
HOLOCENTRIDAE		0	0	0	0.00	7	6	13	0.15	13	0.15
<i>Holocentrus adscensionis</i> (Osbeck, 1765)	3	0	0	0	0.00	7	6	13	0.15	13	0.15
LABRIDAE		0	0	0	0.00	2	10	12	0.13	12	0.13
<i>Halichoeres brasiliensis</i> (Bloch, 1791)	3	0	0	0	0.00	2	9	11	0.12	11	0.12
<i>Halichoeres penrosei</i> Starks, 1913		0	0	0	0.00	0	1	1	0.01	1	0.01
MURAENIDAE		5	2	7	0.08	1	3	4	0.04	11	0.12
<i>Gymnothorax vicinus</i> (Castelnaud, 1855)	2	4	2	6	0.07	1	3	4	0.04	10	0.11
<i>Gymnothorax funebris</i> Ranzani, 1840		1	0	1	0.01	0	0	0	0.00	1	0.01

Table II. (cont.)

FAMILY/TAXON	IPARANA				PECÉM				Pooled Total		
	Group	P1	P2	Total	%	P3	P4	Total	%	N	%
DIODONTIDAE		0	0	0	0.00	9	0	9	1.10	9	0.10
<i>Chilomycterus antillarum</i> Jordan & Rutter, 1897	1	0	0	0	0.00	9	0	9	0.10	9	0.10
CLUPEIDAE		0	0	0	0.00	0	5	5	0.06	5	0.06
<i>Opisthonema oglinum</i> (Lesueur, 1818)	3	0	0	0	0.00	0	5	5	0.06	5	0.06
GOBIIDAE		0	0	0	0.00	0	4	4	0.04	4	0.04
<i>Bathygobius saporator</i> (Valenciennes, 1837)	rare	0	0	0	0.00	0	4	4	0.04	4	0.04
EPHIPPIDAE		2	0	2	0.02	0	0	0	0.00	2	0.02
<i>Chaetodipterus faber</i> (Broussonet, 1782)	rare	2	0	2	0.02	0	0	0	0.00	2	0.02
ARIIDAE		0	0	0	0.00	0	1	1	0.01	1	0.01
<i>Bagre marinus</i> (Mitchill, 1815)	rare	0	0	0	0.00	0	1	1	0.01	1	0.01
EXOCOETIDAE		0	0	0	0.00	0	1	1	0.01	1	0.01
<i>Hyporhamphus unifasciatus</i> (Ranzani, 1842)	rare	0	0	0	0.00	0	1	1	0.01	1	0.01
OPHICHTHIDAE		0	0	0	0.00	0	1	1	0.01	1	0.01
<i>Myrichthys ocellatus</i> (Kaup, 1856)	rare	0	0	0	0.00	0	1	1	0.01	1	0.01
SCORPAENIDAE		0	0	0	0.00	1	0	1	0.01	1	0.01
<i>Scorpaena plumieri</i> Bloch, 1789	rare	0	0	0	0.00	1	0	1	0.01	1	0.01
Total Number		1480	1356	2836	31.77	2912	3179	6091	68.23	8927	100.00
Total Species		20	17	21		34	29	41		46	

be observed between Pecém Pools (3 and 4), or sample Groups B and A, respectively. The pattern of species composition in both pools was characterized by the occurrence of ubiquitous and accessory species from Group 4, and by exclusive species, recorded only at this site (Group 1). Differences between both pools were restrained to the lower number of species and mean abundances of Group 1 recorded on Pool 4 (*Eucinostomus lefroyi*, *Anisotremus surinamensis* (Bloch, 1791), *Haemulon plumierii*, *Sphoeroides testudineus* and *Serranus flaviventris*), as well as by higher abundances of the accessory species from Group 4, when compared to Pool 3. Nevertheless, despite the low abundances and erratic occurrences, some species from Group 3 were exclusive from Pools 3 (*Mugil curema* and *Chaetodon ocellatus* Bloch, 1787) and 4 (*Chloroschombrus chrysurus* Linnaeus, 1766 and *Opisthonema oglinum* (Lesueur, 1818)).

Most indicator species were related to Pecém groups A (e.g., *Abudefduf saxatilis*; *Anisotremus virginicus* (Linnaeus, 1758); *Anisotremus moricandi*; *Labrisomus nuchipinnis*; *Acanthurus coeruleus*) and B (e.g., *Haemulon plumierii*; *Eucinostomus lefroyi*; *Anisotremus surinamensis*; *Chilomycterus antillarum* Jordan and Rutter, 1897; *Serranus flaviventris*). Indicator species at Iparana groups were *Lutjanus jocu*, *Eucinostomus* spp. and the unidentified Engraulidae (Tab. IV).

The distribution of rare species, which were not included in the previous analyses, followed a pattern similar to the observed in the nodal diagram (Fig. 2). Most of the rare species (*Bagre marinus* (Mitchill, 1815); *Bathygobius saporator* (Valenciennes, 1837); *Chaetodon striatus* Linnaeus, 1758; *Halichoeres penrosei*; *Hyporhamphus unifasciatus* (Ranzani, 1842); *Lutjanus griseus* (Linnaeus, 1758); *Micropoperca bonaci* (Poey, 1860); *Mirichthys ocellatus* Bloch, 1787; *Ocyurus chrysurus* (Linnaeus, 1766); *Scorpaena plumieri* Bloch, 1789; *Sphoeroides tyleri* Shipp, 1972) were found exclusively at Pecém pools, whereas only three (*Chaetodipterus faber* (Broussonet, 1782); *Epinephelus adscensionis* (Osbeck,

Table III. Results of Monte Carlo multiple comparisons between sample groups A-D (top) and species groups 1-4 (bottom) at Iparana and Pecém beaches, State of Ceará, Brazil, from June 1998 to June 2000 (**, highly significant; *, significant; ns, non significant; NC, non-comparable).

	A	B	C	D	
1		NC	0.000 **	0.000 **	A
2	0.697 ns		0.000 **	0.000 **	B
3	0.046 *	0.027 **		0.107 ns	C
4	0.041 *	0.333 ns	0.163 ns		D
	1	2	3	4	

1765) and *Gymothorax funebris* Ranzani, 1840) were exclusive to Iparana. *Stegastes variabilis* (Castelnau, 1855) was observed at both localities (Tab. II).

Principal Component Analysis explained approximately 57% of the total variance among samples and species on the first two axes. The analysis revealed gradients similar to the ones found on previous analyses in this study. The first canonical axis explained 47.0% of the total variance and evidenced locality differences, with positive scores for sample groups C and D (Iparana) and negative scores for groups A and B (Pecém).

The distribution of species groups in the canonical space evidenced the main patterns of fish assemblage segregation among sampling localities. Species Group 2 showed positive loadings on the first axis, and was mostly representative of Iparana pools, with highest positive loadings attained by *Eucinostomus* spp., Engraulidae, *L. apodus*, *G. vicinus* and *L. jocu*. Group 3 also attained positive loadings, with two exceptions (*Haemulon steindachneri* and *Acanthurus coeruleus*), in spite of their slightly higher abundance in Pecém pools (Fig. 3). Groups 1 and 4 did not segregate in the first canonical axis, despite of the small negative trend observed in the loadings of Group 1.

The second canonical axis explained 10.5% of the variance and reflected mainly within locality differences with Pecém pools 3 and 4 (sample groups B and A)

Table IV. Indicator species values (INDVAL) for each taxonomic group within sample groups, and averages (Avg) among groups with respective probability values (P; **, highly significant; *, significant; ns, non significant) Highlighted cells show highest INDVAL values for each taxonomic group at Iparana and Pecém beaches, State of Ceará, Brazil, from June 1998 to June 2000.

SPECIES	ANAGRAM	SAMPLE GROUP				p	
		A	B	C	D		
<i>Eucinostomus</i> spp.	EUCSPP	0	0	60	40	0.000	**
<i>Anisotremus moricandi</i> (Ranzani, 1842)	ANIMOR	54	44	0	0	0.003	**
<i>Abudefduf saxatilis</i> (Linnaeus, 1758)	ABUSAX	52	26	3	17	0.000	**
<i>Haemulon parra</i> (Lacepède, 1801)	HAEPAR	43	34	1	21	0.000	**
<i>Lutjanus apodus</i> (Walbaum, 1792)	LUTAPO	29	20	27	23	0.806	ns
<i>Haemulon plumierii</i> (Lacepède, 1801)	HAEPLU	8	89	0	0	0.000	**
<i>Anisotremus virginicus</i> (Linnaeus, 1758)	ANIVIR	56	38	0	3	0.000	**
<i>Acanthurus chirurgus</i> (Bloch, 1787)	ACACHI	50	40	0	7	0.003	**
<i>Sparisoma</i> spp.	SPASPP	34	27	9	27	0.018	*
<i>Eucinostomus lefroyi</i> (Goode, 1874)	ULAFRO	17	77	0	0	0.000	**
<i>Anisotremus surinamensis</i> (Bloch, 1791)	ANISUR	5	78	0	0	0.000	**
<i>Pomacanthus paru</i> (Bloch, 1787)	POMPAR	28	41	4	5	0.044	*
<i>Serranus flaviventris</i> (Cuvier, 1829)	SERFLA	0	69	0	0	0.000	**
<i>Pareques acuminatus</i> (Bloch & Schneider, 1801)	EQUACC	53	16	0	0	0.006	**
<i>Labrisomus nuchipinnis</i> (Quoy & Gaimard, 1824)	LABNUC	47	12	2	5	0.018	*
<i>Chilomycterus antillarum</i> Jordan & Rutter, 1897	CHIANT	0	64	0	0	0.000	**
<i>Acanthurus coeruleus</i> Bloch & Schneider, 1801	ACACOE	58	4	0	1	0.003	**
<i>Lutjanus analis</i> (Cuvier, 1828)	LUTANA	0	55	0	0	0.002	**
<i>Stegastes fuscus</i> (Cuvier, 1830)	STEFUS	0	55	0	0	0.006	**
<i>Spheroides testudineus</i> (Linnaeus, 1758)	SPHTES	2	50	0	1	0.003	**
<i>Halichoeres brasiliensis</i> (Bloch, 1791)	HALBRA	46	3	0	0	0.005	**
<i>Lutjanus jocu</i> (Bloch & Schneider, 1801)	LUTJOC	0	0	44	3	0.010	**
<i>Haemulon steindachneri</i> (Jordan & Gilbert, 1882)	HAESTE	24	15	0	0	0.224	ns
<i>Orthopristis ruber</i> (Cuvier, 1830)	ORTRUB	0	36	0	0	0.023	*
Engraulidae	ENGRAU	0	0	29	7	0.053	ns
<i>Holocentrus adscensionis</i> (Osbeck, 1765)	HOLASC	17	14	0	0	0.241	ns
<i>Gymnothorax vicinus</i> (Castelnau, 1855)	GYMVIC	7	1	7	7	0.940	ns
<i>Mugil curema</i> Valenciennes, 1836	MUGCUR	0	16	0	4	0.212	ns
<i>Chloroscombrus crysurus</i> (Linnaeus, 1766)	CHLCHR	9	0	0	0	0.628	ns
<i>Chaetodon ocellatus</i> Bloch, 1787	CHAOCE	0	9	0	0	0.574	ns
<i>Opistonema oglinum</i> (Lesueur, 1818)	OPIOGL	9	0	0	0	0.599	ns

Table V. Bootstrap analysis comparing Shannon-Wiener and Simpson diversity among sample groups (a) and among tidepools (b). Top values are average Shannon-Wiener and Simpson D diversity at Iparana and Pecém beaches, State of Ceará, Brazil, from June 1998 to June 2000 (** - highly significant; * - significant; ns - non significant).

V (a) Among Groups	A	B	C	D
Shannon	3.27	3.256	3.217	2.045
Simpson D	27.562	28.091	25.769	11.375
A		0.438 ns	0.280 ns	0.037 *
B	0.407 ns		0.318 ns	0.029 *
C	0.774 ns	0.823 ns		0.048 *
D	0.967 *	0.984 *	0.963 *	

V (b) Among Pools	Iparana		Pecém	
	Pool 1	Pool 2	Pool 3	Pool 4
Shannon	1.744	1.7167	2.2917	1.9848
Simpson D	4.618	4.481	7.278	5.577
Pool 1		0.417 ns	1.000 **	0.955 *
Pool 2	0.591 ns		1.000 **	0.966 *
Pool 3	0.000 **	0.000 **		0.001 **
Pool 4	0.046 *	0.032 *	0.998 **	

DISCUSSION

Our work showed that the taxonomic composition of fish species at Pecém and Iparana was consistent with several studies on tidepool fish fauna in the Brazilian coast (FERREIRA *et al.*, 1995; ROSA & MOURA, 1997; ROCHA *et al.*, 1998; FERREIRA & CAVA, 2001), but differed considerably from ROSA *et al.* (1997) and BARREIROS *et al.* (2004).

Compared to studies conducted elsewhere in the world, the species composition also differed significantly. The appropriate literature indicates that intertidal fish communities tend to be dominated by one or a few species from the families Clinidae (BECKLEY, 1985; BENNETT, 1987; PROCHAZKA, 1996), Tripterygiidae and Gobiesocidae (WILLIS & ROBERTS, 1996), Cottidae (YOSHIYAMA, 1981; GROSSMAN, 1982; MORING, 1986, 1990), and Blenniidae and Gobiidae (GIBSON, 1968; STEPIEN, 1990; VARAS & OJEDA, 1990).

Differences may be attributed not only to species geographical distribution and faunal affinities, but also to processes related to pool size (area and/or volume), height of the pool on the shore, wave action (GIBSON, 1982; GROSSMAN, 1982; PROCHAZKA & GRIFFITHS, 1992;

MAHON & MAHON, 1994; UNDERWOOD & CHAPMAN, 1996; SILBERSCHNEIDER & BOOTH, 2001), and sampling methodology (GIBSON, 1999). The works of ROSA *et al.* (1997) and BARREIROS *et al.* (2004), were conducted with anaesthetics or ichthyocides on small sized rock pools (1.44-20.5 m², 13-49 cm deep), often in the high intertidal. Such methods may be more reliable on small areas since they kill all the fish and provide information on cryptic species such as representatives of Blenniidae, Gobiidae, Labrisomidae and Pomacentridae. However, larger fish may not stay in small high intertidal pools due to dramatic variation in environmental conditions during the day (GRIFFITHS *et al.*, 2003).

The prevalence of coastal reef associated families such as Haemulidae, Sparidae and Acanthuridae indicated that a substantial amount of the fish species pool from Ceará's tropical coast was incorporated into the tidepool fish assemblages (LIMA, 1969; LIMA & OLIVEIRA, 1978; ARAÚJO *et al.*, 2000), as many opportunist or secondary resident species (GRIFFITHS, 2003a) moved into the pools at high tide and became trapped at low tide (GIBSON & YOSHIYAMA, 1999). For instance, HORN *et al.* (1999) pointed out that nearly all coastal fish species may, in one time or another during their life cycle, use intertidal habitats for different purposes, including the search for food and shelter from predators.

Monte Carlo permutation model, cluster and nodal analysis showed significant differences between sites (Iparana x Pecém), and suggested some degree of intra-site heterogeneity, especially at Pecém pools (although the differences were non-significant). This may reflect both larger environmental discontinuities and more localized features, such as pool isolation episodes (GIBSON & YOSHIYAMA, 1999), or environmental complexity (BENNET & GRIFFITHS, 1984; PROCHAZKA & GRIFFITHS, 1992) provided by substrate type and algae cover, both acting isolated or interactively. For instance, the relative importance of estuarine related species (*Eucinostomus* spp. and Engraulidae) for community composition was stronger for Iparana pools, which are located near the mouth of the Ceará River estuary, whereas tropical reef species, such as *Stegastes fuscus* (Cuvier, 1830), *Serranus flaviventris*, *Chaetodon ocellatus*, *C. striatus*, *Myrichthys ocellatus*, were found exclusively at Pecém. The environmental gradient provided by freshwater discharge, and subsequent changes in seawater chemistry and turbidity, could not only directly influence the environmental conditions at the pool areas, but also have a localized effect over the species source-pool, from which the tidepool community would draw its components (FUJI, 1988; METAXAS & SCHEIBLING, 1993; DAVIS, 2000).

These results were further supported by PCA with the segregation of Iparana and Pecém along the first component, and Pecém pools 3 and 4 on the second. Iparana related groups 1 and 2 (not significantly different) had no Indicator species but the estuarine *Eucinostomus* spp. This further supported the hypothesis of a greater contribution from the Ceará river estuary to the fish composition of tidepool assemblages at the neighboring Iparana reef. However, *Eucinostomus lefroyi* was also an important component at Pecém and *Bagre marinus*, another estuarine related species, was found exclusively

at that site. *Mugil curema* also occurred sporadically at both sites. Therefore, estuarine forms would thus be an important component of tidepools at both surveyed areas, but *taxon* might vary according to species turnover and local sporadic availability of some species.

On the other hand, the non-significant intra-site differences suggest that the fish access to the pools may be, to some extent, also relayed on a stochastic process (GIBSON & YOSHIYAMA, 1999). Factors such as algae or benthic cover and reef complexity may be more important for cryptic and site-attached species (BENNET & GRIFFITHS, 1984; PROCHAZKA & GRIFFITHS, 1992; SILBERSCHNEIDER & BOOTH, 2001; GRIFFITHS, 2003b), a portion of the fish community that was not properly assessed by the methodology employed here (ENGLISH *et al.*, 1994; GIBSON, 1999). Furthermore, the high proportion of transient species recorded reinforces the idea that there are few, if none, habitat choices during the fish arrival into the pools at high tides. Site-attached fish may stay longer if the habitat conditions, or environmental complexity, are suitable for colonization, and could provide the non-detected intra-site differences. The overall environmental complexity, evaluated based on substrate complexity and algae cover, differed among the surveyed pools. However, despite the significant inter-site differences in species diversity, pools at both localities presented high substrate complexity (Iparana pool 1) and algae coverage (Pecém pool 3 and Iparana pool 2). This reinforces the idea that a proper assessment of the whole fish community should be made with more than one sampling method, in order to determine the true importance of cryptic forms to local diversity and community structure.

The flooding of tidepools during high tides, which provides the access to fish to this ecosystem, is dependent upon factors such as tidal amplitude, local reef topography and distance from shore line (METAXAS & SCHEIBLING, 1993; MAHON & MAHON, 1994; DAVIS, 2000). Our results showed that higher diversity and abundance was attained at Pecém, where pools were shallower and closer to shore. These results contrasted with the findings of GIBSON (1982), PROCHAZKA & GRIFFITHS (1992) and MAHON & MAHON (1994) who suggested that larger pools in the low intertidal might be richer and have a higher proportion of transient species than small high intertidal pools (GIBSON & YOSHIYAMA, 1999). UNDERWOOD & CHAPMAN (1996) observed that pool location in relation to tidal movement rather than pool size may be more important for determining community structure and biodiversity. GRIFFITHS *et al.* (2003) observed that the vertical elevation of rockpools in the intertidal zone influenced the fish assemblage structure of individual rockpools.

Seasonal trends were not detected in our results. This was expected since seasonal environmental changes in tropical areas are more subtle than in temperate waters. BARREIROS *et al.* (2004) found consistent seasonal trends in tidepool ichthyofauna at higher latitude sites in Brazil. Nevertheless, we have not looked into length frequency distributions of fishes. This could show that individual species population structure did not remain constant and that different life history stages used the tidepools throughout the year. In fact, recruits of Haemulidae occurred at certain times of the year (personal observation). Future

studies should address this aspect and further relate patterns with local environmental seasonality.

Abundance estimates through visual census may be biased due to lower counts of cryptic species (ENGLISH *et al.*, 1994; GIBSON, 1999). Nevertheless, the use of anaesthetics or ichthyocides may not be appropriate in larger pools due the high volume and cost of solution required to treat the pool, and the possible impacts on adjacent areas due to dispersion of the compounds. In such cases, visual census with snorkeling may be a more appropriate method. MORING (1993) and GIBSON & YOSHIYAMA (1999) observed that visual census surveys provided a reliable account of the fish community on tidepools, comprised mostly of young partial residents using these habitats as nurseries. Furthermore, the use of visual census may be very appropriate on easily accessible and highly impacted areas. These are non destructive, low cost, easy to conduct methods that may be replicated several times, at different locations for comparisons, providing an advantage for monitoring areas in which tourism and fisheries have already reduced fish populations (CHRISTENSEN & WINTERBOTTOM, 1981; ENGLISH *et al.*, 1994; FERREIRA *et al.*, 1995; WILLIS, 2001).

Although we could not relate these disparities to any of the previously mentioned factors, we believe that human impact could also be an important component determining the variability of fish assemblages in these localities. Intertidal fishes occupy a variety of microhabitats within the reef structure including tidepool waters, patches of seaweed and rock crevices (HORN *et al.*, 1999). As much as reefs are susceptible to human access, intertidal fishes are quite vulnerable to overexploitation and habitat degradation due to pollution and people trampling over the reefs (BRYANT *et al.*, 1998; HORN *et al.*, 1999). On weekdays, artisanal fishers and fish collectors visit the reefs harvesting species from tidepools. We estimated an average of 25 people on the reefs on our monthly visits, either fishing or collecting bait, ornamental fishes or live rock. On weekends, at low tide, tourists and bathers use tidepools for swimming and snorkeling, doubling the number of people on the reef (personal observations). On the other hand, human influence was lower at the locality of Pecém, at the time of our study. We found average daily frequencies of five people visiting the reefs during our study and, other than fishers and occasional swimmers, no other form of exploitation was recorded. The lowest diversity at Iparana tidepools may be a response to the continuous exploitation of intertidal fishes and the reef fauna there. In fact, SYMS & JONES (2000) found that persistent habitat disturbance may cause irreversible changes in fish communities, leading to the extinction of marine populations, including fishes (DULVY *et al.*, 2003). Also, GOMES *et al.* (1995) stated that any changes in the community structure might first be detected through the patterns of abundance of the rare and "satellite" species (*sensu* HANSKI, 1982). In this survey, both sites shared the same ubiquitous (Group 1), or better adapted species, which comprised the core of Iparana tidepools fish community. The lack of many species found at Pecém pools might be a reflection of a medium to long term impoverishment process, related not only to direct human

impacts over the reef area, but also to indirect effects on the Ceará River, and the consequent loss of water quality at nearby coastal areas.

Another example of human impact on tidepool fish communities was the construction of an offshore port facility at Pecém, which started in 1996. The abrupt changes in the coastline altered the local dynamics of sediment transport, which resulted in beach accretion and sand deposition over the reefs, totally filling the tidepools in 2002. Reefs were not exposed since then (personal observation). Our results also showed that it also contributed to a subtle loss of a *quasi* pristine environment, as well as a moderately diverse fish community. Some consequences of these changes are predictable up to a point. As fewer habitats are available to tidepool fishes, we suggest that fish biodiversity may be reduced within certain limits. However, we may not predict, at this stage, what will be the consequences for the recruitment of certain species, or the maintenance of local populations of fishes. Since tidepool ichthyofauna may vary between and within reef sites, conclusions taken from one area may not be generalized to other adjacent sites, and damages caused to one area may not necessarily be mitigated by the maintenance and protection of another area.

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