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# Impact of the Construction of the Harbor at Pecém (Ceará, Brazil) upon Reef Fish Communities in Tide Pools

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## ABSTRACT

*This study aimed to assess the impact of harbor construction at Pecém (Brazil) upon the reef fish communities in tide pools. The monitoring was carried out through a visual census and sea water quality was evaluated by microbiological analyses. From March to December 2001, 1,425 individuals of 17 families and 25 species were registered. The most frequent species were Haemulon parra, Acanthurus chirurgus, Abudefduf saxatilis and Sparisoma axillare. The average species diversity for the whole period was 1.77 bits.ind $^{-1}$. There was evidence that the tide pools gradually silted up, resulting in a reduction in species diversity and richness. The microbiological analyses indicated the presence of faecal coliforms in the water though not at significant levels. The present study could be useful as an early reference for future projects, using the fish communities as indicators for the impact upon the environment of the harbor construction and other human activities.*

**Key words**: marine fishes, environmental changes, sand dredging

## INTRODUCTION

In spite of their acknowledged ecological importance, reef structures around the world are still being directly or indirectly damaged by the human activity. They are being degraded by the large-scale environmental changes caused by variations in temperature, sediments originated from deforestation, pollution, waste, agrochemicals and other forms of discharge. The environmental impact suffered by these habitats is often potentialized by predatory fishing, overexploitation, coastal pollution, anchorage and so forth (White et al., 1994).

Poorly regulated real estate developments along the Brazilian coast have seriously changed the life of the communities relying on the coastal environment for their survival. This is particularly true for the larger building projects such as harbors. The building of a harbor brings with it a range of sedimentological and geomorphological problems (*e.g.* Morais, 1972; Neumann-Leitão, 1994; Neumann et al., 1998). Once operative, a harbor inevitably changes the physical, chemical and biological conditions of the surrounding area,

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sometimes affecting biological communities as well (*e.g.* Sheppard, 1980; Neumann-Leitão and Matsumura-Tundisi, 1998; Neumann-Leitão et al., 1999; Koening et al., 2003).

Very few studies have been published dealing with the impact of harbor construction upon reef fish communities (*e.g.* Adjeroud et al., 2000). The construction of the harbor at Pecém, as part of a larger industrial development zone, has caused considerable changes in the natural environment (Silva, 1997). The analysis of the oils and greases, solids in suspension, parameters physicist-chemistries and faecal coliforms can be used as parameters to evaluate the environmental degradation on port regions (Silva et al., 2000). It is therefore of a great public health concern that these areas are periodically evaluated in regard to their level of microbial contamination (Vieira et al., 2001). The sea pollution results in an increased risk in the recreational use of the beaches since it represents a threat for swimmers, surfers and for the people who depend on ocean resources (Vieira et al., 1998). Local wave patterns have changed leading to extensive sedimentation on the lee side of the harbor structure, as well as to changes in the coastline, erosion and the silting up of adjacent areas (Ceará, 1996).

The objective of the present study was to assess the impact of the construction of the harbor at Pecém (Ceará, Brazil) upon the reef fish communities in local tide pools.

## MATERIAL AND METHODS

The area of study, Praia de Pecém, is a stretch of coastline 65km west of Fortaleza (Ceará, Brazil) under the jurisdiction of the municipality of São Gonçalo do Amarante. The coastline features predominantly quartzitic rock outcroppings of unknown geological age. The rocks, which are rich in iron oxides (ilmenite and hematite) are distinctly layered and display some cross-lamination and stratification (Smith and Morais, 1984). The study included three tide pools 1 km west of the Pecém harbor structure. The three pools, which were at an equal distance from the surf zone, were completely cut off from the sea during the low tide. At the beginning of the experiment, the tide pools had a surface area of 156.0 $m^2$ (pool 1), 48.0 $m^2$ (pool 2) and 120.0 $m^2$ (pool 3); the depth ranges of the pools were 0.2-1.2 m, 0.3-1.0 m and 0.2-0.5 m, respectively. Pools 1 and 2 were physically similar with large, mostly rocky surfaces covered by algae, while pool 3 was already partly silted up, with few remaining rocky crevices and algae.

The fish were counted by underwater visual censuses using intense search, by which a diver determined a fixed itinerary covering the entire area of the study during a pre-established period of time (approximately 30 min in this study). The species identification was always performed in daylight since tide pools in this area allowed for observing the night-active species during daytime as well (Carvalho, 2000). The divers used plastic writing boards for taking down the information on the place and date of sampling, tides, species identification, number of individuals observed and other relevant data. The species were identified visually, but the individuals of uncertain identity were excluded from the data analysis.

From March to December 2001, a total of 17 visual censuses were carried out: one for each tide pool in August, November and December, and two for each pool in the remaining months as the tides were more favorable. The censuses were scheduled for the spring tides up to 0.4 m in order to maintain the pools isolation from the sea. The data analysis used average census values in order to minimize the potential errors derived from the differences in the sampling frequency. In January 2002, the location was visited and there was no tide pools, since they were completely silted up.

The ecological indicators were developed using the indices of diversity (H´) (Shannon and Winner, 1949), richness (R) (Margalef) and eveness (J´) (Pielou, 1969). The calculations were done using the software Basic Spdivers. Bas.

The fish found in the tide pools were characterized by the categories described by Rosa et al. (1997) and modified by Crabtree and Dean (1982): primary residents – the adults and juveniles present throughout the year; secondary residents – only the juveniles observed throughout the year; occasional visitors – fish visiting tide pool areas from the adjacent waters during the high tide; rares or infrequent visitors– fish occurring very sporadically in tide the pools. The fish were considered juveniles when small in comparison to known maximum sizes and/or when displaying the colors and shapes associated with the juvenile stage. The categories of the species frequency were defined afterwards based on the census patterns, i.e the species were grouped for frequency only by the time of data analysis. Four

categories were employed in the present study: very common (>90%), common (51-90%), occasional (21-50%) and sporadic (<21%).

For the microbiological analysis, 500 mL tide pool water samples were collected in amber-colored, sterilized vials and brought immediately to the Microbiology Laboratory of the Marine Sciences Institute (LABOMAR/UFC). The multiple tube technique was used with the protocol described by Mehlman et al. (1984). The most probable number (MPN) of the total and faecal coliforms was estimated following the guidelines of the Bacteriological Analytical Manual (FDA, 2001).

The amount of sediments in the pools was estimated in centimeters by measuring the reductions in maximum depth with a measuring tape.

## RESULTS

Between March and December 2001, the divers counted 1,425 fish belonging to 25 species and 17 families in the three pools (Table 1). Pools 1 and 2 characterized by the large, rocky surfaces covered with the algae accounted for 897 and 351 individuals, respectively, while pool 3 which was mostly silted up accounted for only 177. The most numerous family was Haemulidae with 42% of the total number of the individuals registered, followed by Acanthuridae (20%), Pomacentridae (17%), Scaridae (15 %) and other families (6 %) (Fig. 1). The most frequently occurring species were *Haemulon parra* (37.19%), *Acanthurus chirurgus* (19.86%), *Abudefduf saxatilis* (16.84%) and *Sparisoma axillare* (14.39 %) (Table1).

**Table 1 -** Numbers and frequency (absolute and relative) of fish species observed in each tide pool (Pecém, Ceará).

| Species | Pool 1 | Pool 2 | Pool 3 | Total | % |
|---|---|---|---|---|---|
| *Haemulon parra* (Desmarest, 1823) | 377 | 101 | 52 | 530 | 37,19 |
| *Acanthurus chirurgus* (Bloch, 1787) | 145 | 93 | 45 | 283 | 19,86 |
| *Abudefduf saxatilis* (Linnaeus,1758) | 211 | 26 | 3 | 240 | 16,84 |
| *Sparisoma axillare (*Vallenciennes, 1839) | 73 | 80 | 52 | 205 | 14,39 |
| *Bathygobius soporator* (Valenciennes, 1837) | 8 | 8 | 12 | 28 | 1,96 |
| *Lycengraulis grossidens* (Agassiz,1829) | 19 | 5 | 3 | 27 | 1,89 |
| *Anisotremus virginicus* (Linnaeus,1758) | 19 | 5 | | 24 | 1,68 |
| *Anisotremus moricandi* (Ranzani, 1842) | 13 | 2 | 1 | 16 | 1,12 |
| *Haemulon plumieri* (Lacepède, 1802) | 8 | 5 | | 13 | 0,91 |
| *Lutjanus jocus* (Bloch and Schneider, 1801) | 2 | 4 | 1 | 7 | 0,49 |
| *Sphoeroides testudineus* (Linnaeus, 1758) | 1 | 1 | 4 | 6 | 0,42 |
| *Lutjanus apodus* (Walbum, 1792) | 5 | 1 | | 6 | 0,42 |
| *Pareques acuminatus* (Bloch and Schneider, 1801) | 3 | 2 | | 5 | 0,35 |
| *Lutjanus griseus* (Linnaeus,1758) | 4 | | | 4 | 0,28 |
| *Eucinostomos spp* | 2 | 2 | | 4 | 0,28 |
| *Halichoeres brasiliensis* (Bloch, 1791) | | 2 | | 2 | 0,14 |
| *Scorpaena plumieri* (Bloch,1789) | | 1 | | 1 | 0,07 |
| *Myrichthys ocellatus* (Lesueur,1825) | | | 1 | 1 | 0,07 |
| *Muraenidae* | | 1 | | 1 | 0,07 |
| *Mugil curema* (Valenciennes, 1836) | | 1 | | 1 | 0,07 |
| *Lutjanus analis* (Cuvier, 1828) | | 1 | | 1 | 0,07 |
| *Haemulon steidachneri* (Jordan and Gilbert, 1882) | | 1 | | 1 | 0,07 |
| *Dasyatis guttata* (Bloch and Schneider,1801) | 1 | | | 1 | 0,07 |
| *Bagre marinus* (Mitchill, 1814) | 1 | | | 1 | 0,07 |
| *Acanthurus coerulus* (Bloch and Schneider,1801) | 1 | | | 1 | 0,07 |
| not identified | 4 | 9 | 3 | 16 | 1,12 |
| Total | 897 | 351 | 177 | 1425 | 100 |

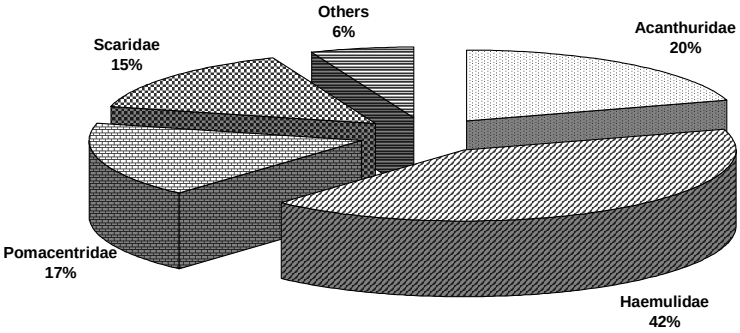


**Figure 1 -** Relative abundance of the fish families in tide pools (Pecém, Ceará) from March and December, 2001.

These findings showed that the category of rare species accounted for as much as 44% of the total number of species, followed by the occasionally occurring species (28%), very common species (16%) and common species (12%) (Fig. 2).

Nine of the species could be classified as occasional (*Bathygobius soporator*, *Lycengraulis grossidens*, *Lutjanus jocu*, *Sphoeroides testudineus*, *Pareques acuminatus*, *Eucinostomus* spp, *Lutjanus analis*, *Mugil curema*, *Bagre marinus*), eight were secondary residents (*Haemulon parra*, *Acanthurus chirurgus*, *Abudefduf saxatilis*, *Sparisoma axillare*, *Anisotremus v*irginicus, *Anisotremus moricandi*, *Haemulon plumieri*, *Lutjanus jocu*), while eight were sporadic (*Lutjanus griseus*, *Halichoeres brasiliensis*, *Acanthurus coerulus*, *Dasyatis guttata*, *Haemulon steidachneri*, Muraenidae, *Myrichthys ocellatus*, *Scorpaena plumieri*).

The diversity, richness and eveness indices decreased in the last two months of the census, probably as a result of the silting up of the tide pools (Fig. 3). The average diversity, richness and eveness for the whole period in the three pools were H' = 1.77, R = 3.31 and J' = 0.55.

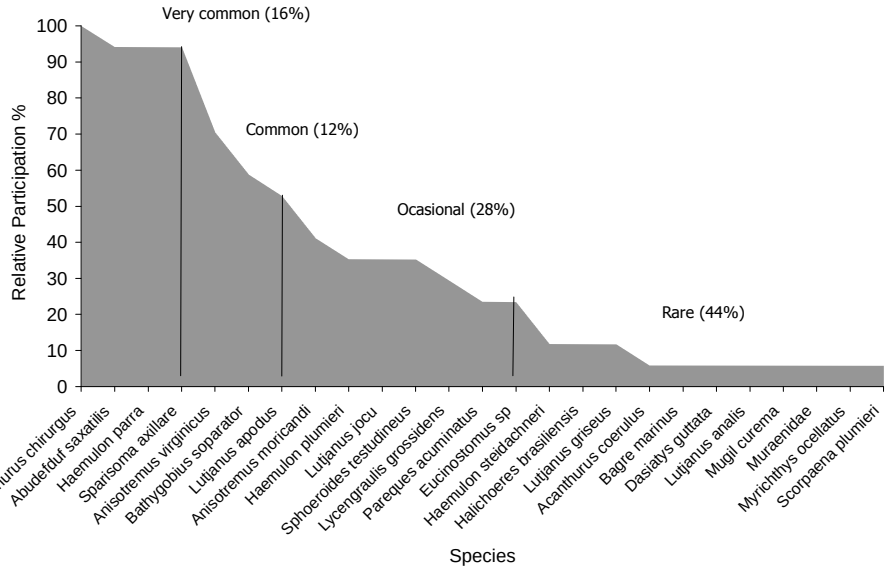


**Figure 2 -** Species frequency patterns in censuses carried out in tide pools (Pecém, Ceará) between March and December, 2001.

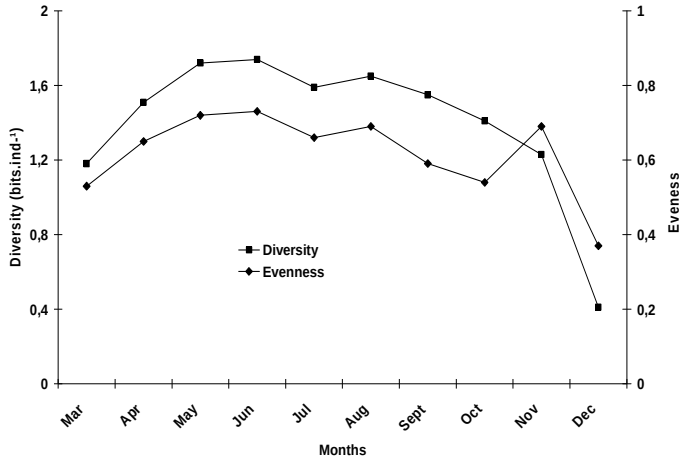


**Figure 3 -** Monthly ecological indices of tide pools in Pecém (Ceará) in 2001.

The microbiological analyses of the tide pool water were performed between March and November 2001, drawing three monthly samples per pool per month (total: 27 samples). All the samples yielded low levels of total coliforms (TC). The pool 1 presented the highest values, especially in the months of March and September (MPN: 230 TC/100 mL), followed by the months of May, July and October (MPN: 90 TC/100 mL). In pool 2, the highest values were observed in March and August (MPN: 150 and 90 TC/100 mL, respectively). For pool 3, the samples drawn in May and September yielded 90 and 230 TC/100 mL, respectively. With regard to the MPN of the faecal coliforms (FC), the highest value observed came from the samples drawn in March from pool 1 (MPN: 230 FC/100 mL). In September, lower values (MPN: 90 FC/100 mL) were registered for pools 1 and 3, and later, in October, for pool 1 (Fig. 4). During the period covered by the study the tide pools at Pecém were gradually silting up. The maximum average depth was reduced from 93.0 cm in March to 35.0 cm in October, and by January 2002 the pools were completely filled up with sediments.

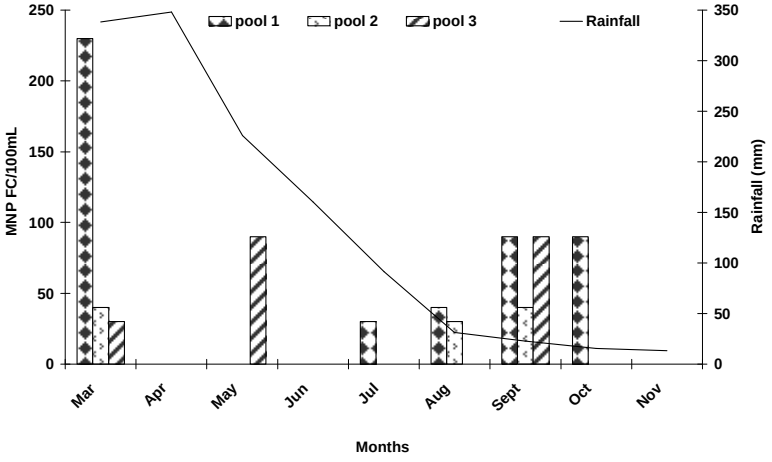


**Figure 4** - Total monthly rainfall and most probable number (MPN) of faecal coliforms (FC) per 100 mL in water samples drawn from tide pools in Pecém (Ceará) between March and December, 2001.

## DISCUSSION

The fish fauna composition depends on a number of factors, including reef location. Studies involving tide pools in Paraíba (Rosa et al., 1997; Silva, 2002) found the families Gobiidae, Blenniidae, Pomacentridae and Labrisomidae to be the most abundant in the region. In the present study, as well as in Carvalho (2000), Cunha at al. (2007) and Cunha et al. (2008), Haemulidae and Lutjanidae were the most abundantly represented families in the tide pools at Pecém and Iparana (Ceará). At the latter location, Gerreidae and Pomacentridae were also relatively abundant (Cunha, 2000). The species most frequently observed in the present study (*H. parra*, *A. chirurgus*, *A. saxatilis* and *S. axillare*) matched with the findings of Carvalho (2000), Cunha (2000), Cunha et al. (2007) and Cunha et al. (in press), the latter suggested the addition of *L. apodus* and *Eucinostomus* species. These seemed to be the most representative intertidal fish species west of Fortaleza, Ceará.

Species distribution is tied up with the reef environment affinity and ecological classification. Classifications basically include the resident, marine-dependent and visiting species and have been supplied with further subcategories by many authors (*e.g.* Crabtree and Dean, 1982; Rosa et al., 1997; Vasconcelos-Filho and Oliveira, 2000). Primary residents in tide pools included *P. acuminatus* and *A. saxatilis*, which were found as both the juveniles and adults, although not throughout the year. The fact that *P. acuminatus* is a wary species while *A. saxatilis* swims freely and non-territorially (Humann, 1999) might have masked their relative abundance in the tide pools at Pecém.

Tide pools are known to serve as nursing grounds for several fish species (Crabtree and Dean 1982). In fact, the presence of the juveniles in the tide pools at Pecém suggested some of the species observed would remain in this habitat during part of or possibly their entire life cycle. These findings showed that the species initially classified as very common became rare towards the end of the study period. The classification by the frequency (ranging from very common to rare) was location-dependent. This has been shown by Feitoza (2001), who found *S. axillare* to be common and *A. saxatilis* and *H. parra* to be occasional residents at the underwater reefs off Risca do Zumbi (Rio Grande do Norte). At Pecém, all the three species were classified as very common. The species diversity index indicates the degree of structural complexity of the community and is considered to be a function of richness and eveness (Omori and Ikeda, 1984). Continuous sedimentation of the environment reduced the availability of shelter and food in the studied tide pools thereby forcing the pool dwellers to move to other areas and leading to reduced ecological indices. The indices reported for Pecém by Carvalho (2000) were somewhat higher (H'= 2.22, R= 4.48 and J'= 0.60), possibly because that study was carried out before the harbor construction with no changed local sedimentological patterns. The diversity index may reflect environmental impacts in several ways. For instance, it may decrease as a result of one or few species dominating the community, or because the individuals of the rare species are replaced by the individuals of more common ones, or because certain species are reproducing more intensely than usual (Omori and Ikeda, 1984). The present findings indicated that the reductions in the fish diversity during the period of the study were caused by the silting up of the environment. The activities of the construction of the harbor in the region led to a loss of the microhabitats capable of offering food and shelter, especially for herbivorous species such as the errant, algae-foraging *A. chirurgus* and *S. axillare* (Moura, 1998). As the pools silted up, the only species observed to increase in the numbers, up to two months before the pools became completely covered by the sediments, were *H. parra* and *A. saxatilis*.

The reef structures offer shelter and food for an impressive array of organisms, such as the communities of small fishes (Sale, 1991). Grunts (Haemulidae) and other groups of fishes which search for the food over sandy bottoms, may become dominant in terms of both biomass and number of individuals (Rosa and Moura, 1997). However, this type of substratum harbors a rich fauna of invertebrates (Hobson and Chess, 1986). Since the grunts thrive on sandy bottoms (*e.g.* Randall, 1967; Sale, 1991; Humman, 1999; Carvalho-Filho, 1999 and Cunha et al., in press), they are likely to benefit more than other groups of the fishes from the increased levels of sedimentation in the tide pools. On the other hand, the turbidity caused by the influx of large amounts of sediments may dislodge the filtering species to areas offering the conditions of visibility required to locate food and ward off the

predators. After the implantation of the Suape Industrial Port Complex in Pernambuco State (Brazil), there was a strong decrease in the phytoplankton density due to high amount of suspended matter (Koening et al., 2003). Modifications of this basin also changed the species composition and trophic structure (Silva et al., 2004). The present study did not observe the presence of microbiological seawater contamination associated with the harbor construction at Pecém. During the monitoring of the tide pools, the level of faecal coliforms did not exceed the limits established by the CONAMA enactment #274 (CONAMA, 2000). According to this law, the seawater is unsuitable for human activities if it contains over 1,000 faecal (thermotolerants) coliforms or over 800 Escherichia coli or over 100 enterococci per 100 mL in more than 20% of samples collected in a five week period in the same place. Likewise, the values of 2,500 faecal (thermotolerants) coliforms or 2,000 Escherichia coli or 400 enterococci per 100 mL observed in the fifth and last sample also make it unsuitable for human activities.The highest levels of the total and faecal coliforms observed in this study came from the water samples from pool 1 during March. Although inserted within the rainy season (January to June in 2001), no other month yielded significant values for the coliform bacilli, suggesting that the rainfalls were not significantly associated with the faecal contamination in the tide pools studied. This observation was similar to that Vieira et al. (1999) in their study of tide pools at Barra do Ceará (an estuary located within the urban zone of Fortaleza). The faecal coliforms in present samples were more likely associated with the presence in the area of fishermen, construction workers and a sewer connected to the harbor construction site. In an earlier analysis, the water samples drawn from the shores of Pecém yielded MPN values in the range 230-430 FC/100 mL (Ceará, 1996). Thus, in the absence of pollution by sewage and waste from the seaside bars and restaurants, the area could be considered suitable for primary human contact, such as bathing. Silva et al. (2000) found no significant signs of pollution by coliforms at Pecém and adjacent areas caused by the harbor construction.

The intense silting up of the area in this study appeared to be the largest the direct impact of the harbor construction upon local tide pool fauna. The phenomenon is commonly observed in the vicinity of artificial harbors and is due to the reflection and refraction of the waves, favoring the rip currents and littoral drift, of the sand dredging and dumping the unwanted sand in the nearby areas (Morais, 1972). At Pecém, the silting was triggered by the building of a temporary terminal required for the unloading of large rocks for the off-shore breakwaters and building material for piers and other structures (Ceará, 1996). As a result of this, the natural transport of the coastal sediments was barred, accumulating east of the pier, while the western coastline was gouged by the erosive forces. A similar pattern was observed when a breakwater (called 'Hawkshaw's Seawall') was built closed to Fortaleza where a new harbor had been projected. The wavebreaker caused the coastline to silt up and the intertidal zone to widen considerably, making impossible to proceed with the harbor construction. However, even when the harbor building project was transferred a couple of miles east to Mucuripe, the silting and erosion continued leading to extensive land losses at Praia de Iracema (Morais, 1981). According to Ceará (1996), the sedimentological changes observed in association with the harbor construction at Pecém could be expected to revert to the original configuration. However, the observations "in loco" two years later showed no signs of reversion. The environmental impact study carried out prior to the construction of the harbor at Pecém provided a list of the fish species occurring in the coastal waters off State of Ceará. This list did not contain any quantitative data or references to the ecosystems.

The present study included the quantitative and qualitative data regarding the fish species occurring in the intertidal zone of the study location. It showed that the increased sedimentation triggered by the building of the harbor at Pecém caused the tide pools to become completely covered by sediments, dislodging at least 25 fish species belonging to 17 families. The water samples from the same area presented faecal coliforms, though not in amounts compromising the human activity. Nevertheless, faecal pollution could become a problem as the local industry and tourism develop and as a result of the emptying of the septic tanks of the anchoring ships. It is hoped that the present study could be useful as an early reference for future projects, using the fish communities as indicators of the impact upon the environment by the harbor construction and other human activities, as well as an aid in the designing

the environmental impact studies. The Tropical Marine Ichthyology Research Group (IMAT) will continue to monitor the area in order to analyze the complete ecological cycle and ascertain whether the tide pools observed in the present study reverted to their original state, including the reestablishment of the fish stocks, as mentioned by the engineers working at the harbor construction site.

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## RESUMO

O objetivo principal desta pesquisa foi estudar os possíveis impactos sobre as comunidades de peixes que vivem em poças de maré na praia de Pecém-CE. O método de censo visual foi utilizado para o registro dos peixes, e a análise microbiológica para verificar a qualidade das águas. No período de março a dezembro de 2001 foram observados 1.425 indivíduos pertencentes a 17 famílias e 25 espécies em três poças estudadas. As espécies mais freqüentes foram *Haemulon parra*, *Acanthurus chirurgus*, *Abudefduf saxatilis* e o *Sparisoma axillare*. A diversidade média de espécies no período foi de 1,77 bits.ind$^{-1}$. Durante a pesquisa foi observado um processo crescente de assoreamento na área de estudo, em decorrência da construção do porto de Pecém. No que concerne à balneabilidade das águas dessa praia, a avaliação não mostrou sinais significativos de poluição microbiológica, embora tenha sido detectada a presença de coliformes fecais. Os resultados desta pesquisa poderão servir como referência pioneira para futuros projetos de monitoramento para áreas que venham a sofrer com atividades de construção portuária.

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