

TOURISM IMPACT ON REEF FLATS IN PORTO DE GALINHAS BEACH, PERNAMBUCO, BRAZIL

Impacto do turismo nos recifes da Praia de Porto de Galinhas, Pernambuco, Brasil

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ABSTRACT

Approximately 60% of coral reefs are currently threatened by several natural and anthropogenic impacts. One of the fastest growing industries in the world and a great producer of organic waste, tourism can have negative impacts on biodiversity and on the functioning of reef ecosystems. This study aimed to find possible anthropogenic impacts related to tourism in reef environments of northeastern of Brazil (Porto de Galinhas Beach, Pernambuco). Water samples were collected for salinity, pH, dissolved inorganic nutrients (ammonium, nitrite, nitrate, phosphate, and silicate), and chlorophyll a analyses during the high and low-season tourism calendar. A greater concentration of ammonium, nitrate, and phosphate was verified during the high tourist season, whereas nitrite, silicate, and chlorophyll a were highest during low tourist season. Trampling and other recreational activities harmful to reefs were also observed in the area.

Keywords: *tourism, nutrients, anthropogenic impacts, Porto de Galinhas Beach.*

RESUMO

Atualmente, cerca de 60% dos recifes de coral estão ameaçados devido a impactos naturais e antropogênicos diversos. Um dos setores empresariais que cresce mais rapidamente no mundo e que produz uma grande quantidade de resíduos orgânicos, o turismo pode trazer impactos negativos na biodiversidade e funcionamento dos ecossistemas recifais. Esse estudo objetivou encontrar possíveis impactos antropogênicos relacionados ao turismo nos ambientes recifais de uma praia do nordeste brasileiro (Porto de Galinhas, Pernambuco). Amostras de água foram coletadas para análises de salinidade, pH, nutrientes inorgânicos dissolvidos (amônia, nitrito, nitrato, fosfato, e silicato) e clorofila a durante a alta e baixa estação turística. Uma maior concentração de amônia, nitrato e fosfato foi verificada durante a alta estação, enquanto o nitrito, silicato e clorofila a tiveram valores mais altos durante a baixa estação. Pisoteio dos recifes e outras atividades de lazer nocivas aos recifes também foram observadas no local.

Palavras-chaves: *turismo, nutrientes, impactos antropogênicos, Praia de Porto de Galinhas.*

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INTRODUCTION

Due to their proximity to big cities and their easy access, reef environments have been heavily affected by human influence (Castro & Pires, 2001) and are destroyed by the very same economic activities they sustain (Wilkinson, 1992; Richmond, 1993). They also receive pollutants by urban, agricultural, and industrial rejects. The presence of tourists and the changes caused to the environment in order to receive them are great threats to marine ecosystems. For example, in the central and southeast Pacific Islands, the removal of corals, sand, and mangroves for construction damages lagoons and reef flats next to big cities; in addition, the roads, airports, and hotels built in these areas negatively impact these environments (Salvat, 2002) and modify the natural overall landscape. Trampling and overfishing are other problems that damage these delicate ecosystems, as observed in Hawaii (Brainard *et al.*, 2002).

Tourism is one of the fastest growing industries in the world, including underwater tourism. Due to their beauty, coral reefs and other reef environments attract hundreds of thousands of tourists and account for a substantial portion of the gross domestic product (GNP) in several countries, such as those of the Caribbean. Nevertheless, unplanned tourism can bring about serious damage to these ecosystems (Bryant *et al.*, 1998).

Such is the case of southern Pernambuco's reef environments, a state in northeastern Brazil whose marine ecosystems suffer heavily from the impact of human activities. Although it is a problem that dates far back, preliminary observations to create the Costa dos Corais Environmental Protection Area - EPA (*Área de Proteção Ambiental Costa dos Corais*) were only carried out in the 1990's, when reefs were found in poor condition near the larger cities. Unfortunately, when the Costa dos Corais Environmental Protected Area was officially created in 1997, the neighboring reef environments of Porto de Galinhas Beach were not included, despite their important coral fauna and the threats to them - only recently this possibility is being discussed.

Nevertheless, years after this protection area was implemented, another study (Steiner *et al.*, 2006) identified several tourism-related problems that threaten the EPA's reef environments: unplanned seaside urban settings, construction of roads and highways to access new tourism-directed enterprises and real estate, changes in the natural landscape (including mangrove deforestation and river transfers), lack of appropriate sanitation and waste

management infrastructure to receive tourists in the high season, air and water pollution from several sources, and direct damage to reefs due to anchoring and trampling.

Like in other regions in Brazil and around the world, tourism has helped promote a large portion of local development in the studied area. Having been repeatedly elected one of the most beautiful beaches in Brazil, tourism has been growing fast in Porto de Galinhas over the past fifteen years. This has created many employment opportunities for the local and bordering population and, thus, tourism has become the main source of jobs and income in the area. However, the lack of planning and organization has generated several problems related to soil use and occupation and the exploitation of the natural resources; this has in turn resulted in ecosystem degradation, especially that of reefs and mangroves.

Nearly 60,000 people arrive at Porto de Galinhas Beach each month during high season and approximately 69% visit the reef formations by walking, snorkeling or scuba diving (MMA/SECTMA/CPRH, 2003). Reef degradation by trampling has been described since 1977 (Woodland & Hooper, 1977) and can limit coral and calcified hydroid presence through physical damage, often causing colony death and overgrowth of other organisms. Trampling also increases sedimentation rates (clogging polyps) and decreases water transparency (affecting zooxanthellae photosynthesis). For the studied area, Barradas *et al.* (2010) observed a higher percentage of bare areas in Porto de Galinhas where people are taken by boat to walk on the reef and practice snorkeling.

In addition to trampling, diving activities can also be very harmful to reef environments - especially when carried out by inexperienced people. This happens due to the damage brought about by hands, the diver's body itself, and the diving equipment and paddle (Epstein *et al.*, 1999; Roupheal & Inglis, 2001). Several studies have related diving practices to damages promoted to reef environments *e.g.* Rogers & McLain Sullo, 1988; Davis & Tisdell, 1995; Allison, 1996; Roupheal & Inglis, 1997; Roupheal & Inglis, 2001; Tratalos & Austin, 2001; Zakai & Chadwick-Furman, 2002). At Porto de Galinhas beach, approximately 1,200 people practice scuba diving each month, and many others practice snorkeling.

Thus, the aim of this study was to relate tourism activities to anthropogenic impacts in the reef environment of Porto de Galinhas Beach by quantifying abiotic conditions, and identifying and describing human activities in the area.

MATERIAL AND METHODS

Porto de Galinhas Beach is located on the southern coast of Pernambuco State (northeastern Brazil), 64 km from its capital city, along which 900-meter long reef formations can be found next to the shore. It has a humid tropical climate with rainy and dry seasons, and a 24°C mean temperature (CPRH, 2001).

Four stations were selected along the reef formation using a GPS (Global Positioning System): 1 - 8°30'73"S, 35°00'43"W; 2 - 8°30'34"S, 34°59'94"W; 3 - 8°30'41"S, 34°59'91"W; and 4 - 8°30'16"S, 34°59'92" W.

Water samples were collected during the low and high tourism seasons, October, 2004 and February, 2005, respectively, both in the dry season. Samples were tested for salinity, pH, dissolved nutrients (ammonium, nitrite, nitrate, phosphate, and silicate), and chlorophyll *a* analyses.

The method described by Strickland & Parsons (1972) and Grasshof *et al.* (1983), was used for the nutrient analyses and UNESCO (1973) for chlorophyll *a* analysis. The pH value was recorded using a Hanna Instrument 8417 potentiometer. Salinity was measured using the method described by Strickland & Parsons (1972). Data was analyzed between seasons using Paired Student's *t* test for the same stations, with Statistica® 6.0 software.

To determine which month had the greatest tourist frequency, human interferences observed in the study area were recorded during visits carried out from October, 2004 to May, 2005 and were photographed for visual evidence.

RESULTS

The human activities observed in the area were: constructions along the beach and as a likely consequence, pronounced erosion, trampling and recreational activities, boat anchoring, collection of material for decoration and aquariums, collection of reef fauna, predatory fishing, mangrove destruction and land filling, sewage discharge directly into the seawater, and great quantities of trash especially plastic. In Brazil, studies on the anthropogenic pressure on reef environments have shown damage due to commercial activities, increase in water turbidity, pollution by sewage, and overfishing *e.g.*, Belém *et al.*, 1986; Coutinho *et al.*, 1993; Leão, 1996; Costa Jr. *et al.*, (2000, 2006); Porto Neto & Marcelino, 2009, Costa *et al.*, 2007 - similar to what was observed in this study.

Table I presents average values for depth, water transparency, water temperature, pH, and

salinity in the four stations studied during low and high tourist season (October, 2004 and February, 2005, respectively).

Table I - Average values for depth, water transparency, water temperature, pH, and salinity in the four stations studied during the low and high tourism seasons (October, 2004 and February, 2005, respectively).

Environmental factors	Low tourism season	High tourism season
Depth	2.5 - 5.0 m	1.5 - 3.5 m
Water transparency	1.75 m	1.90 m
Water temperature	27.7 °C	28.0 °C
pH	8.21	8.45
Salinity	36.38	35.39

The alkaline pH values between 8.2 and 8.4 are characteristic of tropical coastal areas. Salinity showed few variations; Sassi (1991) attributes the high salinity found in the reef environment of Ponta do Seixas (Paraíba State, Northeast Brazil) to the absence of larger rivers in the area. The same is true for the area studied here. The water temperature showed few variations during the period covered, and to Perkins (1974) this homogeneity is associated with the shallow depths characteristic of tropical coastal environments.

The ammonium concentrations observed were significantly different between the two seasons, with a higher average during the high tourist season (Figure 2). No significant differences in the concentrations of nitrate and phosphate were observed between the two seasons, but both showed higher means in February (high tourist season) (Figures 3 and 4). The mean concentrations of nitrite, silicate, and chlorophyll *a* showed significant differences between the two seasons, with higher values during the low tourist season (Figures 5 to 7).

Nutrient concentrations found in this study are similar in value to those found by Machado *et al.*, (2007) in the same region; by Moura & Passavante (1994) at Tamandaré Beach (Pernambuco); and by Feitosa & Bastos (2007) at reef environments of Maracajaú, Rio Grande do Norte. They are all values characteristic of environments free of organic pollution.

The higher values of ammonium, nitrate, and phosphate found in the high tourist season may indicate that the region is receiving a greater supply of nutrients during this period. However, the amount of rain (about 50 mm) at this time of the year was

quite low (Figure 1), which means the large quantity of nutrients might not be due to the influence of rivers or coastal lixiviation. In addition, according to data from Pernambuco's State Environment and Water Resources Agency (*Agência Estadual de Meio Ambiente e Recursos Hídricos - CPRH*), the high values for fecal coliforms underscore the presence of human wastes through rivers, drain channels, and clandestine connections (CPRH, 2001). At Porto de Galinhas Beach, seawater contamination can also occur through percolation due to the sandy soil.

A high percentage of seaweed cover has also been observed in this area (Barradas *et al.*, 2010) and changes in its diversity and/or biomass are seen in impacted environments and hence many species are considered pollution indicators (Hallock *et al.* 1993;

Hallock, 2002; Villaça, 2002). Macroalgal blooms can occur due to higher nutrient concentrations in the water or due to decreases in the populations of herbivorous species. Van Den Hoek (1969) and Foster (1987 *apud* Coutinho *et al.*, (1993) suggest that herbivory – especially that carried out by fish and sea urchins – is necessary for coral reef maintenance. Valentine & Heck (1991) suggest that the abundance of algae is kept low due to the herbivory of sea urchins, which has already been observed by Kilpp (1999) for the reefs of Tamandaré. Barradas *et al.*, (2010) only found 2% sea urchin cover for Porto de Galinhas. The trophic level of inshore waters at Porto de Galinhas varied from mesotrophic to eutrophic and also corroborates studies by Machado *et al.* (2007) and Fonseca *et al.* (2002) for the same locality.

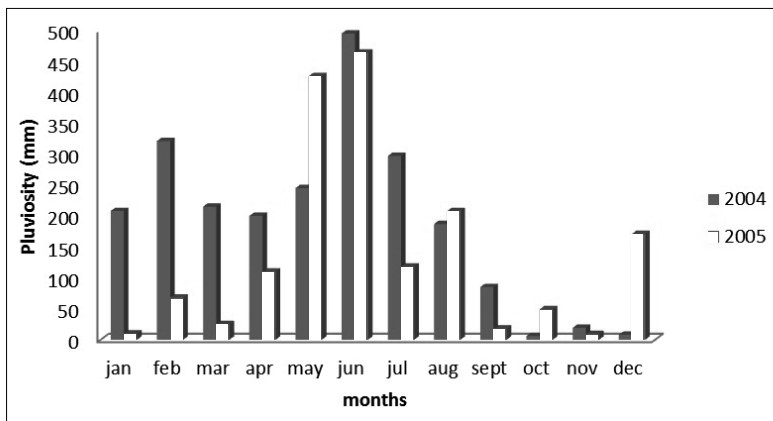
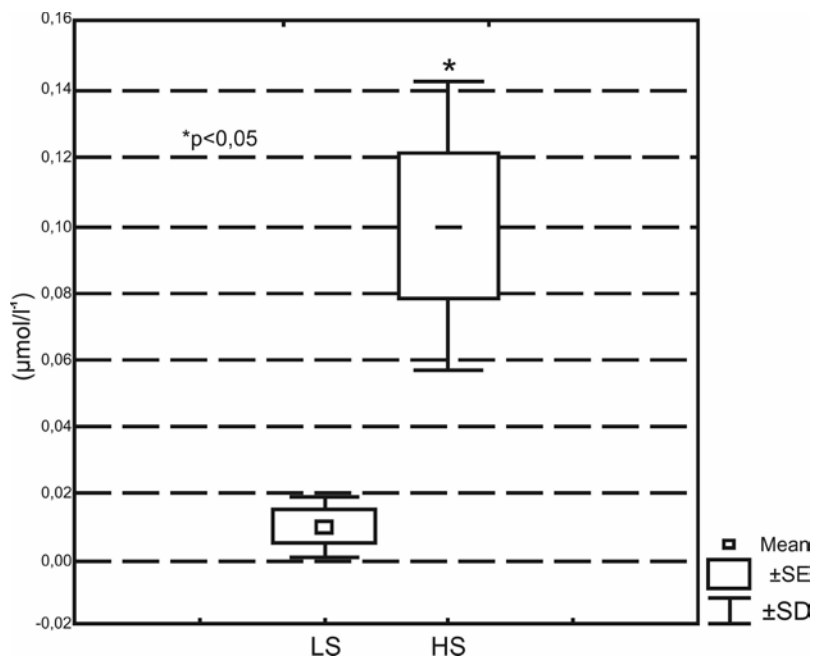


Figure 1 - Rainfall data obtained from the Porto de Galinhas Experimental Station for the years of 2004 and 2005. Source: LAMEPE/ITEP (2010) (a,b).

Figure 2 - Ammonium concentrations at the reef environment of Porto de Galinhas Beach (Pernambuco, Brazil) in October 2004 and February 2005 (LS - low tourist season: $0.01 \mu\text{mol} / \text{l}^{-1}$; HS - high tourist season: $0.10 \pm 0.04 \mu\text{mol} / \text{l}^{-1}$; values shown as Mean \pm SD [$t=-3.65$; $df=3$; $p<0.05$]).



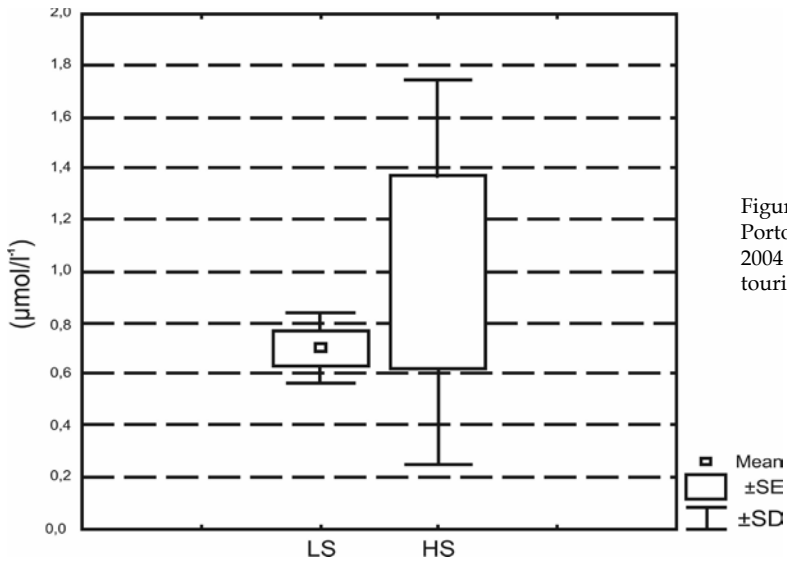


Figure 3 - Nitrate concentrations at the reef environment of Porto de Galinhas Beach (Pernambuco, Brazil) in October 2004 and February 2005 (LS - low tourist season; HS - high tourist season).

Figure 4 - Phosphate concentrations at the reef environment of Porto de Galinhas Beach (Pernambuco, Brazil) on October 2004 and February 2005 (LS - low tourist season; HS - high tourist season).

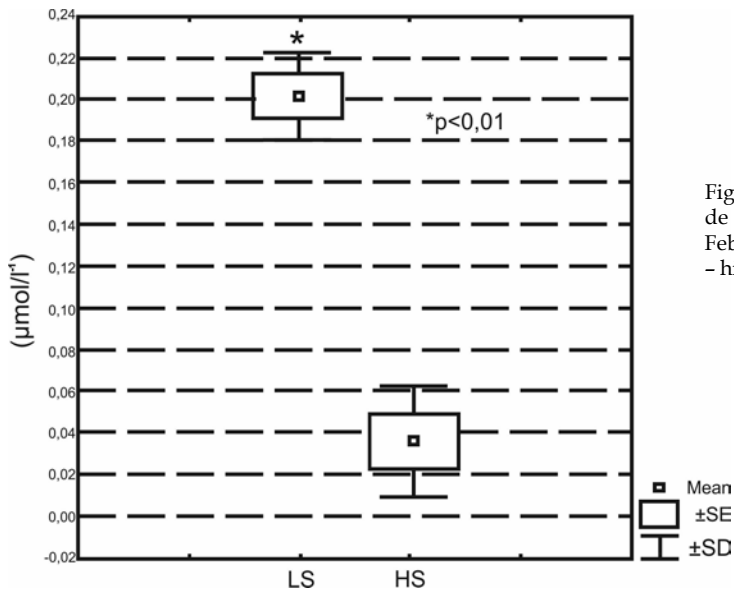
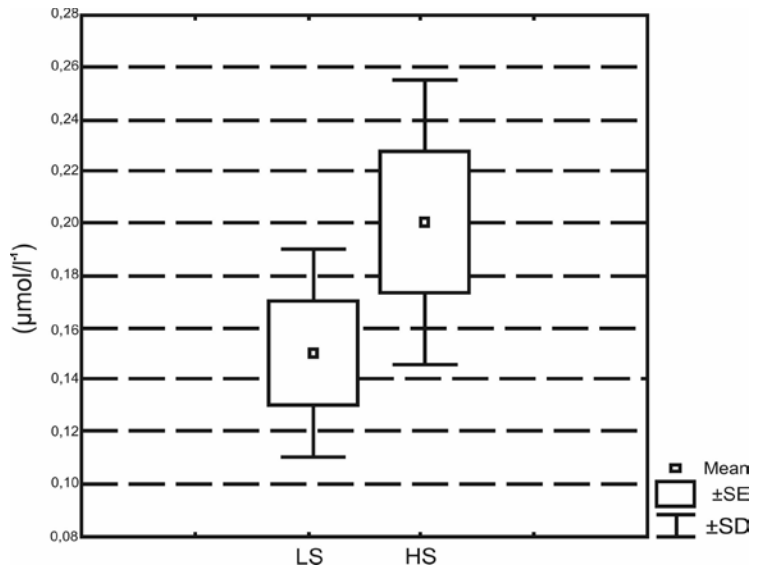


Figure 5 - Nitrite concentrations at the reef environment of Porto de Galinhas Beach (Pernambuco, Brazil) in October 2004 and February 2005 (LS - low tourist season: $0.20 \pm 0.02 \mu\text{mol} / \text{l}^{-1}$; HS - high tourist season: $0.03 \pm 0.02 \mu\text{mol} / \text{l}^{-1}$ [$t=24.8$; $df=3$; $p<0.01$])

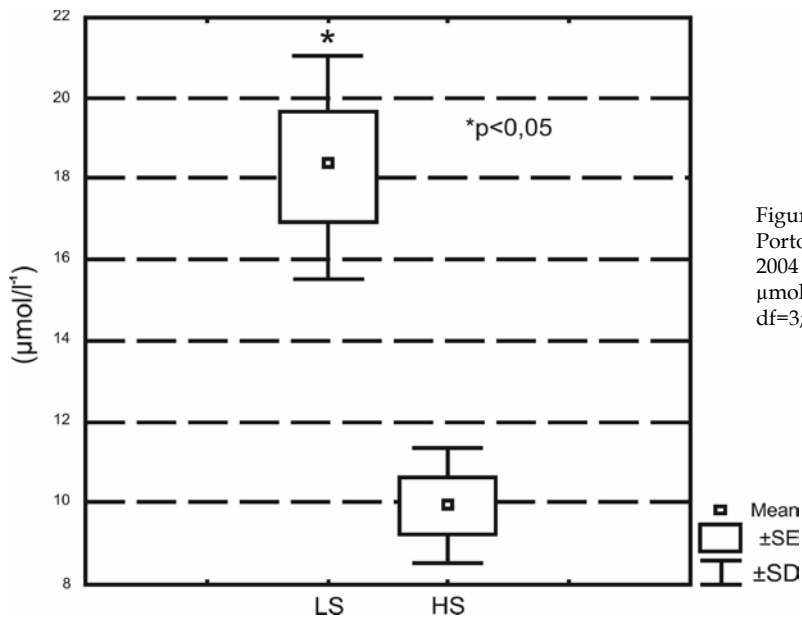
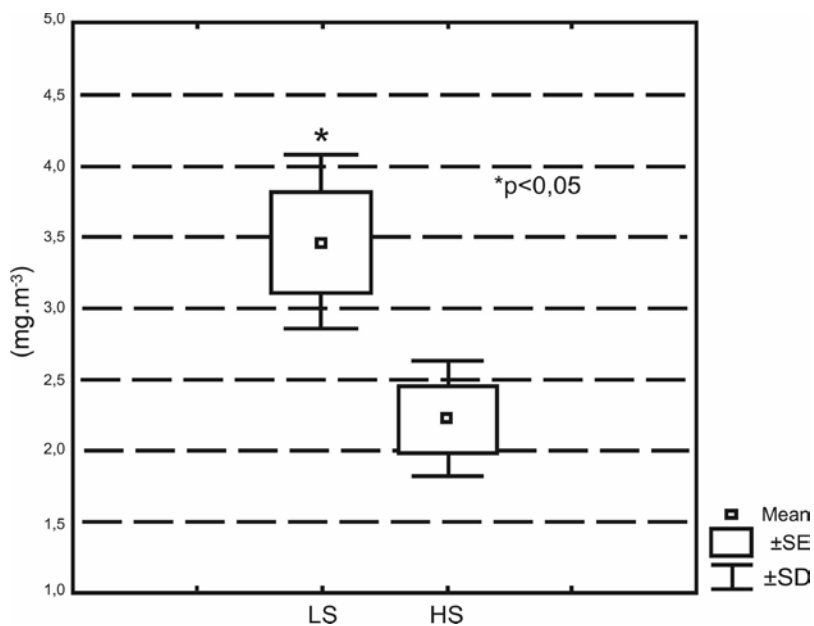


Figure 6 - Silicate concentrations at the reef environment of Porto de Galinhas Beach (Pernambuco, Brazil) in October 2004 and February 2005 (LS - low tourist season: $18 \pm 2.76 \mu\text{mol} / \text{l}^{-1}$; HS - high tourist season: $10 \pm 1.41 \mu\text{mol} / \text{l}^{-1}$ [$t=7$; $\text{df}=3$; $p<0.01$]).

Figure 7 - Chlorophyll a concentrations at the reef environment of Porto de Galinhas Beach (Pernambuco, Brazil) in October 2004 and February 2005 (LS - low tourist season: $3.47 \pm 0.61 \text{ mg} \cdot \text{m}^{-3}$; HS - high tourist season: $2.22 \pm 0.40 \text{ mg} \cdot \text{m}^{-3}$ [$t=8.25$; $\text{df}=2$; $p<0.05$]).



CONCLUSIONS

The reef environment of Porto de Galinhas Beach has been suffering from the effects of unplanned human presence, which has become very common in scenically attractive environments such as these. Data collected here showed that tourism has negatively impacted the area and thus must be accompanied more closely by the relevant regulatory institutions. In order to minimize human anthropogenic stress a few measures could be taken, such as implementing

a sewage collection and treatment system, delimiting areas for boat circulation, to constructing points for boat anchoring, to limiting the number of visitors on the reef per day, providing tourists with correct instructions on how to behave in this environment, prohibiting the collection of marine organisms and predatory fishing, to placing waste baskets along the beach, and improving garbage collection and disposal system.

It is important to note that no interferences will be effective without a good educational

program, since the people who depend on the reef environment for income need to fully understand the importance of that environment in order to contribute to its conservation. Thus, it is necessary that the municipal government participate by supervising the programs implemented.

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REFERENCES

- Allison, W.R. Snorkeler damage to reef corals in the Maldive Islands. *Coral Reefs* v15, p.215-218, 1996.
- Barradas, J.I.; Amaral, F.D.; Hernández, M.I.M.; Montes, M.J.F.; Steiner, A.Q. Spatial distribution of benthic macroorganisms on reef flats at Porto de Galinhas Beach (northeastern Brazil), with special focus on corals and calcified hydroids. *Biotemas*, v.23 n.2 p. 61-67, 2010.
- Belém, M.J.C.; Rohlf, C.; Pires, D.O.; Castro, C.B. SOS corais. *Ciência Hoje*, v.5, n.26, p.34-42, 1986.
- Brainard, R.; Friedlander, A.; Gulko, D.; Hunter, C.; Kelty, R.; Maragos, J. Status of coral reefs in the Hawaiian Archipelago, p.237-250, in Wilkinson, C.R. (ed.), *Status of coral reefs of the world*. Chapter 13. GCRMN Report, Australian Institute of Marine Science, Townsville, , 2002.
- Bryant, D.; Burke, L.; McManus, J.; Spalding, M. Reefs at risk: A map-based indicator of threats to the world's coral reefs. *World Resources Institute*, 60 p., Washington, 1998.
- Castro, C.B. & Pires, D.O. Brazilian coral reefs: what we already know and what is still missing. *Bul. Mar. Sci.*, v.68, p.1-15, 2001.
- Costa, C.F.; Sassi, R.; Costa, M.A.J.; Brito, A.C.L. Recifes costeiros da Paraíba, Brasil: usos, impactos e necessidades de manejo no contexto da sustentabilidade. *Gaia Scientia*, v.1, p.1-14, 2007.
- Costa Jr, O.S.; Leão, Z.M.A.N.; Nimmo, M.; Attrill, M.J. Nutrifcation impacts on coral reefs from northern Bahia, Brazil. *Hydrobiologia*, v.440, p.307-315, 2000.
- Costa Jr, O.S., Attrill, M.J., Nimmo, M. Seasonal and spatial controls on the delivery of excess nutrients to nearshore and offshore coral reefs of Brazil. *J. Mar. Syst.*, v.60, p. 63-74, 2006.
- Coutinho, R.; Villaça, R.C.; Magalhães, C.A.; Guimaraens, M.A.; Apolinário, M.; Muricy, G. Influência antrópica nos ecossistemas coralinos da região de Abrolhos, Bahia, Brasil. *Acta Biol. Leopold.*, v.15, n.1, p.133-144, 1993.
- CPRH. *Diagnóstico sócio-ambiental do litoral sul de Pernambuco*. Agência Estadual de Meio Ambiente e Recursos Hídricos, 122 p., Recife, 2001.
- Davis, D. & Tisdell, C. Recreational scuba diving and carrying capacity in marine protected áreas. *Ocean Coast. Manag.*, v.26, p.19-40, 1995.
- Epstein, N.; Bak, R.P.M. & Rinkevich, B. Implementation of a small-scale "no use zone" policy in a reef ecosystem: Eilat's reef-lagoon six year later. *Coral Reefs*, v.18, p.327-332, 1999.
- Feitosa, F.A.N. & Bastos, R.B. Produtividade fitoplanctônica e hidrologia do ecossistema de Maracajaú-RN. *Arq. Ciên. Mar*, v.40, n.2, p.26-36, 2007.
- Fonseca, R.S.; Passavante, J.Z.O.; Maranhão, G.M.B.; Muniz, K. Ecossistema recifal da Praia de Porto de Galinhas (Ipojuca, Pernambuco): biomassa fitoplanctônica e hidrologia. *Bol. Téc. Cient. CEPENE*, v. 10, n.1, p.9-26, 2002.
- Grasshof, K.; Ehrardt, M. & Kremling, K. *Methods of seawater analysis*, 2. Verlag Chemie, 317 p., New York, 1983.
- Hallock, P. Evolution and function of coral reefs. p.1-24, in Ciley V. (ed.). *Earth system: history and natural variability*. Eolss Publishers, Oxford, 2002.
- Hallock, P.; Muller, K.F.E. & Halas, J.C. Coral reef decline - anthropogenic nutrients and the degradation of western Atlantic and Caribbean coral reefs. *Research and Exploration*, v. 9, p.:358-378, 1993.
- Kilpp, A.M. *Efeitos da população do ouriço Echinometra lucunter sobre a comunidade bentônica em um recife de Tamandaré-PE*. Tese, Universidade Federal de Pernambuco, 81 p., Recife, 1999.
- LAMEPE/ITEP. Chuvas observadas no período de janeiro a dezembro de 2004 em Pernambuco. Available on <http://www.itep.br/LAMEPE.asp>. 2010a.

- LAMEPE/ITEP. Chuvas observadas no período de janeiro a dezembro de 2005 em Pernambuco. Available on <http://www.itep.br/LAMEPE.asp>. 2010b.
- Leão, Z.M.A.N. The coral reefs of Bahia: morphology, distribution and the major environmental impacts. *Na. Acad. Bras. Ciên.*, v.68, p.439-452, 1996.
- Machado, R.C.A.; Feitosa, F.A.N.; Bastos, R.B.; Travassos, R.K. Dinâmica da biomassa fitoplanctônica e parâmetros hidrológicos no ecossistema recifal de Porto de Galinhas, Pernambuco, Brasil. *Bol. Têc. Cient. CEPENE*, v.15, n.2, p.17-29, 2007.
- MMA SECTMA. *Diagnóstico do turismo nos municípios do Cabo de Santo Agostinho, Ipojuca e São José da Coroa Grande - Relatório Final*. Secretaria de Ciência, Tecnologia e Meio Ambiente/ Agência Estadual de Meio Ambiente e Recursos Hídricos, 76 p., Recife, 2003.
- Moura, R.T. & Passavante, J.Z.O. Biomassa fitoplanctônica da Baía de Tamandaré, Rio Formoso-Pernambuco, Brasil. *Trab. Oceanogr. Univ. Fed. PE*, v.23, p.1-15, 1994.
- Perkins, E.J. *The biology of estuaries and coastal waters*. Academic Press, 678 p., London, 1974.
- Porto Neto, F. & Marcelino, S. C. Zooplâncton como bioindicadores da qualidade das águas, p. 107-126, in Leitão, S. N. & El-Deir, S. (org.), *Bioindicadores da qualidade ambiental*. Instituto Brasileiro Pró-Cidadania, Recife, 2009.
- Richmond, R.H. Coral reefs: present problems and future concerns resulting from anthropogenic disturbance. *Amer. Zool.*, v.33, p.524-536, 1993.
- Rogers, C.S. & McLain Sullo, E.S. Damage to coral reefs in Virgin Islands National Park and Biosphere Reserve from recreational activities. *Proceedings of the 6th International Coral Reef Symposium*, p.405-410, 1988.
- Rouphael, A.B. & Inglis, G.J. Impacts of recreational scuba diving at sites with different topographies. *Biological Conservation*, v.82, p.:329-336, 1997.
- Rouphael, A.B. & Inglis, G.J. "Take only photographs and leave only footprints"?: An experimental study of the impacts of underwater photographers on coral reef dive sites. *Biological Conservation*, v.100, p.281-287, 2001.
- Salvat, B. Status of southeast and central pacific coral reefs "Polynesia mana node": Cook islands, French Polynesia, Kiribaiti, Niue, Tokelau, Tonga, Wallis and Futuna. p.203-215, in Wilkinson, C.R. (ed.), *Status of coral reefs of the world*. Chapter 11. GCRMN Report, Australian Institute of Marine Science, Townsville, 2002.
- Sassi, R. Phytoplankton and environmental factors in the Paraíba do Norte estuary, Northeastern Brasil: composition, distribution and quantitative remarks. *Bol. Inst. Oceanogr.*, v.39, n.2, p.93-115, 1991.
- Steiner, A.Q.; Eloy, C.C.; Amaral, J.R.B.C.; Amaral, F.M.D. & Sassi, R. O turismo em áreas de recifes de coral: considerações acerca da Área de Proteção Ambiental Costa dos Corais (Estados de Pernambuco e Alagoas). *OLAM - Ciência e Tecnologia*, v.6, n.2, p.281-296, 2006.
- Strickland, J.D.H. & Parsons, T.S.A. Practical handbook of seawater analysis. *Bull. Fish. Res. Board Can.*, v.167, p.1-311, 1972.
- Tratalos, J.A. & Austin, T.J. Impacts of recreational diving on coral communities of the caribbean island of Grand Cayman. *Biological Conservation*, v.102, p.67-75 2001.
- UNESCO. *International Oceanographic Tables*. Wormly, 141 pp, 1973.
- Valentine, J. & Heck, K. The role of urchin grazing in regulating subtropical seagrass meadows: evidence from field manipulations in the Northern Gulf of Mexico. *J. Exper. Mar. Biol. Ecol.*, v.154, p.215-230, 1991.
- Villaça, R. Recifes biológicos, p. 229-248, in Pereira, R.C. & Gomes, A.S. (eds.), *Biologia Marinha*. Interciência, Rio de Janeiro, 2002.
- Wilkinson, C.R. Coral reefs of the world are facing wide spread devastation: can we prevent this through sustainable management practices? *Proceedings of the 7th International Coral Reef Symposium*, v.1, p.11-21, 1992.
- Woodland, D.J. & Hooper, N.A. The effect of human trampling on coral reefs. *Biological Conservation*, v.11, p.1-4, 1977.
- Zakai, D. & Chadwick-Furman, N.E. Impacts of intensive recreational diving on reef corals at Eilat, northern Red Sea. *Biological Conservation*, v.105, p.179-187, 2002.