

EFFECTS OF TOURISM ACTIVITIES ON CORAL REEF COMMUNITIES IN THE PUNTA FRANCES NATIONAL MARINE PARK, CUBA.

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ABSTRACT

An interdisciplinary assessment of SCUBA diving impacts and carrying capacity levels was conducted in the Punta Frances National Marine Park (PFNMP), Isle of Youth, Cuba. No evidences of SCUBA related impacts on coral reef communities were found. Nonetheless, this should not be taken as a final statement, given that a more precise sampling design is needed to overcome the problems with the power of the test. Other factors that also might be affecting coral reefs in the PFNMP, which were not taken into consideration in this study, could include snorkel diving by cruise ship tourists on near shore reefs, illegal commercial fishing that takes place within the area that removes large fish from the park. Finally, Carrying capacity results showed that, apparently, this area is still far from reaching an internationally accepted number of divers above which coral reef damage becomes evident. However, other aspects such as anchoring and uneven use of dive site may be interacting, decreasing carrying capacity levels in the PFNMP.

Key words: recreational diving; carrying capacity; coral reefs; environmental impact; ASW, Cuba.

RESUMEN

Se realizó una evaluación interdisciplinaria del posible impacto del buceo recreativo sobre las comunidades de arrecifes de coral en el Parque Nacional Marino de Punta Francés (PNMPF), Isla de la Juventud, Cuba. Aunque no se encontraron evidencias de impacto negativo del buceo sobre las comunidades de arrecife de coral en el área, esto no debe ser tomado como definitivo debido a que se debe mejorar el diseño de muestreo empleado para obtener una mayor potencia en la prueba. Otros factores que pudieran estar influyendo negativamente en el PNMPF, aunque no se tuvieron en cuenta, pudieran ser buceo en apnea realizado por los curceristas, pesca ilegal dentro del área y pesca comercial en áreas adyacentes que pudiera estar removiendo peces adultos del área. Por último, el estudio sobre capacidad de carga indicó que aparentemente el área se encuentra en niveles bajos de explotación por el buceo de acuerdo a los estándares internacionales, por encima de los cuales los daños al arrecife comienzan a ser evidentes. No obstante otros aspectos como el anclaje en el arrecife y el uso no equitativo de los sitios de buceo pudiera disminuir los niveles de capacidad de carga del PNMPF.

Palabras clave: buceo recreativo; capacidad de carga; arrecifes coralinos; impacto ambiental; ASW, Cuba.

Recurring management failures and the global decline of marine resources have triggered a worldwide demand for change in the way coastal and ocean resources are managed (Bohnsack and Ault, 1996; Field *et al.*, 2002; Sobel and Dahlgren, 2004). Traditionally management measures have tended to be reactive and sectoral, allowing a great margin for malfunction. Conversely, proactive and integrated approaches are becoming more relevant, and as a result a change to ecosystem-based management is taking place (Bohnsack and Ault, 1996; Cicin-Sain and Knecht, 1998; United Nations Environment Program, 2001; Sobel and Dahlgren, 2004).

Economic benefits derived from Marine Protected Areas (MPAs) are various and include both, the sale of extracted resources and the non-extractive

use of marine resources. Among the non-extractive resource use activities, recreational SCUBA (Self Contained Underwater Breathing Apparatus) diving ranks as the most important one, at least in tropical environments, including coral reefs. According to Dignam (1990) and Tabata (1992) SCUBA diving is one of the fastest growing sports in the world and it is undertaken, preferably, in pristine areas. As a result the impact of SCUBA diving tourism on coral reefs is a growing research topic.

Several studies in MPAs around have been designed to determine the level of SCUBA diving activity that does not compromise the reef resource. This level has often been termed as "capacity" (Davis and Tisdell, 1995(a); Hawkins and Roberts, 1997; Gallo *et al.*, 2002). As pioneers

of this work, Hawkins and Roberts (1992, 1993, 1994, 1997) undertook SCUBA diving impact studies at a popular dive resort in Egypt called “*Sharm-el-Sheikh*”. Results from these studies suggested that coral reefs might endure high levels of SCUBA-dive use, but this might not last long. Nonetheless, some aesthetic damage is expected to occur mainly to the most fragile coral species (branching). Hawkins and Roberts also suggested that the response of this ecosystem to the number of tourists (divers) follows an exponential model, suggesting the figure of 5 000 to 6 000 dives per year as a maximum limit beyond which reef degradation might appear.

Dixon *et al.* (1993) and Scura and van't Hof (1993) produced one of the most important contributions to the understanding of ecological impacts of SCUBA diving. They reported a critical value, above which impacts on coral communities from SCUBA-dive activities would become visible and compromise the sustainability of the industry. According to these authors, a usage rate of more than 5 000 dives per year per site in the Bonaire Marine Park (BMP) would significantly degrade coral reef quality, thus compromising the sustainability of the SCUBA tourism industry. From this figure they suggested a park carrying capacity of approximately 200 000 dives per year. Although these results are limited in their prediction capacity because of the lack of long-term monitoring, they provide a good starting point for estimation of carrying capacity.

The Punta Frances National Marine Park (PFNMP) constitutes one of the most pristine marine environments in the Cuban archipelago. Its clear, warm waters, sandy beaches, diverse marine flora and fauna, and impressive underwater geography make the area an unforgettable experience for those that visit it. These natural features have been the main reasons for the tourist usage the area has experienced for more than twenty years.

Recreational SCUBA diving has long been the most important activity in the PFNMP. Since 1976, this area has been visited by thousands of divers from all over the world. Recreational SCUBA diving ranks as the most important tourism activity in tropical marine environments, including coral reefs (Dignam, 1990; Tabata, 1992). Several studies in MPAs have been designed to determine the level of SCUBA diving activity that will not compromise reef resources. This paper is intended to assess from an interdisciplinary perspective the impacts, if any, of recreational SCUBA diving on the coral reefs of the PFNMP, and also to provide an

estimation of the SCUBA divers' carrying capacity in the MPA.

MATERIALS AND METHODS

Study site

The PFNMP is located at the southwest end of the Isle of Youth, specifically on the Carapachibey peninsula. It stretches from what is called Punta Pedernales to Cabo Frances (Fig. 1). The PFNMP encompasses an area of 4 610 ha, of which 1 596 ha represent land and 3 014 ha are ocean (Centro Nacional de Areas Protegidas, 2002).

Eighteen field trips were undertaken from January 2001 to June 2003 using the research vessel Felipe Poey from the University of Havana. These trips lasted for about 10 days each and more than 150 SCUBA immersions were made in depths ranging from 3 to 20 meters.

Biological data

During the first trip, informal interviews were held with three dive instructors and two tourist boat skippers to differentiate among dives sites on the basis of their intensity of use (heavy, moderate, light). According to them it was possible to distinguish among heavily dived and non-dived areas; moderate dived sites were not present.

Subsequently, two main biotopes were identified within the defined usage zones: spur-and-groove and reef wall. Spur-and-groove is a common reef biotope present in the deep “forereef” area. It consists of alternate channels of sand and rock lines running perpendicular to shore. Depths of this biotope oscillate around 13 m to 17 m. Reef-wall biotope represents an ancient shore line which is underwater now, and appears as an escarpment that generally drops from 5 m to 12 m. Differences in fish and coral abundance, species composition, and diversity indexes have been reported for these two biotopes in Cuba (González-Sansón *et al.*, 1997a; de la Guardia *et al.*, 2004a).

A total of four combinations of usage level-biotope areas were thus identified, and within them three replicate sites were allocated (Table 1, Fig. 2). These replicates sites were actual diving buoys, when it was possible, or sites selected within the non-use areas.

Relative abundance of selected fish species was estimated using a modification of the Stationary Visual Census Technique (Bohnsack and

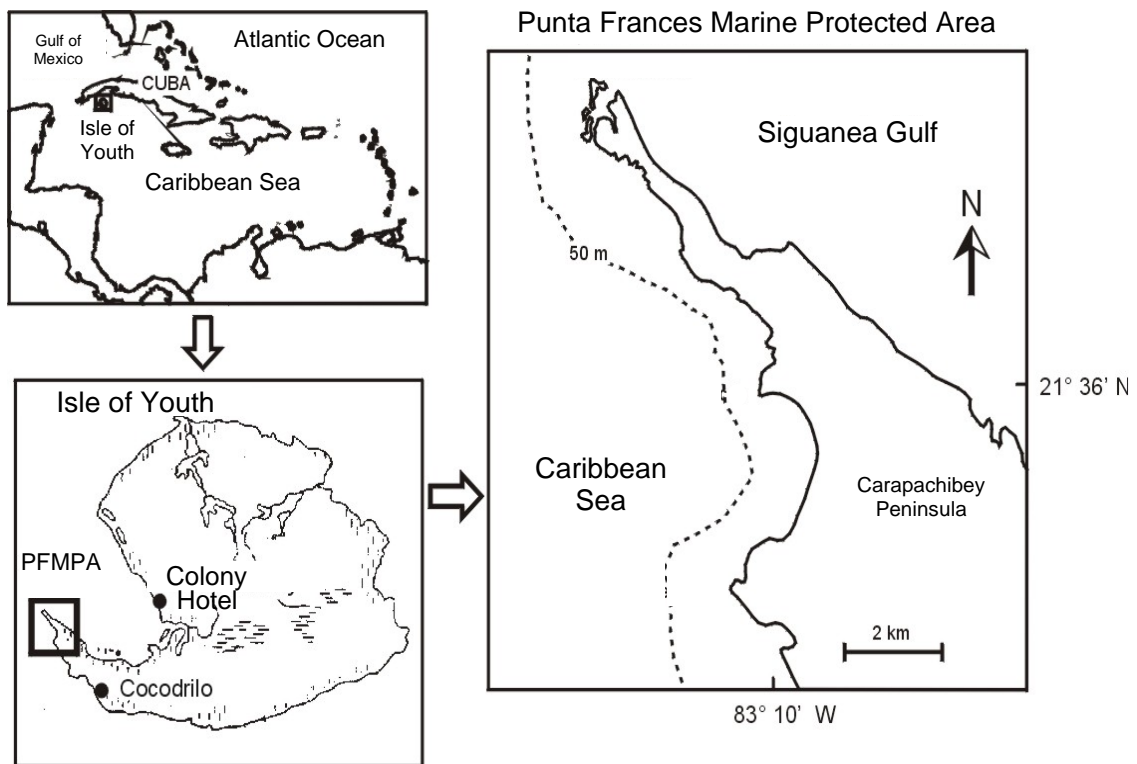


Fig. 1. Map showing study site.

Table 1. Combinations of usage level-biotope strata identified for this work. (B: Buoy, Ped: Pedernales, B-RC: buoy RC; B-M and B-P are random names; numbered buoys refer to actual dive sites).

		USAGE LEVEL	
		Heavily used (H)	Non used (N)
BIOTOPE	Spur and groove (S)	B-7 (21°35.2539'N, 83°10.2396'W)	B-21 (21°35.9676'N, 83°10.7525'W)
		B-14 (21°35.5049'N, 83°10.4284'W)	B-25 (21°36.0020'N, 83°10.8740'W)
		B-50 (21°35.1540'N, 83°10.2320'W)	Ped. (21°34.7574'N, 83°10.4888'W)
	Reef Wall (W)	B-36 (21°37.3980'N, 83°12.5330'W)	B-RC (21°36.4259'N, 83°10.9851'W)
		B-40 (21°36.8360'N, 83°11.7960'W)	B-M (21°36.8928'N, 83°11.4845'W)
		B-34 (21°37.1582'N, 83°12.2263'W)	B-P (21°36.6343'N, 83°11.1902'W)

Bannerot, 1986). The difference between the published method and the one used in this work is that our cylinder census volume had 5 m radius rather than 7.5 m, and not all fish species were counted and measured. Instead, only commercially important species (i.e. those interesting to divers and fishermen), all herbivores, and all territorial species were considered. There were two reasons

for doing this. Firstly, counting and measuring all fish species would have meant more time in terms of doing the fish censuses, and this would have counted against the time needed to do other censuses (coral cover, rugosity). Secondly, given the fact that we were looking for SCUBA-dive impacts, it was this author's opinion that these impacts should have first been observed on

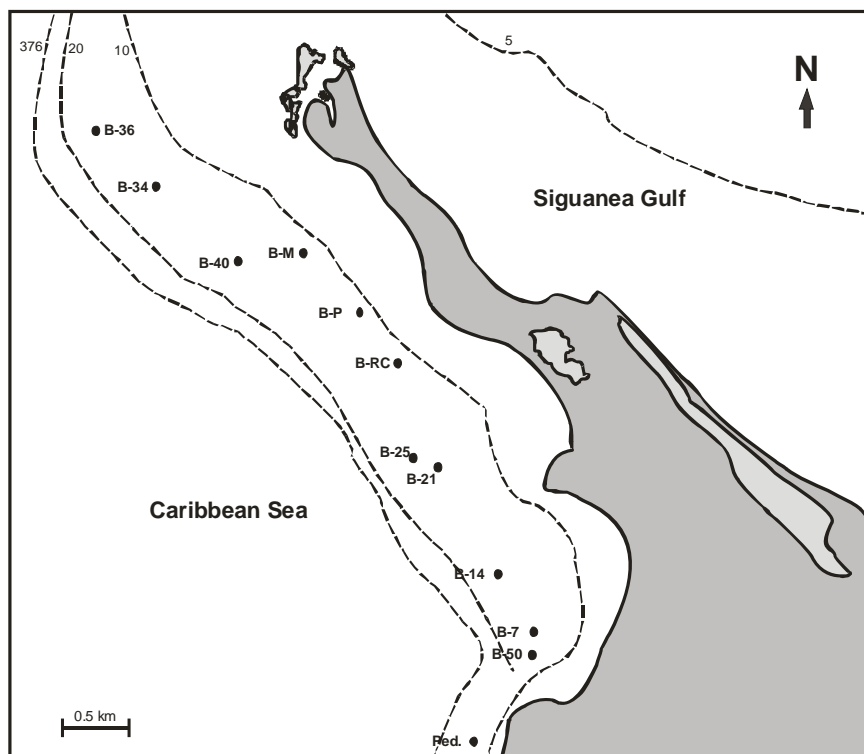


Fig. 2. Map showing sampling sites at Punta Frances Marine Protected Area. B: Buoy

charismatic fish species such as the commercially important, the herbivores and the territorial species.

Benthic community structure was assessed in terms of proportional cover using the line intersect method (Rogers *et al.*, 1994; English *et al.*, 1997). Percent cover of live coral, recently dead coral, old dead coral, macro algae, gorgonian, sponges, and rock-sand substrate were estimated. As a separate variable, bottom complexity, also known as rugosity, was measured using the chain transect method (Rogers *et al.*, 1994; English *et al.*, 1997).

Socioeconomic data

The human population in the PFNMP is diverse and mobile. It is composed of tourists who visit the area to undertake SCUBA diving, as well as tourists arriving on cruise ships. There are also Cuban nationals who work for different stakeholders in the MPA. On any given day, except during cruise ship visits, there may be around 50 people at the PFNMP. During cruise visits, this number increases significantly, typically into the four to six hundreds.

A total of 256 questionnaires were distributed to tourist divers that visit the area. Questionnaires were utilized to get a sense of what reef attributes tourists would like to see in a dive, to assess the conservation status of the PFNMP with regard to those reef attributes preferred by divers. This permitted me to compare the PFNMP with other MPAs, and to evaluate tourist satisfaction with the dive and the place.

No questionnaire was distributed to cruise tourists. First, there was a lot of uncertainty about the cruise visit day; indeed, during the study period, the cruise operation stopped due to economic and political causes. Second, I knew that cruise tourists come to the PFNMP just because it was part of the package they bought, and not because SCUBA diving was a first option in their vacation needs. This is not true for tourists at the Colony Hotel; they come to the PFNMP just for the sake of diving. Third, cruise tourists only stay at the PFNMP for a few hours, and this amount of time was not sufficient for them to become acquainted with the PFNMP. By contrast, tourists at the Colony Hotel stay there for approximately 10 days.

At the same time, a total of 14 questionnaires were administered to SCUBA dive instructors and boat skippers who work for the Colony Hotel (9 dive instructors and five boat skippers). In these cases, questionnaires were designed to get a sense of the conservation status of the PFNMP, assess the MPA in relation to the attributes preferred by tourists in a dive, and get an estimation of the current level of exploitation in terms of the number of divers. In all cases, tourists as well as dive instructors and boat skippers, anonymity and confidentiality were assured. Results from both sets of questionnaires were codified and data entered for analysis in SPSS 12.0 for Windows.

Economic information was obtained from Colony hotel officials. Most of the information consisted of time series data, which is depicted below.

- Number of visitors at the Colony Hotel (1997-2003)
- Income from tourism activities at the Colony Hotel (1997-2003)
- Dive distribution per site (Dive boat's logbook) (1996-2001)

Data analysis

All biological data were tested for normality and (log +1) transformed as required. To determine whether sampling was representative, the cumulative numbers of species vs. counts curves were prepared for each combination of factors (HS, HW, NS, NW as in Table 1). Analysis of normality and scale transformation were done using SPSS 12.0 for Windows. Microsoft Excel 2002 for Windows was used for the construction of the accumulated number of species vs. counts curves.

Determination of the power of the test was done using Gpower 2.0 software (Faul and Erdfelder, 1992). The log of total abundance of fish was used in an *a priori* power analysis to estimate the number of replicates necessary to achieve 90% and 70% power. Additionally, a *post hoc* power analysis was also performed for the same variable (log (fish abundance)) to actually estimate the power of this experiment. In both cases, the tests were done on the outputs of Analysis of Variance (ANOVA).

A balanced, two-way ANOVA (fixed effects) was performed to estimate differences between levels of use and biotopes regarding fish abundance, fish biomass, coral cover (live, dead), algal cover, and rugosity. SPSS 12.0 for Windows software was used to conduct the analysis. Estimates of fish biomass were obtained using previously published

length-weight relationships for marine fishes of Cuba (Claro and Garcia-Arteaga, 2001).

Multivariate analysis was also performed to explore patterns of distribution between usage-level and biotopes regarding fish abundance (all fish combined and commercially important species), and percent cover. A hierarchical classification was performed using the Percent Similarity Coefficient as a similarity index and the clustering method employed was the Unweighted Pair Group Average (UPGMA). A Principal Component Analysis (PCA) was also applied to explore for patterns of significance in the distribution of data found in the cluster analysis. The Multivariate Statistical Package (MVSP) 3.13m for Windows was used to undertake these multidimensional analyses.

RESULTS AND DISCUSSION

Although not all areas were sampled with the same intensity, around 16 counts seemed enough to obtain a representative sample (Fig. 3). This finding is particularly relevant given the importance of ensuring an appropriate sampling effort to guarantee precision and accuracy in the experiment (Underwood, 1997; Babbie and Benaquisto, 2002).

The issue of the power of a test has been under debate for many years. Scientists have always been worried about controlling type I error. Therefore, $\alpha=0.05$ has been used as a magical number (Underwood, 1997). The acceptance of this "almost mandatory" number, however, means that type II error becomes larger; that is accepting H_0 when it is not valid. This fact could be very serious in experiments that seek to explore for human induced-impacts on natural resources because by accepting this outcome, we are predicting that there are no impacts when in reality they are occurring (Underwood, 1997). In a real life situation this could be catastrophic, because management measures are taken based on incorrect prediction. Factors such as sample size, sample variability and effect size determine the power of a test (Underwood, 1997).

In the experiment to test for the effect of SCUBA diving use at reef sites at PFNMP, it was found that in order to obtain a power of 90%, 72 replicate measures per site-intensity combination would have been necessary. This number of replicates is not logistically possible for this experiment. Firstly, the area is not big enough to allow for the establishment of 72 truly independent replicates,

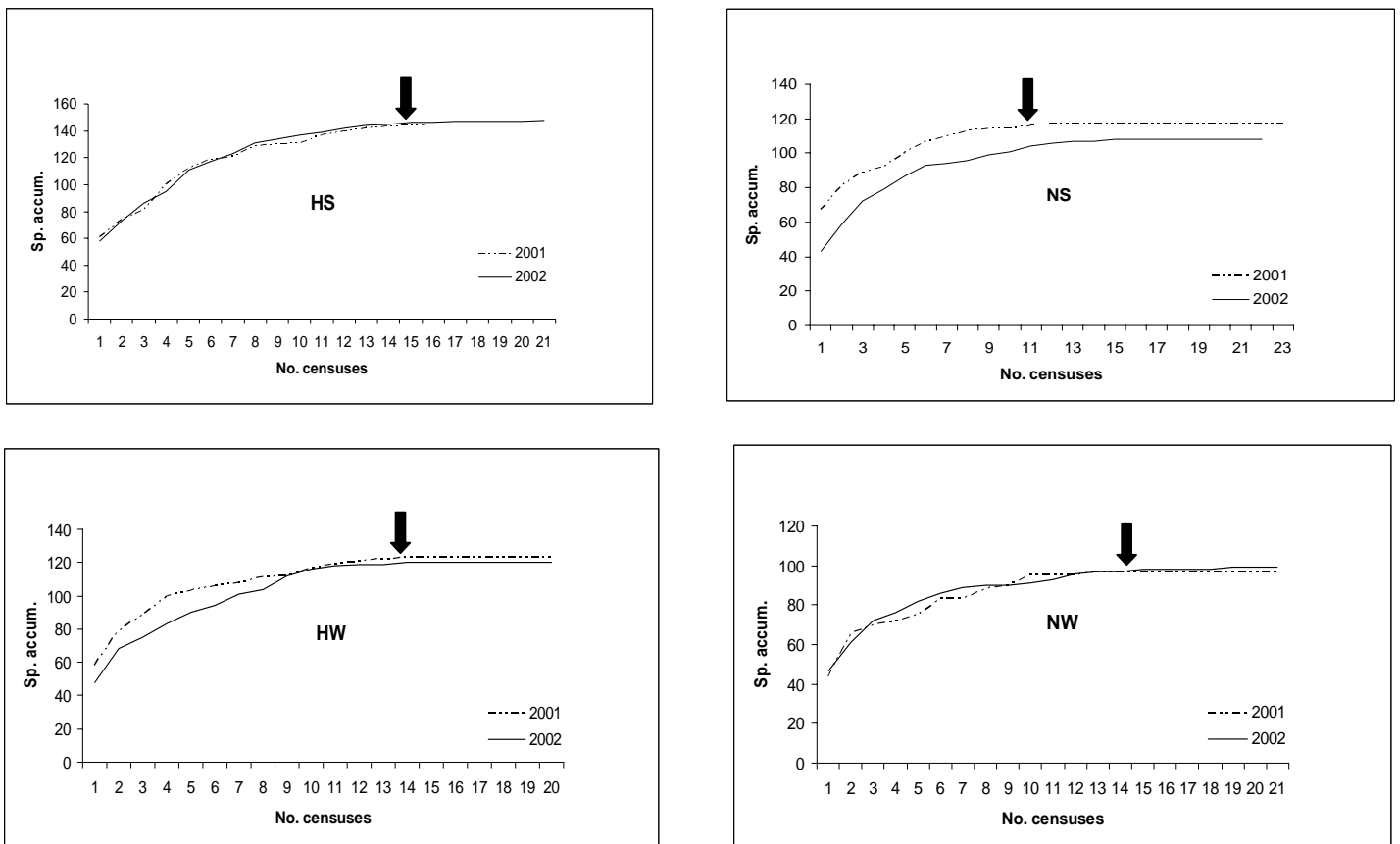


Fig. 3. Accumulated number of species vs. counts for the four factor combinations (HS: heavily used-spur and groove; HW: heavily used-wall; NS: non used-spur and groove; NW: non used-wall). Black arrows show the number of counts where the curve becomes asymptotic. Total number of counts made in each site-intensity combination can be obtained from the count axis.

and secondly the time required to undertake such a massive task would have been excessive.

When analyzing for a power of 70%, results showed that 48 replicates would have been necessary. Although this number seems more plausible, the issue of enough physical space within the PFNMP and replicate independence remains a constrain. In ecological studies, independence of samples constitutes the most important assumption that should be respected when using the F distribution to explore for significant differences (Underwood, 1997). Other assumptions such as homogeneity and normality are important as well, but not as crucial as independence of samples (Underwood, 1997).

The *post hoc* analysis showed that this experiment had a power of 30.87%. Although it is not high, it should be considered that large variability is a reality that affects all ecological experiments. Thus,

the key issue here is not to struggle for a higher power in the experiment. It is rather, to acknowledge the limitations of the experiment, and make the implications clear to everybody, so the conclusions drawn from it can be effectively implemented and not misunderstood (Hatcher, personnel communication).

Generally fish are abundant and diverse within the PFNMP. The most common species are those typical of coral reefs that have not been significantly impacted by human activities. However, the low abundance of large fish, especially predators, belonging to the families Lutjanidae (*Lutjanus spp.*, snappers) and Serranidae (two species of the genus *Epinephelus*, locally known as nassau grouper and jewfish, and several species of the genus *Mycteroperca*, locally known as black grouper and tiger grouper), are noticeable. This fact could be the result of the illegal fishing that takes place within the area, as well as the commercial fisheries that

take place outside the area (near the boundaries of the MPA). Bohnsack (1993) described this as “fishing the line”, it is considered one of the benefits that MPAs could provide to commercial fisheries.

On the other hand, the lack of these fish in the PFNMP contrasts to the finding of Eklund *et al.* (2000) who discovered large black grouper aggregations within certain MPAs in the Florida Keys National Marine Sanctuary. It is this author's opinion that the pattern identified should not be considered a benefit for the fisheries. Since the PFNMP area is very small (only 3 014 ha), in comparison with the surrounding area. Significant exports in biomass and larvae should not be expected from it. Furthermore, larval dispersion and adult migration patterns have not been studied in the PFNMP, so it is difficult to predict whether the area constitutes a source of fish larvae and biomass.

Specimens of the Acanthuridae (*Acanthurus* spp.) and Scaridae (*Scarus* spp. and *Sparisoma* spp.) families are specialized herbivores that constitute a key element in the structure and composition of coral reef fish communities, given the control they exert over the algal growth on the reef (Hughes, 1994; Aronson and Precht, 2000; Williams and Polunin, 2001). These two families are very well represented in the PFNMP, although high algal cover (between 40% and 60%) has also been reported (Centro de Gestión y Servicios Ambientales y Tecnológicos, 2001; de la Guardia *et al.*, 2004b). This fact suggests that there might be some kind of nutrient input to the PFNMP that is offsetting grazing losses to these herbivore fish (Lapointe *et al.*, 1997; Lapointe, 1999). Williams and Polunin (2000) have found that despite a strong negative correlation between herbivore biomass and algal cover, the latter has remained high in some parts of the Caribbean. These researchers found, that the macro algal-grazer interaction does not follow a simplistic linear model. Instead it might be influenced by other factors, such as the development of defense mechanisms by macro algae against the grazing activity of herbivores. Hence, factors such as algal palatability should also be considered.

Contrary to what was expected, high-use sites showed significant higher means of total fish abundance ($F=11.136$; $p<0.05$), commercial fish abundance ($F=5.249$; $p<0.05$), and fish biomass ($F=7.704$; $p<0.05$) in comparison with non-used sites. This could be interpreted as meaning that SCUBA diving may not be affecting fish communities' structure in the PFNMP, and that SCUBA diving concentrates along these sites

because they are more attractive to divers. Questionnaires support this latter interpretation, firstly, because fish abundance was one of the most preferred reef attributes divers would like to see, and secondly because 86.1% of the tourists ranked the PFNMP in good quality condition regarding this variable.

Biotores also significantly differed in total fish abundance ($F=5.658$; $p<0.05$) and fish biomass ($F=6.266$; $p<0.05$), which appears to be a consequence of significant differences found in the structural complexity (rugosity) between the two biotores ($F=8.191$; $p<0.05$). Higher structural complexity means more habitats and shelter opportunities available for fish; therefore an increase in fish abundance should be expected in those areas with higher structural complexity. Kaufman (1983) postulated that the loss of spatial heterogeneity could reduce the carrying capacity of the reef. At the same time, higher structural complexity could explain the higher fish biomass also found in this biotope. Large fish occur mostly at greater depths because food tends to be more abundant there. Rudd and Tupper (2002) reported higher abundance of Nassau Grouper (*Epinephelus striatus*) in deep and structurally complex reef formations such as spur and groove, in the Turks and Caicos Islands. Also, Gonzalez-Sansón *et al.* (1997a) reported significant differences between spur and groove and wall biotores in relation to fish community structure and abundance for Cuban reefs.

Abundance of herbivore fish did not show significant differences between usage levels ($F=4.266$; $p>0.05$), although it did between biotores ($F=11.149$; $p<0.05$). In this case higher means of herbivore fish were found in the spur and groove biotope than in the wall biotope. A more detailed analysis of this aspect showed that no significant differences were found between biotores regarding macroalgae cover ($F=1.900$; $p>0.05$), which may lead us to think that instead of macroalgae abundance as the reason for herbivore fish distribution in this area, the structural complexity (rugosity) once again may be responsible for these findings. A regression analysis was conducted between these two last variables (abundance of herbivore fish and rugosity) and it did not show any relation between these two variables ($F=0.223$, $p>0.05$, $r^2=0.022$). In fact the regression coefficient was lower than expected.

To further explore this issue a multiple regression analysis (stepwise method) was applied among

herbivore abundance, as dependent variables, and percent cover of live coral, recent dead coral, old dead coral, macroalgae, gorgonians, sponges, rock-sand substrate, number of divers, and number of visits as independent variables. Result shows that percent cover of sponges explains 69.2% of the error ($F=22.466$, $p<0.05$, $r^2=0.692$). This was completely unexpected and no biological explanation was found. However, neither of the two SCUBA-related variables showed relations with herbivore abundance, supporting the notion that SCUBA diving is not affecting natural communities.

Sessile invertebrates (sponges, gorgonians, and corals) are very well represented in the PFNMP, although signs of deterioration were seen. High numbers of dead coral colonies, algal and cyanophyte cover was observed. A relatively high incidence of bleaching and black band disease was also present. These events had previously been reported by de la Guardia *et al.* (2004b), who found that 20% of the coral colonies at the spur and groove biotope had signs of deterioration due to diseases and bleaching. These authors did not find any correlation between these events and SCUBA dive intensity in the area.

Coral cover was rather low and varied from 10 to 25% throughout the MPA. Alcolado *et al.*, (1998) found even lower coral cover percentages at similar biotopes in Cayo Coco, on the north shore of Cuba and de la Guardia *et al.* (2004a, b) also found low coral cover (less than 20%) for the PFNMP in 2001. Lower percentage of coral cover was found at sites located in the north of the PFNMP; while sites located in the south had higher coral cover. This could be explained by the fact that sites located in the south have more oceanic influence than sites located at the North of the PFNMP. Oceanic waters, although not rich in nutrients, are clean and have more stable salinity and temperature than waters coming from the Siguanea Gulf. It was observed that sites located in the north side of the PFNMP are receiving higher levels of terrestrial inputs (sediments and fresh water). Significant differences were found only between biotopes with a higher mean of coral cover in the spur and groove area ($F=11.066$; $p<0.05$) (Fig. 4). This result matches that of de la Guardia *et al.* (2004b) who also found significant differences between biotopes regarding coral cover and the spur and groove biotope.

The ratio of recent and old mortality varied evenly along the park, since no significant differences were found for biotopes and usage levels ($F=2.272$; $p>0.05$ and $F=0.214$; $p>0.05$ respectively). Old

mortality probably reflects past alterations suffered by the coral, although it is hard to estimate when they occurred. Recent mortality seems to have been inflicted by coral-related diseases, and not by SCUBA diving.

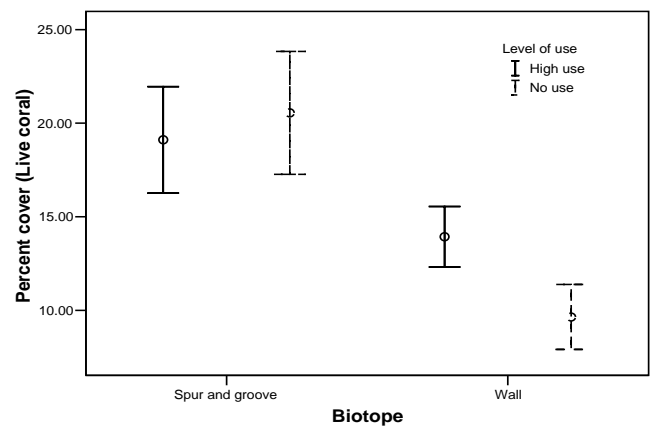


Fig. 4. Percent cover of live coral. Circles represent means; bars represent Standard Error of the means.

Multivariate analysis has been reported as a useful tool to explore relationships between large set of variables, especially when statistical tests do not allow differentiating between groups of samples (Gonzalez-Sansón *et al.*, 1997b). Fig. 5 shows the cluster for the multivariate analyses done with total fish abundance. In general terms, groups are not well formed. Nonetheless, it appears that usage level does not seem to be a grouping factor. Instead groups are primary distinguished according to biotoes.

Fig. 6 shows a similar cluster analysis done for abundance of commercial fish. In this particular case, no clear groups were formed. Therefore, it was not possible to identify any possible pattern of distribution of sites according to this variable. Fig. 7, on the other hand clearly shows a pattern of distribution similar to figure 5, where groups were formed by biotope and not by level of use. This last cluster was done using data on percent cover.

These results match findings by Gonzalez-Sansón *et al.* (1997b) and de la Guardia *et al.* (2004b) and could be explained in two ways. Firstly, SCUBA dive use has not had any effect on coral reefs in the PFNMP, so there is no differentiation in terms of usage level. Secondly, the scale (in terms of working at the group level of: live coral, macro

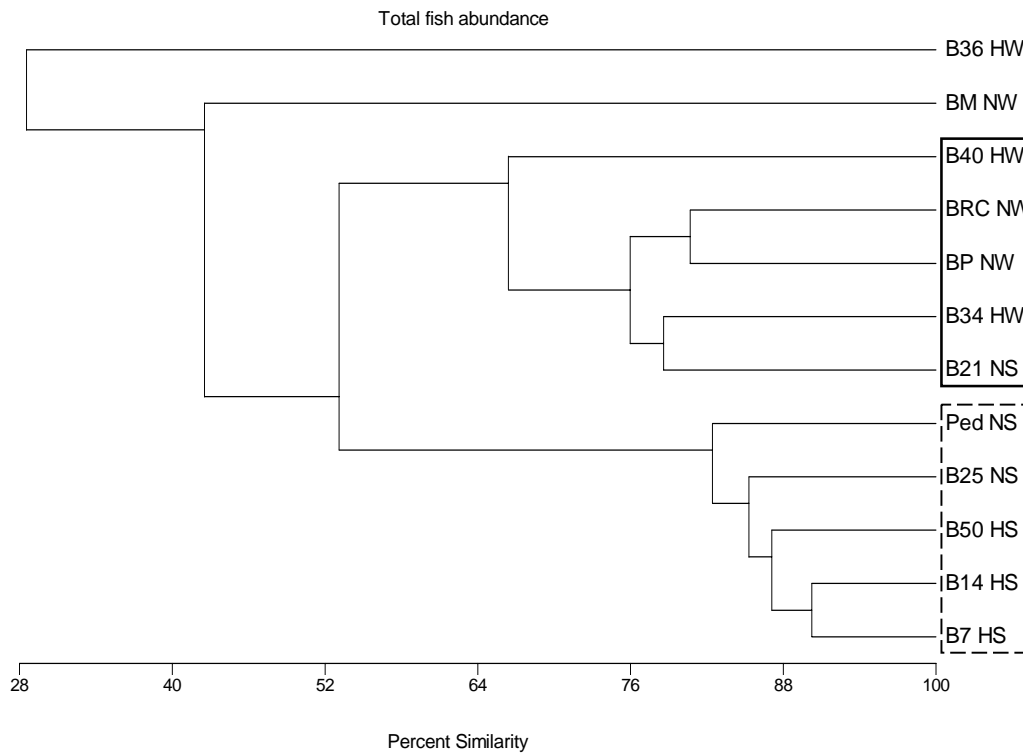


Fig. 5. Dendrogram showing similarity between sites for total fish abundance. (HS heavily use-spur and groove; HW: heavily used-wall; NS: non used-spur and groove; NW: non used-wall; B7: buoy 7; B14: buoy 14; B21: buoy 21; B25: buoy 25; B34: buoy 34; B36: buoy 36; B40: buoy 40; B50: buoy 50; BM: buoy M; BRC: buoy RC; Ped: Caleta de Pedernales; BP: buoy P).

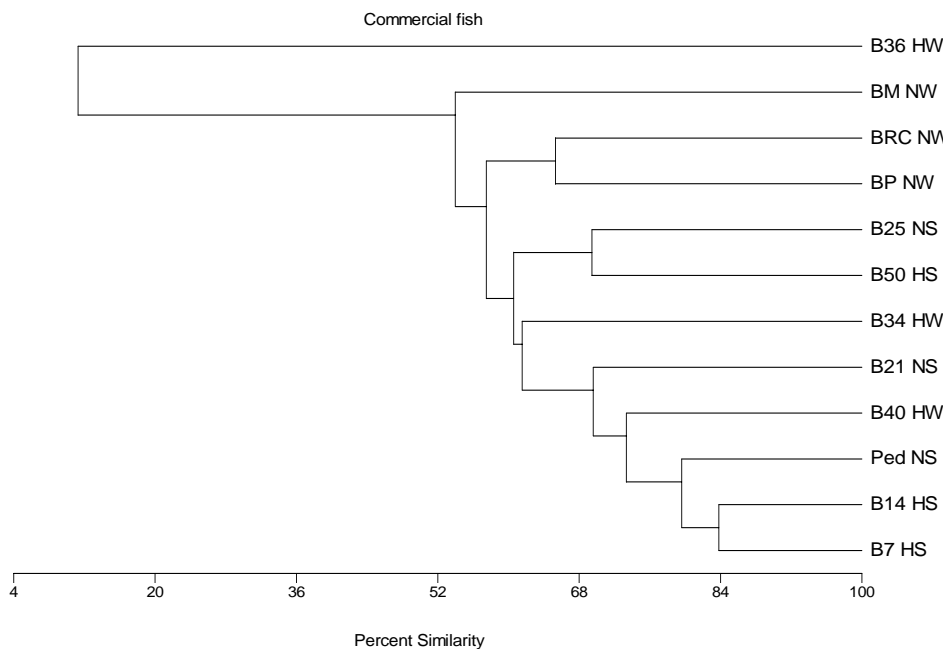


Fig. 6. Dendrogram showing similarity between sites for commercial fish abundance. (HS heavily use-spur and groove; HW: heavily used-wall; NS: non used-spur and groove; NW: non used-wall; B7: buoy 7; B14: buoy 14; B21: buoy 21; B25: buoy 25; B34: buoy 34; B36: buoy 36; B40: buoy 40; B50: buoy 50; BM: buoy M; BRC: buoy RC; Ped: Caleta de Pedernales; BP: buoy P).

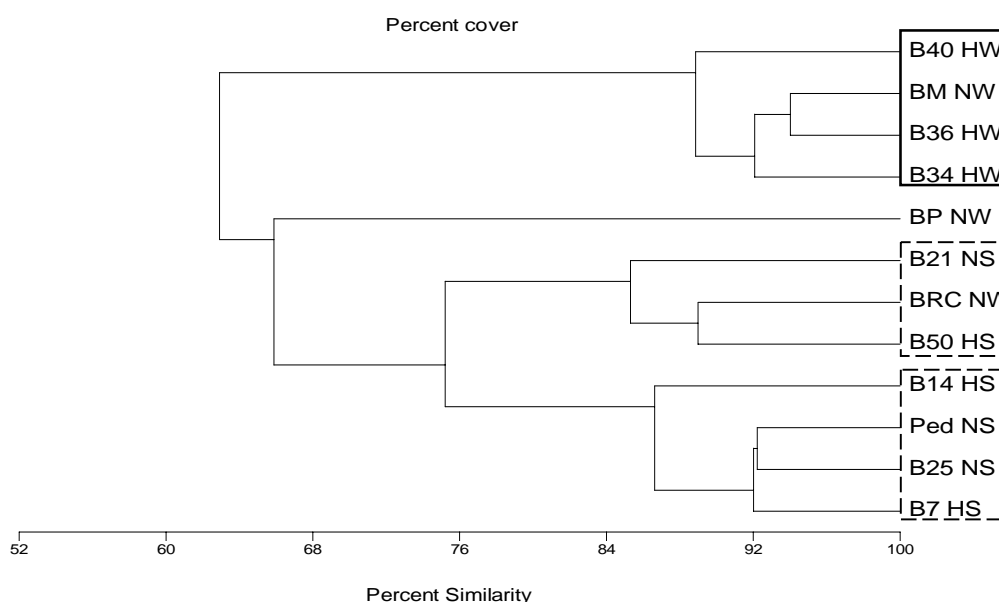


Fig. 7. Dendrogram showing similarity between sites for percent cover of live coral. (HS heavily use-spur and groove; HW: heavily used-wall; NS: non used-spur and groove; NW: non used-wall; B7: buoy 7; B14: buoy 14; B21: buoy 21; B25: buoy 25; B34: buoy 34; B36: buoy 36; B40: buoy 40; B50: buoy 50; BM: buoy M; BRC: buoy RC; Ped: Caleta de Pedernales; BP: buoy P).

algae, sponges,) used in this study did not allow for differentiating between use levels. The first option seems more plausible according to results obtained in interviews. The second option, on the other hand, might show that at the current stage of MPA exploitation, a more detailed level of analysis should be applied. In this case, it may be better to work at the species level instead of the percent cover of coral forms and other sessile organisms.

This finding contradicts Edinger and Risk (2000), who concluded that definitions of reef status based solely on percentage of live coral cover should be supplemented with other indices, such as conservation class, that more accurately predict biodiversity value and fisheries potential.

This fact leads to the conclusion that a shift in the scale and complexity of analysis is needed. No longer are species-specific indexes being used exclusively to answer questions related to management issues in coral reefs. Instead, more general approaches are being taken, such as coral morphology and presence/absence indexes. It seems possible from this study, however, that when you are dealing with impacts below significant levels, detection might be possible if the work is done at the species level.

To further explore the distribution of groups found in the cluster analysis a PCA was applied for fish abundance data. Clark and Warwick (1994) reported PCA as the longest-established method, and although the relative inflexibility of its definition limits its practical usefulness, it makes it more suitable to multivariate analysis of environmental data than species abundance or biomass. Nonetheless, it is still widely used, and is of fundamental importance. Also, ter Braak and Prentice (1988) advised the use of linear ordination methods, such as PCA, over non-linear ordination methods, such as Detrended Correspondence Analysis and Canonical Correspondence Analysis when the community variation (gradient) is within a narrow range.

Results of the analysis showed a clear separation along axis 1 between B36 and the rest of the sites (Fig. 8A). This is the consequence of the fact that B36 showed a higher abundance of fish in comparison with other sites. This difference introduces a great variance in the data which is reflected in PCA, which separates B36 from the rest of the sites along axis 1. There is also some distribution along axis 2, which appeared to be related to biotopes. To explore this, B36 was removed from the analysis, and results showed the formation of two clear groups along axis 1 with biotopes as the main criteria for separation (Fig.

8B). No explanation was found for B21, which despite being representative of the spur and groove biotope, appeared related to the wall biotope group. PCA results strongly support what has been previously found through ANOVA and cluster analysis: SCUBA diving may not be a determining factor that explains coral reef community structure and distribution in the area.

Carrying capacity of the Punta Frances National Marine Park.

Fig. 9 shows gross incomes to Colony Hotel from tourist activities in the PFNMP. Incomes, although lower than earnings from cruise visits, are significant, and have been the Colony Hotel's *raison d'être* throughout its existence.

It is notable that since 1998 there has been a steady decline in incomes from SCUBA diving, and in the number of tourists (Fig. 9). When asked about this, hotel officials expressed that there is no obvious reason for the decrease in the number of dive tourists.

It is this author's opinion, however, that deterioration of hotel facilities, a decline of service, SCUBA diving safety issues, cruise company competition, and loss of competitiveness with other Cuban SCUBA-related companies might be the prime reasons behind this reduction in visitors. It should be noted that external factors such as the United States' blockade against Cuba, market/diver fatigue, loss of novelty of the area, global recession effects on tourism, and the September 11th terrorist event might have also influenced this situation.

An important question that arises here is whether or not perception of deterioration of the PFNMP could have provoked this steady reduction of incomes to the Colony Hotel. To explore this question, a survey of tourist divers, dive instructors, and boat skippers that operate in the area was conducted.

In general, tourist divers were pleased with the quality of the PFNMP as a dive destination. There were no negative comments about the PFNMP, instead, the majority of complains were related to hotel conditions and organizational issues. When asked about their opinion regarding the conservation status of the PFNMP, 45.7% and 40% considered the PFNMP in excellent and in very good condition, respectively. Also 85.6 % of the respondents considered dive sites at the PFNMP as

excellent, and 55.5% found no evidence of damage in the area. Tourists considered human-related causes as the culprit for some environmental deterioration signs in the PFNMP (Fig. 10). According to them, pollution, SCUBA diver impacts, high sedimentation, anchoring on the reef, and fishing were the main reasons for the current status of the PFNMP. Tourist divers in the PFNMP considered themselves as dedicated divers (57.8%), with more that 100 dives in their lives (55.1%). Also, 68.1% of them considered the quality of diving as the determining factor when choosing their vacation destiny. These results provide evidence thin the PFNMP still holds a natural appeal that made it the prime dive destination in Cuba some 25 years ago. Also given their diving experience, tourist opinions should be considered credible.

Opinions from dive instructors and boat skippers, on the other hand, were more distributed among response options provided in the questionnaire. Their work experiences in the area ranked from 9 to 25 years, and 64.3% of the respondents have made more than 500 dives in the PFNMP. When asked about rating the current conservation status of the PFNMP, 21.4% of dive instructors and boat skippers responded as "regular", 42.9% "good", and 28.6% as "very good". One might conclude that the PFNMP has not suffered significant deterioration due to exploitation; nonetheless, some damage has occurred. Overall, 85.7% of the respondents stated that there is evidence of damage in the PFNMP, and mentioned "human-related causes", such as intense fishing, poor surveillance, boat traffic, and diver impacts (Fig. 10). Also, when asked to compare the PFNMP today with the PFNMP a few years ago, the majority of responses (57.1%) concentrated around "regular" to "good" options. Among the main causes, they mentioned fishing, poor surveillance and enforcement, SCUBA diver impacts, and boat traffic in the area.

There are some points of divergence between tourist divers and dive instructors regarding the main causes of the PFNMP deterioration. It was noticeable that tourists mentioned anchoring as a cause, while instructors did not. Some years ago, anchoring was strictly prohibited in the PFNMP, and mooring buoys were available. As time passed, mooring buoys were lost due to the effect of surge and waves coupled with lack of maintenance. There are no mooring buoys in the PFNMP now, and diving boats drop anchor at certain sites to undertake diving activities. It would not be fair to say that this always happens, because boat

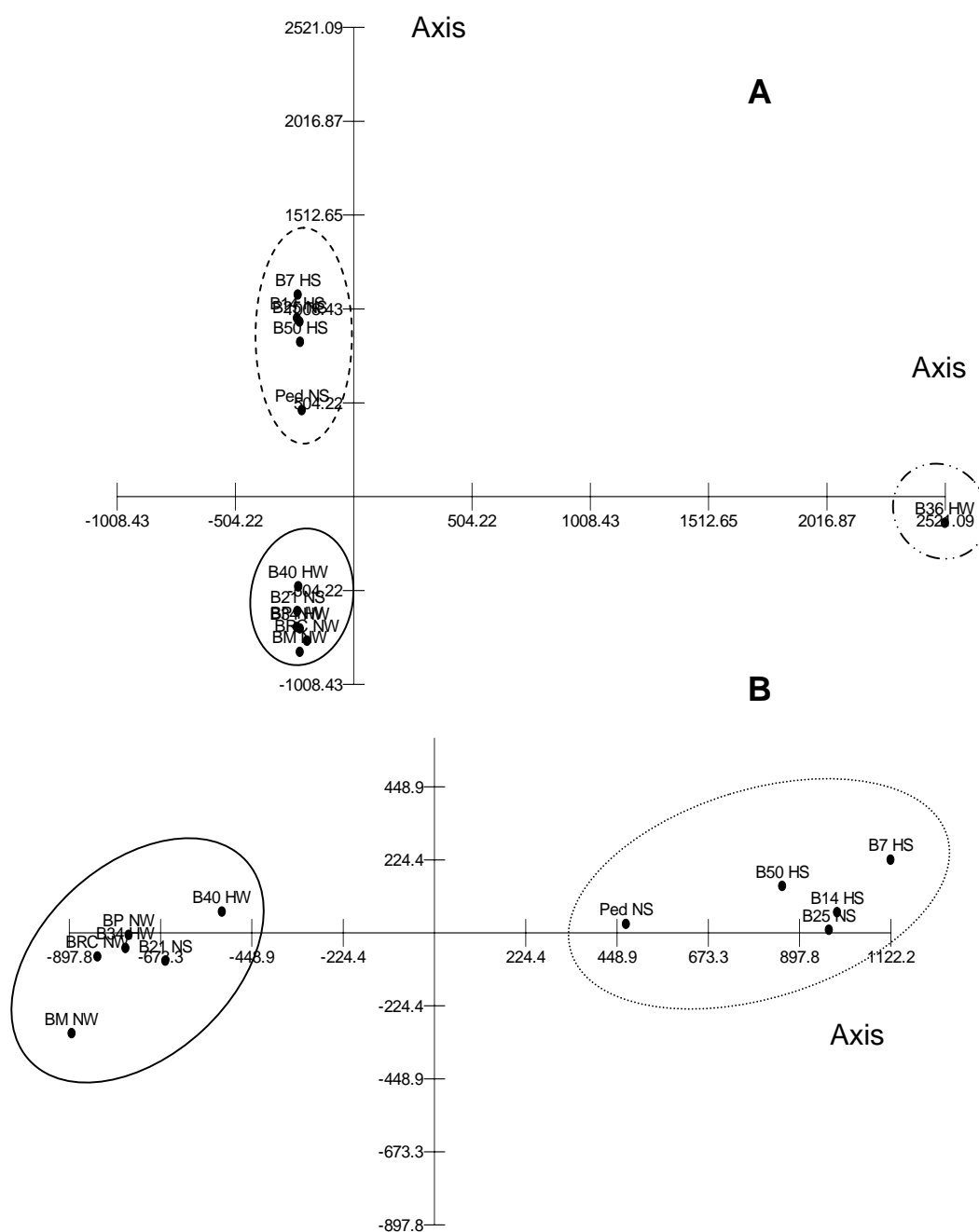


Fig. 8. Scatter plot showing PCA results. A: for all sites, B: with B36 HW excluded. (HS heavily use-spur and groove; HW: heavily used-wall; NS: non used-spur and groove; NW: non used-wall; B7: buoy 7; B14: buoy 14; B21: buoy 21; B25: buoy 25; B34: buoy 34; B36: buoy 36; B40: buoy 40; B50: buoy 50; BM: buoy M; BRC: buoy RC; Ped: Caleta de Pedernales; BP: buoy P).

skippers and dive instructors are very concerned with the PFNMP conservation. When the weather conditions allow, they do not drop anchors and undertake what they call a drift dive operation. This issue should be of foremost importance for

CITMA staff in the PFNMP and for the Colony Hotel. Many authors have identified anchoring as having one of the most important on long lasting negative impacts on the health of coral reefs

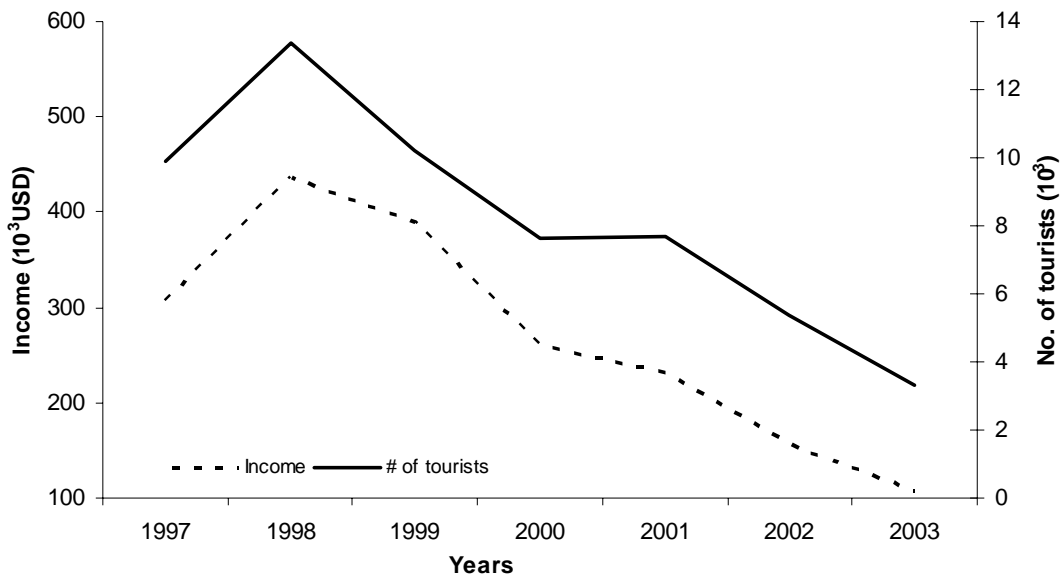


Fig. 9. Annual gross incomes of the Colony Hotel from tourist activities at Punta Frances Marine Protected Area. (Source: Colony Hotel)

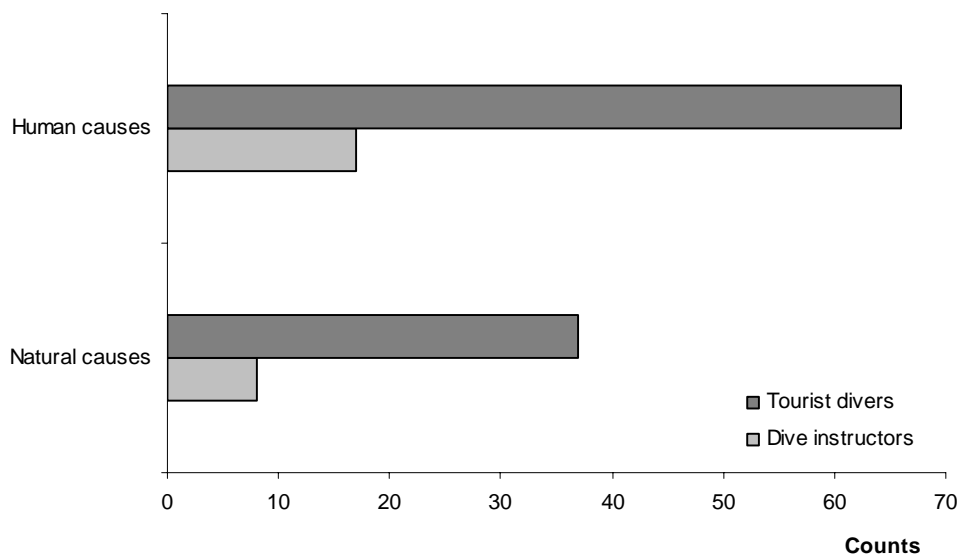


Fig. 10. Main causes of Punta Frances Marine Protected Area deterioration according to dive instructors and boat skippers.

(Davis, 1977; Rogers *et al.*, 1988; Jameson *et al.*, 1999).

Another important aspect mentioned either by tourists and dive instructors was impacts from divers. A large amount of scientific material has been produced dealing with this problem and some authors have called it carrying capacity. Colony officials kindly provided us with information from

the boat's log books. According to them, the PFNMP receives an average of 7 149.3 tourist divers per year. Assuming an even distribution of divers and that each diver does two dives per site, then yearly average dives per site would be 255.33 (Fig. 11). This number is remarkably low compared with others diving destinations in the Caribbean, such as the Bonaire Marine Park, which receives around 17 000 divers per year (Dixon *et al.*, 1993).

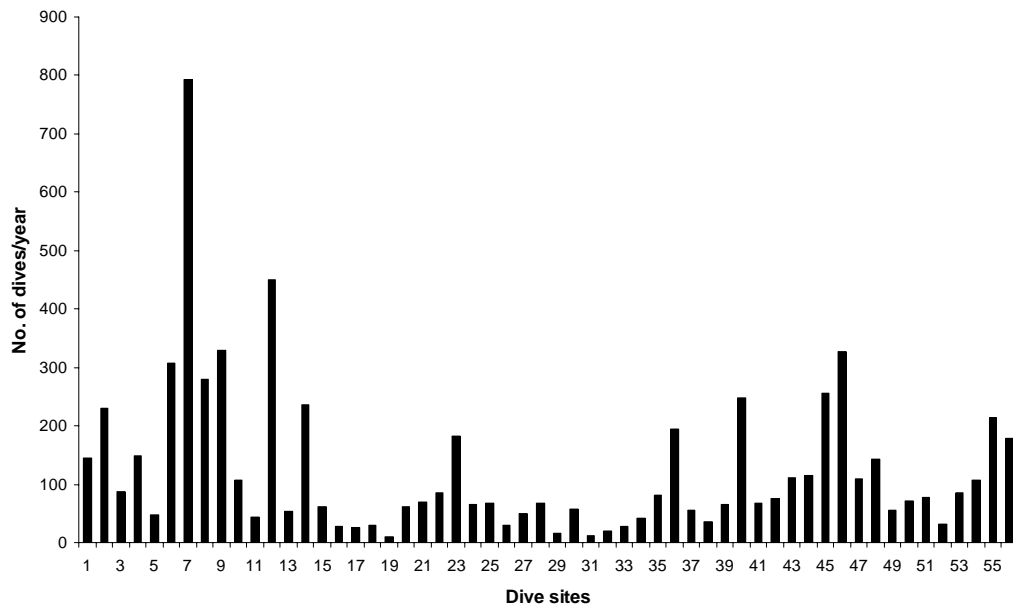


Fig. 11. Dive intensity at Punta Frances Marine Protected Area. Source: Boat's log books.

Hawkins and Roberts (1997) found a first order polynomial relationship between percentage of damaged coral colonies and number of dives ($r^2=0.88$). These authors set figures of 5 000 to 6 000 dives per site per year as a threshold level above which SCUBA diving may cause detrimental effects on coral reef. This finding coincided with Dixon *et al.* (1993) findings for Bonaire Marine Park. Using the figures provided by Hawkins and Roberts (5 000 to 6 000), and assuming an even used of the existing 56 diving sites in the PFNMP, the area can hold up to 336 000 dives per year. Undoubtedly, the PFNMP is still far from reaching its carrying capacity levels in terms of SCUBA diving use.

Nonetheless, this estimation should be seen with caution. Figures provided by Hawkins and Roberts (1997) and Dixon *et al.* (1993) only took into account the number of dives and percentage of damaged coral colonies, and assumed that damage to corals was only caused by divers. In reality, carrying capacity is a function of many other factors such as: number of people entering the water, means of accessing the water (anchoring, shoreline, boardwalks), activity (diving, snorkelling, with gloves), diver experience (training and education), existing management tools (fines, visitor facilities, restricting access), natural physical conditions (depth, topography, currents, waves), type of corals (form and fragility), extent of other stresses (natural and human induced), and the level of acceptable change (Gallo *et al.*, 2002).

The PFNMP dive sites have not been evenly used for many years (Fig. 11), which mean that diving pressure is concentrated on a few sites, making then more susceptible to damage. Also, although anchoring is not allowed it does occur, introducing another uncontrolled variable to the system. The PFNMP is also the site of other economic activities, such as cruise tourism and illegal fishing, as well as natural events, such as hurricanes, that also affect the area very frequently. Therefore, a precautionary approach should be taken when planning for SCUBA dives because the carrying capacity level in the PFNMP might be lower than that reported by Dixon *et al.* (1993) and Hawkins and Roberts (1997).

CONCLUSIONS

Even though strong evidence exists about damage caused by SCUBA diving to coral reefs in other locations (Hawkins and Roberts, 1992, 1993, 1994, 1997; Davis and Tisdell, 1995b) this does not appear to be the case in the PFNMP. SCUBA diving is considered as an activity with residual and sub-lethal effects in the longer term. This, together with the fact that site selection for SCUBA diving is a function of their quality, makes any impact detection very difficult (Hawkins and Roberts, 1992, 1993; Chadwick-Furman, 1997).

Other factors that also might be affecting coral reefs in the PFNMP, which were not taken into

consideration in this study, could include snorkel diving by cruise ship tourists on near shore reefs, illegal fishing that takes place within the area, and commercial fisheries that removes emigrants from the park. The catches from these later two activities is not known, so it is not possible to say how many fish are actually removed from the MPA. Also, according to interviews, cruise ships appear to be inflicting a greater impact on the PFNMP coral reefs, although this assertion needs to be tested. Cruise ships are increasingly visiting the park, and this appears likely to continue into the future. The actual effects of these large ships hovering over the reef are unknown. Issues such as underwater noise pollution and sewage discharge from ships should also be examined.

From this study it can be concluded that SCUBA diving has no apparent impact on the coral reefs in the PFNMP at present. Nonetheless, this should not be taken as a final statement, given that a more precise sampling design is needed to overcome the problems with the power of the test. Furthermore, it appears that the analysis should be conducted at the species level for some sessile organisms, especially coral colonies, when looking for human-induced impacts at a low level.

It is also important to stress the importance of time scale in this type of study. In this particular case two years were considered sufficient to detect human-induced changes in coral reef communities. Nonetheless, this author considers that a longer period of time may have produced superior results, especially for long-lived species that have turnover times much longer than two years.

It can be concluded that evidences found in this study indicates that deterioration of the PFNMP has not been a reason for the declining trend in income experienced by the Colony Hotel. The PFNMP still holds sufficient natural attractiveness to draw attention from the diving industry. To support this it can be said that no loss of amenity values related to diving was perceived. Davis and Tisdell (1995b) stated that before any signs of physical deterioration appear due to high levels of SCUBA-diving, amenity values are first affected, and proposed assessing diver's perceptions to determine this.

Questionnaires used in this study aimed to measure diver's perceptions, and results presented did not provide any indication of declining amenity values. Additionally, no significant impacts from diving over the coral reefs were proved through the

biological assessment to the PFNMP dive sites. Finally, 95.3% of the diving tourists did not consider the place to be overcrowded, and 57.2% of the dive instructors and boat skippers shared the same opinion. Nonetheless, a precautionary approach is recommended to be used when planning and managing SCUBA diving in the PFNMP. Carrying capacity results showed that, apparently, this area is still far from reaching an internationally accepted number of divers above which coral reef damage becomes evident. However, other aspects such as anchoring and uneven use of dive site may be interacting, decreasing carrying capacity levels in the PFNMP.

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