DEPARTMENT FOR INTERNATIONAL DEVELOPMENT

STRATEGY FOR RESEARCH ON RENEWABLE NATURAL RESOURCES

NATURAL RESOURCES SYSTEMS PROGRAMME

FINAL TECHNICAL REPORT

DFID Project Number

R6783

Project title

Ecological and social impacts in planning Caribbean marine-reserves

Project Leader

Nicholas Polunin

Organisation

University of Newcastle

NRSP Production System

Land/Water Interface

Date (revision)

January 2000

Executive Summary

According to the 1997 DFID White Paper, policies and actions which promote sustainable livelihoods, and protection and better management of the natural environment, are two of three objectives to be pursued towards the aim of poverty elimination. Marine protected areas (MPAs) fit into this framework for the Caribbean because they are the means most prominently aimed there at addressing coastal resource management issues and have been shown to be able greatly to enhance the value of coastal areas through tourism in developed locations, yet the majority of MPAs that have been gazetted remain in need of management. As part of the RNRKS, this study generated new knowledge relevant to improved planning of MPAs, through greater understanding especially of the circumstances and perceptions of fishers who are most disadvantaged by MPA developments, and of the ways in which MPAs might be capable of improving reef habitat which is the focus of most diving activities. The ecological study (January 1997 to April 1998) was based on sites at five major Caribbean locations (Belize, Cuba, Grand Cayman, Jamaica and Barbados) where comparisons were made between effectively protected and unprotected areas. It demonstrated in particular that fish attributes of reefs (e.g., total abundance, and numbers of rare and large fishes) were those most appreciated by divers at degraded sites in Jamaica and that these attributes were most likely to be more abundant in MPAs that were effectively managed in areas which were otherwise intensively exploited (Output 1). Using participant observation at two locations in Jamaica, the social study (April 1998 to July 1999) helped especially to characterise the fishers' perceptions that the MPAs concerned in Negril and Montego Bay were for the benefit of tourism, not fisheries, and that tourism development was a principal cause of degradation of the marine environment. The study also highlighted social heterogeneity of the fishers as a substantial challenge for managers seeking to communicate with and involve fishers in MPA developments (Output 2). Building on these findings, and combining them with management expertise and research results from across the region, the project drafted guidelines for improved planning of MPAs in the Caribbean (Output 3).

CONTENTS

BACKGROUND

RESEARCH CARRIED OUT TO DATE AND RESEARCHABLE CONSTRAINTS IDENTIFIED

It has been concluded and widely accepted that most Caribbean marine reserves (hereafter marine protected areas [MPAs]), have not achieved the objectives for which they were gazetted and are in need of management (Stanley 1995). Although certain MPAs in some more developed territories (e.g. Saba, Guadeloupe), can be considered to have been successful, the question remains as to what constrains MPA development at regional level, in spite of widespread demand.

As with other forms of development, so with MPAs, advantages are readily disseminated by interested parties, but disadvantages are insufficiently recognised; those adversely affected are often ignored. Economic valuation of reefs and MPAs is in its infancy, and assessments of economic benefit of MPAs appear to have been confined to those areas where negative impacts of development are small (notably Saba and Bonaire in the Netherlands Antilles; Dixon *et al*. 1995). The principal disadvantage of MPA development falls on those who used marine resources within an area before it was protected from exploitation, and there has therefore been some attention given to improved quantification of benefits. After an earlier phase where increase in abundance and size of fishery-target species within MPAs was quantified, a number of projects are currently focused on one principal expected benefit of marine reserves to fishers, namely the movement of exploited species from MPAs out into fishing-grounds. Studies in BVI and Jamaica (Munro & Watson 1999), St Lucia (A Mitchell et al., unpublished data), and Barbados (Chapman & Kramer 1999) stand greatly to increase understanding of whether, how and under what conditions, fishers might benefit from such movements and the greater availability of useful species. However, most MPAs have in practice been planned with a view to protecting nature and offering foci for ecotourism. MPAs might benefit fishers through tourism, but this depends upon their acceptance of tourism as a source of livelihood. This acceptance might be gained if fishers could understand better the linkages between tourism and the value attached to reefs by divers.

MPAs will tend to be disadvantageous to fishers as extractive resource users, but protection from fishing may have ecological effects which might benefit fishers through other means, especially tourism. There has been scarcely any work on how cessation of fishing might reverse reef degradation, whether and how this might influence diving tourism and provide opportunities for fishers to benefit (Williams & Polunin 1997). There has been assessment of how reef fishing has adversely affected reef ecosystems, particularly in Jamaica, but there has to date been no work carried out on the reversal of ecosystem effects of fishing in areas protected from fishing. The expectation is that when fishing pressure is reduced, target species will increase in abundance and reef condition should revert to what it formerly was. However, understanding of the system dynamics of reefs is very poor, and study of important processes such as predation and recruitment has been severely neglected.

In spite of the evidence that many MPAs are not being properly managed, there appear to have been no attempts systematically to interpret the political and social issues surrounding planned MPA development in densely-populated areas such as Jamaica. The scope for involvement of stakeholders generally, and of fishers in particular, in MPA schemes where tourism is involved has been indicated by recent work being conducted by CANARI in St Lucia. Application of such an approach to socially more complex areas such as Jamaica, where effects of fishing are considered more drastic and disadvantage to fishers more crucial, has scarcely been attempted.

DEMAND

Marine protected areas (MPAs) are a major focus of coastal management action, as recognised for example by the Caribbean Conservation Association (CCA), yet 75% of gazetted MPAs in the Caribbean are considered to be in need of management support (Stanley 1995). The needs to evaluate coastal ecosystem productivity and predict effects of man-induced influences on sustainability are a major part of the UNESCO Coastal Regions in Small Islands (CSI) project. The United Nations Environment Programme (UNEP) through its Caribbean Environment Programme (CEP) is addressing site-specific analyses of coastal ecosystem degradation as major focus of activity for the Caribbean in a GEF project. The Small Island Developing States (SIDS) Action Plan, defined at a meeting in Barbados in 1994, gives considerable attention to coastal and marine resources and 'tourism resources', the latter including an identified need to involve local populations in management of protected areas set aside for tourism. The International Coral Reef Initiative (ICRI), as a result of a 1995 Consultation on Coastal Resource Management in the Tropical Americas supported largely by USAID, identified several key needs, including those to evaluate and integrate human impacts in and out of MPAs, and to involve stakeholders more in coastal resource management. The Caribbean Natural Resources Institute (CANARI) has decided to focus much of its effort on identifying processes and policies leading to greater local participation in managament of natural resources; this is achieved through experimental field studies and case histories. The NRSP Land-Water Interface Production System Portfolio conducted a coastal zone ecosystems programme development visit in the Caribbean in January 1996. Appendix 2 of the report of the visit specifies individuals who identified MPAs and their management as a major set of Caribbean coastal zone issues which should be addressed by research. Arising out of this, a position paper for funding of L/WI coastal zones research in the Caribbean identified MPAs as one of two principal foci of research.

PROJECT PURPOSE

The Purpose of the present project was to identify impacts of marine reserves on stakeholders and reef condition, and contribute to a strategy to optimise benefits of Caribbean marine reserves to local stakeholders. The objectives of the ecological part of the project (Output 1) were to determine what attributes of reefs diving tourists most preferred, to compare reef areas subject to different levels of management with respect to those attributes, and ultimately to infer what management if anything might do at large scale to reverse degradation. The anthropological research (Output 2) focused on the social impacts of MPAs on local fishing populations. This involved study of the social and economic aspects of fishing, local people's assessment of the costs and benefits of MPAs, and of the degree to which these affect the likelihood that the people will support MPA development projects. The objectives of the remainder of the project (Output 3) were to develop and promote sustainable resource-use strategies, disseminate the research results within the region, and contribute to improved future planning of MPAs in the Caribbean.

RESEARCH ACTIVITIES

STUDY LOCATIONS AND SCOPING OF STUDY

Ecological study (N.V.C. Polunin & I.D. Williams)

The original intention of the project had been to focus entirely on Jamaica, for which a series of suitable locations, including those effectively protected from exploitation, intended for protection and unprotected from exploitation, was considered to exist. At the first workshop in April 1997, however, it was recognised that at the principal MPAs involved, protection had proved ineffective (Discovery Bay) or had recently broken down (Montego Bay) (Polunin *et al*. 1997). The Montego Bay Marine Park Trust advised that effects of management should still be discernible in the Montego Bay Marine Park (original legislation in 1974, but official declaration in 1992) no-fishing zone. The Negril Marine Park was only formally declared in 1998 (Table 1), but the Negril Coral Reef Preservation Society reported that local management arrangements were in place in 1997. It was thus agreed with the Project Consultative Group that the project should follow the option in the Project Memorandum of also investigating effectively-protected localities outside of Jamaica, including Barbados (Barbados Marine

Reserve), Belize (Hol Chan Marine Reserve), Trinidad & Tobago (Buccoo Reef Marine Park), and Cuba (Punta Frances National Park), in addition to Montego Bay and Negril (Polunin *et al*. 1997). Later enquiries led to the conclusion that Buccoo Reef was not yet sufficiently protected, and after consultation with the Project Consultative Group it was decided that one of few other well-protected localities in the Caribbean was on Grand Cayman. The project therefore carried out its work at six locations, two in Jamaica, and the other four elsewhere in the Caribbean region (Fig. 1). The Negril location proved not to contain sufficient reef habitat, so it was not used for the purpose of comparing levels of management on reefs, but data from two reef areas in Negril (Fig. 1) were used for the correlation analysis of grazer and algal data (see below). To look for any effects of management or fish abundance that might only be apparent in certain seasons, Belize study sites were visited twice, 6 months apart: first in September 1997, then in March-April 1998.

Social study (J.G. Carrier & L.F. Robertson)

As originally conceived, the project was planned so that there would be an alternation of anthropological and ecological inputs and thus substantial scope for interaction between the disciplines, however this alternation was precluded by DFID, and the research components were therefore conducted sequentially.

For the social impact study, Montego Bay was the primary research location, and Negril was the secondary, comparative research location. Although there were formal MPAs in both locations, both were still in the process of planning their management strategies. There was no location in Jamaica where a MPA was more developed than these. Hence, both fitted the primary criterion of the present research, for they were locations 'where a marine reserve is planned, and hence where political activities relating to reserves are especially visible' (Project Memorandum, p12). Montego Bay and Negril could be considered to typify the geographical pattern of Jamaica's north and west coast. Coastal shallows are fairly narrow and the reef fisheries are fairly restricted. The main fishing grounds are within 3 km of the shore, often much less than that. In both research locations as well, fisheries are small-scale and artisanal. Fishers predominantly sell their catch for money, but the amount of fish caught is relatively small, as is the money earned.

Fig. 1 Locations studied in the Caribbean

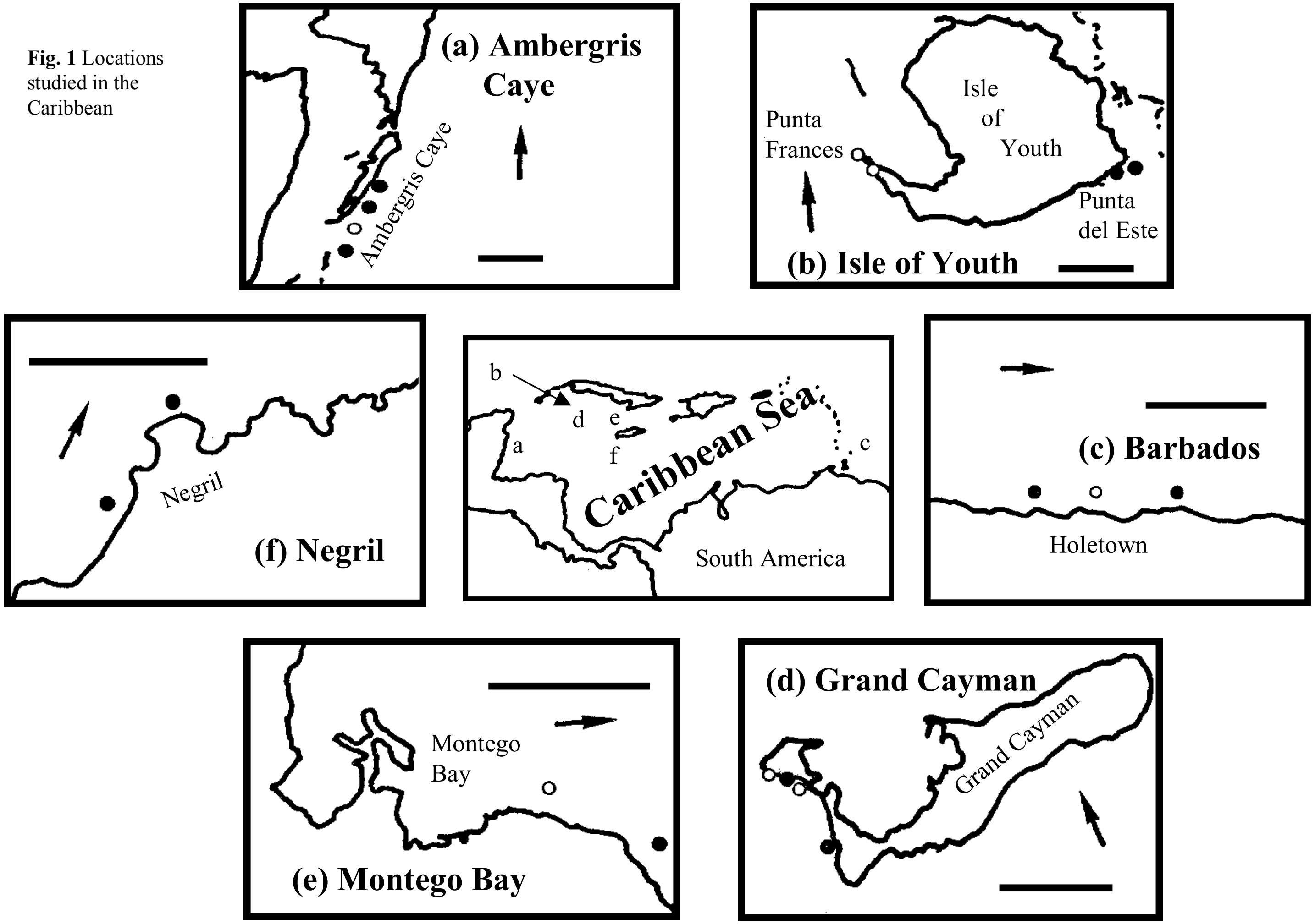


TABLE 1 Summary of survey locations, with date of gazettement (Montego Bay [original legislation in 1974, formal declaration in 1992], Negril, Barbados, Hol Chan, Grand Cayman) or other legal instrument of closure (non-issue of fishing licences at Punta Frances; J. Angulo Valdez, pers. comm. 1998)

Location	MPA from	Survey period	Area	Shallow area	Deep area	Position
Montego Bay	1992	4/97	northern no-fish zone	P	P	77° 56.0’ W, 18° 29.6’N
Jamaica	(1974)		northern dive/fish zone	U	U	77° 55.4’ W, 18° 30.3’N
Negril	1998	5/97		U1	U1	78° 21.6’ W, 18° 19.2’N
Jamaica				U2	U2	78° 20.1’ W, 18° 22.3’N
Marine Reserve	(1981)	6/97		P		59° 38.5’ W, 13° 10.9’N
Barbados			South of Reserve	U1		59° 38.5’ W, 13° 09.6’N
			North of Reserve	U2		59° 38.5’ W, 13° 12.1’N
					P	59° 38.8’ W, 13° 10.8’N
Ambergris Caye	1987	9/97, 3-4/98	Hol Chan Cut	P	P	87° 58.6’ W, 17° 52.1’N
Belize			San Pedro Cut	U1	U1	87° 56.5’ W, 17° 56.1’N
			Mata Cut	U2		87° 54.9’ W, 17° 58.6’N
			Mexico Rocks Cut		U2	87° 54.1’ W, 17° 59.7’N
			Caye Caulker Cut		U3	87° 59.3’ W, 17° 48.4’N
Grand Cayman	1986	10/97			P1	81° 23.4’ W, 19° 20.3’N
C.I.					P2	81° 24.1’ W, 19° 21.8’N
					U1	81° 23.7’ W, 19° 21.5’N
					U2	81° 23.5’ W, 19° 18.7’N
Isle of Youth	(1978)	4/98	Punta Frances		P1	83° 10.4’ W, 21° 36.4’N
Cuba					P2	83° 09.7’ W, 21° 35.3’N
			Punta del Este		U1	82° 31.5’ W, 21° 32.8’N
					U2	82° 35.8’ W, 21° 31.2’N

The prime area in Montego Bay was Whitehouse, a small residential area about five kilometres from the centre of the city. It is the only residential fishing area in Montego Bay, and hence best suited as the site of most intensive participant observation. Whitehouse itself is divided into two sub-units, Top Whitehouse and Bottom Whitehouse, which are described below. Whitehouse is next to the Montego Bay airport, on the eastern boundary of the Marine Park. It contains many people who fish regularly, and it serves as a fishing beach for many others who live elsewhere. The subsidiary area in Montego Bay was River Bay, in the downtown area of the city, located just south of the Pier 1 development, and approximately in the middle of Marine Park waters. It is only a fishing beach, and no one lives there.

The prime area in Negril was Orange Bay, a small town to the north of Negril town and well within the Negril Marine Park boundaries. The town of Orange Bay contains a number of fishers, though the Orange Bay fishing beach also serves some fishers who live elsewhere. The subsidiary area within Negril was Negril River, a fishing beach in Negril town. Like River Bay, it is primarily a beach, though over the past few years it has become built up to a degree, and a few people now live there. Even so, the vast majority of Negril River fishers live scattered in towns and villages in the area.

The social research (Output 2) had to be modified in one important respect, the study of those involved in the tourist industry. This decision was made reluctantly, but was felt necessary in order to allow the research on local fishing populations to proceed as intended, research that addresses more directly the concern for local participation and equitable development.

One factor which it was not possible to anticipate was the degree that Jamaican fishers were suspicious of and hostile to the marine parks. Such attitudes were not universal among fishers, but they were quite common. Consequently, any study of those in the tourist industry would have to have been surreptitious, and was effectively impossible.

It was anticipated that Jamaican fishers would be suspicious of outsiders, and this proved to be the case. The field researcher was never accepted by all members of the Whitehouse and River Bay fishing communities: indeed, even after extended field work, there were some who still thought that the researcher was an agent of the United States Drug Enforcement Administration. (Sympathetic fishers said that the DEA has carried out a number of covert operations in Jamaica.) At a practical level, this general suspicion was apparent in the fact that if the researcher were absent from the fishing beach for a day or so, that absence was noted and commented upon, and the researcher was asked about the absence subsequently. This in turn meant that it would have been risky to take the time that would be required for a study of those in the tourist industry, a study that would have required repeated absence from the fishing beach.

This risk was compounded by the fact that the researcher became well known to many Jamaicans in Montego Bay and Negril. Thus, even when she was away from Whitehouse or Orange Bay, her movements were likely to be observed and talked about among the fishers she was studying. This was especially the case concerning the tourist industry. The researcher was particularly likely to know and be known by lower-level workers in this industry: boat drivers, divers, water-ski operators, even desk clerks. Consequently, were she to approach people in the tourist industry, it would almost certainly be observed and commented upon.

Further, many fishers were highly suspicious of the two Marine Parks, and associated those Parks closely with the tourist industry. Any sustained contact with those in the tourist industry would, then, not only have been apparent to fishers, but would have identified the researcher with the tourist-Marine Park interests in the area, and made research among fishers difficult to the point of being impossible.

In effect, then, any serious effort to communicate with those in the tourist industry in the field would have been apparent to the fishers who were the main focus of the social research, and would have jeopardised the main goal of this aspect of the research.

As we said, the decision not to attempt to study the tourist industry was taken with reluctance. However, it was judged that the extended study of local fishers was more important, both to the research project and to the general development and ecological issues that the project addresses, than the study of those in the tourist industry, a group whose interests are addressed at least indirectly in the study of diver preferences.

METHODS OF STUDY

Ecological study (N.V.C. Polunin and I.D. Williams)

Diver preferences for reef attributes

During March-May 1997, a survey of the preferences of divers for reef attributes was conducted by Ms Joy Douglas of the Executive Secretariat Limited, Kingston, Jamaica, using questionnaires distributed to both dive operators and tourist divers (details in Douglas 1997). One hundred divers were questioned in Negril and a further 95 in Montego Bay. The dive operators surveyed were five out of nine listed by the Jamaica Tourist Board for Negril and five out of 10 for Montego Bay. The principal question put to the dive operators was 'which underwater factors most govern your choice of dive sites?' and respondents were asked to rank each of 14 attributes (reef structure e.g. drop-offs; big fishes; other large animals; variety of fishes; abundance of fishes; variety of corals; large corals; coral cover; unusual fishes; unusual corals; unusual sponges; unusual algae; lobsters crabs etc.; other) on a scale from 1 (not very important) to 5 (most preferred). The principal question put to the divers was 'what are the features of the marine environment which you most prefer to see on a dive? (1 = not very important 5 = most preferred)' and they were also asked similarly to rate the specific diving locality involved, the request being: 'please rate Montego Bay/Negril in terms of the following (1 = poor 5 = excellent)'. For the diver preferences, respondents were again asked to rank each of the 14 attributes on 1-5 scales. In all three cases, a mean rating could be calculated for all respondents, and in the case of the divers, it was possible to use the returns from the survey to derive a measure of the disparity between what divers liked generally to see and what they saw in practice at the localities concerned for the 14 attributes, by subtracting the mean ratings of each attribute from the two questions one from the other.

Assessment of reef condition

The following terminology is used throughout:

- **'Location'** is the locale or geographic region in which a set of surveys was carried out. In general each location was based around an MPA.
- The study '**areas'** within a location included one or more areas within the MPA and one or more areas outside of the MPA. As far as it was possible, study areas were selected to be 1.5 to 2 km long stretches of continuous reef.
- Each reef area was sub-sampled by dividing it into 12 to 15 sections of 125-150m long reef (depending on the extent of the reef habitat), and randomly selecting 5-6 of these as study **sites.**
- At each site, between 4 and 6 replicate fish counts were carried out. Data from replicate counts within each site were always pooled, so that the lowest level of analysis is always that of sites.

An exception to the above sampling design was used on the Barbados shallow reefs (west coast of Barbados, centred around the Barbados Marine Reserve). There, reefs are not continuous along the shore, but consist of small sections of spur-and-groove reef separated by 50 to 800m wide areas of sand and rubble. The three reef areas selected for comparison there were (1) the 2.2 km (length of coastline) of the Barbados Marine Reserve itself, (2) the 2.2 km of coastline immediately south of the Reserve, and (3) the 2.2 km of coastline immediately north of the Reserve. The five largest portions of reef in each of the areas were selected as the study sites.

Surveys were conducted on 'deep' reefs, i.e. (depth 12-15m) and 'shallow' reefs (i.e. depth <6m). The same survey method was used at all deep sites, but because of considerable differences in reef structure and fish density, the same methods could not be used at two of the shallow locations, namely the Barbados Marine Reserve and Ambergris Caye in Belize.

Surveys of deep reefs (12-15m) and Jamaican shallow reefs (6m)

Each survey was conducted by a pair of divers, one counting fish and the other taking photographs of the benthos. Randomly-selected study sites were located using a GPS. On entering the water, both divers swam immediately to the prearranged survey depth, and began the survey, working in a pre-arranged direction along the depth contour.

Fish census

The leading diver made 4 or 5 fish counts using a modification of an existing stationary UVC method (Bohnsack & Bannerot 1986), in which all target fishes were counted within an imaginary cylinder of fixed diameter extending from the reef up to the water surface. Four replicates cylinders of diameter 15m (Jamaica and Barbados) or five 10m diameter cylinders (Belize, Cayman) were carried out per survey dive. Fish densities from each location were later normalised by converting fish-counts to numbers per $100m^2$ of reef area. Fish counts were conducted on areas of hard-bottom, haphazardly separated by approximately 20m estimated by counting fin-kicks; fish were identified primarily from Humann (1989).

Fishes in six families, namely snappers (Lutjanidae), groupers (Serranidae), surgeonfishes (Acanthuridae), parrotfishes (Scaridae), triggerfishes (Balistidae), and grunts (Haemulidae), were counted. The procedure was for the diver to count relatively mobile fishes (Balistidae and pelagic Lutjanidae, i.e. *Ocyurus chrysurus*) before entering the cylinder. A diameter line was then laid out. The diver would then return to the centre of the cylinder and fix on reference points around the outside of the cylinder using the diameter line as a guide. Once the dimensions of the cylinder had been fixed mentally, fishes of the remaining families were counted in three slow 360° turns with, where possible, the observer remaining in the centre of the cylinder. The aim was to make an instantaneous count in each sweep; fish moving into the cylinder in sections already swept were ignored. In the first sweep, acanthurids were counted, in the next haemulids and demersal lutjanids were counted, and in the last, scarids were counted. Because of the tendency for serranids to retreat into crevices but otherwise to be relatively stationary, the position of serranids was noted on all sweeps unless it was obvious that they had just moved into the cylinder. Fish were identified to species and an estimated length (cm) was recorded for each individual. Only fishes estimated to be longer then 12cm were recorded, because we considered that larger fishes would be more likely to have more impact on the benthos and were likely to be more vulnerable to fishing. Accuracy of length estimates was established by initially practising with pre-cut lengths of electrical cable of known length and then maintained by regularly checking estimates of length of benthic objects with a scale on the side of the recording slate. For each fish censused, biomass was estimated, using previous published mass-length relationships for Caribbean fishes (Bohnsack & Harper 1988). All fish counts were performed by the same observer.

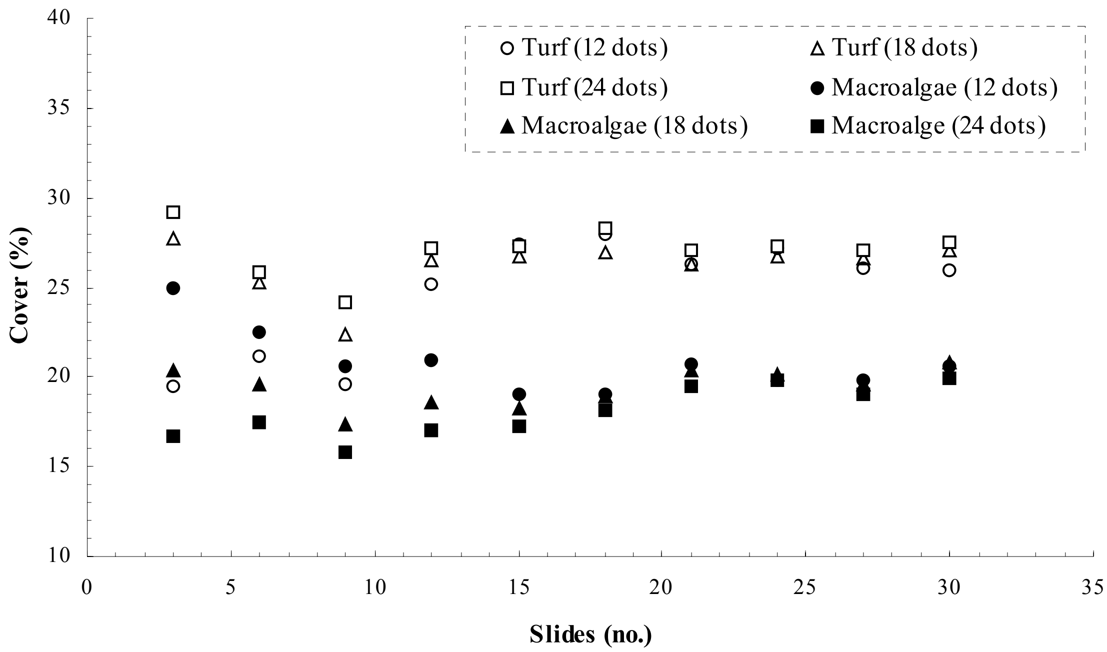
Benthic survey

The second diver laid out a 100m transect line, directly following the line taken by the first, and photographs were taken at 30 points along the line, the exact distances along the transect having been previously randomly selected and written on a small slate carried by the diver. The camera was kept at a fixed distance from the reef by use of an adjustable spacer pole attached to the camera. Colour slides were taken using a Nikonos V underwater camera with a 15mm lens and twin flashes. Percent cover of benthic organisms was estimated by projecting slides onto a grid of 2.5cm-diameter circles. The category of organism at the centre of each circle was recorded. Algae and other biota were identified from Littler *et al*. (1989) and Humann (1990).

Benthic organisms were recorded in the following categories: 'bare' substratum, sand, hard coral (by species), sponge, gorgonian, other invertebrates (by family), crustose coralline algae, mixed turf (mixed species assemblages of diminutive algae with canopy height of <1cm), fleshy macroalgae (more upright and anatomically complex algae with frond extension of >1cm, recorded to genera), and blue-green algae. The benthic algal communities involved are multi-layered, so it was commonly the case that crustose coralline algae were present under an upper layer of macroalgae. The photographic method used only allowed the top canopy to be seen, and therefore almost certainly underestimates the amount of crustose coralline algae present.

At each location, a cumulative coverage graph was created for each of the categories of interest to check that accuracy of estimate would not have been improved by increasing the sample size or number of points per slide (Fig. 2).

(a)



(b)

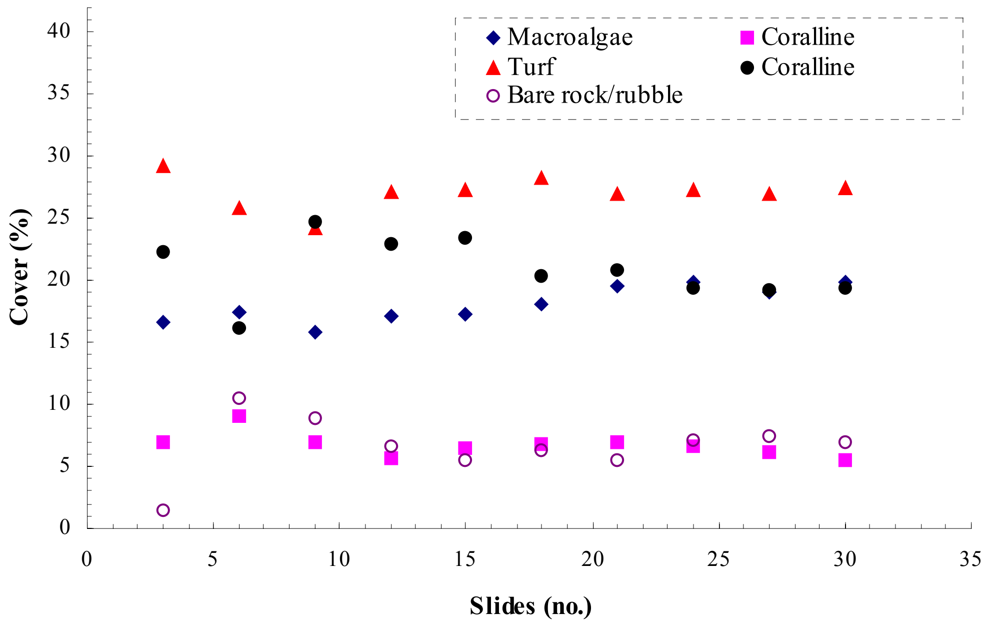


Fig 2 Effects of (a) different numbers of dots per slide and (b) different numbers of slides, on the estimated substratum cover by different categories of the benthos

Modifications to survey methodology for Belize shallow reefs

Shallow reef areas in front of Ambergris Caye are very patchy, with small areas of coral separated by large areas of seagrass and sand. The most consistent habitat among all study locations was deemed to be the 1-2m deep rubble zone approximately 50-100m behind the reef crest, and therefore sites were selected from that zone in all study areas. As the habitat is comparatively flat, and as fish numbers were relatively low, it was decided to effectively increase the sample size of fish counts by counting all fishes within or passing through the 10m-diameter fish census cylinder within a 10-minute period, rather than do instantaneous counts. Another characteristic of the rubble zone was that the areas of rubble were frequently broken up by patches of sand and seagrass, and so it was not possible to find 100m long stretches of consistent habitat, therefore, a single 35m long transect line was laid out and photographs were taken at 1m intervals along the line.

Modifications to survey methodology for Barbados shallow reefs

The shallow reefs surveyed around the Barbados Marine Reserve consist of small sections of spur-and groove reef starting close to shore. The shallow reefs are separated by wide expanses of sand and rubble, so that within each study area, there were very distinct reefs, the 5 largest of which within each area were selected as study sites. We chose to survey the fore-reef zone on these shallow-reefs, i.e. the zone beginning at the reef crest (about 1m deep) and extending offshore (in most cases less than 50m and to a depth of about 3m). Within each site, the areas of solid substratum (the spurs) were widely separated, so it was not possible to use a single 100m transect line laid parallel to shore, as was done in the benthic survey at the deeper sites. Instead, starting from the southern edge of each site, and working northwards, the first 6 spurs with forereef longer than 20m were surveyed. On each spur, a 20m transect line was laid out, beginning from the seaward edge of the spur (or at 3m deep, if the spur extended into deeper water) and running along the middle of the spur towards the reef crest. In total therefore, 120m

(6 x 20 m) of transect were surveyed using otherwise the same method as at the deeper sites. As visibility was sometimes low and because patches of hard substratum were usually only 3-4 m wide, UVC cylinders were not appropriate for censusing fish populations. Instead, at each of the six spurs selected for the benthic survey, two 4 x 20 m belt transects were surveyed, one on the northern edge of the spur and the other on the southern edge of the spur, each belt transect being centred on the boundary between spur and groove.

Quantification of *Diadema* abundance

The sea-urchin *Diadema antillarum* was either extremely rare or not present on reefs on the deeper reefs (≥12m) surveyed; the highest density found in preliminary surveys was $0.02m^2$ at one site in Grand Cayman. However, *Diadema* were locally abundant at shallow sites, at least in patches, so the following methods were used to census them: at Barbados and Belize sites, by counting all *Diadema* within 2m wide belt transects centred on the transect lines along which benthic photographs were taken; and, at Jamaican sites, by counting all urchins within the cylinders used for fish UVCs.

Quantification of habitat characteristics

With a view to making allowance for any broad habitat differences among sites censused, visual estimates were also made of dominant components of the benthos within each area sampled (i.e. % coral, % sand., % rubble, and where relevant % seagrass). The structural complexity (rugosity) of the substratum was also estimated on a 6 point scale: 0 = no vertical relief; 1 = low and sparse relief; 2 = low, but widespread relief; 3 = moderately complex; 4 = very complex with numerous caves and fissures; and 5 = exceptionally complex with high coral cover and numerous caves and overhangs.

Statistical analysis

Prior to any analysis of variance (ANOVA), a test for homoscedasticity (Levene's) was conducted, and when necessary, data transformations were applied, namely ln(x+1) in the case of fish biomass data, and ln(x+0.01) in the case of fish numerical abundance data; no transformations were necessary for other data. Univariate techniques were carried out using

Minitab statistical software release 11 (Minitab 1996), and multivariate statistics by PRIMER (Carr 1997; Clarke & Warwick 1994).

Analysis of habitat characteristics

Two methods were used to test for differences in habitat characteristics among or between study areas at each location, namely ANOVA for individual habitat characteristics and ANOSIM for multivariate data (Carr 1997; Clarke & Warwick 1994). Where ANOVA or ANOSIM of the habitat data showed significant differences among the study areas, we tried to resolve those differences by excluding the data from one site in each area that contributed most to the habitat differences among or between areas. If there were no significant differences in habitat characteristics among areas using those remaining sites, we would then use that sub-set of sites for all future analyses. When it was not possible to resolve differences in that way, we tried to estimate the likely importance of the difference in habitat on the fish abundance we found in each area by calculating the Pearson Correlation Coefficient between fish abundance and the habitat variable concerned.

Analysis of fish reef condition data

Within study locations, differences in fish diversity, abundance and biomass were tested using ANOVA, and, where there where significant differences, Tukey's studentised range tests were used to evaluate those differences. Fish diversity was calculated in two ways: species richness (total number of species in surveys) and Shannon-Wiener diversity (H' calculated using the formula $H' = -\sum p_i \ln p_i$, where p_i is the proportion of the total count or biomass arising from the *i*th species). At most study locations, one protected area and one or more unprotected areas were compared using 1-way ANOVAs, but at two locations (Caymans and Cuba) 2-way designs were used as, at those locations, two protected areas were compared with two unprotected areas. For the Caymans data, a 2-way nested ANOVA was used with area as a random factor nested within management status (fixed factor being level of management, namely protected or unprotected). For the Cuban data, a crossed design was used with reef-type (fringing or barrier) and management level (protected or unprotected) as the two factors.

Mann-Whitney U tests were used to look for differences in the median body-size of common species of fishes. To increase the number of species for which there were sufficient data to perform tests, data were pooled into two categories, namely 'all protected sites' and 'all unprotected sites', and tests were carried out on all species for which n≥10 for both 'protected' and 'unprotected' data.

Using the pooled data, the mean abundance and biomass of all species at protected and unprotected sites were calculated for each location. The proportion of species with greater abundance and/or biomass at protected and unprotected sites were compared with a binomial distribution, which assumed that there was equal likelihood of a species being most abundant in protected as in unprotected sites, to determine the probability of such a proportion arising by chance.

Analysis of benthic reef condition data

Within study locations, differences in coral cover and diversity were tested using ANOVA, and, where there where significant differences, Tukey's studentised range tests were used to evaluate those differences. ANOVA is robust to many types of non-normality (Underwood 1981), but Levene's test was used to test for homogeneity of variances because this had more substantial implications for the analysis (Underwood 1997). As above, diversity was calculated in two ways, namely species richness and Shannon-Wiener diversity (H'). As with the fish data, most study areas were compared using 1-way ANOVAs, but a nested 2-way design (areas within management status) was used for the Caymans and a 2-way design (management status crossed with reef type) for the Cuban data. To enable us to look for broad differences in reef benthos, ANOVAs were also performed on two other benthic categories, namely macroalgae and a composite category representing all the benthic categories maintained particularly by grazing (turf algae + 'bare' rock + crustose-coralline algae). Differences in these categories among areas were again tested using ANOVA.

To look for differences in community structure, we used non-parametric multivariate methods from the PRIMER suite of programmes (Carr, 1997; Clarke & Warwick, 1994). Within study locations, differences in benthic community structure were tested using ANOSIM, and where there were significant differences between areas, SIMPER tests were used to determine which benthic categories contributed most to the overall differences found. Percent cover data used in multivariate analysis was double square-root transformed, and similarity among sites calculated using the Bray-Curtis coefficient.

Large-scale correlations between herbivorous fish abundance and benthic algae

To enable us to look for broad relationships between herbivorous fish and benthic algal communities, we pooled biomass of parrots and surgeons into a single category 'herbivorous fish', and benthos into two categories, namely 'macroalgae' and the composite category, TBC. To determine whether there was a relationship between the abundance of herbivorous fish and coverage of algal categories we calculated the Pearson's correlation coefficient between the biomass of herbivorous fishes and the coverage of each of the algal categories. To enable us to look for broad relationships between herbivorous fish and benthic algal communities across all study sites, we grouped fishes into two classes, namely herbivorous (parrots and surgeons) and non-herbivorous (snappers, grunts, groupers and triggers), and benthos into two categories, namely macroalgae, and grazed substrata.

Social study (J.G. Carrier & L.F. Robertson)

The research was based on intensive and long-term interaction with local fishing people. In Montego Bay, this meant about a year (April 1998 to March 1999) spent living in or near Whitehouse, a residential area of the city, though the researcher made return visits while studying the Negril sites. In Negril, this meant about three months (March to June 1999) living in Orange Bay. In addition, subsidiary research was carried out at the same time at an additional fishing location in each site, River Bay for Montego Bay, and Negril River for Negril. These subsidiary sites were studied in order to provide an additional check on and comparison with the respective main sites.

The groups studied varied with location and area. For Whitehouse and Orange Bay, the groups amounted to all those who regularly fished from these areas. For the subsidiary areas, the groups studied were necessarily less exhaustive of the fishers who used these areas. For River Bay, the group studied was effectively those who used the area frequently, though as we explain below, the nature of River Bay means that this was a fluid group. For Negril River, the group was an unknown but probably moderate proportion of those who fish there, acceptable given the finding that what was being discovered there did not depart in any substantial way from what had been learnt at the main Negril area, Orange Bay.

The main research technique was standard participant observation, especially interacting with people on a daily basis, going fishing with them, discussing why they were undertaking the activities that they were. This technique made it possible to gain the confidence of local people, which was especially important in these areas, where people were relatively suspicious of outsiders asking about their activities. This technique also made it possible to observe, rather than merely ask, and so to see actual practices and the ways that they departed from the more formal statements that people made about them. The contrast between formal statement and actual practice was beneficial in allowing greater insight into people's explanations of what they did than could have been obtained through surveys or discussion groups. The marked fluidity of the population of fishers justified the decision to rely on intensive field research rather than on surveys of samples. However, semi-structured and unstructured interviews were held with some fishers, to allow more detailed consideration of some of the issues of concern in this study and to act as a check on the information gathered during participant observation.

Fishers were interviewed in different ways throughout fieldwork. Informal semi-structured interviews were conducted with a sample of fishers in the Montego Bay area first. This enabled the researcher to be introduced to other fishers in the area through the social networks of which the fishers interviewed were a part. After the researcher came to know the majority of fishers at each beach, subjects were selected to be interviewed on an individual basis rather than in groups. (Group interactions were, of course, observed in the normal way during field work.) This made it more likely that fishers would give their own opinions, not influenced by what others said. It also enabled interview subjects to speak about other fishers, which they would not have been able to do if others were present. Fishers were selected at each beach by various criteria. For the Montego Bay sites, 26 men were interviewed at Bottom Whitehouse, 10 at Top Whitehouse and 25 at River Bay. For the Negril area sites, 28 men were interviewed at Orange Bay and 25 at the Negril River fishing beach. Subjects were selected in part to make sure that users of different types of gear were represented. (At each beach there were some who did not wish to be interviewed).

At all beaches it was very important that a range of fishers were selected on their political and economic standing at the fishing beach. Leaders of each beach were interviewed: at River Bay and Negril these were members on the co-operative committee; at Whitehouse they were individuals who were more considered to speak for fishers. At all beaches except Top Whitehouse, leaders were distanced from the majority of fishers: they were part-time fishers and they spent very little time on the fishing beach, and fishers felt they did not represent them properly. Leaders (apart from River Bay) were also more open-minded about the Parks than other fishers normally were. This was especially so at Negril and Orange Bay, as leaders there had long-standing contact with Park management, whereas other men had no contact at all. At each site, poorer fishers (those who did not own their own equipment) were selected along with those who were considered more wealthy, as this allowed greater understanding of the conflicts among fishers and of the range of different opinions on the Parks.

Because Montego Bay was the prime location of research, a number of general issues were identified from there. The report on Negril will be somewhat briefer and, because of the lengthier treatment of Montego Bay, more descriptive. Work at the two sites covered roughly the same issues, but the issues did not match each other exactly.

OUTPUTS

ECOLOGICAL IMPACTS (N.V.C. Polunin & I.D. Williams)

Diver preferences

The diving tourists surveyed in Negril and Montego Bay indicated that variety of fishes,

TABLE 2 Mean ranking (1-5 scale) of reef attributes by the sample of diving tourists (n = 195) when asked what they preferred to see on dives generally. Based on data from Douglas (1997)

Reef attribute	Ranking of reef attributes
Variety of fishes	4.32
Abundance of fishes	4.16
Variety of corals	4.13
Other large animals	3.99
Unusual fishes	3.92
Coral cover	3.66
Big fishes	3.57
Reef structure	3.50
Unusual corals	3.50
Large corals	3.26
Lobsters, crabs etc..	3.20
Unusual sponges	3.15
Unusual algae	2.31

abundance of fishes, variety of corals, other large animals and unusual fish were significantly more highly ranked than the other attributes at dive areas generally (Table 2). An index of disparity between what divers said they preferred generally at dive localities and how they actually rated the dive sites in Negril and Montego Bay was derived by subtracting mean ranks of each attribute for dives generally from mean ranks of each attribute from the dives in Jamaica; the intention was to determine what divers were most disappointed by at a location where both fish and coral communities are substantially degraded. The divers sampled indicated that other large animals, big fishes, variety of fishes, unusual fishes and abundance of fishes were the reef attributes most lacking at the Jamaican localities (Table 3). The divers were not so apparently disappointed by reef-benthos attributes including coral cover and variety of corals that they had rated highly for diving localities generally, even though coral cover and diversity were low at the Jamaican locations where they had been diving. It was concluded that fish attributes were amongst the most important which management might enhance in marine protected areas, and the project therefore aimed to compare densities of large fishes ('big fishes'), fish diversity and species richness ('variety of fishes'), and fish density and biomass ('abundance of fishes'), between protected and unprotected marine areas in each locality. The project also aimed to compare coral diversity and species richness ('variety of corals') and coral cover (Table 3), as well as cover of benthic algal communities as major components of reef degradation.

Visually-assessed habitat characteristics of reef areas

No differences in habitat data were discerned between protected and unprotected areas at either

TABLE 3 Disparity between (a) mean ranking by divers of attributes generally preferred on dives and (b) mean ranking of the same attributes by the same divers for Negril and Montego Bay dive areas in Jamaica. Based on data from Douglas (1997)

Reef attribute	Disparity between rankings of reefs generally and actual areas
Other large animals	-1.64
Big fishes	-1.12
Variety of fishes	-0.97
Unusual fishes	-0.87
Abundance of fishes	-0.81
Lobsters, crabs etc..	-0.50
Variety of corals	-0.33
Coral cover	-0.11
Unusual corals	0.10
Large corals	0.19
Reef structure	0.25
Unusual sponges	0.36
Unusual algae	0.49

depth in Montego Bay, in Barbados, on shallow Belize reefs, or on deep Belize reefs, when, in the last case, the data from one outlier site were removed from each area (Table 4). Although there were differences among areas in the Caymans, there were no differences between protected and 'replenishment' (fished) sites. Cuba was the only location for which there were significant ANOSIM differences between management levels, and 2-way ANOVA indicated that mean coral cover and rugosity were both lower in the unprotected areas than the protected areas. Correlation indicated that there were significant relationships between grouper density and both rugosity and coral cover, and between rugosity and triggerfish numerical abundance (Table 5). Thus for the Cuban areas there were potential habitat effects confounding any management-level differences, particularly in any differences involving groupers or triggerfishes.

TABLE 4 Results of ANOVA comparing habitat data between protected and unprotected areas at all localities

Location	ANOSIM p	Differences in habitat variables by 1-way ANOVA
Mo Bay (5m)	0.151	none
Mo Bay (15m)	0.563	none
Barbados (2m)	0.179	none
Belize (2m)	0.065	none[1]
Belize (12m)	0.089	Rubble (p<0.05) range was from 6.7% (San Pedro) to 1.7% (Caye Caulker), Hol Chan was 3.8%
Belize (12m)[2]	0.381	none
Caymans (12m)	0.077	nested ANOVA (areas within management level): none
Cuba (12-15m)	<0.001	2-way ANOVA (reef type and management level): rugosity p<0.001 mean range 2.3-4.1; coral cover p<0.001 mean range 4.8-11.6%; both variables, unprotected sites < protected sites

(1) % sand was ln(x) transformed to meet requirement of homogeneity of variance
(2) areas BEC5, BES2, BEH5, and BEM2 removed from the analysis

Fish abundance and biomass

One-way ANOVA indicated very few species-level differences between management levels at any locality, but high variability within the data meant that at the species level there was little power in the test. The binomial test indicated, however, that a high proportion of those fish species present tended to show greater numerical abundances and/or biomasses in protected than in unprotected areas (Table 6). In all cases there were more species found only in protected than

TABLE 5 Results of correlation between all fish groups and both rugosity and coral cover at protected (n = 16) and unprotected (n = 12) sites in Cuba: * = p<0.05, other comparisons NS

Fish family	Rugosity:		Coral cover:	
	Protected	**Unprotected**	**Protected**	**Unprotected**
Grouper	0.261	-0.556*	0.489*	0.551*
Snapper	0.441	0.271	-0.202	-0.140
Trigger	-0.581*	-0.493	-0.171	0.369
Grunt	-0.060	0.372	0.316	-0.141
Parrot	-0.079	0.578	-0.194	-0.116
Surgeon	-0.224	-0.358	-0.049	0.386
All fish	0.002	0.200	0.095	0.208

in unprotected areas, the differences being especially great for the Caymans and Cuba, with large snappers and groupers being especially prominent in this regard (Table 7). There were, however, parrotfish and snapper species in particular which were only recorded in unprotected areas in certain locations. The detailed results will now be reported location by location.

Montego Bay

In shallow water (6m depth), two species of groupers and snappers were found exclusively in the reserve (Table 7), while abundances and biomasses of grunts, parrotfishes, surgeonfishes and all fishes combined were greater in the protected area than in the unprotected area (Tables 8-9). On deep (15m) reefs, there was no substantial evidence from biomass or abundance data for effects of management (Table 10-11), but three snapper and two grunt species were found only in the protected area (Table 7). Fish biomass tended to be especially great in the protected relative to the unprotected area for snappers (shallow reef) and grunts (shallow and deep reefs)(Table 13).

Barbados

Comparison between the MPA and unprotected areas was only possible for the shallow reefs. All 17 fish species present and all fish families tended to have greater abundances and biomasses in the MPA than unprotected areas (Table 6), but the differences were significant

TABLE 6 Number of species recorded in surveys at each location, and the number of those species with higher mean biomass or numerical abundance in protected (P) than in unprotected (U) sites. Results of binomial test: * = p<0.05 ** = p<0.01 *** = p<0.001

Location	Species recorded (No.)	Species with greater biomass in P than U (No.)	Species with abundance in P > U (No.)
Shallow sites (<6m)			
Montego Bay	21	14	14
Barbados	17	17***	16***
Belize	26	21**	21**
Deep sites (12-15m)			
Montego Bay	19	11	12
Caymans	26	18*	16
Belize	27	20**	20**
Cuba	34	23*	22

only at family level, namely for snapper and parrotfishes (Tables 8-9), while a grouper and a grunt species were found only in the Reserve (Table 7). The mean biomass in the MPA relative to the unprotected area tended to be particularly great for grouper and snapper (Table 12), although the former did not represent a significant difference (Table 8).

Belize

On the shallow reefs, 21 out of the 26 fish species observed had greater abundance and biomass in the MPA than in unprotected areas (Table 6). All families tended to show greater abundance

TABLE 7 Fish species recorded only in protected sites or unprotected sites at all localities

Species found only in MPA	Species found only unprotected areas
MONTEGO BAY (15m)	
Lutjanus analis Mutton snapper	*Sparisoma radians* Mahogany snapper
Lutjanus apodus Schoolmaster	*Acanthurus chirurgus* Doctorfish
Ocyurus chrysurus Yellowtail snapper	*Melicthys niger* Black durgon
Haemulon aurolineatum Tomtate	
Haemulon plumieri White grunt	
Sparisoma chrysopterum Redtail parrotfish	
MONTEGO BAY (6m)	
Epinephelus adscensionis Rock hind	*Lutjanus analis* Mutton snapper
Epinephelus cruentatus Graysby	*Cantherhines pullus* Orangespot filefish
Lutjanus apodus Schoolmaster	*Haemulon carbonarium* Caesar grunt
Ocyurus chrysurus Yellowtail snapper	*Sparisoma chrysopterum* Redtail parrotfish
Scarus vetula Queen parrotfish	*Sparisoma radians* Bucktooth parrot
Sparisoma rubripinne Redfin parrotfish	
BARBADOS (1-3m)	
Epinephelus adscensionis Rock hind	(none)
Anisotremus surinamensis Black margate	
BELIZE (12m)	
Epinephelus striatus Nassau grouper	*Lutjanus mahogoni M*ahogany snapper
Mycteroperca bonaci Black grouper	*Lutjanus synagris* Lane snapper
Lutjanus jocu Dog snapper	
Lutjanus analis Mutton snapper	
Cantherhines pullus Orangespot filefish	
BELIZE (<2m)	
Lutjanus analis Mutton snapper	*Lutjanus synagris* Lane snapper
Ocyurus chrysurus Yellowtail snapper	*Scarus vetula* Queen parrotfish
Haemulon parra Sailor's choice	
CAYMANS (12m)	
Epinephelus guttatus Red hind	*Sparisoma rubripinne* Redfin parrotfish
Lutjanus griseus Grey snapper	
Melicthys niger Black Durgon	
Haemulon aurolineatum Tomtate	
Haemulon album White margate	
Acanthurus chirurgus Doctorfish	
CUBA (12m)	
Mycteroperca bonaci Black grouper	*Lutjanus jocu* Dog snapper
Mycteroperca interstitialis Yellowmouth grouper	*Sparisoma rubripinne* Redfin parrotfish
Lutjanus analis Mutton snapper	
Lutjanus griseus Grey snapper	
Canthidermis sufflamen Ocean triggerfish	
*Lutjanus mahogoni M*ahogany snapper	
Anisotremus surinamensis Black margate	
Anisotremus virginicus Porkfish	

TABLE 8 Biomass of fishes (g/100m^2) by location, family and area (P = protected; U = unprotected), on shallow reefs. Results of 1-way ANOVA: * = p<0.05,** = p<0.01, *** = p<0.005 (- = insufficient data); Tukey's studentised range test was used to determine which areas the difference was significant between (at p<0.05). Different survey methods were used so absolute values are not directly comparable among locations. Barbados areas: U1 = South of Barbados Marine Reserve (BMR), U2 = North of BMR. Belize areas: U1 = San Pedro, U2 = Mata Cut

Family	Mean ±SD	Mean ±SD	Mean ±SD	p	Comparisons
MONTEGO BAY (6m)	**P**	**U**			
Grouper	**96.2** ±43.3	**101.9** ±49.6		NS	
Snapper	**32.7** ±73.1	**3.8** ±8.5		-	
Trigger	**8.2** ±18.4	**6.9** ±9.5		-	
Grunt	**53.5** ±34.7	**12.8** ±12.4		*	P>U
Parrot	**338.2** ±116.6	**200.4** ±96.8		<0.1	
Surgeon	**164.1** ±62.6	**91.3** ±62.4		NS	
TOTAL	**692.9** ±239.3	**418.6** ±99.9		*	P>U
BARBADOS (3m)	**P**	**U1**	**U2**		
Grouper	**23.7** ±27.4	**4.0** ±5.9	**3.1** ±5.6	NS	
Snapper	**119.1** ±101.8	**13.2** ±17.1	**42.0** ±50.0	p<0.1	
Trigger	**8.0** ±11.0	**1.7** ±3.9	**2.9** ±4.0	NS	
Grunt	**1032.6** ±1211.3	**582.5** ±184.2	**770.1** ±319.5	NS	
Parrot	**279.7** ±153.9	**41.2** ±45.2	**158.8** ±140.3	*	P>U1
Surgeon	**421.4** ±288.0	**298.6** ±397.6	**208.3** ±152.9	NS	
TOTAL	**1884.5** ±1182.6	**941.2** ±421.2	**1185.2** ±503.2	NS	
BELIZE (2m)	**P**	**U1**	**U2**		
Grouper	**39.0** ±53.1	**15.9** ±13.6	**22.4** ±26.2	NS	
Snapper	**1576.0** ±1390.2	**233.8** ±147.6	**215.7** ±115.7	*	P>U1,U2
Trigger	**318.7** ±198.9	**41.8**±78.1	**28.8** ±42.4	***	P>U1,U2
Grunt	**843.9** ±375.8	**410.2** ±08.8	**538.3** ±111.6	*	P>U1
Parrot	**726.9** ±494.8	**416.5** ±189.7	**444.1** ±124.1	NS.	
Surgeon	**1938.9** ±1153.2	**783.8** ±467.5	**738.8** ±207.8	*	P>U1,U2
TOTAL[1]	**5443.3** ±1740.2	**1901.9** ±716.8	**1988.2** ±495.3	***	P>U1,U2

(1) $\log_e(x+0.01)$ transformed

and biomass in the MPA than unprotected areas and there were significant differences for snapper, triggerfishes, grunt, parrotfishes, surgeonfishes and all fishes combined (Tables 8-9). Two snapper species and a grunt were observed only in the MPA, although another snapper species and a parrotfish were also seen only in the unprotected areas sampled (Table 7); parrotfish biomass was actually greater in one of the unprotected areas (Table 9). On the deep reefs (12m depth), 20 species out of the 27 observed had greater abundance and biomass in the MPA than unprotected areas (Table 6), but in no case did Hol Chan alone have the highest abundances or biomasses; rather, Hol Chan and Caye Caulker together had greater abundances or biomasses of groupers, parrotfishes and all fishes combined (Tables 10-11). While two small

TABLE 9 Numerical abundance of fishes (/100m^2) by location, family and area (P = protected; U = unprotected), on shallow reefs. Results of 1-way ANOVA: * = p<0.05, ** = p<0.01, *** = <0.005 (- = insufficient data); Tukey's studentised range test was used to determine which areas the difference was significant between (at p<0.05). Note that different survey methods were used, so absolute values are not directly comparable, among locations. Barbados areas: U1 = South ofBMR, U2 = North of BMR. Belize areas: U1 = San Pedro, U2 = Mata Cut.

LOCATION Family	**Mean** ±SD	**Mean** ±SD	**Mean** ±SD	**p**	**Comparisons**
MONTEGO BAY (6m)	**P**	**U**			
Grouper	**1.5** ±0.6	**1.7** ±1.0		NS	
Snapper	**0.1** ±0.3	**0.0** ±0.1		-	
Trigger	**0.1** ±0.2	**0.1** ±0.1		-	
Grunt	**0.5** ±0.3	**0.1** ±0.1		*	P>U
Parrot	**4.9** ±1.0	**3.0** ±1.3		*	P>U
Surgeon	**1.9** ±0.7	**1.0** ±0.5		<0.1	
TOTAL	**9.1** ±1.2	**5.9** ±1.3		**	P>U
BARBADOS (3m)	**P**	**U1**	**U2**		
Grouper	**0.1** ±0.1	**0.0** ±0.1	**0.1** ±0.1	NS	
Snapper	**1.5** ±1.8	**0.3** ±0.3	**0.8** ±1.0	NS	
Trigger	**0.1** ±0.1	**0.0** ±0.0	**0.0** ±0.1	NS	
Grunt	**10.0** ±11.3	**6.7** ±8.2	**7.9** ±3.6	NS	
Parrot	**2.0** ±1.0	**0.4** ±0.1	**13** ±0.8	*	P>U1
Surgeon	**4.6** ±3.0	**3.2** ±4.1	**2.1** ±1.4	NS	
TOTAL	**18.3** ±12.3	**10.6** ±5.3	**12.2** ±5.5	NS	
BELIZE (2m)	**P**	**U1**	**U2**		
Grouper	**0.6** ±0.7	**0.4** ±0.3	**0.5** ±0.5	NS	
Snapper	**6.5** ±4.8	**2.8** ±1.6	**2.8** ±1.2	<0.1	
Trigger	**0.5** ±0.3	**0.2** ±0.2	**0.2** ±0.2	<0.1	
Grunt	**8.7** ±5.0	**4.9** ±2.4	**5.1** ±1.9	NS	
Parrot	**4.8** ±1.3	**4.8** ±1.4	**6.6** ±1.3	<0.1	
Surgeon[1]	**16.7** ±9.3	**8.8** ±5.0	**8.5** ±2.4	NS	
TOTAL	**37.8** ±7.2	**21.8** ±7.6	**23.7** ±5.6	***	P>U1,U2

(1) $\log_e(x+0.01)$ transformed

snappers were observed exclusively in the unprotected areas, two large groupers and two large snappers were seen only in the MPA (Table 7). The biomass in the MPA was especially great relative to the unprotected area for snapper and triggerfish on shallow reefs (Table 13). In contrast to the results from the September study (Tables 10-11), in March, the deep sites in Belize tended to show no effect of management on fishes; Caye Caulker (U3) tended to have more fish in biomass and numerical-abundance terms than other areas (Table 12).

TABLE 10 Fish biomass (g/100m^2) by location, family and area (P = protected; U = unprotected) on deep reefs. Results of ANOVA on management level and reef type: * = <0.05, **=p<0.01,***=p<0.005; Tukey test used to determine between-area differences (p <0.05). Cuba reef types: B = barrier, F = fringing. Belize areas: U1 = San Pedro, U2 = Mexico Rocks, U3 = Caye Caulker. Cayman areas: P1 = South P2 = North U1 North = U2 = South (Fig. 1)

LOCATION Family	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	p P v U	p Reef
MONTEGO BAY (15m)	**P**		**U**			
Grouper	**127.1** ±95.0		**229.8** ±80.4		NS	
Snapper	**98.5** ±139.6		**0.0**		P only	
Trigger	**0.0**		**44.1** ±77.2		U only	
Grunt[1]	**62.8** ±57.6		**6.8** ±10.5		<0.1	
Parrot	**372.8** ±168.0		**366.6** ±205.8		NS	
Surgeon	**134.4** ±71.8		**92.8** ±28.8		NS	
TOTAL	**795.6** ±261.8		**740.1** ±347.6		NS	
BELIZE (12m)	**P**	**U1**	**U2**	**U3**		
Grouper	**698.0** ±380.1	**239.7** ±21.0	**243.0** ±84.7	**597.8** ±221.1	** P,U3> U1,U2	
Snapper	**698.5** ±410.7	**696.9** ±279.8	**346.4** ±188.5	**522.6** ±298.2	NS	
Trigger	**608.2** ±489.8	**130.3** ±83.1	**292.4** ±291.4	**585.8** ±559.9	NS	
Grunt	**174.7** ±183.2	**152.4** ±121.4	**77.9** ±159.9	**318.9** ±146.8	NS	
Parrot	**801.9** ±471.6	**513.3** ±198.0	**389.8** ±393.9	**843.3** ±342.1	NS	
Surgeon	**295.9** ±125.6	**274.2** ±138.6	**255.6** ±85.0	**349.7** ±143.6	NS	
TOTAL	**3277.2** ±1199.3	**2006.8** ±136.5	**1605.2** ±739.6	**3218.1** ±960.3	* P,U3>U2	
CAYMANS (12m)	**P1**	**P2**	**U1**	**U2**		
Grouper	**488.2** ±420.3	**430.3** ±208.5	**494.2** ±290.0	**444.7** ±178.9	NS	
Snapper	**456.6** ±374.7	**407.9** ±410.3	**469.0** ±526.2	**1122.9** ±584.4	NS	
Trigger	**19.8** ±30.8	**16.4** ±26.7	**0.0** ±0.0	**0.0** ±0.0	P only	
Grunt	**349.6** ±139.1	**235.8** ±119.6	**194.8** ±37.7	**535.3** ±226.6	NS	
Parrot	**867.0** ±319.4	**845.5** ±245.4	**860.1** ±318.5	**633.0** ±201.4	NS	
Surgeon	**110.1** ±28.7	**191.2** ±102.3	**93.7** ±32.5	**165.5** ±79.0	NS	
TOTAL	**2291.4** ±443.1	**2127.2** ±924.1	**2111.9** ±635.2	**2901.4** ±802.0	NS	
CUBA (12m)	**P1 (B)**	**P2 (F)**	**U1 (F)**	**U2 (B)**		
Grouper	**514.7** ±270.9	**726.4** ±406.7	**327.7** ±332.3	**321.5** ±204.0	*P>U	NS
Snapper	**322.3** ±251.8	**905.1** ±455.7	**349.9** ±527.1	**350.3** ±559.9	NS	<0.1
Trigger	**311.1** ±255.8	**320.3** ±356.4	**22.1** ±33.1	**274.0** ±201.8	<0.1	***P>U
Grunt	**511.7** ±105.5	**434.6** ±253.6	**334.8** ±328.3	**247.2** ±140.9	*P>U	NS
Parrot	**634.9** ±262.4	**569.6** ±133.0	**712.3** ±253.0	**445.1** ±110.1	NS	NS
Surgeon	**304.2** ±58.7	**325.7** ±141.1	**326.3** ±104.3	**288.5** ±70.3	NS	NS
TOTAL	**2598.8** ±366.0	**3281.7** ±854.3	**2073.1** ±1012.1	**1926.6** ±620.8	***P>U	NS

(1) $\log_e(x+1)$ transformed

TABLE 11 Numerical abundances (g/100m^2) of fish by location, family and area on deep reefs (12-15m). Results of 1-way ANOVA: * = p<0.05, ** = p<0.01, *** = p<0.0005; Tukey's studentised range test was used to determine which areas the difference was significant between (at p<0.05). Cuba reef types: B = barrier, F = fringing. Belize areas: U1 = San Pedro, U2 = Mexico Rocks, U3 = Caye Caulker. Caymans areas: P1 = South P2 = North U1 North = U2 = South (Fig. 1)

LOCATION **Family**	**Mean** ±SD	**Mean** ±SD	**Mean** ±SD	**Mean** ±SD	**p** **P vs U**	**p** **Reef**
MONTEGO BAY (15m)	**P**		**U**			
Grouper	**2.2** ±1.2		**3.5** ±1.0		<0.1	
Snapper	**0.2** ±0.2		**0.0**		P only	
Trigger	**0.0**		**0.4** ±0.6		U only	
Grunt	**0.7** ±0.7		**0.1** ±0.1		<0.1	
Parrot	**4.4** ±1.4		**4.5** ±1.6		NS	
Surgeon	**1.6** ±0.6		**1.2** ±0.3		NS	
TOTAL	**9.0** ±3.0		**9.6** ±2.8		NS	
BELIZE (12m)	**P**	**U1**	**U2**	**U3**		
Grouper	**4.3** ±1.3	**3.2** ±0.5	**2.8** ±1.1	**4.8** ±1.7	<0.1	
Snapper	**2.7** ±1.4	**1.5** ±1.3	**1.2** ±0.9	**3.0** ±1.5	NS	
Trigger	**0.4** ±0.3	**0.4** ±0.3	**0.2** ±0.3	**0.7** ±0.3	<0.1	
Grunt	**5.7** ±3.5	**6.0** ±2.9	**2.7** ±1.5	**4.4** ±2.3	NS	
Parrot	**7.8** ±2.4	**5.1** ±1.2	**3.7** ±1.3	**7.7** ±2.2	* P,U3>U2	
Surgeon	**3.6** ±1.3	**3.1** ±1.3	**3.1** ±0.7	**3.8** ±1.5	NS	
TOTAL	**24.4** ±7.3	**19.2** ±3.7	**13.6** ±4.3	**24.4** ±7.0	* P,U3>U2	
CAYMANS (12m)	**P1**	**P2**	**U1**	**U2**		
Grouper	**4.7** ±1.5	**4.6** ±1.1	**3.7** ±0.7	**4.3** ±1.4	NS	
Snapper	**0.7** ±0.6	**0.8** ±0.8	**0.6** ±0.3	**0.7** ±0.4	NS	
Trigger	**0.1** ±0.1	**0.1** ±0.2	**0.0** ±0.0	**0.0** ±0.0	P only	
Grunt	**3.4** ±1.6	**2.2** ±1.3	**2.0** ±0.8	**5.4** ±2.5	NS	
Parrot	**4.8** ±1.2	**6.7** ±1.4	**6.9** ±2.6	**4.2** ±1.5	NS	
Surgeon	**1.1** ±0.2	**1.7** ±0.9	**0.9** ±0.3	**1.9** ±0.8	NS	
TOTAL	**14.8** ±3.4	**16.1** ±2.1	**14.2** ±2.8	**16.5** ±4.4	NS	
CUBA (12m)	**P1 (B)**	**P2 (F)**	**U1 (F)**	**U2 (B)**		
Grouper	**2.3** ±0.6	**2.9** ±1.3	**1.2** ±0.5	**1.7** ±0.9	***P>U	NS
Snapper	**1.3** ±1.0	**2.6** ±1.4	**1.3** ±1.5	**0.9** ±0.6	*P>U	*F>B
Trigger	**0.8** ±0.7	**0.8** ±0.9	**0.1** ±0.1	**1.0** ±0.8	NS	<0.1
Grunt	**4.1** ±0.9	**3.0** ±0.9	**2.2** ±1.4	**2.1** ±1.3	***P>U	NS
Parrot	**6.3** ±1.7	**6.5** ±1.3	**7.3** ±1.5	**5.3** ±1.2	NS	*F>B
Surgeon	**3.1** ±0.8	**3.3** ±1.1	**3.7** ±1.3	**3.7** ±0.7	NS	NS
TOTAL	**17.8** ±2.3	**19.1** ±1.5	**15.8** ±3.1	**14.6** ±2.8	***P>U	NS

Cayman Islands

One grouper, one snapper, two grunts and a triggerfish (*M. niger*) were observed only in the protected areas (Table 7). There were no significant differences between MPAs and unprotected areas on the deeper reefs involved, in either biomass (Tables 10 and 12) or numerical abundance (Table 11) terms. Comparison of areas indicated that the replenishment area (no spear fishing, but other forms of fishing permitted) indicated as U2 in Tables 10-11 was significantly different from the other areas in fish abundance and biomass terms, but slight differences in habitat combined with the fact that this areas was on the edge of a reef channel could explain this as much as any difference there may been between this and the other 'replenishment' area.

Cuba

Two large groupers, three snappers, a trigger and two grunts were only observed in the protected areas, as against one snapper and a parrotfish only found in the unprotected areas (Table 7). There were significant differences between the MPA and unprotected areas for grouper, triggerfish, grunts and all fish combined in biomass terms (Table 10), and snapper but not triggerfish in numerical abundance (Table 11); in all these cases the abundances/biomass were greater on average in the MPA than in the unprotected areas. Significant differences between reef types for snappers, triggerfishes and parrotfishes (Table 10-11) indicate that habitat may be

TABLE 12 Biomass (g/100m^2) and numerical abundance (/100m^2) of fish families in March/April at deep sites in Belize. Results of ANOVA: *=p<0.05, **=p<0.01,***=p<0.005; Tukey test used to determine between-area differences (at p<0.05). P =Hol Chan, U1 = San Pedro, U2 = Mexico Rocks, U3 = Caye Caulker

Family	**Mean** ±SD	**Mean** ±SD	**Mean** ±SD	**Mean** ±SD	**p**
BIOMASS	**P**	**U1**	**U2**	**U3**	
Grouper	**260.1** ± 107.6	**178.1** ± 42.5	**236.1** ± 133.6	**405.7** ± 179.4	* U3>U1
Snapper	**219.6** ± 125.3	**86.4** ± 105.1	**130.4** ± 99.3	**83.5** ± 58.2	<0.1
Trigger	**406.4** ± 488.1	**115.6** ± 132.2	**298.7** ± 313.8	**426.8** ± 321.6	NS
Grunt	**591.1** ± 391.4	**620.8** ± 442.4	**591.4** ± 251.3	**913.5** ± 538.3	NS
Parrot	**546.0** ± 155.4	**581.7** ± 334.4	**582.1** ± 227.4	**1049.0** ± 447.1	* U3>P,U1,U2
Surgeon	**260.3** ± 44.9	**391.9** ± 83.7	**496.3** ± 110.1	**489.6** ± 190.5	** U2,U3>P
TOTAL	**2283.5** ± 802.4	**1974.5** ± 730.5	**2335.0** ± 631.7	**3368.1** ± 1179.7	<0.1
ABUNDANCE	**P**	**U1**	**U2**	**U3**	
Grouper	**3.5** ± 1.3	**2.3** ± 0.5	**2.8** ± 1.2	**3.1** ± 1.5	NS
Snapper	**1.4** ± 1.2	**0.6** ± 0.7	**1.0** ± 0.8	**0.7** ± 0.4	NS
Trigger	**0.7** ± 0.6	**0.2** ± 0.3	**0.6** ± 0.5	**1.0** ± 0.8	NS
Grunt	**5.3** ± 3.5	**5.1** ± 3.1	**5.1** ± 2.3	**8.1** ± 5.5	NS
Parrot	**6.4** ± 1.8	**4.9** ± 1.8	**5.7** ± 2.6	**8.5** ± 2.2	* U3>U1
Surgeon	**3.1** ± 0.5	**4.9** ± 1.2	**5.8** ± 1.1	**5.7** ± 2.1	** U2,U3>P
TOTAL	**20.5** ± 4.3	**18.0** ± 4.2	**20.9** ± 4.2	**27.0** ± 8.3	<0.1

influential, and the Cuban protected areas did have greater rugosity and coral cover than the unprotected areas (Table 4); these were differences which were likely to be important especially in the case of groupers (Table 5). The likelihood that factors other than management can explain fish abundance and biomass differences is greatest in Cuba of all locations, given the spatial separation of the protected and unprotected areas (Fig. 1).

Fish diversity

There was no evidence for greater species diversity or species richness of fishes in protected areas than in unprotected areas on shallow reefs of Montego Bay, Barbados or Belize or deep reefs of the Caymans (Table 14). In protected areas on deep reefs in Montego Bay, Belize and Cuba, species diversity and/or richness were greater than in the unprotected areas involved (Table 14).

TABLE 13 Ratios (P:U) of mean biomass or abundance of fishes by family at protected sites (P) to mean biomass or abundance at unprotected (U) sites (all sites pooled) on shallow reefs in Montego Bay, Barbados and Belize and deep reefs in Montego Bay, Belize, the Caymans and Cuba.

Family	MO' BAY:		B'DOS	BELIZE:		C'MAN	CUBA
	Shallow	Deep	Shallow	Shallow	Deep	Deep	Deep
BIOMASS							
Grouper	0.9	0.6	6.7	2.0	1.9	1.0	1.9
Snapper	8.6	P only	4.3	7.0	1.9	0.5	1.8
Trigger	1.2	U only	3.4	9.0	1.0	P only	2.1
Grunt	4.4	9.2	1.5	1.8	1.3	0.8	1.6
Parrot	1.7	1.0	2.8	1.7	1.4	1.1	1.0
Surgeon	1.7	1.4	1.7	2.5	1.0	1.1	1.0
ABUNDANCE							
Grouper	0.9	0.6	3.0	1.8	1.2	1.2	1.8
Snapper	4.0	P only	2.8	2.6	1.4	1.1	1.8
Trigger	1.0	U only	3.3	2.8	1.0	P only	1.5
Grunt	4.0	8.7	1.4	1.8	1.3	0.7	1.7
Parrot	1.7	1.0	2.5	0.9	1.4	1.0	1.0
Surgeon	1.8	1.3	1.7	2.0	1.1	1.0	0.9

Density of large fishes

The low frequency of large fishes in Montego Bay generally was especially marked, and the densities of all fishes tended to be higher in all fish ≥30cm in all areas except for the Caymans (Table 15). Although a few species of fishes had significantly greater average sizes outside protected areas than within, many more were larger within the protected areas, and these differences were especially marked in shallow water in Belize (eight out of 12 species) and Cuba (4/9 species)(Table 16).

TABLE 14 Shannon-Wiener species diversity (H') and species richness of fishes in protected and unprotected areas, in shallow and deep water. Results of 1-way ANOVA: * = p<0.05, ** = p<0.01, *** = p<0.005; Tukey test used to determine between area and reef differences. Cuba reef types: B = barrier, F = fringing. Barbados areas: U1 = South of BMR, U2 = North of BMR. Belize shallow areas: U1 = San Pedro, U2 = Mata Cut; Belize deep areas: U1 = San Pedro, U2 = Mexico Rocks, U3 = Caye Caulker. Caymans areas: P1 = South, P2 = North, U1 = North, U2 = South (Fig. 1)

Diversity variable	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	p P vs U	p Reef
SHALLOW						
MONTEGO BAY	**P**		**U**			
H'	**1.8** ±0.3		**1.9** ±0.3		NS	-
Species richness	**8.8** ±2.7		**9.0** ±1.4		NS	-
BARBADOS	**P**		**U1**	**U2**		
H'	**1.7** ±0.2		**1.4** ±0.1	**1.5** ±0.2	NS	-
Species richness	**12. 4** ±1.6		**8.2** ±0.7	**9.8** ±1.2	NS	-
BELIZE	**P**		**U1**	**U2**		
H'	**2.2** ±0.2		**2.1** ±0.2	**2.2** ±0.1	*P>U1	-
Species richness	**16.2** ±1.8		**12.2** ±2.3	**13.5** ±2.3	NS	-
DEEEP						
MONTEGO BAY	**P**		**U**			
H'	**2.0** ±0.2		**1.8** ±0.1		*	-
Species richness	**10.0** ±1.2		**8.0** ±1.2		*	-
BELIZE	**P**	**U1**	**U2**	**U3**		
H'	**2.4** ±0.2	**2.4** ±0.1	**2.3** ±0.1	**2.2** ±0.3	NS	-
Species richness	**16.4** ±2.9	**15.6** ±1.1	**12.4** ±1.8	**12.4** ±3.2	*	-
CAYMANS	**P1**	**P2**	**U1**	**U2**		
H'	**10.8** ±1.2	**12.3** ±1.9	**10.2** ±0.8	**11.3** ±1.4	NS	-
Species richness	**2.0** ±0.1	**2.2** ±0.1	**2.0** ±0.1	**2.0** ±0.1	NS	-
CUBA	**P1 (B)**	**P2 (F)**	**U1 (F)**	**U2 (B)**		
H'	**2.5** ±0.1	**2.4** ±0.2	**2.2** ±0.2	**2.2** ±0.2	***	NS
Species richness	**16.4** ±1.5	**16.3** ±2.2	**12.9** ±2.0	**12.9** ±2.5	***	NS

TABLE 15 Density (/1000m^2) of all 'large' fish in three length classes (≥30cm <40cm; ≥40cm <50cm; ≥50cm) in protected (P) and unprotected (U) areas on shallow and deep reefs

SHALLOW/DEEP	Location	≥30cm: P	≥30cm: U	≥40cm: P	≥40cm: U	≥50cm: P	≥50cm: U
SHALLOW							
	Montego Bay	0.3	0	0	0	0	0
	Barbados	1.3	0.3	0	0	0	0
	Belize	14.5	0.2	0.7	0	0.4	0
DEEP							
	Montego Bay	1.4	0	0.3	0	0	0
	Belize	9.8	3.8	2.1	0.6	0.4	0
	Caymans	7.6	8.5	2.1	3.0	0.4	1.9
	Cuba	15.7	4.7	4.0	1.7	0.6	0.4

TABLE 16 Results of Mann-Whitney U test of differences in median length. Data were pooled for sites in MPAs (P) and unprotected areas (U)(*=p<0.05, **=p<0.01,***=p<0.005) for species where there were at least 10 individuals in both the protected and unprotected areas.

	Family	SPECIES	LOCATION			
SHALLOW			**MO' BAY**	**B'DOS**	**BELIZE**	
	Grouper	*Epinephelus cruentatus*	-	-	*** P>U	
		Epinephelus fulvus	NS	-	-	
	Snapper	*Lutjanus apodus*	-	-	*** P>U	
		Lutjanus mahogoni	-	*** P>U	-	
	Grunt	*Haemulon chrysargyreum*	-	*** P>U	-	
		Haemulon flavolineatum	-	*** P>U	* U>P	
		Haemulon plumieri	-	-	* P>U	
		Haemulon sciurus	-	-	*** P>U	
	Parrot	*Scarus croicensis*	NS	-	* U>P	
		Scarus taeniopterus	-	NS		
		Sparisoma aurofrenatum	* P>U	NS		
		Sparisoma chrysopterum	-	-	NS	
		Sparisoma rubripinne	-	-	* P>U	
		Sparisoma viride	NS	NS	*** P>U	
	Surgeon	*Acanthurus bahianus*	NS	NS	NS	
		Acanthurus chirurgus	-	-	*** P>U	
		Acanthurus coeruleus	-	NS	*** P>U	
DEEP			**MO' BAY**	**BELIZE**	**C'MANS**	**CUBA**
	Grouper	*Epinephelus cruentatus*	NS	NS	NS	*** P>U
		Epinephelus fulvus	NS	NS	NS	*** U>P
	Snapper	*Lutjanus apodus*	-	NS	** U>P	
		Ocyurus chrysurus	-	NS	* P>U	* P>U
	Trigger	*Melicthys niger*	-	-	-	*** P>U
	Grunt	*Haemulon flavolineatum*	-	NS	NS	*** P>U
		Haemulon plumieri	-	NS	NS	NS
		Haemulon sciurus	-	NS	-	
	Parrot	*Scarus croicensis*	NS	*** U>P	NS	NS
		Scarus taeniopterus	-	-	NS	NS
		Sparisoma aurofrenatum	NS	NS	NS	
		Sparisoma viride	NS	NS	NS	NS
	Surgeon	*Acanthurus bahianus*	NS	NS	-	
		Acanthurus coeruleus	-	NS	* P>U	

Coral and algal cover, coral diversity and general reef benthos

In general, no differences were detected in macroalgal, coral or turf-algal cover, coral diversity or *Diadema* sea-urchin density between protected and unprotected areas on shallow reefs in Montego Bay, Barbados or Belize (Table 17). The only exception to this was that macroalgae were more abundant in the benthos in the Barbados Marine Reserve than in unprotected areas to the North or South, but the cover of macroalgae was still generally low. On deep reefs, *Diadema* was rare and there was greater hard-coral cover in the protected than unprotected areas in Belize and Cuba (Table 17). The Cuban protected area also had higher macroalgal cover and less substratum covered by grazed algae (turf and crustose-corallines) than the unprotected areas examined (Table 17). Given the habitat differences between protected and unprotected areas in Cuba (Table 4), these differences are as attributable to site effects other than management as they are to management effects. In March/April, macroalgal cover was greater and grazed (turf + bare + coralline) algae cover less on shallow reefs in protected than in unprotected areas (Table 18). At the deeper sites, the protected area had least grazed substratum and most macroalgae, while Caye

TABLE 17 Substratum cover (%) by various groups in the benthos, coral diversity (H') and *Diadema* density in protected and unprotected areas on shallow reefs. Results of ANOVA: * = p<0.05,** = p<0.01, *** = p<0.005; Tukey test used to determine between-area differences. Barbados areas: U1 = South of BMR, U2 = North of BMR. Belize areas: U1 = San Pedro, U2 = Mata Cut

Benthos variable	**Mean** ±SD	**Mean** ±SD	**Mean** ±SD	**p**	**Tukey's**
MONTEGO BAY (6m)	**P**	**U**			
Macroalgae	**47.4** ±12.2	**38.8** ±19.6		NS	
Hard coral	**12.1** ±5.4	**12.3** ±7.1		NS	
Turf+bare+coralline	**33.0** ±5.7	**42.7** ±8.5		NS	
Coral diversity (H')	**1.7** ±0.2	**1.6** ±0.1		NS	
Diadema/m^2	**0.1** ±0.1	**0.4** ±0.3		NS	
BARBADOS (3m)	**P**	**U1**	**U2**		
Macroalgae	**2.6** ±1.7	**0.6** ±0.6	**0.2** ±1.7	**	P>U1,U2
Hard coral	**18.7** ±9.4	**25.9** ±11.6	**14.3** ±15.1	NS	
Turf	**42.5** ±23.1	**36.1** ±8.2	**48.8** ±17.1	NS	
Coralline algae	**32.7** ±17.6	**34.4** ±6.1	**35.1** ±7.4	NS	
Coral diversity (H')	**1.0** ±0.3	**0.9** ±0.3	**0.6** ±0.2	NS	
Diadema/m^2	**3.5** ±2.1	**7.2** ±1.3	**7.1** ±2.0	NS	
BELIZE (2m)	**P**	**U1**	**U2**		
Macroalgae	**6.7** ±5.0	**4.4** ±1.7	**11.3** ±10.9	NS	
Hard coral	**5.1** ±3.3	**7.4** ±4.2	**5.7** ±4.8	NS	
Turf + Coralline	**35.0** ±9.9	**28.1** ±7.5	**24.0** ±6.9	NS	
Coral diversity (H')	**0.6** ±0.6	**0.5** ±0.4	**0.6** ±0.6	NS	
Diadema/m^2	**<0.1** ±0.1	**0.1** ±0.1	**<0.1** ±<0.1	NS	

Caulker (U3), which had the greatest biomass of grazing fish, particularly parrotfish (Table 7), had most grazed substratum and least macroalgae (Table 18).

TABLE 18 Substratum cover (%) by various groups in the benthos, coral diversity (H') and *Diadema* density in protected and unprotected areas on deep reefs. Results of ANOVA: * = p<0.05,** = p<0.01, *** = p<0.005; Tukey test used to determine differences between areas and reef types. Belize areas: P =Hol Chan, U1 = San Pedro, U2 = Mexico Rocks, U3 = Caye Caulker.

Benthos variable	**Mean** ±SD	**Mean** ±SD	**Mean** ±SD	**Mean** ±SD	**p** **P vs U**	**p** **Reef**
MONTEGO BAY (15m)	**P**		**U**			
Macroalgae	**70.4** ±5.3		**69.6** ±7.7		NS	
Hard coral	**9.1** ±3.6		**6.6** ±2.2		NS	
Turf + bare + coralline	**17.3** ±7.7		**20.2** ±4.7		NS	
Coral diversity (H')	**1.7** ±0.3		**1.4** ±0.2		NS	
BELIZE (12m)	**P**	**U1**	**U2**	**U3**		
Macroalgae	**21.2** ±5.2	**20.2** ±4.7	**18.1** ±2.5	**24.8** ±3.2	NS	
Hard coral	**15.3** ±2.2	**10.6** ±4.2	**11.4** ±2.8	**7.9** ±2.0	** P>U3	
Turf + bare + coralline	**53.1** ±4.2	**59.1** ±8.0	**52.5** ±3.9	**55.6** ±4.5	NS	
Coral diversity (H')	**1.9** ±0.2	**1.8** ±0.1	**1.7** ±0.3	**1.9** ±0.2	NS	
CAYMANS (12m)	**P1**	**P2**	**U1**	**U2**		
Macroalgae	**32.2** ±4.5	**28.6** ±4.2	**35.6** ±9.2	**25.6** ±5.9	NS [1]	
Hard coral	**22.1** ±4.2	**23.3** ±6.7	**22.0** ±6.2	**14.6** ±4.7	NS [1]	
Turf + bare + coralline	**37.6** ±3.2	**39.1** ±3.8	**35.8** ±6.0	**50.2** ±8.1	NS [1]	
Coral diversity (H')	**1.4** ±0.2	**1.5** ±0.2	**1.4** ±0.2	**1.5** ±0.4	NS [1]	
CUBA (12m)	**P1**	**P2**	**U1**	**U2**		
Macroalgae	**48.6** ±1.8	**49.7** ±4.4	**34.5** ±6.0	**39.8** ±11.3	***[2]	NS [2]
Hard coral	**12.9** ±3.2	**13.3** ±5.2	**6.4** ±1.5	**6.4** ±1.7	***[2]	NS [2]
Turf + bare + coralline	**36.9** ±4.1	**35.2** ±3.0	**51.5** ±5.0	**46.0** ±8.1	***[2]	NS [2]
Coral diversity (H')	**1.7** ±0.2	**1.9** ±0.5	**1.9** ±0.7	**1.90** ±0.8	NS [2]	NS [2]

(1) Nested ANOVA (2) Crossed ANOVA

TABLE 19 Substratum cover (%) by various groups in the benthos in protected and unprotected areas on shallow and deep reefs in Belize in March/April. Results of ANOVA: * = p<0.05,** = p<0.01, *** = p<0.005; Tukey test used to determine differences between areas. Belize areas: P =Hol Chan, U1 = San Pedro, U2 = Mexico Rocks, U3 = Caye Caulker.

	Mean ± SD	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**p**
Shallow (2m)	**P**	**U1**			
% Macroalgae[1]	**29.7** ± 18.2	**6.6** ± 5.0			*** P > U1**
% Turf & coralline	**29.5** ± 9.1	**40.3** ± 6.7			*** U1>P**
Deep (12m)	**P**	**U1**	**U2**	**U3**	
% Macroalgae	**28.7** ± 5.7	**22.9** ± 4.4	**28.4** ± 4.1	**18.7** ± 4.4	***** P,U2>U3**
% Coral cover	**20.4** ± 3.4	**12.4** ± 5.5	**11.6** ± 12.7	**12.7** ± 2.5	***** P>U1,U2,U3**
% TBC ('grazed')	**47.6** ± 4.8	**62.1** ± 7.6	**57.6** ± 5.6	**65.0** ± 5.2	***** U1,U2,U3>P**

(1)√ transformed

Large-scale correlations between grazers and algal abundance

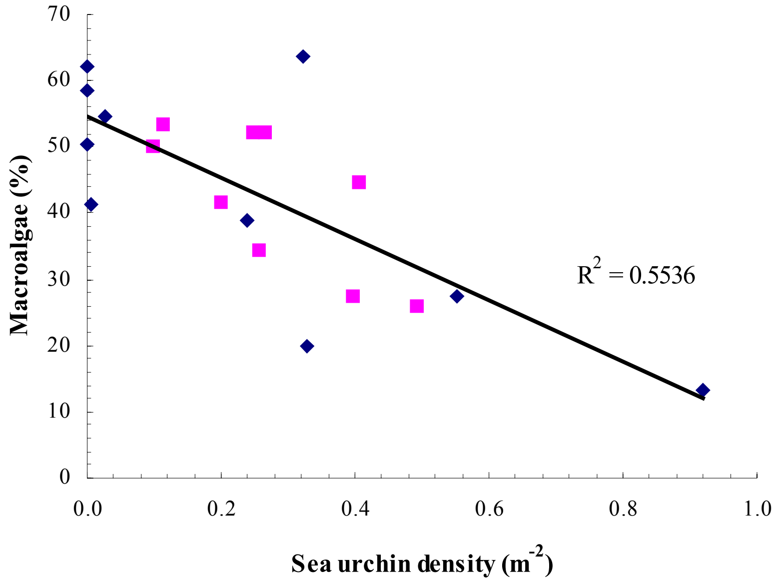
Correlations of macroalgae with fish and *Diadema* density in Jamaica

Two types of large grazers have been implicated in the macroalgal overgrowth of Caribbean reefs, namely the sea-urchin *Diadema*, and herbivorous fishes especially in the families Scaridae and Acanthuridae. *Diadema* was relatively abundant at the shallow sites (Table 16) and all but absent on the deep reefs examined. For the shallow sites where *Diadema* was most abundant, there were significant negative relationships between macroalgal cover and *Diadema* density, as illustrated by pooling of all sites from Montego Bay and Negril in Jamaica (Fig. 3a); for the same sites, the correlation between macroalgae and grazing fishes was non-significant (Fig. 3b).

Large-scale correlations between herbivorous fish and algal cover

Among the 19 areas, there was an approximate 6-fold difference between the highest and lowest estimates of herbivorous fish biomass, from 2.7g/m^2 at one area in Negril to 17.1g/m^2 in Barbados. Other than the Jamaican reefs, which had clearly lower abundance of herbivorous fishes, the abundance of herbivorous fishes was broadly similar on most surveyed reefs, namely 7.9-11.9g/m^2 at 13 of the 15 areas outside Jamaica (Table 20). Other than on the Barbados reef, coral cover was everywhere lower than 25%, and frequently around 10% or less (Table 20). As well as having the highest coral cover, Barbados reefs also had relatively high levels of space-occupation by sponges and other invertebrates, so that in total around 50% of the substratum on the Barbados reefs was occupied by corals and other invertebrates. In contrast, space occupation on other reefs was nowhere higher than 30%, ranging between 20 and 30% on Cayman reefs, but 15% or lower on all other surveyed reefs (Table 20). On all but the Barbados reefs, 70-90% of the substratum was available for colonisation by algae (Table 20), but there were very large differences in the algal assemblages among study areas. Macroalgae ranged from less than 4% on the Barbados reef to over 70% on reefs in Montego Bay (Table 20, Fig. 4a). Grazed substratum (turf + bare + coralline algae) ranged from around 20% on Jamaican reefs to around 60% on reefs in Belize (Table 20, Fig. 4b).

(a)



(b)

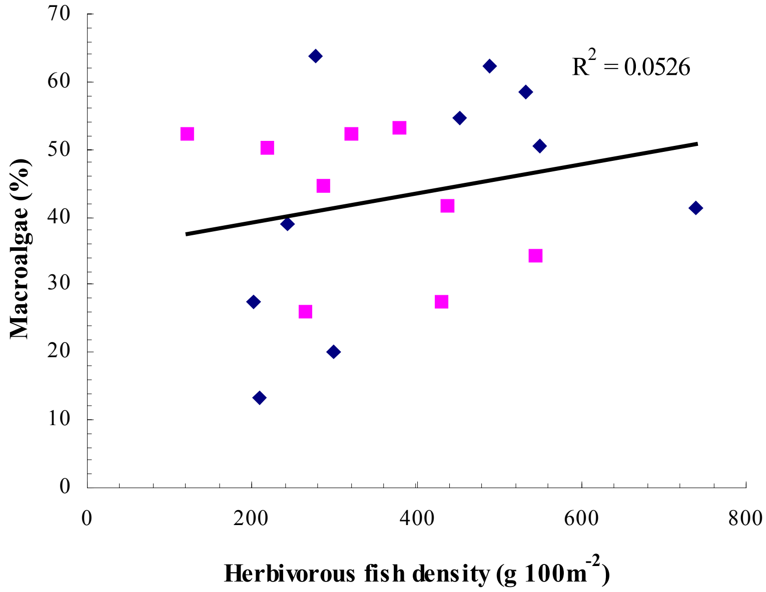


Figure 3 Plots of macroalgal cover (%)against (a) numerical density of *Diadema* and (b) biomass of herbivorous fishes on shallow reefs in Montego Bay (◆) and Negril (■)

TABLE 20 Mean biomass (in bold, SE in brackets) of herbivorous fishes and substratum cover (in bold, SE in brackets) by different categories of the benthos in all areas.

Location			Mean (SE) cover (%)									
	(n)	Herb. fish g/m^2	Coral	Sponge	Other invert	Total inverts	Macro-algae	Cr'ose algae	Turf	Bare	Other	Available to algae
Barbados Marine	**5**	**17.1**	**36.3**	**6.9**	**6.1**	**49.3**	**3.9**	**17.7**	**28.0**	**0.0**	**1.1**	**50.7**
Reserve		(2.1)	(5.0)	(1.1)	(1.5)	(3.7)	(0.9)	(3.9)	(2.3)	(0.0)	(0.3)	(3.7)
Ambergris Caye	**6**	**9.7**	**20.4**	**1.9**	**1.3**	**23.6**	**28.8**	**10.9**	**33.2**	**3.5**	**0.0**	**76.4**
Belize		(1.5)	(1.4)	(0.6)	(0.3)	(1.5)	(2.3)	(1.3)	(2.1)	(0.5)	(0.0)	(1.5)
	6	**8.1**	**12.4**	**1.1**	**1.4**	**14.8**	**22.9**	**11.6**	**46.9**	**3.6**	**0.1**	**85.2**
		(5.1)	(2.2)	(0.3)	(0.4)	(2.8)	(1.8)	(1.6)	(2.4)	(0.7)	(0.1)	(2.8)
	6	**10.8**	**11.6**	**1.1**	**1.1**	**13.8**	**28.5**	**10.0**	**43.8**	**3.8**	**0.1**	**86.2**
		(1.0)	(1.2)	(0.3)	(0.2)	(1.2)	(1.7)	(1.9)	(1.6)	(0.5)	(0.1)	(1.2)
	6	**15.4**	**12.7**	**1.6**	**1.5**	**15.9**	**18.7**	**12.0**	**48.1**	**5.0**	**0.3**	**84.1**
		(2.4)	(1.0)	(0.2)	(0.3)	(1.4)	(1.8)	(1.9)	(1.2)	(0.7)	(0.1)	(1.4)
Grand Cayman	**6**	**9.8**	**22.3**	**3.7**	**3.6**	**29.6**	**32.4**	**13.1**	**24.0**	**0.7**	**0.1**	**70.4**
		(1.3)	(1.7)	(0.5)	(0.7)	(1.4)	(1.8)	(0.5)	(1.7)	(0.2)	(0.0)	(1.4)
	6	**10.4**	**23.5**	**0.6**	**5.9**	**30.0**	**28.8**	**15.7**	**23.1**	**0.6**	**1.7**	**70.0**
		(1.0)	(2.7)	(0.1)	(1.1)	(2.8)	(1.7)	(1.1)	(2.2)	(0.1)	(0.7)	(2.8)
	6	**9.5**	**22.2**	**1.3**	**3.4**	**27.0**	**36.0**	**13.8**	**21.9**	**0.5**	**0.7**	**73.0**
		(1.2)	(2.5)	(0.5)	(0.6)	(2.4)	(3.7)	(1.3)	(1.8)	(0.2)	(0.5)	(2.4)
	6	**8.0**	**14.9**	**3.3**	**4.1**	**22.4**	**26.1**	**14.5**	**33.8**	**2.8**	**0.3**	**77.6**
		(1.0)	(2.1)	(1.2)	(0.6)	(1.9)	(2.4)	(2.0)	(3.0)	(0.2)	(0.1)	(1.9)
	6	**11.9**	**13.4**	**3.3**	**5.0**	**21.7**	**23.0**	**23.5**	**26.0**	**1.5**	**4.2**	**78.3**
		(0.8)	(0.8)	(1.0)	(0.3)	(1.4)	(2.0)	(2.0)	(1.5)	(0.4)	(1.6)	(1.4)
	4	**12.9**	**19.5**	**1.4**	**4.6**	**25.4**	**16.6**	**14.7**	**37.4**	**2.1**	**3.9**	**74.6**
		(1.5)	(2.6)	(0.6)	(0.4)	(2.4)	(1.9)	(2.9)	(2.3)	(0.5)	(0.7)	(2.4)
Montego Bay	**5**	**5.1**	**9.2**	**0.9**	**1.1**	**11.1**	**70.8**	**3.5**	**13.4**	**0.5**	**0.6**	**88.9**
Jamaica		(1.0)	(1.6)	(0.3)	(0.2)	(2.0)	(2.4)	(0.7)	(1.5)	(0.3)	(0.3)	(2.0)
	5	**4.6**	**6.6**	**1.0**	**1.2**	**8.8**	**70.2**	**4.4**	**15.0**	**1.1**	**0.5**	**91.2**
		(1.0)	(1.8)	(0.6)	(0.8)	(3.1)	(3.3)	(0.8)	(1.7)	(0.2)	(0.2)	(3.1)
Negril	**5**	**3.3**	**5.9**	**4.0**	**1.1**	**11.1**	**64.6**	**4.4**	**16.6**	**2.0**	**1.4**	**88.9**
Jamaica		(0.3)	(0.2)	(0.4)	(0.3)	(0.8)	(1.6)	(0.4)	(1.5)	(0.1)	(0.5)	(0.8)
	5	**2.7**	**9.5**	**2.0**	**0.7**	**12.2**	**67.7**	**4.0**	**14.9**	**0.9**	**0.3**	**87.8**
		(0.3)	(2.0)	(0.4)	(0.2)	(2.0)	(2.3)	(0.4)	(0.6)	(0.3)	(0.0)	(2.0)
Cuba	**6**	**8.6**	**12.9**	**1.1**	**0.3**	**14.4**	**48.7**	**7.4**	**28.8**	**0.7**	**0.0**	**85.6**
Punta Frances		(1.1)	(1.3)	(0.5)	(0.1)	(1.4)	(0.7)	(0.8)	(1.9)	(0.2)	(0.0)	(1.4)
	6	**9.6**	**13.3**	**1.3**	**0.3**	**15.0**	**49.7**	**6.7**	**27.2**	**1.4**	**0.0**	**85.0**
		(1.1)	(2.1)	(0.6)	(0.1)	(1.9)	(1.8)	(1.1)	(1.6)	(0.4)	(0.0)	(1.9)
Cuba	**6**	**10.8**	**6.6**	**1.2**	**3.0**	**10.8**	**35.7**	**12.8**	**40.1**	**0.6**	**0.1**	**89.2**
Punta del Este		(1.5)	(0.6)	(0.3)	(0.3)	(1.1)	(2.3)	(1.6)	(2.3)	(0.2)	(0.0)	(1.1)
	6	**7.6**	**6.8**	**0.6**	**1.6**	**9.0**	**41.8**	**10.0**	**38.5**	**0.3**	**0.4**	**91.0**
		(0.6)	(0.8)	(0.1)	(0.3)	(0.7)	(4.4)	(1.5)	(3.3)	(0.1)	(0.1)	(0.7)

Both in terms of fish numbers and cover of algae, areas tended to be grouped by location: Jamaican areas had the lowest abundance of herbivorous fish, highest coverage of macroalgae and least coverage of grazed substrata; the single Barbados area was at the other extreme (low cover of macroalgae and high abundance of herbivorous fish); areas in Belize, Cuba and Cayman fell somewhere in between (Table 20, Fig. 4). Herbivorous fish biomass was highly significantly negatively correlated with macroalgal cover ($r = -0.892$, $p<0.001$, Fig 4), and highly significantly positively correlated with coverage of grazed substratum ($r = 0.740$, $p<0.001$, Fig 4). The amount of grazed substratum on the Barbados reef was clearly limited by the fact that only 50% of the substratum was available to algae (at all other reefs, total grazed substrate was considerably less than total space available to algae), which explains why the data point for Barbados grazed substratum fell much lower than the general trend for increased grazed substratum with increased herbivorous fish biomass (Fig. 4b). Without the data from the Barbados reef, the correlation between grazed substratum and herbivorous fish biomass was even greater ($r = 0.827$, $p<0.001$).

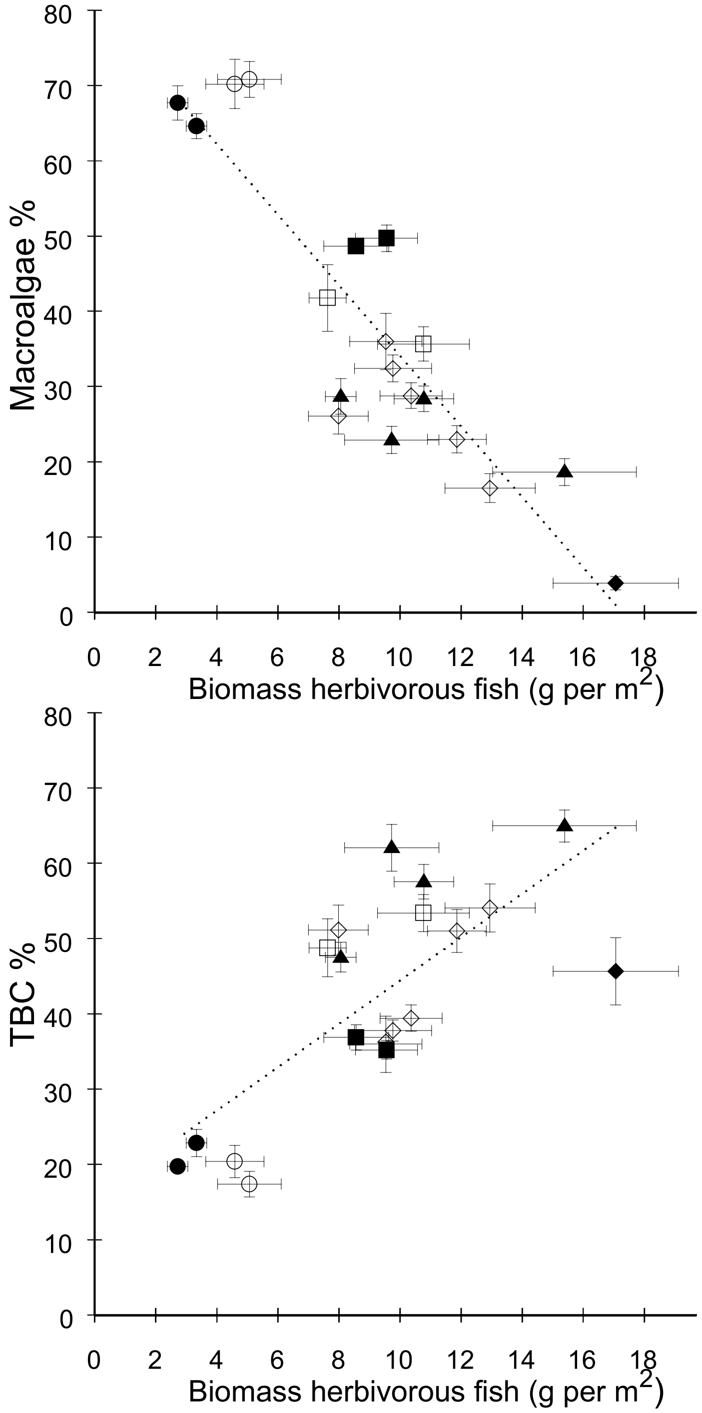


Figure 4 Plots of cover of (a) macroalgae and (b) grazed substratum (TBC = turf + bare + coralline algae) against biomass of herbivorous fish. Locations: Barbados (◆), Ambergris Caye, Belize (▲), Grand Cayman (◊), Negril (●), Montego Bay (○), and Cuba (Punta Frances = ■; Punta del Este = □). Lines of best fit added to each graph

SOCIAL IMPACTS (J.G. Carrier & L.F. Robertson)

Jamaican fishing

Jamaica, like most of the English-speaking Caribbean, has an open-access fishery, and fishers say that all people have a right to fish on the sea, as long as they do not trouble the next fisher. In fact, it appears as though coastal waters in Jamaica resemble what is called 'family land', land held by all the children and grandchildren (and so on) of the person who originally acquired the land. While family land can not support all the people who have rights in it, it is important and valued even so. This is because family land is a safety net, a place where you can go when you are down and out, a place where you can stay for a while and find food and help until you are able to support yourself again with other resources or other work: 'For the greater part of family members, the land has been a place where they might go whenever they are in need, but not a place where they actually have chosen to live' (Olwig 1997, p 151). If this assumption is correct, then the sea is significant for the many people who do not actually fish, just as family land is significant for the many family members who do not actually live on it. Moreover, this significance is greater than the sheer economic reward that may come from fishing, which may be only modest. In addition, it is important as a token of security available to people simply by virtue of their being Jamaican. As we shall see below, these perceptions and values affect fishers' attitudes toward marine reserves.

With its open-access fishery, Jamaica is distinguished from societies with indigenous systems of marine territory or ownership rights, which can act as systems of fisheries management (see, for example, Carrier 1981; Cordell 1989; Johannes 1978; McCay and Acheson 1987; see generally Robertson and Carrier n.d.). To say that Jamaica does not have a system of territory or ownership rights is not to say that, in practice, fishing is wholly free for all. Thus, Berkes (1987) argued that fishing beaches in Jamaica act as a kind of territorial system: fishers set most of their traps close to their beach, for those who place them further afield risk losing them; a person wishing to fish from a beach must first be acceptable to the community of fishers who use it. At best, however, what Berkes (1987) described is a set of pragmatic constraints, which are different from the sort of articulated local system of ownership and control found in some other parts of the world. Moreover, Berkes' (1987) argument does not clearly apply to the research areas described here. The fishers who set their traps close to their beach were those who did not have motors on their boats; those who had motors set traps as much as 16 km from their beach, in waters much closer to other fishing beaches than to their own. Also, Berkes's (1987) argument that people need to be known and accepted does not apply to beaches like River Bay and Negril River, which are not part of a residential area. There, many fishers spent little time beyond what was necessary to set off for and return from their fishing, and hence they needed to have little social interaction with other fishers.

Fishing has always been a way of making a living in Jamaica. Men, who vastly outnumbered women among fishers in the two locations, entered into fishing for various reasons: it was something they grew up doing, it was an independent lifestyle, they loved the sea. Recently, however, it has become increasingly common for people to take up fishing because they have no other way of making a living. Although fishing requires skill, it is something that anyone with the necessary equipment can take up fairly easily. This is most true for spear fishing, and over the past 10 years there has been a dramatic increase in those fishing this way, though this was more true for Montego Bay than for Negril. One attraction of spear fishing is that it carries little cost, compared to the more substantial costs of running a boat and perhaps motor that other techniques require. Also, once a person has a spear gun it is easy to find a friend who will teach the techniques of snorkelling and diving. In keeping with our point that coastal waters resemble family land, spear fishers in Montego Bay characteristically came from the ghetto areas of the city and were people who had no other jobs.

Fishing is also a very flexible occupation. It can be given up or reduced when a person has better opportunities elsewhere, and resumed or intensified when times are bad; a common pattern in the two field locations. One corollary of this is that the number of fishers using an area fluctuates substantially over time, making the notion of 'the population of fishers' problematic. Fishing is flexible in another way as well, because it is mainly up to the individual to decide when to go fishing, unless the individual is fishing as crew for someone else. As a corollary of this, many fishers also did some other kind of work. In Montego Bay, this was usually manual labour or work related to the tourist sector. In Negril and Orange Bay, this was usually farming. The degree to which fishing was a person's primary occupation varied. For example, a fisher might go fishing five times a week and be a day labourer whenever possible, or might run a shop or business and go fishing once every two weeks. However, the importance of fishing as a secondary occupation should not be underestimated. Multiple occupations are common in the Caribbean, and allow people to increase their economic security.

Fish stocks around the coast of Jamaica appear to have been shrinking markedly for some decades, through a combination probably of intensive fishing and degradation of habitats through coastal development and pollution. Fishers themselves have not taken any action to resolve the situation, though they all agreed that it was bad and getting worse. Instead, they have intensified their fishing effort, with greater energy put into catching what is left (Aiken & Haughton 1987). The Jamaican government has no national laws on managing fish, though it does have closed seasons on lobster and conch, and the catching of turtles is illegal. There is a system for the licensing of fishers, but there appeared to be no policy to limit the number of licences. The economic situation of Jamaica exacerbates the tendency to fish heavily. As the cost of fishing rises, such as the price of fuel, so does the need to catch more fish, even if this means very small fish. Small fish do not command the price of larger fish, but they can still be sold, and as we said, they can also be given away. In the next section we describe the economic importance of fishing for people in the sites studied.

Economic importance of fishing

Assessments of the number of fishers at each beach were conducted in order to understand the economic importance of fishing to the different sites studied. However, it was found that, to a varying degree at the different beaches, a number of people who did not fish themselves received money because of the existence of the fishing beach. The first and simplest of earning this sort of money was through dressing fish: scaling and cleaning them (for which they received J$20 per pound of fish dressed). The second way was vending, bringing together fish and purchaser (also for J$20 per pound), an odd phrasing that encompasses the different sorts of vending that existed. For instance, River Bay vendors received fish from the fisher and took them to the Montego Bay market to sell, returned the proceeds to the fisher and received a share of the money. On the other hand, at Whitehouse vendors acted more as touts: they advised people passing by that a particular fisher had fish to sell, and received a share of the sale price. Moreover, at each beach there were small businesses - shops, bars and restaurants - that relied on the presence of people on the fishing beach. The number of people receiving an income through fishing and the existence of the fishing beach in the Montego Bay sites is in Table 21. (In this section ‘the fisher’ refers to fishing and activities that are related to it in the ways described in this paragraph.) In Whitehouse and River Bay, vendors and dressers were mostly men. This work was sporadic. At River Bay, vending was possible only if there was insufficient demand on the beach to buy all the catch, and if the fisher could not store unsold fish at home (usually in a freezer).

At Whitehouse beaches, vendors relied on the existence of passers-by, and they would often dress fish while waiting. Although the money gained from this work was small,

TABLE 21 The number of people gaining an income from the fishing beaches studied in Montego Bay.

	Bottom Whitehouse	Top Whitehouse	River Bay
Approx. no. of area residents of working age	110	28	0*
No. of fishers using beach	31	10	40
No. of resident fishers using beach	17	10	0
No. of people receiving main income from dressing or vending	7	0	6
No. of businesses supported by fishing	3	2	7

(*) River Bay had a few sheds in which some people occasionally slept, but no regular residents.

it was the main income for a number of people in this study.

The small businesses varied in scale. At Whitehouse, the five bars and restaurants were long-established licensed outlets run by women. Each bought fish from local fishers, ensuring a small but steady market for the catch. Each also relied on selling food and drink to fishers and their families, and to those visiting the beach in order to buy fish. At River Bay there were no restaurants, but there were seven stalls, also run by women. These sold mainly drinks, cigarettes and food, but not fish. These stalls were completely dependent on the trade provided by the fishing beach, both fishers and people coming to the beach from the town.

Table 21 shows that, overall, 53 people drew their main income from the two Whitehouse fisheries in on way or another. If we restrict ourselves to resident fishers, the number drops to 39, which is 28% of the number of residents of working age. For River Bay there were also 53 people who drew their main come from the fishery. However, this is a much smaller percent of the pertinent larger population, perhaps 5,000 people of working age living near enough to fish from the beach. Just over 1% of those in the area seems an insignificant amount, but in a city with around 50% unemployment, every living gained is valued.

Table 22 provides parallel information for Negril and Orange Bay. It shows that 47 people gained their main income from the Orange Bay fishery. If we restrict ourselves to residents this drops to 45, or 11% of the resident population of working age. The two vendors were women, and nobody gained a main income from dressing fish. This reflects the relative prosperity of the area and a government development strategy that has attracted people already in work and kept away the squatters and unemployed people found in the other areas studied. Despite the prosperity of Orange Bay, the fishing beach remains important as fishing has been a traditional source livelihood there.

TABLE 22 The number of people gaining an income from the fishing beaches studied in the Negril area.

	Orange Bay	Negril
Approx. no. of area residents of working age	400	900
No. of fishers using beach	40	60
No. of resident fishers using beach	38	55
No. of people receiving main income from dressing or vending	2	4
No. of businesses supported by fishing	5	3

Negril fishing beach had 67 people relying on it, the largest number of all the sites studied. This reduces to 62 if we restrict ourselves to resident fishers, 7% of the total population of about 900 people of working age in the area. Like River Bay, this beach is in a place with significant squatter communities, made up of people moving into this tourist area looking for work. As in Orange Bay, fishing is valued in Negril in part because it has been a traditional occupation: Negril was a fishing community before the growth of tourism.

The actual income of a fisher varies according to the fishing seasons (and phases of the moon, but not as substantially). There are low catches of reef fish in February-April; they are high catches of Jack fish in August and in September-November of what fishers call ‘running fish’. These are fairly large fish, mostly yellow-tailed snapper, that are believed to pass through the area with the stormy weather of this time of the year, hurricane season. In order to estimate the income earned from fishing in the prime site, Bottom Whitehouse, weekly recordings were made of fish catches over 12 months (Table 23), a week’s catch in each month to discover seasonal variations in the catch. These data indicate how small the catches have become. In the slacker months, December-June, both fishers were catching below 30 lb. of reef fish a week, and in the real low season, February-April, the first fisher was averaging just over 21 lb. of fish a week and the second 27 lb. On the other hand, in 1994 fish catches in Montego Bay at this time of year were reported to average 16.9 lb. per day for trap fish (Nicholson 1994). This compares to just 7 lb. and 9 lb. a day for fishers studied in 1998-9 (based on the three-day fishing week common to Whitehouse fishers). In August, catches peaked with 44 lb. and 77 lb. being caught in a week, or 14.7 lb. and 25.7 lb. a day, which still left the first fisher below the 1994 low-season average. The running-fish season was also poor, which was especially disappointing as fishers normally relied on the high season catch to support themselves and buy gear for the next year. In previous years fishers reported catching over 100 lb. of fish a week, while this season

TABLE 23 Fish catches of two trap-and-trolling fishers at Bottom Whitehouse: one week's catch in each month, with the amount earned from the sale.

				May 1998	**June**
				9lb bonito 21lb pot $3,240	7lb bonito 19lb pot $2,840
				27lb bonito 26lb pot $5,280	5lb bonito 24lb pot $3,280
July	**August**	**September**	**October**	**November**	**December**
12lb kingfish 24lb pot $4,100	44lb pot 4lb lobster $6,280	10lb barracuda 31lb pot $4,720	40lb pot $4,800	29lb pot 12lb lobster $5,880	22lb pot 15lb lobster $4,890
33lb pot $3,960	77lb pot (mainly jack) $9,240	37lb pot (incl. grouper) $4,440	61lb pot (mainly yellow tail) $7,320	36lb pot 24lb lobster $9,180	25lb pot 29lb lobster $7,350
January 1999	**February**	**March**	**April**		
18lb pot 7lb lobster $3,560	17lb pot $2,040	21lb pot $2,520	26lb pot 3lb bonito $3,360		
22lb pot 12lb lobster $5,040	23lb pot $2,760	28lb pot $3,360	30lb pot 6lb bonito $4,080		

their highest catches were just 40 lb. and 61 lb. During the period of study Whitehouse fishers also were relying heavily on catching lobster. Fishers had a good lobster catch, but a number found it very difficult to sell them, even after dropping the price from J$250 per lb. to J$150. Unfortunately, a number of fishers had to leave their lobster at sea as they could not readily sell them, and many lobster eventually died or were stolen.

The costs of entering fishing are high. Capital is needed mainly for a boat and an engine which can be bought either new or second hand. Most people preferred to buy a fibreglass boat as they can last about 20 years, but plywood boats and wooden canoes were still common in River Bay and Orange Bay beaches. Nobody interviewed considered buying a canoe, but some fishers still bought plywood boats, which cost J$15,000-J$35,000. Other initial costs depend on the method of fishing involved. Costs did not vary significantly across the different sites, and Table 24 presents costs that would have been incurred by a fisher in Whitehouse, the main site. This table shows that initial costs for entering into trap and trolling fishing would range between J$180,000 and J$325,000, depending primarily on whether new or second hand boats and engines were bought. (All other gear to make traps and for line would be bought new.) Considering that the two fishers whose catches were presented in Table 23 earned about J$120,000 and J$180,000 (see Table 25), start-up costs were significant. Government credit no

TABLE 24 Initial costs of entering into different types of fishing.

Boat (28 feet fibre glass)	Traps (to make 5)	Trolling Bait (artificial)	Gas Containers	Handline Hooks
New J$170,000 Used J$70,000-J$100,000	Wire J$4,400 Sticks J$500 Nails J$100 Lacing wire J$150	J$1,500 (5 @ J$300)	J$1,650 (3 @ J$550)	J$480 (4 packs @ J$120)
Engine (50HP)	**Trap Rope**	**Trolling Line**	**Hand line**	**Netting**
New J$140,000 Used J$70,000-J$80,000	J$1,500 (5 lb./pot, 5 pots @ J$60 per lb)	J$4,500 (300 yd @ J$1,500/100 yd)	J$1,500 (3 rolls @ J$1500/9lb roll)	J$15,000 - J$32,000 (100 lb/net @ J$150-J$320/lb)

longer being available, many men looking to go into fishing relied on either money from other work, finding a patron or renting another fisher's equipment.

Table 25 Costs and income of trap and trolling fishing, from fishers used in Table 23.

Annual costs	Estimated annual gross income	Estimated annual net income	Estimated weekly net income
J$88,300	J$208,997	J$120,697	J$2,321
J$103,850	J$282,923	J$179,073	J$3,444

Although a fisher's net income was small, it is still in line with other lower-class work available in Montego Bay and in the Negril area. The estimated weekly net income for the two fishers (J$2,321 and J$3,444) is comparable to the income of those working in the tourist industry. For example, a waiter in a hotel could expect to earn J$2,500 weekly and a scuba-diving guide between J$2,000 and J$3,500. However, many fishers were not interested in working in other industries as they did not allow the same independence in working as fishing.

TABLE 26 Occupations of men and women living in Bottom Whitehouse.

Occupation	Men	Women	Total	% of residents of working age
Unemployed	12	22	34	31
Unskilled, manual and service	19	12	31	28
Fishing-related	22	2	24	22
Tourism	9	8	17	15
Paid domestic	0	4	4	4

The attraction of fishing for Bottom Whitehouse residents of working age is presented in Table 26. It shows that more men were engaged in fishing than in any other type of work. Only a very small amount of women living there gained a main income from the fishery, but it is very rare for women to go fishing anywhere in Jamaica. Overall, the fishery was the main occupation of 22% of those of working age, while 31% were unemployed. In Top Whitehouse also (see Table 27), more people were involved in the fishery than in any other type of occupation: 35.7% of those of working age, while 25% were unemployed.

TABLE 27 Occupations of men and women living in Top Whitehouse.

Occupation	Men	Women	Total	% of residents of working age
Unemployed	1	6	7	25
Unskilled manual and service	3	5	8	29
Fishing-related	10	0	10	36
Tourism	3	0	3	11
Paid domestic	0	0	0	0

Those involved in fishing were commonly the primary contributor of a household. There were 72 households in Bottom Whitehouse, of which 21 received an income from fishing and fishing related work. The corresponding figures for Top Whitehouse were 10 and 7 (Table 28).

TABLE 28 Number of households in Whitehouse sites gaining income from the fishery.

	Bottom	Top
Total households	72	10
Households receiving income from the fishery	21	7

Of the 21 households in Bottom Whitehouse that gained an income from the fishery, 10 derived all their income from that source (5 of these were young men living alone). A further 9 households depended on the fishery for 75%-99% of their income. For Top Whitehouse, 5 out of 7 households depended on the fishery for all of their income, and none relied on it for 75%-99% of their income (Table 29).

Fishers in Montego Bay

Although we have aggregated fishers in the preceding section, they were by no means a homogeneous group. Three main ways whereby fishers differentiated among themselves were found, a differentiation that affects their political response to marine reserves. The first way was the type of fishing gear used. The second was the fishing beach that fishers use. The third was the perceived wealth of an individual fisher, which was also related to the degree to which fishing was a full-time or part-time occupation.

Five different methods were found to be used in fishing, namely trap (sometimes called pot), net (both seine and trammel), hook-and-line (conducted at night), trolling and spearing (either with snorkel or scuba). Most fishers had used various means of fishing at one

TABLE 29 Whitehouse households receiving income from the fishery.

Household	Total people in household	Children in household	No. in fishery	Total Working	% income from fishery
BOTTOM WHITEHOUSE					
1	3	0	1	1	100
2	1	0	1	1	80
3	1	0	1	1	100
4	6	4	1	1	100
5	1	0	1	1	100
6	6	4	1	1	100
7	1	0	1	1	100
8	10	3	3	5	80
9	2	0	2	2	100
10	6	2	1	3	50
11	7	3	2	3	75
12	6	2	2	2	100
13	1	0	1	1	100
14	1	0	1	1	100
15	1	0	1	1	85
16	1	0	1	1	90
17	1	0	1	1	85
18	1	0	1	1	90
19	1	0	1	1	90
20	1	0	0	0	80[1]
21	3	2	0	0	60[2]
TOP WHITEHOUSE					
1	5	2	1	1	30
2	4	0	2	2	100
3	8	4	1	3	40
4	4	1	2	2	100
5	1	0	1	1	100
6	2	0	2	2	100
7	1	0	1	1	100

(1) Supported by Bottom Whitehouse household 8.
(2) Supported by Bottom Whitehouse household 7.

time or another in their lives; however, the majority used just one or perhaps two methods at any one time. Furthermore, techniques were not distributed uniformly across the research locations (see Table 30 for information on the two Montego Bay areas). At Whitehouse, fishers did not use nets or hook-and-line for fishing. Instead, traps predominated: of the 41 fishers there, 35 used traps; of the six who did not, only one fished regularly. Also, most fishers also went trolling, either inshore (on what is called 'the bank') or offshore (out on 'the deep'), especially when they were on their way to and from the areas where they had set their traps. Just two Whitehouse fishers combined trap fishing and spear fishing. In contrast, all five methods of fishing were used at River Bay, where approximately 13 net fishers, 11 trap fishers, 14 hook-and-line fishers, three who went trolling and three who went spear fishing, were identified. Five fishers combined more than one method of fishing.

TABLE 30 Types of fishing in Montego Bay

Location	Trap	Net	Hook-and-line	Trolling	Spear
River Bay	11	13	14	3	3
Whitehouse	35	0	0	most	2

This difference in type of fishing was not just technical. It had an important socio-political corollary, in that fishers who used a technique tended to be suspicious or uncertain of those who used other techniques. This was most pronounced with regard to spear fishers. Commonly, those who used other techniques did not even consider spear fishers to be fishers at all, but called them 'shooter men'. Trap fishers were especially suspicious of spear fishers, as the latter were known to steal fish from traps. Trap fishers regarded this as extremely serious. At the same time, however, they knew that there was very little that they could do about a spear fisher unless they caught the man in the act of stealing fish from one of their traps. This happened very rarely, and we heard of only one case of a spear fisher caught in the act. It happened that a trap owner was diving with a spear gun at the time. A fight followed and the trap owner ended up shooting the spear fisher in the head, though not fatally. Because of their concern with theft from their traps, most fishers who did not themselves use spear guns supported a ban on spear-gun fishing by the Montego Bay Marine Park.

We wrote that another way that the fishers within Montego Bay differentiated themselves was geographically, according to the fishing beach that they used. This distinction reflects the fact that Whitehouse and River Bay were quite distinct socially and economically.

We have already written that Whitehouse is not just the location of a fishing beach, but is also a residential area. Not all the people who lived there fished, and not all the people who fished from that beach lived there. Even so, by being a residential area it has characteristics that distinguish it from River Bay. We also wrote that Whitehouse is itself divided into two areas, called 'Top Whitehouse' and 'Bottom Whitehouse', the two separated by a playing field and some unused land. Top Whitehouse is much smaller than Bottom; it had only about 40 inhabitants, in comparison to nearly 200 at Bottom Whitehouse. Also, much more than Bottom Whitehouse, Top Whitehouse is a place where residents fish and those who use the beach are residents. Thus, Top Whitehouse had only four fishing boats and 10 people who fished from the beach, all of whom were residents, out of a population of about 40. On the other hand, Bottom Whitehouse had about 20 boats and 31 fishers, only 17 of whom lived in the area, out of a population of about 200 (Table 31).

TABLE 31 Numbers of residents, boats, total fishers and resident fishers in Top and Bottom Whitehouse

Location	Residents	Boats	Total fishers	Resident fishers
Top Whitehouse	40	4	10	10
Bottom Whitehouse	200	20	31	17

On the other hand, the River Bay beach was not an area where fishers lived. There was a building that fishers used to store gear, and some fishers might have slept or even lived there for a time. However, nobody officially resided there and nobody called it home. However, this does not mean that there was no one at the beach, for something was going on and people were doing things at all times during the day. Some fishers might be occupied repairing or making nets or traps, a number of people would be selling food and drink, people from town would have come to the beach to enjoy the breeze or do a bit of gambling.

River Bay beach had about 64 boats, though there were only about 40 fishers. The type of boat at River Bay was also something that distinguished it from Whitehouse. At Whitehouse Beach, all the boats were made of fibreglass and all had outboard motors. This combination of boat and motor was the technology that all fishers desired. At River Bay beach, on the other hand, there were only three boats made of fibreglass, the rest being made of wood, and only nine of the 65 boats had motors. In this sense, River Bay fishers were generally considered a poorer set of fishers than those at Whitehouse.

This introduces the third of the ways that fishers routinely distinguished among themselves, namely perceived wealth. Although fishers as a group were considered to be poor, the fishers studied did not see each other as equally poor. Put in other words, some fishers were considered much richer than others, a distinction which was significant among those at each beach.

As a practical matter, those seen as the richest fishers were those who owned their own boats, especially if the boat was made of fibreglass. Equally, a number of people who fished had a paying job, and the existence of such a job was often the basis of the judgement that the individual involved was rich. Indeed, having such a job could enable a fisher to buy his own boat. Perceived differences in wealth were perhaps the most significant social difference among fishers. This is because one fisher did not like to see another one doing well. There were fishers who were said to be ‘grudgeful’, and such people might go so far as to damage the equipment of a fisher seen to be richer. At the same time, people said that those who had money did not like to see others coming up in the world, and that the more successful would try to hinder those who were rising. The most common form this took was when the owner or captain of a boat did not pay his crew properly. It was mainly this fear of being restricted by the better off that led most fishers at River Bay to fish by themselves.

We have described three main ways that Montego Bay fishers differentiated each other. All of these, but especially economic differentiation, have consequences for the Marine Park, because they reduce the chances of co-operation among fishers, although this is also associated with the way that fishers tended to value independence. This lack of co-operation among fishers was manifest by the fact that, while both River Bay and Whitehouse beaches formally had fishing co-operatives, neither presently was operating. At a more mundane level, the lack of co-operation meant that most fishers did not care about other fishers so long as they themselves were doing all right. Put differently, these fishers were, and were seen to be, very independent people, a practice and a perception that echoes the historical association of fishers with autonomy, self-reliance and skill in much of the English-speaking Caribbean (see Price 1966). The other side of this autonomy and self-reliance was the common assumption that each fisher was simply ‘out for himself’ and had opinions that were different from those of the next man, both of which led to a lack of cooperation among fishers.

This lack of co-operation, with its associated fragmentation, has two important socio-political consequences for the operation of the Marine Park. First, it means that there is no collective involvement by fishers with the Montego Bay fishery, and hence little chance of collective involvement with the Marine Park, for a crucial element of social life necessary for that involvement is missing:

> Effective community involvement and management require a strong community structure. Community groups or institutions ... must be willing and able to take responsibility. Core groups may be identified through community leaders; they may be derived from an existing institution or may emerge as plans for resource management are being formulated and roles are being defined. If possible, core groups should be formed from existing or traditional community groups or institutions (White et al. 1994, p 111).

Second, there is little willingness among fishers to make a sacrifice for the common good, the sort of sacrifice that a marine protection regime entails. Sacrifice is likely to be made only if there is perceived to be a real and immediate benefit to the individual fisher, who will not give up using a particular gear or fishing in a particular area simply because it would serve the general good at some point in the future.

Deterioration of the environment in Montego Bay

In spite of the heterogeneity of the Montego Bay fishers, there were some matters about which fishers generally agreed. Here we look particularly at their understanding of the changes in their marine environment, and of the causes of those changes. These are important because they directly shape and justify fishers' political responses to the Marine Park.

One important thing that fishers agreed on was that fishing was not what it used to be, and they said that this was the case whether they had been fishing for more than 40 years or less than five. In other words, the experience of all fishers was that things had steadily been getting worse. All fishers reported that, when they first started fishing, there used to be more fish. The older fishers also reported how, at one time, they used to be able to draw just one or two traps and catch over 100 lb of fish, more than they could expect to sell. This was very different from the situation in the present, when drawing eight or 10 traps might bring in only 5 lb of fish.

Fishers not only agreed on the deterioration, they also agreed on the cause. The decline was attributed primarily to the development of the Montego Bay area. This development had been driven by the growth of the tourist sector. When tourism was first considered in Montego Bay, a common assumption was that it would be appropriate to build a handful of small hotels of 10 or 20 rooms, 'in keeping with the local surroundings' (Taylor 1993, pp 145-146). Events turned out very differently. Montego Bay is now Jamaica's second largest city, with 56 hotels and over 5,000 rooms (Bunce & Gustavson 1998, p 75). In spite of the original, common expectation of a few, small hotels and a modest tourist sector, the reality since the 1970s has been a focus on large hotels catering to mass tourism, and this continues as new, large hotels are still being constructed along the north coast, to the east of the city.

Fishers saw these hotels and the industry of which they are a part as having had a substantial, negative effect on Montego Bay's marine environment. The building of these hotels entailed the destruction of a significant amount of the original coast, particularly a number of mangrove stands, which were breeding grounds for fish. The damage caused was not limited to construction. For instance, fishers said that some of the hotels pumped their sewage and waste water, which often contained chemicals used in cleaning, straight into the sea. Fishers said that this did not just damage the coral reefs in the bay, but the hotels' effluent also caused fish to move away from the area.

While the growth of the tourist industry had had direct effects that fishers saw as damaging to the environment, it had also had damaging indirect effects, through the associated growth of the city. The most noteworthy of these, according to the fishers, had been the dredging and filling associated with the construction of the freeport area and the land filling along the sea front of the centre of Montego Bay. According to the fishers, the construction of the freeport involved severe damage to the largest mangrove stand in the bay, in the Bogue Lagoon, as well as damage to a large area of reef. The expansion of the down-town area entailed land filling along about a kilometre of the seafront, and the associated damage of a large area of the reef.

Montego Bay fishers, then, saw the factors associated with the growth of the city as the main cause of the deterioration of the fisheries, and they saw these factors as eliminating or harming the areas where fish preferred to live. Pollution caused by construction and hotel waste and the destruction of large areas of mangrove had caused fish to move away. It was true that a portion of the Bogue Lagoon mangrove area remained, was still a breeding ground, and was a protected area under the Marine Park, with no fishing allowed at all. Fishers said, though, that this area was subject to heavy pollution from urban sources in the area, and that the construction of the freeport had blocked the natural flow of tide, further harming the lagoon's waters.

Although fishers strongly believed that environmental damage caused by the growth of Montego Bay was the greatest cause of the deterioration of the fisheries, they were also aware that some fishing practices contributed to this. For instance, they disliked spear fishers because they were considered to catch very small fish and lobster, and so decreased breeding stocks. The perceived catching of juveniles affected fishers' perceptions of other fishing techniques, as well. People were concerned that trap fishers, who generally used a mesh of 1 inch, were catching fish that were below breeding age. Equally, seine net fishers, who operated in the shallow seagrass areas, did not only catch the very small fish, but killed everything in the area.

These perceptions of the damage caused by different sorts of fishing and different sorts of fishers were generalisations that were not necessarily accurate. Not all spear fishers shot very small fish, and in fact they defended themselves by saying that at least they could see what they were catching, and so avoided very small fish; not all trap fishers used 1-inch mesh. However, these generalisations were manifest as part of a general tendency for each person to see other kinds of fishers, rather than himself, as part of the cause of the deterioration of the fisheries. None the less, as the number of fish continues to decline, fishers are left catching the smaller fish simply in order to catch anything at all. As those who used the small mesh said, they had to catch the little fish in order to buy a loaf of bread.

Perceptions of the Marine Park in Montego Bay

The Montego Bay Marine Park is a 15.3 km^2 area of water with Montego Bay city at its centre. It extends from the Montego Bay airport to the north, to the Great River to the southwest. Within these boundaries the Park is zoned into different use areas. At the time of this research there was one 'no take' area, a marine sanctuary situated in an area behind the freeport, called the Bogue Lagoon. (There were plans to change the zoning within the Park.) There was also a no-fishing area in front of the main tourist beach, called Doctor's Cave reef, but other activities such as diving and boat trips were permitted. The Park also banned spear fishing in all of its waters and prohibited the cutting of mangroves. The Park had a patrol boat and wardens to enforce these rules. The most enforced rule was the ban on spear fishing, and wardens attempted to prosecute some spear fishers. If other fishers were caught in inappropriate zones they were normally given a warning or might have had their equipment confiscated. Although these regulations existed, many fishers simply ignored them or were confused about them. Everyone was aware of the ban on spear fishing, though a number of men still fished in the area and felt that they had the right to do so. These men normally fished in large groups, and so were difficult for the Park wardens to arrest. Wardens had also been threatened by such men on various occasions. There is general lack of awareness about the use of zones within the Park boundaries and a tendency for fishers to feel that there was a move towards a total ban on fishing within the whole of the Park.

The general perception of the Montego Bay Marine Park among Whitehouse and River Bay fishers was unfavourable. Nearly all the fishers spoken to did not consider the Park to be of benefit to them. There were a number of different reasons for this. At both beaches, fishers perceived the Park to be there in order to benefit tourism and the tourist industry. Fishers thought this was because, they said, nothing was ever done about the negative effects that the tourist industry had on the area. Fishers said that, time and time again, they had told 'the Marine Park people' that certain hotels were pumping raw sewage into the sea, but that nothing had been done about it. Fishers also said that the water sports activities in the area adversely affected the fisheries and the marine environment. For instance, there were a number of boats that took tourists out snorkelling, and fishers said that this caused damage to the reef. This was of especial concern to Whitehouse fishers, as there was a large, all-inclusive hotel close to Whitehouse, which operated a cruise catamaran in the mornings and evenings. Fishers said that this boat crossed the marine channels in the area, and had damaged a large amount of the reef nearby. They also said that tourists who went snorkelling and diving often stood on the corals, killing them, and that jet skis and party boats drove fish away from the area as they were so noisy.

Not only did Montego Bay fishers see that the Marine Park was for the benefit of the tourist sector, many also considered that it operated at the expense of local fishers, who were penalised in order to make the area more attractive to tourists. This was especially the case among some of the River Bay fishers and the spear fishers who used the area most. Spear fishing is banned completely in all areas of the Marine Park, and the spear fishers said that it was not right that they, who grew up by the sea, should be penalised for trying to make a living when they fished in Park waters. Their sense of anger was increased by what they saw as a Park management made up of people who had come from all over the country and who did not understand about fishing.

Montego Bay fishers also had mixed feelings about the protected area of Bogue Lagoon. The fishers generally respected this area as a breeding ground, but some saw its benefits as limited and objected to some aspects of its management. As we already noted, fishers sid that the creation of the freeport had done so much damage, and that there was now so much pollution in that area, that the Bogue Lagoon was not adequately re-stocking the Montego Bay area. More specifically, net fishers argued that the area should not have been off limits altogether. They said that Bogue Lagoon was the most suitable area to catch bait fish (sprat), and that when they caught bait fish they did not trouble the other fish in the area. They argued, moreover, that their inability to catch bait fish in the lagoon had negative consequences for other fishers. This was because the absence of bait fish meant that other fishers could not buy the bait that they needed to go fishing themselves. In addition, some fishers said that even though general fishing should not be allowed in the protected area, when the weather was rough the rules should change. As Bogue Lagoon was the only area that could still be fished at such times, opening it to fishing during bad weather would have allowed fishers to catch some fish, rather than their being unable to fish because of rough weather, sometimes for a week or more.

Most of the aspects of fishers' response to the Marine Park that we have discussed thus far were common to most fishers in Whitehouse and River Bay. However, there were some factors that divided fishers' responses to the Park. Particularly, and reflecting the strong independence that characterises these fishers, they were concerned that the Park could benefit some fishers at the expense of others. The fishers who gave some support to the idea of a marine park were those who saw themselves as relatively unaffected by it. This category was mainly hook-and-line fishers at River Bay. Although they expressed some concern that the

Park generally had troubled fishers from their beach, they tended to say, 'still, they don't trouble me'. This sort of reaction was also found among the Whitehouse fishers and the spear fishers who fished outside the Park area. Generally, these fishers were not against the Park, or at least did not feel oppressed by it, as others did. However, Whitehouse fishers still felt that they received little benefit from the Park, as the bay waters were still being polluted and as there was still plenty of spear fishing going on within the Park boundaries. Otherwise, they felt that they would benefit from the Park sometimes in rough weather, because in those circumstances they said that fish tended to come out of the Park waters and into their fishing grounds. Therefore, Whitehouse fishers generally perceived the Marine Park as not doing anything noticeable that was beneficial to them, but they supported the idea of ridding the area of spear fishing. In fact, however, an effective ban on spear fishing in Park waters could end up harming Whitehouse fishers, as it would probably lead spear fishers who had been using the Park waters to start fishing in the Whitehouse area, where they would not only catch fish, but possibly steal fish from Whitehouse fishers' traps. This displacement of spear fishers into the Whitehouse area could be alleviated by extending the Park boundaries. However, while this could help Whitehouse fishers, it would probably serve only to shift the displacement of spear fishers to fishing areas farther to the east.

Thus far we have described main aspects of the attitudes of Montego Bay fishers to the Marine Park. We want to close this section with a description of what most fishers would like the Park to do, which is to say, what most fishers thought the Park could do that would benefit them and the fisheries. First, most fishers would have liked to see the Park deal with the sewage and pollution problem in the area. This would not only solve an important problem in the Bay and improve fish stocks, but also deal with the fishers' concern that they were the only ones being penalised for the condition of the Bay's waters. Second, fishers wanted the Park to help them with fishing equipment. Interestingly, when they were asked what benefit the Park had been to them so far, a number of fishers mentioned only one thing, namely the mesh exchange that the Park operated for trap fishers. In this exchange, fishers exchanged traps with 1-inch mesh for rolls of 1.5-inch mesh wire. From the fishers' perspective, the results of this exchange were not wholly beneficial. Thus, a number of fishers said that with the larger mesh they could not catch anything; others said that they caught fewer fish, but the ones they caught were of a good size. Instead, the main benefit fishers saw in the exchange was the fact that they received the new wire for free, though this benefited only the trap fishers. The fishers at River Bay would, as well, like help with gear, including netting and line, but also better boats and motors, which would enable them to go fishing outside the Marine Park.

Fishers in Negril

Negril fishers used all five of the fishing methods found in Montego Bay. Trap, long-line and trolling were the most common, followed by net and spear fishing. As in Montego Bay, some Negril fishers used the smaller mesh sizes, including 1-inch mesh.

As with Montego Bay, fishers in Negril were prone to see those who used techniques different from their own as more likely to catch small fish. Among the different techniques used in the area, the one that caused the greatest concern was seine netting. There were reports that fishers in the Savanna-La-Mar area still used dynamite, and all Negril fishers condemned this. All the fishers who did not use seine nets would have liked to see it stopped and thought that eliminating it would bring great benefit to the fisheries. They had criticised and argued with the two or three fishers who use these nets, but without effect, and many Negril fishers were now trying to get an outside authority to resolve the problem by banning the use of the seine net in the area. However, Negril fishers also believed that, in the event of a ban, the affected fishers should receive compensation because they would be losing their livelihood. In contrast to the seine net fishers, the group of fishers who were seen as least destructive were the long-line fishers. As in Montego Bay, because these people fish in deeper waters, they did not see themselves as being affected by the Negril Marine Park management regime. Indeed, these fishers did not see themselves as being related to or affected by the Marine Park at all; because they generally caught bigger fish with this technique, they said that they were 'not into the small fish business', which they saw as the concern of the Marine Park.

There were approximately 40 fishers at Orange Bay beach. The most common method of fishing was the trap, which the men used from plywood or fibreglass boats with motors. Many fishers said that they would like to see the ending of the 1-inch mesh that some trap fishers still used. There were about 10 older fishers who fished by hand line at night from canoes at the edge of the harbour; there were only one or two spear fishers. Fishers at Orange Bay decided amongst themselves that there should be no seine-net fishing in the harbour, as this was a breeding ground for fish. Consequently, no Orange Bay fishers used this technique, and they did not let fishers from other areas use the nets in the harbour either. Orange Bay fishers were relatively more able to protect their grounds than were fishers in Whitehouse, River Bay or Negril River because the area was more enclosed. An additional factor was that fishers at Orange Bay were more united than were fishers in the other areas studied. Although they were not formally organised, all fishers at the beach lived in or came from Orange Bay itself, which had been a mixed fishing and farming community for as far back as anyone knew. There is, then, a sense that the beach and bay belonged to the people at Orange Bay, a sense not found in Negril or the two Montego Bay areas, as these waters were now effectively occupied by the tourist sector.

There were approximately 60 fishers using the Negril River. This number doubtless has fluctuated considerably over the years, but Davenport's (1956) estimate suggests a significant long-term decline; in the middle of the 1950s there were about 200 fishers using the area along the Negril beach (now the tourist strip), the Square and the West End. Similarly, the majority of fishers interviewed in the present study had been fishing for 15 years or more. This is in accord with our suggestion of a decline in the number of fishers, as it suggests that recently there had been a decline in the number of people taking up fishing. The most likely reason for this was that it had become more expensive to become a fisher (see Tables 24 and 25, above, and the related discussion). Also, carrying out fishing had become more expensive with the rising price of fuel, which now took up about half the total value of a fisher's catch. Finally, there was no credit assistance for these costs.

Negril fishers had a co-operative at their beach, presently centred on a store where men from any beach in the area could buy gear, including wire, netting and parts for motors. Officially the co-operative was operating, but fishers reported that it was not running properly. However, they were reluctant to talk about why this was so, which suggests a conflict between the fishers and those on the co-operative executive committee, especially since some fishers complained that the one man who was supposed to represent them and to run the shop was hardly seen nowadays. The store was presently being run by a member of staff of the Fisheries Division.

The deterioration of the environment in Negril

As was the case in Montego Bay, fishers in the Negril area thought that the biggest problems they faced were due to the deterioration of the environment. In Negril itself, the establishment of tourism in the 1960s and 1970s was extremely important in this deterioration. Perhaps the central event was the building of Norman Manley Boulevard, the main road to Negril from the north, which involved the partial draining and destruction of the Great Morass. The building of the road was followed by the construction of hotels along it, the destruction of mangrove areas, the growth of population and the seemingly-inevitable problem of inadequate sewerage treatment. Associated with the partial drainage of the Great Morass and the growth of tourism and population more generally was the state of the Negril River, which was seriously polluted by sewerage and agricultural run-off. The main environmentalist organisation in Negril, the Negril Coral Reef Preservation Society (NCRPS), was aware of these problems, but was limited in what it could do about them.

In Orange Bay, fishers faced one main environmental problem. When the main road was built to link Orange Bay to Negril, the Salt Creek was diverted so that it no longer ran into the harbour at Orange Bay. That harbour is very sheltered, and the diversion of Salt Creek meant that it was no longer being flushed by water from the land. The result was that the water around the edges of the harbour area was stagnant, and was polluted as a result of the operation of boat motors and the cleaning of fish, so that the harbour was not as productive a breeding ground as it used to be. Fishers reported that when the river was diverted, mechanisms were put in place that would allow the original water course to be used in emergencies, suggesting that it might not be very difficult to re-open the old course again. However, it may be that Salt Creek is as heavily polluted as the Negril River, in which case re-opening the old course might not benefit fishers very much.

Perceptions of the Marine Park in Negril

Negril Marine Park is over 40 km^2, bounded on the north by the Davis River and on the south by Savannah River. The Park was still in the process of designating zones within its boundaries. It had no ban on spear fishing, but did protects it mangroves.

Although the NCRPS has invited fishers to various meetings that they have held, the Negril River fishers have rarely attended, showing a lack of interest in the Negril Marine Park, which the NCRPS manages, and their plans. Consequently, there was a lack of awareness of what the Park was about. As in Montego Bay, fishers generally thought that the Park was created to benefit tourism. This view was even held by a fisher who had attended a number of meetings and considered himself a good friend of the Park's executive director; he firmly believed the Park was not there to benefit fishers. Another fisher stated that he had seen a marine park on the south coast of Jamaica, and the only fishing he saw in the area was sport fishing, so he knew the Negril Marine Park would not be concerned with small artisanal fishers. He expected the Park to build a new pier to house the big tourist boats that would soon appear.

Orange Bay fishers were even less aware of the Marine Park than those at Negril River. This was mainly due to the perception that the Park was concerned only with the area immediately around the town of Negril, which is 16 km from Orange Bay. Some Orange Bay fishers did set their traps in the Negril area, but fishers who did not set their traps in the shallows also saw themselves as divorced from Park operations. We need to stress that Orange Bay fishers had no animosity toward the Park; they simply knew little or nothing of its plans and actions. This ignorance stems mainly from the absence of communication among fishers. There were two fishers at Orange Bay who especially supported the Park, and one was on the Park's executive committee. These two men attended all the pertinent meetings, but did not relay what they had learnt to the other fishers, simply because the Park was not a topic of conversation among fishers.

A striking example of this absence of communication was a meeting held in June 1999 by the NCRPS and the Negril Environmental Protection Trust (NEPT) to discuss Park management. Various parties attended the meeting, including representatives of the tourist sector, government agencies, the National Water Commission and fishers. About 10 fishers from Negril River and four from Orange Bay attended. The most important issues for the fishers at the meeting were the proposed use zones within the Park's boundaries and the levying of user fees. Two of the no-fishing zones proposed by Park management were at Green Island and Orange Bay and covered well-known breeding areas, and generated no objections. Unlike Montego Bay fishers, Negril and Orange Bay fishers saw no-fishing zones as a useful way to regenerate fish stocks. The third proposed zone, at Long Bay in a tourist area, generated some debate and was left unresolved. A representative of the Jamaican National Resource Conservation Authority proposed that fees be levied on users of Park waters, and suggested that fishers be charged J$1,000 per year, less than commercial users like dive shop operators. When asked a few days after the meeting, Negril River fishers who had not attended rarely knew anything about it. A few had heard that fishers were going to have to make some payment which they strongly objected to; one fisher said that he had objected at the meeting but that nobody heard him.

As was the case with Whitehouse and River Bay, fishers using the Orange Bay and the Negril River beaches thought that they would benefit from the Park most if it helped in providing better beach facilities, including a proper fishers' building to store equipment and to provide shelter. Fishers also needed toilets, water and electricity to power freezers to store fish. Fishers at Orange Bay said that a navigation light in the area would help them, as there was very little lighting in the area that fishers could use to guide themselves into the harbour at night. Negril River fishers also said that the river had silted up so much that it was becoming dangerous to get boats in and out of the river's mouth: fishers had to push their boats through water too shallow to allow the use of motors, and when the weather had been bad, some of the boats had turned over. More than anything, fishers wanted the mouth of the river to be dredged.

CONCLUSIONS

Ecological impacts

The survey of recreational SCUBA divers in Negril and Montego Bay indicated that corals and fishes were the most highly rated of the 13 biological attributes mentioned in the questionnaires. Further, using the divers' responses with respect to the diving locations involved, the conclusion was that divers were most disappointed with the low abundances of large animals, big fishes, variety of fishes, unusual fishes and fishes as a whole. These are important observations because diving tourism is recognised to contribute substantially to many local economies (Dixon *et al.* 1995). Foci for future work arising from these observations include improved understanding of the perceptions of divers of reef attributes and particular sites, and the role of MPAs in diving tourism, given the differential experience levels of divers (e.g., Shafer *et al.* 1998). In addition, the basis of dive-site choice by dive operators and the factors which affect selection of locations/countries by diving tourists need to be assessed, because these represent a linkage between coastal management practice and potentially increased revenue derivable from tourism based on diving and reefs.

On the basis of the survey, much of the work became focused on the reef fish fauna, but coral attributes were also included with other biological components of the reef such as macroalgae, because macroalgal over-growth of reefs is a principal focus of much concern for reef degradation in the Caribbean (Hughes 1994).

Based on the Montego Bay workshop in 1997, a series of locations were selected where it was felt that there were reefs effectively protected from fishery exploitation. In the absence of suitable time-series data for most localities, the approach was to compare protected and unprotected areas in terms of the diver-preference variables and in terms of certain other ecological characteristics.

Using visually-assessed habitat characters, it was found that, overall, there were significant differences between protected and unprotected areas only at the locality in Cuba, although differences in individual variables which might confound management effects were indicated also for the deep reefs in Belize; the latter, however, could be eliminated by excluding certain sites from the data. The variables involved in Cuba, namely rugosity and coral cover, proved to be significantly correlated with grouper and triggerfish abundance.

In general, protected areas tended to have a high proportion of species with greater biomass and abundance, several more species found exclusively in them, if anything greater biomass and abundance of fishes on deep and shallow reefs, greater species diversity or richness, more large fishes, and greater mean lengths of fishes, than outside them. The greatest differences in protected over unprotected areas were in grouper, snapper, triggerfishes and grunts. Omitting the Barbados Marine Reserve, a crossed ANOVA (factors location [Belize, Caymans, Cuba and Montego Bay] and management status) of fish numerical-abundance and biomass data indicated greater numbers of piscivorous fishes and biomass of all fishes in MPAs than unprotected areas ($p < 0.001$ and < 0.03, respectively), although biomass and numerical data for other fish groups were not significant. Numerical abundance of unusual fishes (2-way ANOVA, $p < 0.001$) and species richness of fishes overall ($p < 0.0001$) were also significantly greater in shallow sites of MPAs than those of unprotected areas, again excluding the Barbados data. Promising areas for future research include the means potentially available to management to sustainably enhance desirable attributes such as large fish and other animals in diving areas, and the perceptions of fisheries with respect to the opportunities represented by the greater value of the reef fish resource to tourism than to fisheries

Effects on large grazing fishes, namely parrotfishes and surgeonfishes, were relatively minor, according to the assessment methodology used. Since the no-fishing zone of the Montego Bay Marine Park was not being actively enforced at the time of the study, it is possible that the greater abundances of certain fishes observed in the MPA remained from earlier effective management, although that has always been partial, since trap fishing has continued to be permitted. It appears that the MPAs examined tended to offer in greater abundance those things which the divers indicated they missed most at the degraded Jamaican diving localities. The near-absence of any effect (only triggerfish) in the Caymans protected areas is probably related to the very low prevailing fishing pressure. In Cuba, snapper, grunt and all fishes combined showed differences between management levels that were not linked to the differences in visually-assessed habitat features observed.

In general, there were very few differences in the reef benthos between protected and unprotected areas, the principal exceptions being greater cover of macroalgae in protected sites in Barbados and Cuba than in unprotected sites, which was the opposite of what would have been expected had protective management increased the abundance of grazers and these had reduced macroalgae. However, grazers were generally not more abundant in the MPAs in Cuba and Barbados than in the unprotected sites. Hard-coral cover was found to be greater on the deep protected reef in Belize, but evidence for this being associated with greater abundance of grazing fishes was equivocal.

The survey of the two Jamaican locations indicates that in shallow water the sea-urchin *Diadema* is likely to be a major factor determining the abundance of macroalgae, while grazing fishes may not be important on the shallow degraded reefs studied. In the deeper sites, however, variations in macroalgal cover were consistent with the hypothesis that abundance of herbivorous fish was a factor, but there are limitations to such analysis. If there were a causative relationship between herbivorous-fish abundance and macroalgal cover and this were related to grazing intensity, then it is also apparent that at present the MPAs studied are not promoting the levels of grazing which are necessary. A promising area for future research includes the means potentially available to management to reduce undesirable features such as macroalgal over-growth (e.g., Rogers *et al*. 1997; McClanahan & Muthiga 1998).

The present study has indicated that MPAs, when effectively enforced, may well enhance reefs in those features which diving tourists most appreciate. This is a significant point of information for planners, given the need to see how management might contribute to improved diving experiences for diving tourists, and the economic benefit that tourism is capable of bringing to local communities generally (Dixon *et al*. 1995).

Social impacts

In both Montego Bay and Negril, marine protection regimes were still being formulated and established, which made the locations suited to an analysis of the political factors affecting local fishers' responses to MPAs. The main influence on that response was fishers' political-economic approach to the marine environment, one that situated coastal waters in terms of the historical and contemporary political economy of Jamaica in general, and Montego Bay and Negril in particular. The main factors identified were (1) the tradition of open-access fishing; (2) the perceived importance of tourist development for the deterioration of the marine environment; (3) the perception that the Montego Bay and Negril Marine Parks were sacrificing the well-being of fishers in order to protect tourism. These factors were all important, though they affect political responses to MPAs in different ways depending upon people's location and the type of fishing that they undertake.

The first factor mentioned was that the Jamaican fishery has open access, so that everyone has a right to fish. Moreover, it appears likely that there is a parallel between coastal waters and the institution of family land. If this is so, fishing has significance in Jamaica as an economic resource in times of personal need, as suggested by the spread of spear fishing among the urban poor of Montego Bay. The fact that the fishery is, and is seen to be, free to all, means that there is a general, though variable, resistance to the closure of coastal areas to fishing of any sort, and hence to the two marine parks that were the sites of this research. This resistance is not absolute; rather, fishers argued that those whose livelihoods were adversely affected by fishing restrictions deserved compensation, especially help in taking up another form of fishing.

The specific form taken by this resistance to the Parks varied with circumstance. Because Whitehouse fishing beach, for instance, is just beyond the boundaries of the Montego Bay Marine Park, the restriction on fishing is relatively insignificant and the resistance was not very intense. Even here, however, spear fishers appeared to feel more threatened by Park policies which ban spear fishing altogether, than did trap fishers, who are not restricted by Park policies except for the fishing sanctuary at Bogue Lagoon, which is some distance from Whitehouse. The situation was different at River Bay. Because this fishing beach is in the middle of the Park, and is closer to Bogue Lagoon, fishers felt more threatened by the Park. In fact, the River Bay resistance to the Park was disproportionate to Park policies thus far, as only spear fishing had been banned totally within the Park boundaries. However, at River Bay, and to a degree at Whitehouse, there was the reasonable perception that existing Park restrictions and boundaries were likely to be extended in the future. It is this perception that appears to underlie present resistance to the Park. Again, the situation was different again at Orange Bay, where some proposed Park restrictions, especially some of the no-fishing zones, accorded with what fishers themselves were urging to improve the fisheries.

A number of factors that distinguish fishers of different sorts were identified, and these factors also affected people's perception of the Parks. Five different forms of fishing were in common use, and the effect that the Park had on a fisher varied according to the technique a fisher used. Hook-and-line and trolling were not presently affected in any material way by the policy of either Park, and those who used these techniques were neither constrained by the Parks nor, generally, very concerned about them. Spear fishing was banned throughout the Montego Bay Marine Park, which generated clear opposition to the Park, though the general absence of spear fishing in the two Negril areas meant that such a ban was unlikely to have been much of an issue there. Nets and some traps were affected by limitations on the areas where they could be used, so the response of those using these techniques was roughly intermediate between spear fishers and hook-and-line or trolling fishers. The social situation was made more complex by the fact that different beaches could differ in the common techniques used there, as illustrated by findings for River Bay and Whitehouse. It was also made more complex in Montego Bay by the fact that Whitehouse fishers, whose beach is outside the Park boundaries in any event, used motorised boats and hence could travel relatively long distances to fish, while River Bay fishers, whose beach is in the middle of the Park, generally did not have motors on their boats, and so were especially concerned by the effort involved in travelling far enough to fish outside Park boundaries. This was not an important factor in the Negril area. So, the different responses to the Park of those who used different beaches could reflect not only the spatial location of the beach with regard to the Park and the general attitudes among fishers who used those beaches, but also the uneven distribution of techniques and equipment among different beaches.

The second main factor identified was the perceived importance of tourist development for the degradation of the fisheries, especially in Montego Bay, which is the prime tourist destination in Jamaica. As this indicates, fishers were not indifferent to the state of the fisheries, and they did recognise that some techniques are harmful. However, they did not see their activities as the main cause of the problem. In both areas, tourism has grown tremendously over the past three decades, and brought with it growing populations, growing pressure on the land and sea, and growing strain on urban services. Older fishers spoke of long-term changes that had adversely affected the marine environment, while both older and younger pointed to specific contemporary aspects of tourism that were damaging.

This second main factor was linked to the third mentioned, namely the perception that the two Marine Parks were oriented more to facilitating tourism than to protecting the fisheries. To a degree, this perception was fuelled by the key role played in the formation of these Parks by expatriate divers and dive operators, closely associated with the tourism sector. To a degree, it was fuelled also by the fact that these Parks have much less formal authority over tourist activities and developments than they do over fishing. To a degree, it was further fuelled by the fact that the Parks' efforts to affect tourist activities were less visible to fishers than were their efforts to affect fishing activities. This perception that the Parks were oriented toward tourism was fuelled additionally by the common perception that the two Parks had done little or nothing to benefit local fishers. Fishers in River Bay wanted help with gear and equipment. In Orange Bay and the Negril River, they wanted assistance in getting to their beach basic amenities such as running water and electricity. This may be seen to reflect a grasping attitude on the part of fishers, but equally it can be seen as a concern that they receive something in return for giving up their rights to fish in Park waters.

Finally, efforts by the Marine Parks to deal with these negative perceptions and to benefit fishers are made more difficult by something else described previously, namely the fragmentation and suspicion common among fishers themselves. At the simplest level, this makes it especially difficult to pass information to fishers, as illustrated above for Negril fishers. More generally, it means that involving fishers in park management in any significant way will be much more difficult than it would be if fishers already had active local groups or organisations, such as co-operatives. In their absence, parks need either to encourage the development of groups or establish individual relationships with a large proportion of local fishers.

There are concrete steps that the Parks can take to encourage support among local fishers, such as helping them secure basic amenities at their beaches and strengthening the weak or moribund co-operatives. However, it is also true that local fishers' responses to the Montego Bay and Negril Marine Parks were couched in terms of the political economy of Jamaica as a whole, characterised as it has been by an increasing reliance on tourism over the past few decades. To generate political support among local fishers, Park management may have to be seen to address the environmental problems that fishers associate with mass tourism.

Research on the social politics of marine reserves

The social research carried out as part of this project was fruitful in an unanticipated way. It became apparent that the social and political (in the broad sense) factors that affect support for marine reserves by local fishing populations extend much more broadly than this project had envisaged. (It is worth noting that intensive study of a small number of sites is a research technique particularly likely to uncover such unanticipated ramifications.) Two general sorts of factors emerged clearly during the course of this research.

The first was the nature of fishers' environmental models and understandings, most visible in this research in the alternative account of degradation of the marine environment offered by local fishers, an account that stressed habitat degradation rather than fishing activ ity. It is apparent from the review of literature prepared as part of Output 2 that awareness of local people's environmental understandings can be important in generating support for marine reserves and in their operation. However, it is also apparent that there has been relatively little attention paid to this in studies of local fishers in the Caribbean. This topic will be pursued under an ESRC research grant of £170,000 to J.G. Carrier dealing with two sites in Jamaica, that is expected to begin in the middle of 2000, R000238377: Environments, Institutions, Environmental Conservation: A Caribbean Study.

The second was the importance of the nature and operation of the marine reserve organisation, both its routine internal management and its general policies and orientations. The Parks in Montego Bay and Negril both are clear reflections of the personality and orientation of the dominant individual in each. This is, perhaps, to be expected, given that these Parks both are still in the formative stage, still being run largely as volunteer organisations even though they have formal legal status as Jamaican national parks, income and employees. These individual personalities and orientations reflect the background and interests and social networks of these dominant individuals, and appear to have a marked effect both on the ways that those people perceive and value the marine environment and on the ways that those people perceive and value local fishing populations. These in turn affect the ways that local people perceive and value these marine reserves. Aspects of this topic are included in a research proposal submitted by Stephen Jameson to the McArthur Foundation entitled 'Triggering NGO's: Growing attachment to place and the likelihood of marine and coastal conservation'.

Guidelines for MPA planners

The workshop on 'Ecological and social impacts in planning Caribbean marine reserves' which took place during 12-13 July 1999, was co-sponsored by the University of the West Indies Centre for Environment & Development and attended by 18 specialists in MPAs from within the region, and nine from outside the Caribbean doing work within it. The first day was devoted firstly to case histories of MPA development and management (with presentations on Buccoo Marine Park, Florida Keys Marine Sanctuary, Discovery Bay no-fishing area, Hol Chan Marine Reserve, Punta Fances National Park, Buck Island, Soufrière Marie Management Area and Montego Bay Marine Park), and then to results of research relevant to MPA development, including those from the present investigation. The second day was spent discussing the key management issues, then the major research issues, in MPA development, and the end-point was a set of guidelines towards improved future planning of MPAs.

The discussion of guidelines on the second day of the workshop was organised to ensure that the participants and audience participated as actively as possible. The justification for this decision was that those people were a significant proportion of those with experience with MPAs in the region as managers and researchers. Consequently, it was important to take into account their perceptions of the degree to which guidelines should be general or specific, advisory or directive. Generally they preferred general and advisory guidelines, arguing that the situation of different MPAs in the region differed too much to allow specific and directive guidelines. Because the audience and participants were effectively a large part of those who would be expected to benefit from this project, it was thought appropriate to accept their arguments. To have done otherwise might have allowed a set of guidelines that reflected better the findings of this project, but at the cost of reduced acceptance in the region.

On the basis of the collective experience of the workshop participants, it was felt that future planning of MPAs would be improved if managers not only considered a number of points in drawing up plans and subsequently managing MPAs, but also were to benefit from future research. The draft guidelines for MPA management included the following. (1) The objectives of MPA organizations need to be explicit and verifiable, and their attainment should be measurable within a specific time-frame. If not attained, MPA management must be prepared to consider shutting down or switching management policy and/or objectives. Assessment should ideally be by external review. (2) In addition to ecological consequences, MPAs need to address the social and economic impacts, both positive and negative, of management strategies. This consideration would be enhanced through interactive involvement of the relevant NGOs, and private and public groups, from the initial planning through to implementation. (3) MPA organizations need to evaluate their ecological and socio-economic base in relation to the goals of the MPA concerned before establishing any management plan. They should be helped in this by establishing linkages at national, sub-regional and regional levels with relevant groups to learn from the experiences of others and gain support from them. The following points for future management-targeted research were identified: (1) The succesesses and failures of Caribbean MPAs, particularly in financial and socio-political terms, need to be critically evaluated, and efforts made to explain them so that valid lessons can be drawn from them. (2) There needs to be greater understanding of how processes potentially predictable at large scale, such as larval dispersal, influence local ecological processes such as biological recruitment. (3) Attention needs to be given to the processes by which stakeholders make decisions about MPA co-management, and the ways these decisions can be creatively influenced. (4) The social, economic and political foundations of MPA management need to be assessed and monitored over time, to assist understanding of the implications of particular management regimes for subsequent changes in socio-economic and political conditions. These guidelines towards improved planning of MPAs in the Caribbean are being finalised with participants via email, and will be disseminated to the wider community in the Caribbean and beyond via the newsletters InterCoast (University of Rhode Island, USA), Out of the Shell (Dalhousie University, Canada) and CEPNEWS (UNEP, Kingston), and via the University of the West Indies Centre for Environment & Development Web site.

REFERENCES

Aiken KA, Haughton MH (1987) Regulating fishing effort: the Jamaican experience. *Proceedings of the Annual Gulf and Caribbean Institute* **40**: 139-150.

Berkes F (1987) The common property resource problem and the fisheries of Barbados and Jamaica. *Environmental Management* **11**: 225-235.

Bohnsack JA, Bannerot SP (1986) A stationary visual census tenchique for quantitatively assessing community structure of coral reef fishes. *NOAA Technical Report* NMFS-41

Bohnsack JA, Harper DE (1988) Length-weight relationships of selected marine fishes from the southeastern United States and the Caribbean. *NOAA Technical Report* NMFS-SEFC 215

Bunce L, Gustavson K (1998) *Coral Reef Valuation: A Rapid Socioeconomic Assessment of Fishing, Watersports, and Hotel Operations in the Montego Bay Marine Park, Jamaica and an Analysis of Reef Management Implications*. Report, Project RPO 681-05. Washington, DC: World Bank.

Carr MR (1997) PRIMER User Manual. Plymouth, UK: Plymouth Marine Laboratory

Carrier JG (1981) Ownership of productive resources on Ponam Island, Manus Province. *Journal de la Société des Océanistes* 37: 205-217.

Chapman MR, Kramer DL (1999) Movements of fishes with and among frining coral reefs in Barbados. *Environmental Biology of Fishes* : 1-14

Cordell J (ed.) (1989) *A Sea of Small Boats: Customary Law and Territoriality in the World of Inshore Fishing*. Cambridge, MA: Cultural Survival.

Clarke KR, Warwick RM (1994) Change in Marine Communities: An approach to statistical analysis and interpretation. Plymouth, UK: Plymouth Marine Laboratory.

Davenport W (1956) A comparative study of two Jamaican fishing communities. PhD dissertation, Yale University.

Dixon J, Fallon Scura L, van't Hof T (1995) Ecology and microeconomics as 'joint products': the Bonaire Marine Park in the Caribbean. pp 127-145 In *Biodiversity Conservation* (ed. CA Perrings). Kluwer: Amsterdam

Douglas JE (1997) Survey of diver preferences for reef attributes in Montego Bay and Negril Jamaica. Final report. Unpublished report, Department of Marine Sciences, University of Newcastle, 17 +42 pp

Hughes TP (1994) Catastrophes, phase shifts, and large-scale degradation of a Caribbean coral reef. *Science* **265**: 1547-1551

Humann P (1989) *Reef Fish Identification*. Orlando FL: Vaughan

Humann P (1990) *Guide to Reef Creatures*. Orlando FL: Vaughan

Johannes RE (1978) Traditional marine conservation methods in Oceania and their demise. *Annual Review of Ecology and Systematics* **9**: 349-364.

Littler DS, Littler MM, Bucher KE, Norris JN (1989) *Marine Plants of the Caribbean*. Washington DC: Smithsonian

McCay B, Acheson J (eds) (1987) *The Question of the Commons: The Culture and Ecology of Communal Resources*. Tucson: University of Arizona Press.
Minitab (1996) Minitab Release II. State College, Pennsylvania: Minitab Inc.
Munro JL, Watson M (1999) Caribbean Marine Protected Areas Project: the role of marine protected areas in fisheries management and biodiversity conservation in coral reef ecosystems. Technical Report – Phase 1 – 1996-1998. Unpublished report, Tortola, BVI: ICLARM
Nicholson, W.E. 1994. *A Project for the Assessment of the Montego Bay Marine Park's Impact on the Local Fishing Industry. Final Report*. An ICOD/CCA/NRCA Fisheries Project. Montego Bay, Jamaica: Montego Bay Marine Park.
Olwig KF (1997) Caribbean family land: a modern commons. *Plantation Society in the Americas* **4**: 135-158.
Polunin NVC, Carrier J, Woodley J (1997) Ecological and social impacts in planning Caribbean marine reserves: summary of a workshop, Richmond Hill Inn, Montego Bay, Jamaica, 14-15 April 1997. Unpublished report, Department of Marine Sciences, University of Newcastle, 12pp
Price R (1966) Caribbean fishing and fishermen: a historical sketch. *American Anthropologist* **68**: 1364-1383.
Robertson LF, Carrier JG (n.d.) Socio-economic aspects of marine protected areas. *Reviews in Fish Biology and Fisheries* (forthcoming).
Shaffer CS, Inglis GL, Johnson VY, Marshall NA (1998) Visitor experiences and perceived conditions on day trips to the Great Barrier Reef. *CRC Reef Research Technical Report* 21
Taylor FF (1993) *To Hell with Paradise: A History of the Jamaican Tourist Industry*. Pittsburgh: University of Pittsburgh Press.
Underwood AJ (1981) Techniques of analysis of variance in experimental marine biology and ecology. *Oceanography Marine Biology Annual Review* **19**: 513-605
Underwood AJ (1998) *Experiments in Ecology*. Cambridge: Cambridge Univversity
White AT, Hale LZ, Renard Y, Cortesi L (eds) (1994) *Collaborative and Community-Based Management of Coral Reefs: Lessons from Experience*. West Hartford, CT: Kumarian Press.
Williams I, Barr I, Polunin N (1997) Related current or planned studies in the Caribbean region. Unpublished report, Department of Marine Sciences, University of Newcastle, 12pp
Williams I, Polunin NVC (1997) Reef condition and recovery in the Caribbean. Unpublished report, Department of Marine Sciences, University of Newcastle, 27pp.

CONTRIBUTION OF OUTPUTS

It has been demonstrated in more-developed parts of the Caribbean that marine protected areas can be valuable economically in terms of tourism, but in less developed areas in the region in particular, there has been demand for better understanding of the social factors constraining development of MPAs and of the ecological linkages between MPAs and land-based tourism. This project has better characterised the nature of the challenge faced by managers seeking to communicate with the fishers who are typically most disadvantaged by MPA developments, and identified ways in which negative impacts on such people might be mitigated. In addition, it has highlighted a strong linkage between diving tourism and reef condition, reinforcing the little-recognised role of MPAs in tourism, and providing a basis for increased economic productivity of the marine areas involved.

The research results were discussed at a July 1999 workshop in Montego Bay and were disseminated by email to: (i) marine reserve managers including those of Soufrière (St Lucia Department of Fisheries), St Thomas (US National Parks Service, USVI), Montego Bay (Jamaica), CORALINA (Colombia), Hol Chan (Belize Department of Fisheries), and

Buccoo (Trinidad & Tobago Department of Fisheries); (ii) researchers working on marine reserves including those at the Centro de Investigaciones Marinas (University of Havana, Cuba), CANARI (St Lucia), the ICLARM Office for the Eastern Pacific and Caribbean (BVI), Centre for Marine Sciences (University of the West Indies, Mona), the Jamaican Department of Fisheries (Kingston), and Bellairs Research Institute/McGill University; and (iii) personnel working with regional agencies including NOAA (International Programs Office), CPAT, UNESCO and UNEP, and the company Coral Seas Inc.