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Impacts of recreational SCUBA diving on coral communities of the Caribbean island of Grand Cayman

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Abstract

The impact of recreational SCUBA diving on coral reefs of the Cayman Islands, British West Indies, was assessed from 63 10-m video transects, filmed on reefs in the West Bay area of Grand Cayman. Three high use and three low use dive sites were sampled at distances of c. 15, 55 and 200 m from mooring buoys, in addition to three sites where no diving occurs. Both diver numbers and distance from buoys were found to show highly significant ($P<0.01$) effects on hard coral cover and cover of the major reef-building coral, *Montastrea annularis*. Diver numbers also increased the amount of dead coral and coral rubble. Relative to overall hard coral cover, the proportion of massive corals was smallest at heavily dived sites, but there was a larger proportion of *Agaricia* spp. corals, dead coral and coral rubble at these sites. Our findings suggest the need for a new management approach if the Islands are to conserve the ecological and aesthetic qualities of their most popular dive sites.

Keywords: Diving; Coral; Damage; Tourism; Video transects

1. Introduction

Hard (scleractinian) corals, which create the substratum and structural complexity of coral reefs, are vulnerable to damage resulting from human recreational activities, as their slow growing carbonate substructure is relatively brittle and their polyps are easily crushed. A number of studies have reported how coastal development (Dahl, 1984; Hawkins and Roberts, 1994), boating (Davis, 1977; Tilmant, 1987; Rogers, 1993), snorkelling (Bryceson, 1981; Rogers et al., 1988; Allison, 1996) and walking on reef flats (Woodland and Hopper, 1977; Kay and Liddle, 1989; Neil, 1990; Hawkins and Roberts, 1993) may harm coral communities, and concern has been raised that SCUBA diving, previously thought to be largely benign (Tilmant, 1987), may also constitute a significant impact. Divers damage coral mostly through direct contact, but may also cause harm by stirring up benthic sediment, thereby subjecting coral polyps to increased sedimentation loads (Neil, 1990; Rogers, 1990).

The possible impacts of SCUBA diving are of especial concern in areas such as the Cayman Islands, where coral reefs are a highly prized part of the natural heritage but where the dive industry is also an important part of the local economy. The islands have had in place, for over a decade, an extensive and well-developed system of Marine Parks (Ebanks and Bush, 1990) and this system has assisted considerably in protecting coral reefs from anchor damage, as well as in protecting important fisheries resources. However, the establishment of a park tends to attract divers (Van't Hoff, 1985), and >350,000 visitors currently dive on Caymanian reefs every year. There is, therefore, the possibility that the benefits to coral communities made through the establishment of the park system will be lost through increasing levels of recreational use.

In recent years some studies have been undertaken to gain quantitative information on damage done by SCUBA diving. Riegl and Velimirov (1991) found that in the northern Red Sea there were higher rates of tissue loss, algal overgrowth and coral breakages in frequently visited areas, although they did not separate SCUBA

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diving from snorkelling as a cause of this damage. Hawkins and Roberts (1992), also working in Egypt, found that in three heavily dived fore-reef slope areas there were significantly more damaged coral colonies, loose fragments of coral, and partially dead or abraded corals than in control areas. Over a 12 month period, they saw a significant increase in damage at the site experiencing the greatest increase in diving. However, they reported that sites may be able to sustain 10,000–15,000 dives per year without serious degradation.

Dixon et al. (1993) found a negative effect of diving on coral cover on the Caribbean Island of Bonaire, and argued that diving was also affecting the biological diversity of coral communities, with highest levels of diversity found at intermediate levels of disturbance. They identified one cause of these relationships as anchoring prior to the establishment of dive mooring buoys, but suggested sustained damage may occur at 4000–6000 dives per year. With data from the same study site, Hawkins et al. (1999) argued that levels of overall coral cover have been unaffected by use of up to 6000 dives per year, but that lower levels may be required to maintain coral community composition.

The discrepancies between these studies suggest that more work needs to be done to establish the effect of diving at different dive locations. With this in mind, a study was undertaken on the West Bay area of Grand Cayman to establish the degree to which present diving practices are sustainable. This was an ideal location for a study of this type, with some of the world's most intensely dived sites occurring alongside low intensity and undived areas, subject to similar geographic and oceanographic conditions, and afforded a high degree of protection from other anthropogenic impacts.

2. Methods

Fieldwork was conducted in the West Bay area of Grand Cayman in July and August 1996. Sites with apparently similar oceanographic and geographic characteristics were selected. All the sites were located along the north–south axis of the mid-reef terrace at the west side of the island, at a depth of c. 11 m and with a maximum distance of 15 km between sites (Fig. 1).

Nine sites in total were studied, based on a census of the island's major dive operators carried out in 1994 (Madigan Pratt and Associates, 1995): the three sites experiencing the highest levels of use by divers (*high intensity sites*), the three experiencing the lowest levels of use (*low intensity sites*), and three sites at random in a no-diving area (*undived sites*). High intensity sites were Paradise Reef (17,827 dives in 1994), Aquarium (8700), and Royal Palms (6001), and the low intensity sites Armchair (794), Smith's Cove (754) and Jax Dax (588). In the case of the undived sites, although some diving may possibly have occurred in these areas, it would have been at minimal levels, due to the sites' distance from shore and the absence of mooring buoys. The absence of mooring buoys would also prevent entry into the water being concentrated in any one area at these sites.

The data were obtained using a Sony TR500 Hi8 video camera in an underwater housing. A stainless steel rod attached to the camera housing was used to ensure a distance of 40 cm between the lens and substratum. A red ambient light filter was placed over the lens to compensate for light attenuation. No additional lights were required.

At each dive site a 200 m transect tape was run out from the dive mooring parallel to shore. Three sets of three 10-m transects were then filmed at *near*, *mid* and *far* distances, giving a total of nine transects per site. For the near distance, transects were filmed along the tops of the first three coral spurs more than 15 m from the mooring pin, and for the mid distance the three spurs closest to 55 m from the pin were chosen. The far distance transects were filmed at the three coral spurs

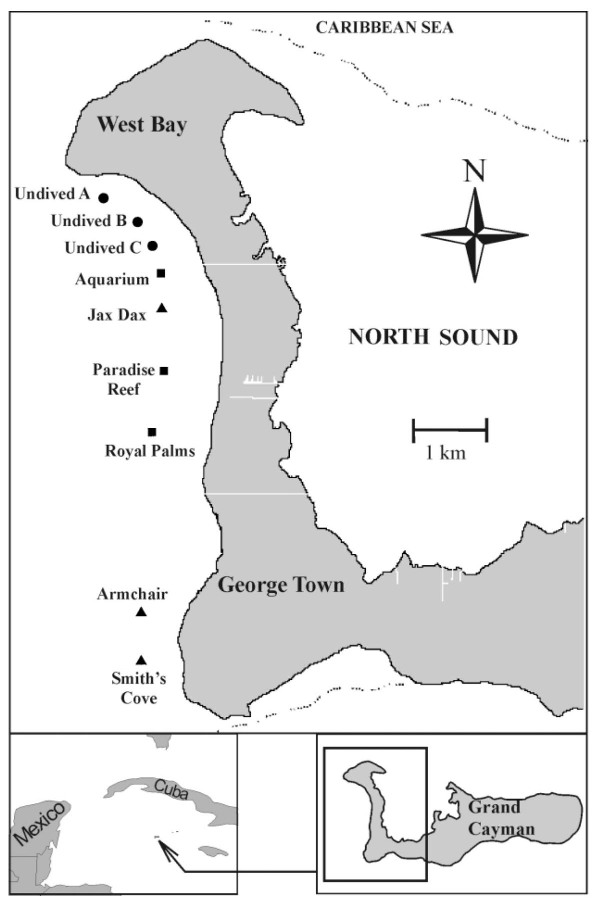

Fig. 1. Maps showing the location of the nine study sites within the West Bay diving area of Grand Cayman, around Grand Cayman, and in the Caribbean sea. ●, Undived sites; ▲, low intensity dive sites; ■, high intensity dive sites.

closest to the 200 m mark, except in the case of the Aquarium site, where the far distance was at c. 115 m, to avoid filming near an adjacent dive site. In each of the three undived sites the three coral spurs closest to the anchor were selected.

To film the individual 10-m transects a tape measure was placed along the highest part of the coral spur closest to the near, mid or far distance points. To avoid observer bias, the 10 m transect tape was positioned so that the 5 m mark crossed the 200 m transect tape at the appropriate distance from the dive mooring. The camera was held vertically 40 cm above the substratum and, using the stainless steel rod as a guide, was moved along the transect at a constant speed (c. 4 cm per s). This was repeated for all nine transects at each site.

The completed video transects were played on a Sony EVO – 9700 video editing deck. After the first frame of each transect, subsequent frames were selected by freezing the frame so that the lowest point on the central vertical axis of the frame corresponded with the highest point on the central vertical axis of the previous frame. Differences in topography meant that the number of frames analysed varied between 20 and 31, giving a total of 1548 frames for the 63 transects.

In order to obtain quantitative data for each frame, an acetate sheet containing 30 randomly placed transparent dots was placed over the screen of the video monitor. For individual frames, the substrate or organism under the centre of each dot was recorded. Algae, sponges, branching and encrusting soft corals were classified as such, *Agaricia* spp. were identified to genus, and all other living organisms were identified to species level. Non-living categories included rock, sand, coral rubble and dead coral. Dead coral consisted of non-living hard coral which was attached to the substrate and where the species (or genus in the case of *Agaricia* spp.) could be clearly recognised. "Coral rubble" consisted of loose objects clearly of hard coral origin. Coral species were identified using Humann (1993).

The effect of diving on community composition was analysed using one and two factor ANOVA, using percentage cover in each frame for the following variables: % hard coral, % soft coral, % dead coral, % coral rubble, % massive coral, % *Agaricia* spp., and % *Montastrea annularis*. The last three cover types were analysed separately from overall hard coral cover, of which they constitute a part, as it was thought that they might act as better indicators of stress. The % massive coral category consisted of *Colpophyllia natans, Diploria clivosa, D. labyrithiformis, D. strigosa, M. annularis, M. cavernosa,* and *Siderastrea siderea*. Species number per frame was also analysed.

Two factor ANOVA was used to analyse the effect of distance from the mooring buoy (near, mid and far) and diving intensity (high and low) on these variables, using data from the three high and three low intensity sites. One factor ANOVA was used to analyse the effect on these variables of diving intensity (high, low and undived), using data from the near distances of the six dive sites, together with the data from the three undived sites. One factor ANOVA was also used to assess the effect of distance at high and low intensity sites analysed separately. For the ANOVA analysis, all percentage data were expressed as proportions and then arcsine square-root transformed, to satisfy normality and equality of variance assumptions of ANOVA (Sokal and Rohlf, 1995). Where the results of the ANOVA analyses indicated significant effects, *t*-tests were used to analyse which intensity or distance groups were significantly different from one another.

Relative to overall hard coral cover, the proportion of massive corals, proportion of *Agaricia* spp., proportion of *M. annularis,* proportion of coral rubble and proportion of dead coral were calculated for each combination of diving intensity and distance (note that these calculations were performed on the sum of each cover type per treatment, and not on a per-frame basis). This was done to isolate the effect of diver damage on these cover types considered separately from overall coral cover, which they might be expected to track.

A key assumption of this study was that diving intensity should decrease with distance from the dive mooring. In the study area, the topography of the mid terrace reefs is such that divers can travel 180° between due North, West and South and remain at a similar depth and over coral. An easterly course from the dive mooring would take a diver out over sand planes to the deep terrace reefs and the west wall. The diving intensity measured as divers per unit area is therefore likely to decrease as divers move away from the immediate vicinity of the dive mooring.

3. Results

One and two factor ANOVA and *t*-tests (Table 1), combined with graphical output (Fig. 2a), showed that high intensity sites had significantly lower % hard coral than low intensity and undived sites, and also revealed a significant effect of distance on coral cover (see also Table 2, which gives mean values for each combination of distance and intensity). However, the effect of distance was significantly different at high intensity and low intensity sites — at high intensity sights the mid and far distances had significantly higher cover than the near distance. With the exception of the mid distance at Royal Palms, graphical output revealed a positive trend between distance and coral cover across all three of the high intensity sites (see Fig. 2a, inset).

Most of the hard coral at these sites consisted of massive corals (68%), and % massive coral generally followed the same pattern as that of % hard coral, although differences with intensity were more pronounced and at high intensity sites differences with distance were less so (Fig. 2b, Table 1). Similar effects of intensity and distance were shown for % cover of the massive coral *M. annularis*, which made up 55% of hard coral cover (Fig. 2c, Table 1). With the exception of distance at high intensity sites, all these effects were highly significant (Table 1).

Agaricia spp., which represented 21% of total hard coral cover, appeared to peak at intermediate levels of disturbance (far distance of high intensity sites and near distance of low intensity sites), with cover generally increasing with distance at high intensity sites and decreasing with distance at low intensity sites (Fig. 2d, Table 1).

There was a highly significant effect of intensity on % dead coral, with 3.66% cover at high intensity sites, 1.80% at low intensity sites and 1.68% at undived sites (Fig. 2e, Table 1). Much of the significance of this result was due to the very high levels of dead coral at Paradise Reef (see Fig. 2e, inset). No clear effect of distance was shown.

For % coral rubble, there was a highly significant effect of diving intensity, with high intensity sites showing higher levels than undived sites, and the near distance of high intensity sites showing higher levels than the near distance of low intensity sites. There was no clear effect of distance. Much of the high statistical significance level for the *two factor intensity* result was due to very high levels at the mid distance of high intensity sites (Fig. 2f, Table 1).

For soft corals, when the six dive sites were compared at three distances, cover was significantly higher in high than in low intensity sites. When the near distances of sites were compared, cover was considerably higher at high intensity and undived sites than at low intensity sites. Although no overall effect of distance was found to be significant, the interaction between distance and intensity gave a high significance level ($P=0.001$), with all three high intensity sites showing a marked trough at mid distances (Fig. 2g, Table 1).

Hard coral species number followed a similar trend to hard coral cover. However, differences were less pronounced, with the effect of distance found to be not significant (Fig. 2h, Table 1).

It was apparent from the insets to Fig. 2a, b and c that for % hard coral, % massive coral and % *Montastrea annularis* there was considerably lower cover at Royal Palms than at the two other high intensity dive sites. *t*-Tests were therefore conducted to analyze the effect of intensity on these three variables, after removing the Royal Palms data from the analysis. These tests revealed that cover of all three variables was still significantly lower at high intensity than at low intensity sites. When undived sites and the near distances of high and low intensity sites were compared, % hard coral and % massive coral were still significantly lower at high intensity sites than at undived sites or low intensity sites. Cover of *M. annularis* was still significantly lower at the near distance of high intensity than at undived sites. It was also lower, although not significantly lower,

Table 1
Analysis of the effects of diver numbers (*intensity*) and distance from buoys on seven hard coral community variables and on % cover of soft corals[a]

Variable	1 Factor intensity	2 Factor intensity	2 Factor distance	2 Factor intensity×distance	Distance at low intensity	Distance at high intensity
% Hard coral	*** H < L, H < U	*** H < L	** N < M, N < F	**	NS	*** N < F, M < F
% Massive coral	*** H < L, H < U	*** H < L	NS	NS	* N < M	NS
% *M. annularis*	*** H < L, H < U, L < U	*** H < L	** N < F	NS	** N < F	NS
% *Agaricia* spp.	NS	NS	NS	***	* N > M, N > F	** N < F
% Dead coral	*** H > L, H > U	*** H > L	NS	NS	NS	NS
% Coral rubble	* H > U	*** H > L	NS	***	* N > M, M < F	*** N > F, M > F
% Soft coral	*** H > L, L < U	* H > L	NS	***	NS	*** N > M, M < F
Species number	*** H < L, H < U	*** H < L	NS	NS	NS	NS

[a] *t*-tests: intensity: H = high , L = low, U = undived; distance: N = near, M = mid, F = far. In One Factor ANOVAs the near distances of high intensity, low intensity and undived sites were compared; in Two Factor ANOVAs high and low intensity sites were compared at near, mid, and far distances. Where ANOVA results were statistically significant ($P<0.05$), two sample *t*-tests were conducted to show which categories of intensity or distance showed significant differences ($P<0.05$), and are indicted below the ANOVA result.

*$P>0.05$. **$P>0.01$. ***$P>0.001$. ANOVA: NS, not significant.

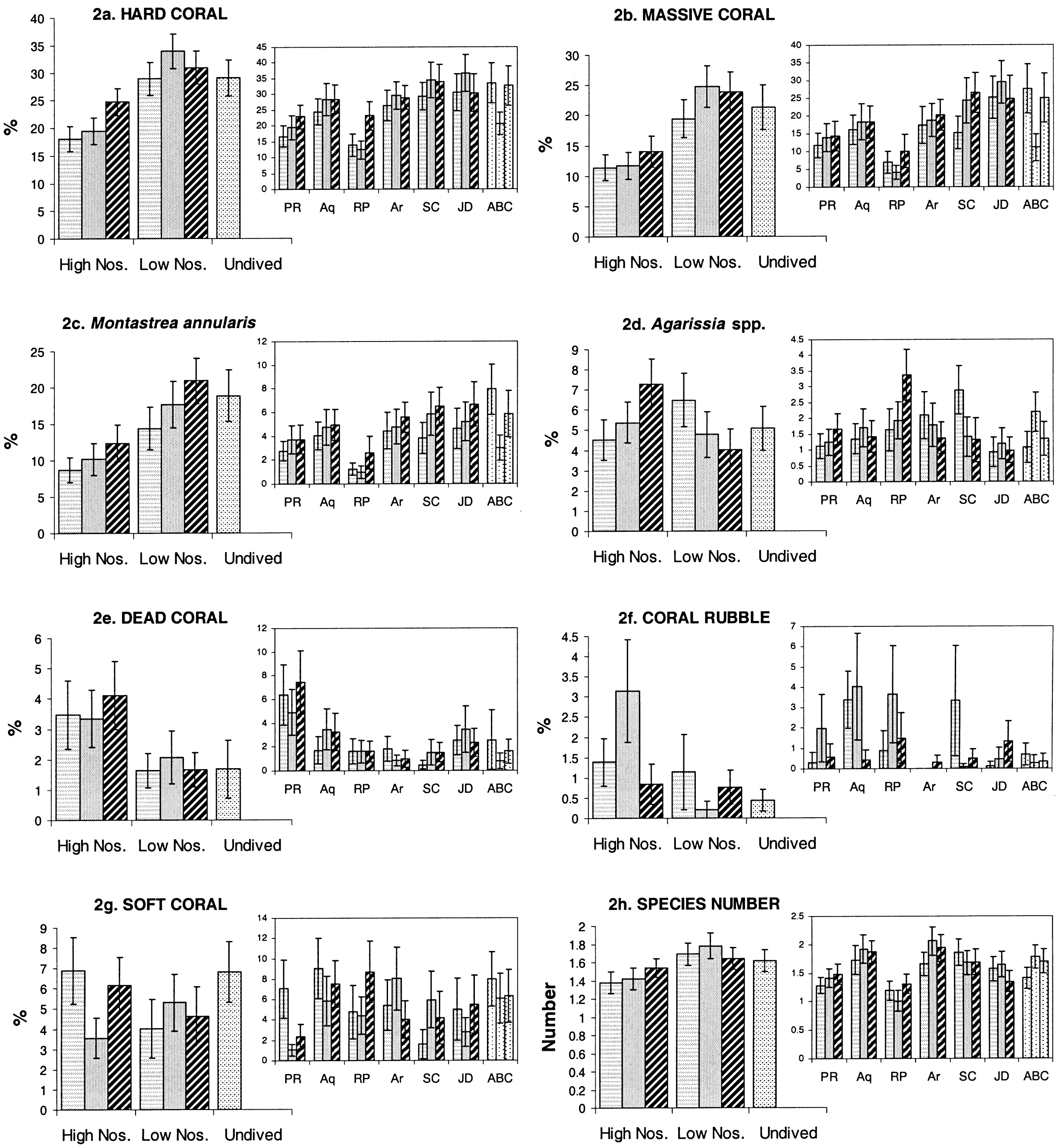

Fig. 2. (a–h). Effects of SCUBA diving on eight coral reef variables (mean ± 2 SE) comparing near, mid and far distances from mooring buoys for high and low intensity dive sites, and three undived sites. Insets show the same variables for the nine individual sites. Diver numbers in 1994: Paradise Reef (PR) 17,827; Aquarium (AQ) 8,700, Royal Palms (RP) 6,001; Armchair (Ar) 794; Smith's Cove (SC) 754; Jax Dax (JD) 588; Undived sites (A,B,C) zero or negligible. ▤, near distance; ▥, mid distance; ▨, far distance.

at the near distance of high intensity sites than at the near distance of low intensity sites (high intensity = 3.31 ± 0.34; low intensity = 4.32 ± 0.44).

A higher proportion of hard coral cover was of massive type at low intensity and undived sites than at high intensity sites. However, there was little difference at the near distance of high and low intensity dive sites and no clear trend in proportion of massive corals with varying distances (mean values for near, mid and far distances, respectively, at high intensity: 0.63, 0.60, 0.57; low intensity: 0.67, 0.73, 0.77; undived: 0.74). Differences between high intensity sites and low intensity and undived sites were less pronounced when the Royal Palms site was excluded from the analysis (Fig. 3).

The proportion of hard coral consisting of *M. annularis* was similar at near, mid and far distances of high intensity sites and the near and mid distance of low intensity sites. However, it showed an increase at the far distance of low intensity sites and at undived sites (mean values for near, mid and far distances respectively at

Table 2
Mean values of % cover for seven hard coral community variables and for soft corals, at near, mid and far distances from mooring buoys, at sites with high and low diver numbers and at undived sites

Variable	High diver numbers			Low diver numbers			Undived sites
	Near	Mid	Far	Near	Mid	Far	
% Hard coral	18.04	19.48	24.69	28.9	33.93	30.97	29.04
% Massive coral	11.42	11.69	14.07	19.44	24.71	23.88	21.34
% *M. annularis*	8.77	10.16	12.39	14.41	17.69	20.91	18.85
% *Agaricia* spp.	4.53	5.38	7.29	6.48	4.77	4.03	5.08
% Dead coral	3.48	3.35	4.12	1.64	2.07	1.67	1.68
% Coral rubble	1.39	3.15	0.85	1.14	0.21	0.76	0.44
% Soft corals	6.89	3.57	6.16	4.02	5.32	4.64	6.82
Species number	1.38	1.42	1.54	1.69	1.78	1.64	1.62

high intensity: 0.49, 0.52, 0.50; low intensity: 0.50, 0.52, 0.68; undived: 0.65). When the Royal Palms site was excluded, values were higher for the near and mid distances of high intensity sites than at low intensity sites (high intensity sites: near = 0.55, mid = 0.60, far = 0.56).

A larger proportion of hard coral cover consisted of *Agaricia* spp. corals at high intensity sites than at low intensity and undived sites (mean values for near, mid and far distances respectively at high intensity: 0.25, 0.28, 0.30; low intensity: 0.22, 0.14, 0.13; undived: 0.17). Differences were less pronounced when the Royal Palms site was excluded, with all three distances at high intensity sites showing slightly lower cover than the near distance of low intensity sites (Fig. 3).

Relative to living hard coral cover, there was a larger proportion of dead coral at high intensity sites than at low intensity sites, but the differences were small between the three distances at each intensity level (mean values for near, mid and far distances, respectively, at high intensity: 0.19, 0.17, 0.17; low intensity: 0.06, 0.06, 0.05; undived: 0.06; Fig. 3). Equivalent figures for the proportion of coral rubble were high intensity: 0.08, 0.16, 0.03; low intensity: 0.04, 0.01, 0.02; undived: 0.02 (Fig. 3).

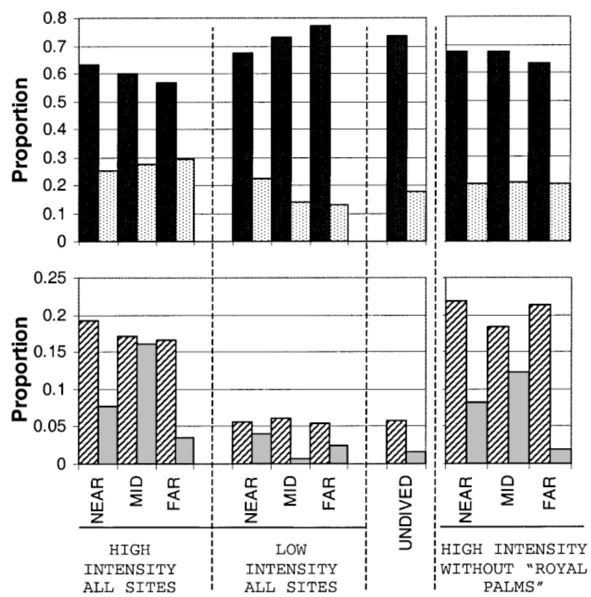

Fig. 3. Comparison of high intensity, low intensity and undived sites at near, mid and far distances from mooring buoys. Above: proportions of massive corals and *Agaricia* spp. within live hard corals. Below: proportions of dead hard coral and coral rubble relative to live hard coral. ▒, *Agaricia* spp.; ■, massive corals; ▒, coral rubble; ▨, dead coral.

4. Discussion

4.1. Is diving having an impact?

These results suggest that diving is having a significant impact in areas subject to high levels of use. Hard coral and massive coral cover were considerably lower where diver numbers were high, and cover at these sites became increasingly greater as one moved away from the dive mooring buoy. There was also more dead coral and coral rubble at high intensity sites. For all three of the high intensity sites, areas furthest from the buoy had higher hard coral cover than near or mid distances (in the case of Aquarium the difference between the mid and far distance was very small (28.43 versus 28.48), but the far distance of this site was sampled much closer to the mid distance than at the other sites).

Massive corals were analyzed separately as it is thought that they may be particularly vulnerable to diver damage (Hawkins et al., 1999). Results supported this to some degree, in that the difference in % cover between high intensity sites and the other study areas was more pronounced than for overall coral cover, as a higher proportion of hard corals were of massive form in low intensity and undived sites. Within massive corals, *M. annularis* may be a particularly sensitive indicator of diver damage, with high intensity sites having low levels of cover, and a positive trend between distance and cover manifested at both high and low intensity. The health of massive corals, and of *M. annularis* colonies in particular, is important, as they are the main reef building corals at these sites, with reefs developing towards a *Montastrea*-dominated climax community, interrupted by occasional hurricanes.

The hard coral genus *Agaricia* spp. was analyzed separately as it was thought that a preponderance of these corals might be indicative of stress from diving. They are thought to be rapid colonizers but are not as vulnerable to breakages as branching forms, and therefore might be expected to benefit from the opportunities for colonization offered by damage to established corals. The results lend some support to this hypothesis, in that there was a peak in *Agaricia* cover at intermediate levels of disturbance and a higher proportion of *Agaricia* relative to other hard corals at high intensity sites.

Diving may also be affecting species diversity, as numbers of hard coral species in this study generally track hard coral cover. However, poorer survivorship in areas subject to high disturbance will to some degree be offset by the colonization opportunities made available by diver damage, which may explain why the effect of diving on species numbers appears weaker than it does for hard coral cover. One might also expect divers to seek out areas of high species diversity, with the result that these areas may still compare well with less frequently dived sites even after any impact from diving. This comment applies also to the effect of diving on coral cover, as areas of high coral cover are likely to represent attractive areas for divers.

For soft corals, the lack of any clear relationship with either distance or intensity is consistent with the widely held but seldom tested view that these fast growing corals are able to withstand disturbance better than hard corals. On the other hand, it is odd that cover was significantly higher at both high intensity and undived sites than at low intensity sites. However, it should be noted that the % soft coral variable consisted of a wide variety of species and growth structures. The rather confusing results for this variable may therefore be due to some species thriving under very undisturbed conditions and other species thriving when disturbance levels are high.

4.2. Possible effects of anchor damage and fish feeding

A possible objection to the conclusion that diving is having a significant impact is that we may in fact be seeing the after-effects of anchor damage prior to the installation of mooring buoys, rather than present diving activities. Anchoring is known to cause considerable and long lasting damage to coral communities in some locations (Rodgers, 1993; Glynn, 1994). Dixon et al. (1993) blamed anchoring, prior to installation of mooring buoys in the early 1980s, for lower coral cover at dived than at undived sites in Bonaire. However, environmental authorities have made a considerable effort to protect Caymian reefs from anchor damage; anchoring on coral spurs has been illegal since 1976, and since 1986 it has been illegal for any boat over 60 feet (c. 19 m) to anchor where this study was conducted, with practically every boat using the mooring buoys (owners of small boats can readily anchor in the sandy grooves of the island's spur and groove reef system without damage to coral, but in any case prefer to use the buoys). Furthermore, our methodology to some degree obviates picking up such historic damage, by studying the ridge tops of coral spurs, which are the areas least likely to have been impacted by anchoring. Finally, the much higher levels of dead coral at high intensity than at low intensity sites tends to suggest continuing damage, as identifiable dead coral is to some degree a measure of the turnover rather than accumulation of dead coral over time; after dead coral has been exposed for a time it either erodes, and hence would be classified as rock, or is overgrown by other organisms. It is especially noteworthy that Paradise Reef, with over twice as many divers as any of the other sites, has over twice as much dead coral, but not a large amount of coral rubble, which would be more likely to be indicative of anchor damage.

It may also be argued that fish feeding by divers could have had a larger impact on coral communities than direct contact (touching) or indirect contact (stirring up sediment). Fish feeding may attract predatory fish such as sharks into an area, which in turn damage the reef when seeking prey. However, sharks have never been reported in the West Bay area and fish feeding, although it does occur (Burgess et al., 1994), is discouraged. A study of fish assemblages conducted in 1999 (Pattengill-Semmens and Semmens, pers. comm.) indicated that windward or leeward location of a site was the primary influence on fish community composition on Grand Cayman's reefs. However, the authors argued that divers may have had an influence on fish communities, as abundance scores were lower for Grand Cayman than for the Little Cayman, which has been less frequently visited by divers.

4.3. Conservation and management

As dive-based tourism is an important revenue earner for the Cayman Islands Government, the appeal of the islands' dive sites is an important resource. A number of studies report how dive quality (Dixon and Sherman, 1991; Pendleton, 1994) and the "wilderness experience" (Hundloe, 1979; Mckinnon et al., 1989; Kenchington, 1993) are important factors for divers when choosing a site, but it is unclear how important are factors such as coral cover and species diversity. Hawkins and Roberts (1994) express the opinion that "many divers seek destinations with warm clear waters regardless of what there is to see", and Tabata (1989) commented that if there are other attractions such as wrecks and tame fish, neither pristine conditions nor biological diversity are required to make a site popular with divers. However, in one questionnaire 75% of divers said that aesthetics was the single most important factor in their choice of resort (Medio et al., 1997). Furthermore, as noted by Hawkins and Roberts (1992), even when the biological features of reef communities may not differ much between areas subject to low and high levels of use, the aesthetic differences can be striking, and the authors' subjective experience during this study bore this out. In heavily dived areas, even where overall coral cover was good, the reefs generally looked more 'knocked about', there was a notable absence of flourishing formations of delicate branching corals and barrel sponges in heavily dived areas, and more patches of dead coral. In this study, the low levels of coral cover and of species numbers at the near and mid distances of high intensity sites are particularly significant, as these are the areas which divers will most often see when visiting the Cayman Islands.

Our results therefore suggest that there is a need for more management of diving activities if the most popular sites are to maintain their aesthetic appeal and biological characteristics. Such management might be directed either towards changing the behaviour of divers, such as better environmental education (Medio et al., 1997), banning access for users thought to cause most damage (e.g. novices and photographers), introducing charges/transferable permits to reduce diver numbers at intensely dived or sensitive sites (Davis and Tisdell 1996), or resting some sites from all diving activity.

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