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EFFECT OF BRIEFINGS ON RATES OF DAMAGE TO CORALS BY SCUBA DIVERS

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Abstract

Observations were carried out in the Ras Mohammed National Park (Sharm el Sheikh, Sinai, Egypt) both to determine the rates of damage to corals by SCUBA divers and to assess the effectiveness of environmental education in reducing these. A single environmental awareness briefing reduced the rate of divers' contact with reef substrates from 1·4 to 0·4 contacts per diver per 7 min observation period. At the same time, the proportion of contacts that were voluntary, and so mainly directed at non-living substrate, increased to 63·8%. As a result, the rates of contact with living corals (as opposed to non-living substrates) decreased from 0·9 to 0·15 instances per diver per 7 min. This rate of contact prior to briefings is estimated to correspond to c. *500 potentionally damaging contacts per day at the most heavily used dive sites, equivalent to* c. *15 incidents* m^{-2} $year^{-1}$. *Copyright © 1996 Elsevier Science Limited*

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INTRODUCTION

Incidental damage to corals by visitors is becoming increasingly significant as an environmental impact affecting coral reefs. Several studies have described how reef walking (Woodland & Hooper, 1977; Liddle & Kay, 1987; Kay & Liddle, 1989; Neil, 1990; Hawkins & Roberts, 1993) and snorkelling and SCUBA diving (Bryceson, 1981; Tilmant, 1987; Tilmant & Schmahl, 1982; Rogers *et al.*, 1988; Hawkins & Roberts, 1992) break or abrade corals. Furthermore, increased levels of suspended sediment, which may occur as a result of coastal tourism development and of tourist activities such as boating and swimming, can lead to mortality of both hard and soft corals (Neil, 1990; Rogers, 1990; Riegl & Velimirov, 1991; Stafford-Smith & Ormond, 1992). As a result, there has been growing concern that in popular diving areas the establishment of marine parks may not of itself prevent the degradation of the coral reef communities (Ward, 1990).The Ras Mohammed National Park in the Egyptian Red Sea was established to protect one of the world's best known SCUBA diving areas (Holliday & Wood, 1989) and has subsequently been extended to cover the whole Egyptian coast of the Gulf of Aqaba, from the peninsula at Ras Mohammad itself, to the border with Israel. The fringing and patch reefs around Ras Mohammad are amongst the best developed in the region, and support many of the fish and invertebrate species that are endemic to the Red Sea (see Edwards & Head, 1987). The National Park now receives over half-a-million visitors per year, while individual dive-boat moorings are estimated to experience up to 20,000 dives per year. Damage due to divers is now the main cause of coral mortality at the most heavily used sites (Medio, in prep.), and quantitative studies have demonstrated differences in live coral cover between heavily used and unused areas. Riegl and Velimirov (1991) found that on reefs with a high frequency of visitors, major tissue loss, algal overgrowth and coral breakage were significantly higher than on reefs with a low frequency of visitors. Similarly, Hawkins and Roberts (1992) found that on fore-reef slopes there were significantly more damaged coral colonies, loose coral fragments, and partially dead or abraded corals in areas heavily used by divers than in control areas. Comparable similar studies in Australia (Davis *et al.*, 1995) and the Caribbean (Dixon *et al.*, 1993, 1994) have confirmed diver impact as a major management issue within protected areas.

Salm (1986*a*,*b*) introduced the concept of a reef's carrying capacity, i.e. the number of users which a reef can tolerate without becoming significantly degraded. Hawkins and Roberts (1992) found from repeat surveys of broken and abraded corals that at two out of their three sites the amount of damaged coral did not increase significantly over a 12 month period, suggesting a currently sustainable level of use by divers. However, in order to model what levels of use may be sustainable at what levels of coral cover, information is required on the actual rates of damage to corals, and to date few data are available to assess either these rates or the precise manner in which diver damage is caused. The present study was undertaken, in the same area as that

by Hawkins and Roberts, in order to provide, from direct observation, data on the rates of damage by SCUBA divers to corals and other reef organisms. It was also intended to test the possibility of reducing these rates of damage by exposing divers to environmental awareness information and briefings.

METHODS

The study was undertaken in the Red Sea at sites within the boundaries of the Ras Mohammed National Park, Southern Sinai, Egypt (Fig. 1). The first dive for each group took place at a relatively sheltered and current-free shallow (12–18 m) site near Ras Umm Sid. The remaining dives took place at sites characterized by different degrees of wave and current conditions, at some of which it was easier, and at others more difficult, for inexperienced divers to avoid contacting corals.

Observations were made over 8 weeks on groups of divers from a dive centre in a hotel catering mainly for Italian tourists. Each had purchased a 5 day, 10-dive package from the diving centre. Most were of beginner or intermediate level, but a few were 'divemasters' or 'instructors'. Each week, six divers (three pairs of 'buddies') were chosen at random from a boat party of 10–15 divers. Each pair of divers was then observed for 7 min per dive, and the number of contacts made with the substrate recorded. Contacts were classified as voluntary or involuntary, and as affecting hard or soft coral or other reef organisms. Where contact was with a living hard or soft coral, it was noted whether the coral was obviously broken, crushed or abraded by the contact. Where the contact was with a sandy substrate, it was noted whether sediment was kicked up, potentially causing increased sedimentation loads on nearby corals.

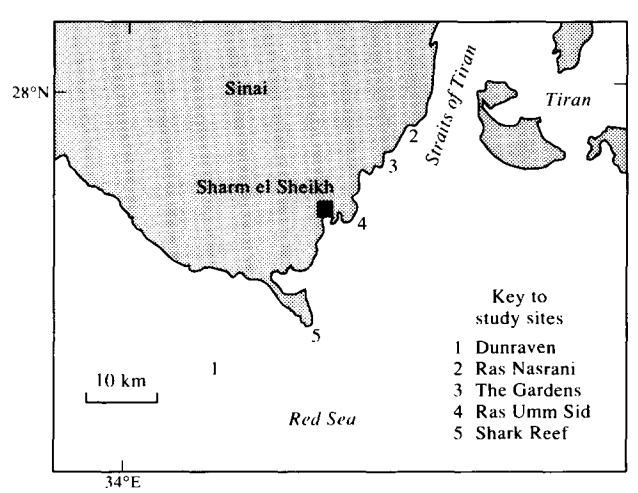

Fig. 1. Map of the Ras Mohammed area (South Sinai, Egypt) showing the major diving sites at which observations on diver behaviour were made.

Divers were followed at a distance typically of 3–8 m. The divers were not aware of the nature of the experiment, as the scientist in the party appeared to be a tourist simply recording information on a slate for personal interest.

During five of the 8 weeks, the effect of an environmental briefing on diver behaviour was tested. This briefing, given at the end of dive 3, covered various aspects of coral biology, impacts caused by divers and the concept of a protected area, supported by photographs, sketches and diagrams. Subsequently, underwater, all divers were shown the different forms of live reef cover such as hard and soft coral, sponges, clams, etc., identified by reference to an illustrated underwater slate. Non-living substrata (bare rock, coral fossil and recently dead coral) also were shown to demonstrate that a significant portion of any reef can be touched in a selective fashion without causing apparent damage. In order to test the effectiveness of these ecological briefings, the number of contacts recorded in the experimental weeks for each diver during each dive were analysed in two sets, to provide the mean rate of contact for each diver both before and after the briefing. The numbers of contacts in the control weeks were similarly analysed in two separate sets and a paired sample t-test used to compare the two sets of means for each week. An independent t-test was used for all other comparisons.

RESULTS

The mean number of contacts per diver per 7 min was 1·0–2·2 both in control weeks and in the experimental weeks prior to the briefing, but fell to 0·24–1·0 contacts after briefing. The difference between the mean number of contacts for the first three dives and the subsequent seven dives was significant in four out of five experimental weeks ($p = 0{\cdot}07$–$0{\cdot}0005$) but not significant in any of the control weeks ($p = 0{\cdot}11$–$0{\cdot}22$) (Table 1). In addition, the mean number of contacts after the briefing

Table 1. Rates[a] of contact to reef during experimental and control weeks

	Dive 1–3	Dive 4–10	t^b	p
Experimental weeks (briefing after dive 3)				
1	1·1	0·24	3·84	0·001
2	1·1	0·35	3·31	0·003
3	1·0	0·23	1·9	0·07
4	1·5	0·25	4·06	0·000
5	2·2	1·00	2·83	0·009
Control weeks (no briefing)				
1	1·9	1·5	1·48	0·16
2	2·2	1·3	1·66	0·11
3	1·8	1·0	1·29	0·22

[a]Showing mean number of contacts per diver per 7 min.
[b]Independent t-test.

was significantly lower than that for the seven dives in control weeks (independent sample t-test, $t=-4{\cdot}11$, $p=0{\cdot}009$). Further, the mean rate of contact during control weeks was not significantly different ($t=0{\cdot}13$, $p=0{\cdot}9$) from that prior to the briefings in experimental weeks, whereas the difference with the mean rate of contact following the briefing was highly significant ($t=5{\cdot}84$, $p<0{\cdot}001$) (Table 2).

Some of the divers' contacts with the reef damaged corals, both hard and soft, through breakage, abrasion or crushing. However contacts with live corals causing damage could not always be distinguished from those which did not. Hence, in further analysis all contacts with live corals were considered. Prior to briefings the 1·4 contacts per diver per 7 min observation period included 0·9 contacts with live corals per 7 min. After the briefings, the 0·4 contacts per diver per 7 min observation period included only 0·15 contacts with live coral per diver per 7 min. The greater than proportional reduction in rate of contact with live corals may be explained by changes in diver behaviour. Some contacts made by divers with the reef appeared to be voluntary, others were involuntary. Intentional impacts were mostly (62%) by divers' hands, while involuntary contacts were mostly (71%) caused by the divers' fins. Following the briefing there were significant changes both in the relative proportions of contacts that appeared voluntary as opposed to involuntary (49·6% voluntary before briefings, 63·8% afterwards), and in the proportion of the apparently voluntary contacts that were with living coral (59·45% before briefings, 10·15% afterwards). Voluntary hand contacts on live coral virtually disappeared after divers had been told of the damage that this caused. By contrast, the proportion of unintentional contacts that were with live coral was virtually unaltered (68·9 compared to 69·3%). Thus, after the briefings, only up to 31·6% (as compared to 64·3% previously) of all contacts were to living coral. That the briefings led divers selectively to avoid coral is further indicated by the observation that only 2·2% of voluntary contacts were on non-living substrates such as rock prior to the lecture, but 40·2% following the briefing.

Salm (1985, 1986*a*) and Dixon *et al.* (1994) have pointed out that underwater photographers can be amongst the worst offenders in reef diving. The present data support this view. Divers using cameras and/or videos accounted for 26·6% of the sample and yet were responsible for 72·4% of all contacts. The difference between the two sets of data was highly significant (Mann–Whitney, $p=0{\cdot}0015$).

DISCUSSION

To date, there have been few published estimates of the rates at which tourist SCUBA divers damage or break corals. A recent syudy by Talge (1992) in Florida observed similar rates of contact by individual divers but concluded that no permanent physical damage could be attributed to this impact. However, the present study not only provides an estimate of the rate at which tourist SCUBA divers may damage living corals at the principal diving sites within the Ras Mohammed National Park, but illustrates how educational tools such as the environmental briefings described in this experiment may be used to reduce this rate of damage.

The mean rate of potentially damaging contacts to living corals in the absence of any environmental awareness briefing was estimated at 0·9 incidents per diver per 7 min observation period. Based on this estimate, an indication may be derived of the overall rate of damage to corals at each diving site. Assuming a typical dive lasts for 45 min, that a typical dive boat carries 12 divers (occasionally 15 or more), that each diver has two dives per day, and that an average of two boats is anchored at each mooring (maximum of three allowed but up to six observed), then the typical number of potentially damaging incidents per day per mooring would be *c.* 280. At the most popular dive sites there are typically two or more moorings from which divers cover the same or a substantially overlapping section of reef. This suggests a rate of contact to living corals at a typical dive site within the Park of the order of 500 incidents per day. This figure excludes damage due to snorkellers and land-based divers, who typically cause as much, if not more, damage to corals on the reef flat, through walking over it to gain access to the water, as they do during their dive (Kay & Liddle, 1989; Hawkins & Roberts, 1993).

Furthermore, if the area of reef swum over by divers at each site typically amounts to a 20×50 m section of reef, then the estimated rate of damage would correspond (at 500 incidents per day over an area of

Table 2. Comparison of rates of contact in experimental and control weeks

	Mean number of contacts per diver per 7 min	t^a	p
(1) Control weeks	1·48		
(2) Experimental weeks (before briefing)	1·38	0·13	0·9
(3) Experimental weeks (after briefing)	0·41	5·84	<0·001
(4) Experimental weeks (overall)	0·7	3·95	<0·001

[a]Independent t-test.

10 000 m^2) to 0·05 incidents m^{-2} day^{-1} (i.e. *c.* 15 incidents m^{-2} $year^{-1}$ over a 300 days $year^{-1}$ season). This estimate would only be for the more heavily dived sites, but is the rate at which at least some damage appears probable to living corals. Unfortunately, it was not possible, within the confines of the experimental situation, to quantify the actual extent of damage. It was observed that only rarely might a whole colony be killed, as when a small arborescent colony was knocked over onto a sediment substrate. More frequently, only a portion of a colony was broken or a part of the surface abraded. Even if only 10% of contacts with live coral resulted in permanent injury, the rate would nevertheless be sufficient to account for observations that, at heavily dived sites in the Sharm el Sheikh area, about 10% of hard coral colonies show signs of physical damage (Hawkins & Roberts, 1992).

Given this conclusion, it is encouraging to confirm that diver behaviour may be influenced by the use of educational tools, and SCUBA divers' physical impact on corals considerably reduced. It is worth emphasizing that, following the environmental briefing, there was a change both in the proportions of voluntary and involuntary contacts and in the type of substrate contacted by the divers during voluntary contacts. These observations, as well as the divers' responses to subsequent questioning, support the interpretation that the environmental briefing did stimulate divers consciously to try to avoid unnecessary contacts with living reef elements. In response to these findings, the Ras Mohammed National Park has initiated a training programme for dive-guides and instructors intended to improve the frequency and effectiveness with which environmental briefings are given to all diving groups. The importance of public awareness and of the active participation of those in the tourist industry have been pointed out by Kenchington (1985, 1990, 1992), Salm (1986*b*) and Tilmant (1987). However, results from a questionnaire sent to *c.* 100 marine parks and reserves world-wide show that < 25% of the parks and reserves have implemented diver environmental awareness programmes (Medio, in prep.). More could be achieved if environmentally aware diver-education programmes were initiated by diving federations and associations such as PADI and CMAS, and by tour operators, as well as by individual dive schools and instructors (Kenchington, 1985; Salm, 1986*a*,*b*; Hudson, 1988).

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