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"Take only photographs and leave only footprints"?: An experimental study of the impacts of underwater photographers on coral reef dive sites

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Abstract

Impacts caused by recreational scuba diving on coral reefs vary widely among different dive locations and individual divers. Linear modelling was used to explore a range of individual and situational risk factors associated with divers who damaged corals in the Great Barrier Reef Marine Park. Recreational divers were followed for 10–15 min, and all contacts with, and damage to corals were recorded. Information on the dive site, diving experience, gender, and use of an underwater camera were recorded. Thirty-two out of 214 divers (15%) damaged or broke corals, mostly by fin kicks (95%). Impacts were most likely to be caused by male divers, in the first 10 min of the dive, at sites with a large abundance of branching corals. Specialist underwater photographers caused more damage on average (1.6 breaks per 10 min) than divers without cameras (0.3 breaks per 10 min). To explore the effects of gender and use of a camera further, we issued single-use underwater cameras to 31 randomly chosen divers and compared their behaviour to a control group. Use of a camera had no influence on the rate or amount of damage caused by these naïve photographers, but male divers were more likely to break corals and caused significantly more damage, on average, (1.4 breaks per 15 min) than female divers (0.3 breaks per 15 min). Variability in the amount of damage caused by divers in our sample reflected the very different underwater behaviours exhibited by specialist and non-specialist photographers, and male and female divers. Greater understanding of the causes of harmful behaviours by these groups will allow better targeting of on-site interpretative and cautionary information and may prove to be a more palatable management strategy than regulation of site use.

Keywords: Coral reef; Environmental behaviour; Gender differences; Recreational impacts; Scuba diving

1. Introduction

Dive tourism is a major commercial use of marine protected areas throughout the world. Large increases in this market have been accompanied by concerns about deterioration of marine parks caused by diving and snorkelling (Ward, 1990; Hawkins and Roberts, 1992, 1997; Davis et al., 1995, Davis and Tisdell, 1995; Garrabou et al., 1998; Hawkins et al., 1999; Inglis et al., 1999; Plathong et al., 2000). Divers damage corals and other marine organisms through direct physical contact with their hands, body, equipment and fins (Talge, 1990, 1992; Rouphael and Inglis, 1995). Although the damage done by individuals is often quite minor, there is some evidence that the cumulative effects of these disturbances can cause significant localised destruction of sensitive marine organisms (Garrabou et al. 1998; Hawkins et al. 1999; Plathong et al., 2000).

Research into the management of diver impacts has focused largely on estimating the number of divers that can be accommodated at particular sites before serious damage is done (i.e. the "carrying capacity"; Salm, 1986; Dixon et al., 1993; Hawkins and Roberts, 1994, 1997; Davis and Tisdell, 1995; Garrabou et al., 1998). An implicit assumption of this approach is that the

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effects of individuals are relatively similar or can be averaged over large, homogenous groupings. Recent studies have shown that the problem is considerably more complex than this suggests. Individual divers may vary greatly in behaviour and in the amount of damage that they cause. In a study of 206 divers in the Florida Keys, for example, Talge (1990) reported that around 90% had one or more physical interactions with reef benthos, but less than 2% actually damaged corals. Other studies have reported similar variability in the impacts caused by individuals (Roberts and Harriott, 1995; Rouphael and Inglis, 1995; Harriott et al., 1997; Medio et al., 1997). Given such a small percentage of problem divers, numerical limits on the use of dive sites may unnecessarily deny many the opportunity to experience especially attractive or unique sites. Conservation of these sensitive environments may, therefore, be better facilitated if dive-guides and tourism operators are able to identify potential problem situations and provide divers with cautionary briefings before they enter the water (Medio et al., 1997).

Variation in technical competence, the activities pursued underwater, the extent of pre-dive instruction, physical conditions present during the dive (e.g. wave and current motion), and biological characteristics of the dive site may all affect the frequency with which divers make contact with, and break fragile marine organisms (Harriott et al., 1997; Rouphael and Inglis, 1997). Anecdotal accounts suggest that underwater photographers are particularly problematic. They spend more time closer to living surfaces than non-photographers and may deliberately or unintentionally come into direct contact with marine organisms when attempting to photograph their chosen subject. In the hands of less skilled divers, cameras and other equipment greatly exacerbate problems of buoyancy control, which are the cause of most damaging behaviours. Advances in technology and increased market demand have meant that cheap underwater cameras are now more widely available to divers of a range of levels of experience and competencies. There is, therefore, a real risk that they may contribute to impacts at popular dive locations.

Here, we evaluate the risks posed by underwater photographers and other types of SCUBA divers to sensitive coral reef sites. Our study consisted of two components. In the first, we explored a range of simple descriptors of the divers studied by Rouphael and Inglis (1995) to identify individual and situational risk factors — including use of an underwater camera — that are associated with individuals who damage corals. Second, to determine if use of an underwater camera made divers more likely to cause impacts than non-photographers, we ran a simple experiment in which we issued cameras to a random set of dive tourists and compared their behaviour to a control group.

2. Materials and methods

2.1. Identifying simple risk factors

The first part of our study involved independent observations on 214 divers, selected at random from dive parties visiting the Agincourt Reef complex (116 30′ S, 145 25′ E) in the Great Barrier Reef Marine Park, Australia, between February and July 1994. Six to nine divers were observed per day on separate dives. Randomisation was achieved by assigning a number to the names of each diver on the daily register of the charter operator accessing the sites and using a random number chart to make the selection.

Each subject was observed underwater for 10 min. The dives usually lasted about 30 min and, over the course of the study, approximately equal numbers of divers were observed in the first, second or third 10-min period. Information on the gender of each diver, the site at which they were observed, the time of observation during the dive (i.e. first, second or third 10-min period of the dive), whether they carried a camera and the reported number of dives each had completed since gaining formal qualification was recorded. The latter was obtained from the dive-supervisor with the consent of the individuals involved.

We observed how often each diver made direct physical contact with the substratum, broke or damaged corals, and kicked-up sediments during the dive. Contact or damage was classified according to whether it was made by the diver's hands, fins, knees, gauges or other equipment and by the type of substratum involved. Benthic substrata were recorded as one of seven categories: bare substratum, soft corals, sponges, branching corals, massive corals, columnar coral, encrusting and plate corals (see Rouphael and Inglis, 1995 for a more detailed description of methodology). Observers made every effort to fit in inconspicuously with the dive party and remained behind their subjects in the water, within visual contact (usually 4–6 m away), so that they did not influence the behaviour of divers. Few (< 3%) divers showed obvious signs of being aware of the observer and observations were not used if it was perceived that a diver had modified his or her behaviour due to the presence of the observer or if the diver expressed curiosity about the observers on completion of the dive.

Logistic regression was used to determine which combinations of five independent variables — gender, number of previously completed dives, dive site, observation period, and use of a camera — best predicted two binary measures of damaging behaviours (i.e. whether divers broke or did not break corals during the observation period, and whether divers contacted or did not contact the substratum) The number of completed dives was the only non-categorical independent variable used in the analysis. Categorical variables were coded using a deviation contrast and coefficients derived from these were used to examine how influential each category of each variable was to the average effect of all categories (Norusis, 1993). Forward-stepwise regression procedures were used with an observed significance level of $\alpha = 0{\cdot}05$. The likelihood-ratio test was used to assess whether variables entered into the model should be retained (Norusis, 1993). Similarly, multiple regression was used to explore relationships between the same five independent variables and the number of times divers variously made contact with, or broke corals during their dive.

2.2. *Effects of cameras and gender on diver behaviour*

The experimental study was done at a single dive site in the Agincourt Reef complex that had a large cover (> 20%) of branching corals. Fifty-nine SCUBA divers were selected randomly from visiting dive parties and each was observed underwater using the procedures described above. Approximately half ($n = 31$) of the divers (two per dive party) were issued with Kodak Fun Flash®, single-use cameras at the start of the diving day, ostensibly as a prize for booking a dive trip with the charter operator. Because the overall sample size was constrained by the number of prizes (i.e. cameras) issued on each day, we used a slightly longer period of in-water observation (15 min) for each subject. By randomising the selection of subjects, we ensured that the numbers of male ($n = 33$) and female ($n = 26$) divers included in the study and in each treatment group, were representative of the relative proportions of each gender on the trips. As in the earlier part of the study, quantitative observations were made on the frequency with which individual divers made contact with, and damaged corals. Differences in the mean rate and amount of damage caused by male and female divers, and between photographers and non-photographers were compared by analysis of variance.

3. Results

3.1. *Identifying risk factors*

One hundred and fifty of the 214 divers (70%) observed in the first, descriptive part of the study came into direct physical contact with benthic substrata during the 10-min observation period. On average, each diver made around 5.4±0.63 (mean±S.E.) contacts per 10 min, or around 15 per dive. Most contacts were by fin kicks (58%) or deliberately holding onto corals (32%). Thirty-two divers (15%) were observed breaking corals, with fin kicks being the major cause of damage (95%). All but two instances involved impacts on branching coral colonies which usually resulted in the loss of one or two tips (fragments) of branches per colony. Overall, the mean number of damaging contacts per diver was relatively small (0.40±0.14 contacts per 10 min). The divers we observed varied widely in experience and had completed between one and about 3000 dives since gaining dive qualifications (Mean + S.E. = 75 + 24 dives). Seventy percent of the sample had completed fewer than 40 dives since being trained. There was no correlation between relative experience (number of logged dives) and the number of times divers made contact with ($r = 0.05$, $n = 180$, $P > 0.05$), or damaged corals ($r = -0.03$, $n = 180$, $P > 0.05$).

Three variables used in the logistic regression — gender, dive site and period of observation — were useful predictors of the probability of a diver damaging corals (Table 1). In general, divers were most likely to break corals in the first 10 min of a dive and damage was more likely to be caused by a male diver than a female diver. Female divers caused proportionately fewer fin contacts than males ($\chi^2 = 16.13$, d.f. = 1, $P < 0{\cdot}05$), but were more likely to touch corals and other substrata with their hands ($\chi^2 = 13{\cdot}7$, d.f. = 1, $P < 0{\cdot}05$). The period of observation during the dive (first, second or third 10 min) was the best predictor of the probability of making physical contact with corals (Likelihood ratio statistic = 9.7, 2 d.f., $P < 0{\cdot}01$), with, in general, more contacts being made in the first 10 min of the dive.

Thirty-nine of the 214 divers (18%) used a camera during the observed dive. Overall, similar proportions of photographers and non-photographers broke corals ($\chi^2 = 2.250$, d.f. = 1, $P > 0.10$), but those photographers who did break corals tended to cause more damage on average than divers without cameras. Linear modelling revealed two significant, but relatively weak, predictors of the amount of damage caused by individual divers: "gender" and "use of a camera" (Multiple regression, No. of breaks = constant + gender + camera, $F = 4.933$, $P = 0.0088$, $R^2 = 0.0784$). When the divers were ranked according to the amount of damage that they caused

Table 1
Results of a logistic regression of influences on the probability of individual divers damaging corals during a 10-min observation period

	Walds statistic	d.f.	*P*	*R*
Variables included in the equation[a]				
Gender	4.782	1	0.0288	0.1439
Period of observation	6.711	2	0.0349	0.1420
Dive site	13.435	7	0.0622	0.0000
Constant	0.146	1	0.7020	
Score				
Variables not included in the equation				
Use of a camera	0.406	1	0.5242	0.000
No. of completed dives	0.774	1	0.3791	0.000

[a] Overall model classification accuracy, 88%

(Table 2), underwater photographers were disproportionately represented amongst the most damaging divers (*t*-test of difference in the average rank: $t=3.16$, d.f. = 80, $P=0.025$). Male divers also ranked more highly, on average, than female divers ($t=3.72$, d.f. = 80, $P < 0.001$).

3.2. Effects of cameras and gender on diver behaviour

The 59 divers used in the camera experiment had variously completed between 2 and > 200 dives since being trained (median = 16 dives). Of those for whom we were able to get additional information ($n=39$, 66% of the sample), 79% held Open-water diving qualifications, 16% had Advanced SCUBA training and 5% held Dive-master qualifications. Use of a camera had no detectable influence on the rate at which divers came into contact with, or damaged corals (Table 3). Gender was the only significant correlate of the probability of causing coral damage (Log-likelihood statistic $=-34.869$, d.f. = 1, $P=0.0177$) and of the total amount of damage caused (Multiple regression, $F=5.74$, $P=0.0204$, $R^2=0.105$). Male divers were more likely to break corals ($\chi^2=7{\cdot}08$, d.f. = 1, $P < 0{\cdot}05$) and caused significantly more damage, on average, than female divers (Table 3; Fig. 1).

Again, female divers were more likely to hold or to touch benthic substrata, than their male counterparts

Table 2
Profiles of the 10 most damaging divers in the sample ($n=214$)

Ranking	No. of breakages. 10 min^{-1}	Use of a camera	Gender	Dive experience (No. of dives completed)
1	30	Yes	Male	12
2	16	Yes	Male	5
3	9	Yes	Male	5
4	7	No	Male	100
5	6	Yes	Male	20
5	6	Yes	Male	20
5	6	No	Male	100
8	4	No	Male	150
9	3	No	Male	40
9	3	No	Male	120

Table 3
Analysis of differences between male and female divers who variously used or did not use an underwater camera during their dive

Source	d.f.	MS	F	P
(a)[a]				
Gender	1	11·0	0·4	$P>0{\cdot}25$
Camera	1	0·82	0·03	$P>0{\cdot}25$
Gender×camera	1	44·0	1·6	$P>0{\cdot}20$
Residual	40	27·56		
(b)[b]				
Gender	1	2·87	8·4	$P<0{\cdot}01$
Camera	1	0·01	0·03	$P>0{\cdot}25$
Gender×camera	1	0·73	2·15	$P>0{\cdot}1$
Residual	40	0·34		

[a] (a) = total physical contacts made per diver with corals; Cochran's test for homogeneity of variances, $C=0{\cdot}37$, $P>0{\cdot}05$

[b] (b) = physical contacts that resulted in damage; Cochran's test for homogeneity of variances, $C=0{\cdot}45$, $P>0{\cdot}05$

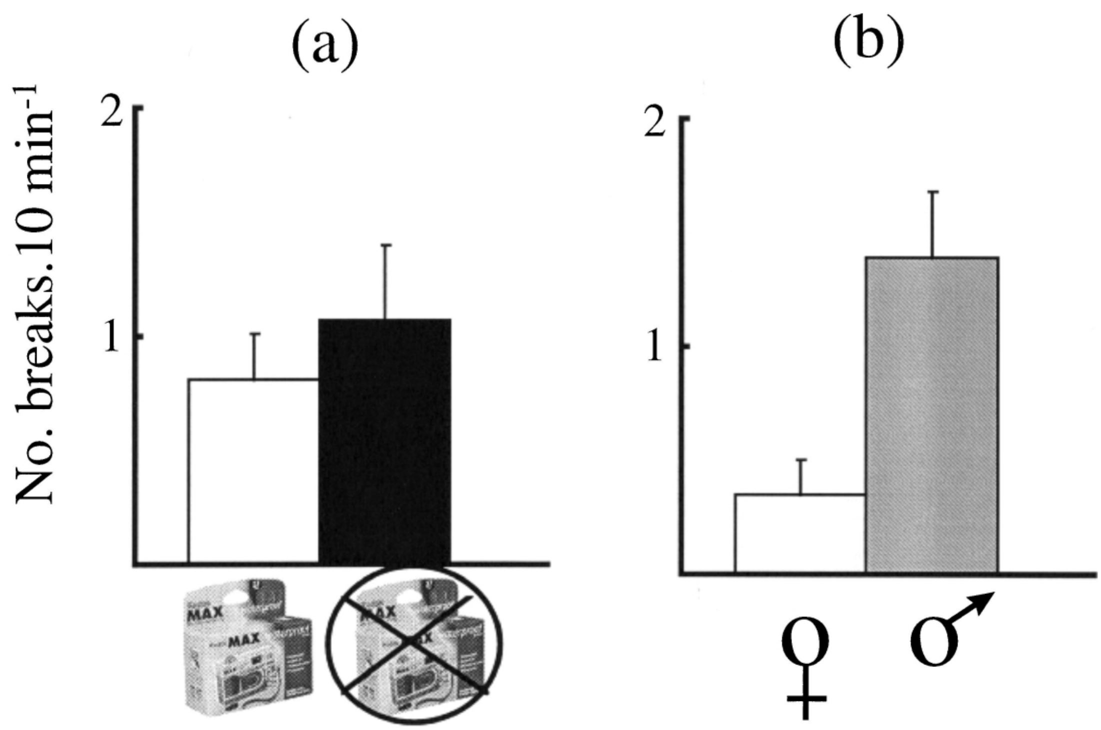

Fig. 1. Mean (+ S.E.) number of corals broken by (a) divers with cameras (open bar) and without cameras (shaded bar), and (b) male and female divers.

($\chi^2 = 5.37$, d.f. = 1, $P < 0.05$) and, in general, divers who exhibited this behaviour tended to be more experienced (Mean + S.E. no. completed dives = 49 + 12) than those who did not touch the bottom with their hands (24 ± 5 completed dives). Indeed, relative experience was the only significant predictor of both the likelihood of a diver making physical contact with living organisms — by hand or fin — (Log-likelihood statistic = −31.725, d.f. = 1, $P = 0.0028$) and of the total number of contacts that the divers made (Multiple regression, $F = 9.301$, $P = 0.0037$, $R^2 = 0.1595$).

4. Discussion

We hypothesised that divers engaged in underwater photography would be more likely to break living corals than other divers because they typically approach the substratum more closely and lack appropriate buoyancy control while taking photographs. Our study provides only limited support for this hypothesis. Divers who were issued with cameras at random caused impacts no more frequently or severely than a control group who were not engaged in photography during their observed dive. It is important, however, to put this finding into context. The experimental population we used consisted of relatively naïve underwater photographers who would not ordinarily include photography as part of their dive activity and who, therefore, may not have developed the specialised behaviours exhibited by more experienced diving photographers. Recreationists who specialise in a particular aspect of their activity often hold quite different environmental attitudes and preferences to non-specialists (Bryan, 1977) and exhibit specific goal-orientated behaviours associated with that activity (Ditton et al., 1992). The study group in our experiment was, therefore, more characteristic of the increasing number of dive tourists who purchase and use cheap, single-use cameras at popular dive locations (the growing majority of underwater photographers) than of specialist underwater photographers. The experiment showed that the normal dive behaviour and impacts caused by this naïve set of divers was not unduly affected by use of an underwater camera. This is important, because changing technology has made affordable underwater cameras available to a much broader range of divers than was previously the case. Our research suggests that in the hands of relatively naïve divers, the cameras do not necessarily create a greater risk of damage to sensitive dive locations.

More specialised underwater photographers typically use bulkier and more expensive camera equipment ("equipment specialists", sensu Bryan, 1977). This group was represented amongst the subjects in the first part of our study, where they proved to be among the most damaging of all of the divers we observed. Specialist underwater photographers often attempted to steady themselves on the substratum whilst taking a photograph and, although this did not lead to a greater propensity for contacting living organisms, the physical contacts that they made caused more damage, on average, than those made by non-photographers. Such behaviours are likely to have been learned by the photographers as they gained experience with this pastime. Research on other recreational activities suggests that as individuals get more committed to a particular specialised pursuit, such as photography, their level of personal and financial investment in the activity increases and their behaviour becomes increasingly directed toward achieving goals recognised as important by their specialist peers (Ditton et al., 1992). Sometimes this can occur at the expense of other goals or values, so that the focus on achieving a successful photograph during a dive, for example, may occasionally override caution about damaging fragile corals. Precautionary warnings by dive guides prior to entering the water might help reduce the impacts of photographers (Medio et al., 1997), but such goal-directed behaviours may prove difficult to alter. Specialised recreationists (such as underwater photographers) are also usually quite experienced in the generalist activity that they pursue (in this case scuba diving) and tend to make evaluations about appropriate behaviours on the basis of their own prior knowledge and values (Watson et al., 1991). They may, therefore, be less likely to modify their own behaviour if it means compromising their ability to achieve the goals they have set themselves for the dive, particularly if they perceive that the amount of damage which they, as individuals, may cause is relatively minor. In this regard, precautionary briefings are likely to be more effective if they stress the potential for cumulative impacts to accrue from the relatively minor effects of many individual divers, rather than by simply focussing on elements of individual behaviour.

Although significant, use of a camera by either experienced or inexperienced photographers explained only a relatively small proportion of the variability in diver impacts. Our data suggest that the greatest risk of impacts occurs at sites with a large cover of fragile organisms (in this case branching anthozoan and hydrozoan corals; Rouphael and Inglis, 1997), in the first 10 min of a dive, when the divers are adjusting their buoyancy, and that impacts are most likely to be perpetrated by male divers.

Indeed, gender differences in the frequency and severity of impacts were the most consistent finding of our study. Male and female divers appear to display distinctly different underwater behaviours, with women generally being more cautious about venturing close to the substratum and, when they did so, being more likely to use their hands, rather than their fins, to support themselves. A corollary was that women divers caused fewer impacts than their male counterparts.

This is consistent with other studies of the environmental attitudes and behaviour of male and female recreationists, which have shown that men tend to be more adventurous and more likely to take risks than women (Hudgens and Fatkin, 1985), less likely to follow instructions (Vrendenburgh and Cohen, 1993; Sirakaya, 1997) and to have a greater propensity towards delinquent behaviour (Rutter and Giller, 1984). In particular, Vredenburgh and Cohen (1993) have shown that male divers are more likely to ignore pre-dive instructions on safety and environmentally benign behaviour than are female divers. Our casual observations suggest that males in a mixed-gender "buddy-pair" also usually led the dive and were more likely to enter caves and overhangs, where there was a greater chance of causing physical contact with the substratum.

On average, male divers in our sample were slightly more experienced than their female counterparts, but there is little evidence to suggest that this seriously confounded our conclusions. In general, there were no strong relationships between dive experience (measured as the number of competed dives) and damaging behaviours. Similarly, Harriott et al., (1997) found no significant differences in the total numbers of contacts or impacts made by divers of different levels of experience. They observed that less experienced divers were generally more cautious and, therefore, were less likely to get into situations where they might damage corals. In a smaller sample on subtropical reefs, however, Roberts and Harriott (1995) reported a trend for divers with more advanced levels of training to make fewer impacts. Our findings should allow dive-masters to target on-site management of divers more effectively so that the risk of impacts is reduced. This may involve giving more explicit pre-dive warnings to male divers and specialist underwater photographers about the extra-care they should take during their dive, particularly in the first 10 min. Other approaches could include provision of safe entry and exit points that allow divers to correct their buoyancy without causing damage before they proceed to more sensitive areas of the site, and by visiting particularly sensitive dive sites later in the trip, once divers have become familiar with their equipment and surroundings. Further research on motivational aspects of diver behaviour may help site managers develop more effective training procedures and pre-dive briefings to help identify and reduce the incidence of damaging behaviours.

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