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Can Egypt's Coral Reefs Support Ambitious Plans for Diving Tourism?

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Abstract. The resort of Sharm-el-Sheikh on the Egyptian Red Sea coast has been undergoing rapid expansion over the past 5 years based on diving tourism. Current facilities can support nearly 50,000 divers per year with 37 sites dived. A 1990 survey showed 17% of sites were heavily used, 66% moderately used and 17% little used. Use ranged between a maximum of approximately 50,000 dives site^{-1} yr^{-1} to less than 1000. Studies of diver effects on reefs suggests that damage levels have stabilised at present maximal diving intensities. However, the Egyptian Government has designated diving tourism a growth sector and ambitious plans aim to increase the number of divers visiting Sharm-el-Sheikh to 850,000 yr^{-1}. Under these plans, diving site use would reach 500,000 dives yr^{-1} assuming no increase in number of sites or change in pattern of use. Even if the number of sites were doubled, there would still be an average of 115,000 dives site^{-1} yr^{-1}. Under the Egyptian Environmental Affairs Agency estimate of 312,500 divers yr^{-1} visiting the area, site use would average 84,500 dives yr^{-1} with present numbers of sites or half this with a doubling of sites. However, unless site use were strictly managed, then even under the EEAA projections diving intensity would reach 100,000+ dives site^{-1} yr^{-1} at the most popular locations. Such levels would be unsustainable and expected to cause serious reef degradation. There is thus an urgent need for the authorities to reconsider present plans for expansion of diving tourism.

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Introduction

It may be a once in a life-time experience, or an addiction requiring a regular fix, but every year an increasing number of people dive on coral reefs. Most of them are from the wealthier industrialized nations, but most coral reefs occur in poorer developing countries. Diver-related tourism offers a major opportunity for developing countries to generate income, and pressure for fast returns on investment is inevitable. In recent years Egypt has produced an ambitious programme for tourist development around the Red Sea Coast, in which diving and snorkelling play a central role. Using Sharm-el-Sheikh as a case study this paper aims to examine whether projected plans are realistic or desirable.

Sharm-el-Sheikh, a small town on the tip of the Sinai peninsula (Fig. 1), has been a popular diving destination for around 20 years. The area's most famous diving site, Ras Mohammed, is considered one of the "seven underwater wonders of the world" (Anonymous 1989). Currently there are facilities for nearly 50,000 divers year^{-1}, but Egyptian tourism authorities hope to increase this to 850,000 over the next 20 years. The Egyptian Environmental Affairs Agency, who are shortly to take over management of the area's reefs, have made a less ambitious projection of 312,500 divers year^{-1}. Using data on diver effects on reefs and patterns of diving site use in the Sharm-el-Sheikh area we will show that such levels of diving activity are likely to far exceed the carrying capacity of the reefs.

Methods

Present patterns of diving intensity and site use are assessed based on a questionnaire survey and cur-

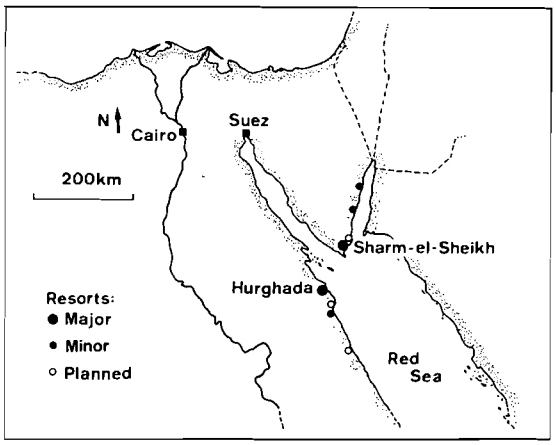

Fig. 1. Present and planned diving resorts on the Red Sea coast of Egypt, showing the location of Sharm-el-Sheikh.

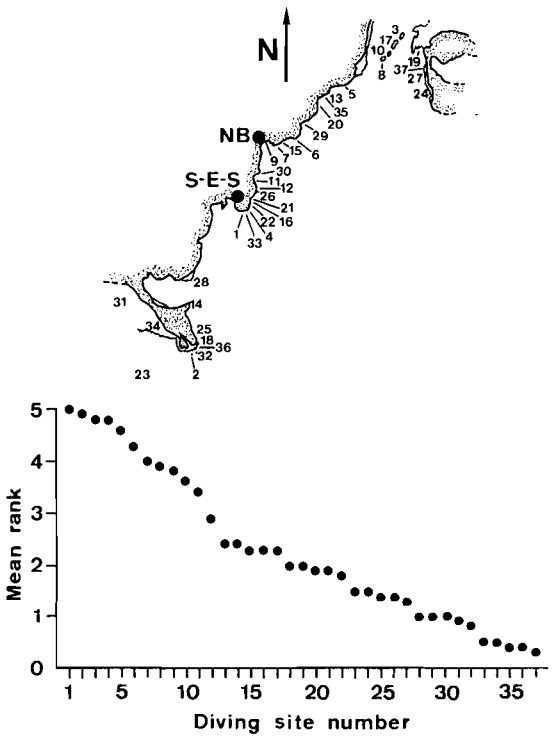

Fig. 2. Diving site use based on a survey of eight diving centres asked to rank site use on a 0–5 scale (0 = never used, 5 = very frequently used; see Methods for other categories). Diving site locations are shown on the map and are numbered with their rank according to the survey. S-E-S = Sharm-el-Sheikh and NB = Na'ama Bay.

rent tourist facilities (January 1992). In May 1990 all the diving centres were asked to make a daily record for one week of their diving destinations, whether dives were by boat or from the shore, number of divers present and number of dives made. Diving centres also ranked their frequency of diving site use on a scale from 0–5: 0 = never, 1 = rarely, 2 = occasionally, 3 = moderately, 4 = frequently, and 5 = very frequently used.

Based on figures derived from the above, future use of diving sites will be calculated under Egyptian projections of 850,000 and of 312,500 divers visiting the area. Following this diver effects on reefs of the area are summarized based on published and unpublished data. Finally a review of reef carrying capacity for tourism is presented and related to the reefs around Sharm-el-Sheikh.

Results and Discussion

Present use of diving sites

Figure 2 shows the pattern of diving site use around Sharm-el-Sheikh in 1990 based on rankings by diving centres. A small number (17%) were used heavily, a large number moderately (66%), and a few very little (17%). This trend is further illustrated in Table 1 which shows quantitative patterns of site use during a seven day period. "Ras Mohammed" and "Tiran" each comprise 7 and 8 diving sites respectively. Although treated separately in the ranking survey they have been combined in Table 1 because dive centres did not keep precise records of locations visited within these two major areas.

Assuming this level of use were maintained year round, an estimated 133,437 dives year^{-1} were made in 1990. However this probably underestimated actual activity for two reasons. Firstly, May was a quiet time of year. During the questionnaire week, three diving centres said they were less busy than usual and four said business was average. One diving centre provided data for a week in November 1989, instead of May 1990. This was a quiet week during a busy time of year. Secondly the number of shore dives does not include people with their own transport. During Egyptian and Israeli holidays shore diving may increase tenfold. Diving from vehicles is restricted to areas with shore access (about 46% of dive sites). The survey also excluded dives from chartered or private dive boats but these probably constituted less than 5% of dives made.

Police records for 1988 showed that in October and November 3,600 and 4,680 divers entered Ras Mohammed by boat (M. Pearson pers. comm.). During October 1,078 visitors came by road, but the proportion of divers was not known. Assuming these months were representative of the whole year and that all divers made two dives at Ras Mohammed, a total of around 100,000 boat dives

Table 1. Results of a questionaire given to eight diving centres showing dives made over a seven day period (7 centres sampled during May, 1 during November).

Site	Total Nos Visits	Total Boat Visits	Total Land Visits	Total Boat Dives	Total Shore Dives	Total Dives
Ras Mohammed	61	58	3	595	11	606
Tiran	60	60	0	593	0	593
Ras Umm Sidd	27	22	5	215	41	256
Ras Nasrani	20	12	8	136	51	187
Far Gardens	17	17	0	139	0	139
Na'ama	17	0	17	0	54	54
Near Gardens	14	10	4	119	19	138
Temple	12	12	0	101	0	101
Tower	11	7	4	52	18	70
Amphoras	10	9	1	75	5	80
White Nights	3	3	0	40	0	40
Tiger Bay	2	2	0	13	0	13
Turtle Bay	1	1	0	10	0	10
Paradise	1	1	0	9	0	9
Unspecified	10	0	10	0	45	45

year^{-1} would have been made there. Since on most trips the dive boats visit "Shark Reef" and some other site within Ras Mohammed nearly half these dives will have taken place at this particularly popular site (ranked second in the survey, Fig. 2).

Present diving capacity of the Sharm-el-Sheikh area

Present diving capacity can be calculated based on the number of available diving boats, and the average length of stay by divers. There are currently 58 boats which carry an average of 10 divers per boat. From Table 1, 90% of diving was by boat and 10% from the shore. Since shore diving was underestimated by the survey it is here assumed that 15% of dives were shore dives. Hence the maximum total number of divers active per day is:

$$(58 \times 10) + 87 = 667 \text{ divers day}^{-1}$$

The average duration of stay by divers in Sharm-el-Sheikh is 7 days (unpublished report). We assume that on average divers do 10 dives during this week (all diving centres operate 5 day, 10 dive discount packages).

Therefore, assuming no change in proportions of boat and shore dives, present facilities can support:

$$667 \times \frac{365}{5} = 48{,}691 \text{ divers year}^{-1}$$

Diving capacity necessary for 850,000 divers year^{-1}

The Egyptian Ministry of Tourism has projected that 850,000 divers will eventually visit Sharm-el-Sheikh each year. If people continue to dive for 5 days in a seven day stay, the number of divers active on an average day will be:

$$850{,}000 \div \frac{365}{5} = 11{,}644 \text{ divers day}^{-1}$$

Assuming 85% are carried by boat, 990 boats of the type currently in use would be required.

At present there are approximately 4,100 beds available in Sharm-el-Sheikh, and approximately 25% of visitors are divers (unpublished report). If this proportion remains constant, it would require approximately 16 times the current infrastructure to accommodate 850,000 divers. Since the Ministry of Tourism's policy is to diversify tourism opportunities, the proportion of visitors who dive is unlikely to increase.

While there is enough land to increase the number of hotels around Sharm-el-Sheikh by this much, to do so would entail potential environmental problems and certainly spoil the area's wild beauty. However coastline topography will make expansion of harbour facilities very difficult. We estimate that a maximum of about 150 boats of the present size could find space in the embayments available, which is far short of the 990 required for 850,000 divers.

Site use assuming no change in number or pattern of use would range from 29,900 to 498,800 dives site^{-1} year^{-1}, with an average of 229,700.

Egyptian Environmental Affairs Agency projections of diving activity

Responsibility for management of the marine environment of the entire coastal area dived from

Sharm-el-Sheikh will soon be passed to the Egyptian Environmental Affairs Agency (EEAA). The EEAA estimate that without regulation, reefs of the area will be ruined by diving within 10 years. Their stated priority is to ensure that tourist development remains within levels which can be sustained without reef degradation.

EEAA projections of diving activity are less ambitious than Ministry of Tourism plans. They foresee that development will peak at approximately 40 hotels with 12,000 rooms, providing facilities for 1.25 million visitors annually. If 25% are divers making 10 dives each then with 37 sites and the present pattern of use, diving intensity would range from approximately 11,000 to 183,400 dives site^{-1} year-1, with an average of 84,500 dives site^{-1} year^{-1}. There would be an average of 4281, divers active day^{-1} carried by 428 boats of the present type.

Tourist impacts on reefs

Countries throughout the tropics have reported examples of how tourism has resulted in reef degradation (Salm 1990). Provision of tourist facilities has caused reefs to be mined for building material (Wells & Edwards 1989), smothered by sediment released during construction (Ormond 1987), and polluted by waste disposed from the completed, functioning developments (Bell et al. 1989). Anchor damage from boats has also been a serious problem (Smith 1988), as have boat groundings in areas subject to heavy boating pressure (Tilmant 1987). Tourist development often attracts a commercial trade in marine curios which can degrade reefs (Wells & Alcala 1987), as can tourists collecting souvenirs or hunting (Bryceson 1981).

Some of these problems have long been recognized and attempts made to ameliorate them, such as provision of mooring buoys and bans on collecting marine curios. However, until recently there has been little concern for the direct impacts divers and snorkellors have on reefs. In comparison with damage caused by the above factors, or natural disturbances such as hurricanes or extreme low tides, divers are often thought to be environmentally benign. In the past, when diving was an uncommon activity, this may have been true. The great increase in the popularity of diving over the past two decades has changed matters. There is now widespread concern that diving and snorkelling are important causes of reef deterioration (Ward 1990).

Several studies have looked at the effects of trampling on coral reef-flats (Woodland & Hooper 1977; Liddle & Kay 1987; Kay & Liddle 1989; Hawkins & Roberts 1993). All found that damage was a function of trampling intensity. Trampling increased cover of bare rock and rubble while it reduced hard coral cover and number of colonies present. Some studies found a reduction in cover of branching corals, but Hawkins and Roberts failed to detect any such change in community structure attributable to trampling on reef-flats of southern Sinai. However they did find smaller coral colonies, with shorter, thicker branches in trampled compared to control areas. Different zones of the reef-flat were shown to vary in their susceptibility to damage by both Kay and Liddle (1989) and Hawkins and Roberts (1993).

Quantitative data on the effects of divers on the deeper zones of reefs are scant. Divers may damage reefs by kicking, holding, kneeling or standing on benthic organisms, and also by resuspending sediment. In a study at Biscayne National Park, Florida, Tilmant (1987) concluded that damage to reefs from recreational activities was slight. However, he studied little used reefs where the maximum number of visitors reached only 1500 per year. By contrast Hawkins and Roberts (1992) found SCUBA diving caused significant damage to reefs around Sharm-el-Sheikh where diving activity was much greater. They studied three sites which received between 5–13,000 dives year^{-1} based on the questionnaire (Table 1), or 19–28,000 based on present diving capacity and assuming no change in site use (Fig. 2). There was more broken coral, fragments of coral reattached to the substratum, partially-dead and abraded corals in areas heavily used by divers than in control areas. Branching corals bore the brunt of the damage. At sites which had been intensively dived for a long time damage did not accumulate over a twelve month period. However damage did increase at a previously little-dived site where diving intensity increased over the course of the study. Unlike trampling on the reef-flat, diving intensity did not reduce coral cover or the number of coral colonies.

Effects on other benthic organisms remain largely unstudied. There was a suggestion of higher sponge cover in dived than control areas in the study by Hawkins and Roberts, but high among site variability made the results inconclusive as were results for soft coral cover.

Assessing the carrying capacity of coral-reefs for tourism

In the absence of regulation, recreational diving on coral reefs poses a threat to a potentially fragile habitat. Managers must assess the carrying capacity of reefs to determine sustainable levels of diving

pressure. Salm (1986) outlined some of the factors affecting carrying capacity as 1) coral community composition, 2) size and shape of the reef, 3) activities to be pursued, and 4) competence of the users. The importance of biological and environmental influences together with diver competence are discussed below and some suggestions for management made.

Community composition. Since coral growth form affects susceptibility to damage, the community composition of reefs is particularly important. Reefs with a high proportion of delicate branching corals are more easily damaged than those dominated by species with robust growth forms. Since much diver damage is due to inadequate buoyancy control, consideration should be given to excluding novice divers from the most fragile reefs, and restricting the total number of divers. However it should be noted that branching corals generally have high growth rates, often regenerate rapidly after fragmentation and are swift colonisers of bare substrata (Loya 1976; Pearson 1981; Highsmith 1982). Reefs dominated by branching corals are also capable of rapid recovery following major disturbances such as hurricanes (Shinn 1976). Such reefs may therefore be resilient to diver damage.

Of importance to managers is that although biological effects may be minor, a small amount of damage to branching corals may greatly reduce the aesthetic appeal of the reef. Hawkins and Roberts (1992) showed that although damaged colonies typically constituted only 5–10% of colonies present on dived reefs around Sharm-el-Sheikh, those reefs appeared heavily damaged.

Underwater trails may be a good way to limit diver movements on a reef and to reduce use of more vulnerable areas of a site. They have been established in many American marine parks (Tilmant 1987). Conversely, by concentrating divers on underwater trails, they may swiftly become damaged and unattractive, as has happened to a trail in the Virgin Islands National Park on St. John (J. Beets pers. comm.).

Topography. Reef topography will also affect carrying capacity. Salm (1986) argued that large irregularly shaped reefs could support more divers than shallow, flat uniform ones of the same area. Irregular reefs would provide more interest to users and in screening their movements from each other would reduce the incidence of potentially damaging inter-group contact.

Diver ability can modify the way reef topography affects carrying capacity. Reefs with vertical faces ("wall dives") should have a high carrying capacity when used by experienced divers, since the latter can hang in the water column without touching the substratum. However novice divers with poor buoyancy control may grab corals to steady themselves. Hence wall diving might sensibly be restricted to experienced divers.

A gently sloping reef with high coral cover should be considered vulnerable because divers can stand on it or hover above it where they can easily kick coral. Shallow patch reefs make good sites for novice divers since they can sit on a sandy sea bed to sort out buoyancy problems rather than on the reef. However, this might also cause problems if large amounts of sediment become resuspended.

Sedimentation can seriously stress corals (Rogers 1990). Resuspension of sand by finning can increase sediment load. This could lead to mortality of species sensitive to sedimentation, particularly in sites which already have a high sedimentation rate. Dead colonies of tabular *Acropora* sp., intact in their growth positions, are commonly observed in dived sites but not on little-dived reefs around Sharm-el-Sheikh (Hawkins 1991). Although the cause of death remains unknown, such colonies may have been stressed by increased sedimentation from diving, perhaps increasing their susceptibility to disease.

Currents and wave action. Sites with strong currents are vulnerable to damage because divers often try to hang on to corals as they get swept along. Installation of underwater ropes could reduce damage at such locations but areas beside ropes can be expected to suffer heavy damage.

Wave action can exacerbate diver damage. Sites exposed to heavy wave action pose particular problems for shore divers. Corals are easily broken by divers getting hurled around crossing the reef-flat or jumping off the reef edge. At certain sites notices warning against shore entry in rough conditions might help preserve the reefs. Conversely, wave action may also reduce susceptibility of some coral species to diver damage, resulting in stockier growth forms and denser skeletons (Brown et al. 1985). Underwater, heavy turbulence doesn't usually affect divers below 5m deep.

Boats vs shore diving. Providing there are adequate mooring buoys, boat diving is probably less damaging to reefs than shore diving. Since trampling by divers can reduce the aesthetic appeal of the reef-flat for others, particularly snorkellers, a suitable management strategy would be to establish fixed access routes to the reef-edge. This would restrict the extent of trampling damage. However as Rogers (1988) and Hawkins and Roberts (1993) have pointed out, snorkellers can also cause considerable damage to corals.

Boat diving carries two additional risks to reefs: groundings and anchor damage. The latter has been a major cause of damage, and still is in many areas. Mooring buoys are probably the most important single factor reducing reef damage from diving.

Diver activities. Observations of diver behaviour suggest that, aside from novices, underwater photographers inflict the greatest amount of damage on reefs. When faced with the challenge of getting a picture, many divers abandon caution. Given the increasing popularity of underwater photography, photographers might be specifically targetted in campaigns to reduce reef damage.

Can Egypt's reefs support projected increases in diving?

Although none of the dive sites around Sharm-el-Sheikh are pristine most tourists are impressed with the reefs. Investigation into what constituted a popular dive site in Hawaii led Tabata (1989) to conclude that other attractions such as tame fish or wrecks can compensate for damage to reefs. Most divers questioned in Sharm-el-Sheikh thought the reefs there compared very favourably with others they had dived on elsewhere in the world, and many had returned after previous visits. Nevertheless the amount of broken and dead coral in the most popular dive sites is noticeable, unattractive and already a cause of concern to dive operators and tourists. A doubling or tripling in damage levels could begin to deter future visitors.

Studies by Hawkins and Roberts (1992, 1993) suggest that present levels of diving appear to be sustainable. However if further increases in diving pressure made corals more susceptible to other forms of stress then the reefs could become threatened. For example Coles and Jokiel (1978) found that temperature tolerance of corals may be lowered if other environmental conditions are suboptimal. Similarly if corals are stressed by diving they may become more susceptible to disease. Studies are required to address these questions.

If diving levels were to increase to the projected 850,000 divers and the current pattern of site use continued unchanged, then the most popular sites would receive 581 divers day^{-1} carried by 58 boats. This density of divers in the water would prevent most individuals from enjoying the reef, and there wouldn't be enough room to accommodate all the boats. Using bigger boats would not solve the problem of too many people underwater, and would create new mooring and safety problems. Space limitations above and below water suggest that present diving intensity at the most heavily used sites (30,000–50,000 dives year^{-1}) is approaching a maximum.

With visitation by 850,000 divers site use would range from 30,000–500,000 dives year^{-1} (assuming the present pattern of site use). Hence the least used sites would receive current maximum diving levels, while diver numbers at the most popular sites would increase by an order of magnitude. Even under the lower EEAA projections of 312,000 divers year^{-1}, site use would still range from 11,000 to 180,000 dives site^{-1} year^{-1}.

Two main options exist to increase the present capacity for diving tourism around Sharm-el-Sheikh. Firstly, the number of dive sites could be increased. However because travel time limits diving time, new sites would be limited by their proximity to Sharm-el-Sheikh. Coastal topography will impose a further limit on number of diving sites. It is estimated that the number of sites could realistically be doubled from the present 37. This figure could be increased further if a greater proportion of divers stayed on live aboard boats, which have a larger range. Such boats would require adequate mooring facilities, otherwise damage from anchor chains would become a serious problem.

The second way to increase capacity, would be to spread diver use more equitably across reefs in accordance with their carrying capacity as judged by the above criteria. If the number of dive sites was doubled to 74, and all were used equally (thus ignoring the important need to consider carrying capacity); with 850,000 divers year-1, each site would receive approximately 115,000 dives year-'. This figure is over double the present maximum, and is likely to be unsustainable. The most heavily dived reefs in the world probably occur within the John Pennekamp National Park, Florida. With over 150,000 dives year^{-1} at the most popular sites, the carrying capacity of these reefs appears to have been exceeded (Ward 1991).

EEAA projections would lead to more realistic levels of diving with an average of 42,500 dives site^{-1} year^{-1} if the number of sites were doubled. This is within the present range of site use. However, unless diving were strictly controlled, the most popular sites would probably receive closer to 100,000 dives year^{-1}. Even though sites might be able to sustain average levels of use, the required boat traffic and underwater congestion from so many divers casts serious doubt on the practicality of increasing tourism to this extent.

To conclude, the planned increases to 850,000 or even 312,500 divers visiting Sharm-el-Sheikh are neither realistic or desirable from the visitors' or environmental point of view. What the area does

require is proper coastal management. At present only a small area around Ras Mohammed and Tiran Island is protected. Present plans to extend coastal management over the whole area surrounding Sharm-el-Sheikh are both essential and timely. However, there is an urgent need for authorities in Egypt to re-examine development plans for the area and for other Red Sea resorts.

In comparison with Hurghada, Egypt's other major diving resort, development in Sharm-el-Sheikh has been environmentally sensitive. Tourism in Hurghada has resulted in coastal infill onto reefs, sewage discharge into the sea, and a flourishing trade in marine curios. So far, this has been avoided in Sharm-el-Sheikh where most hotels and diving centres attempt to promote environmental awareness. There are many signs forbidding the collection of marine organisms and a few tourists have been arrested and fined for breaking these laws. It would be a terrible irony if unrestricted diving eventually ruined the reefs around Sharm-el-Sheikh and thereby reduced the tourist appeal of the area. With careful management of diving activities, Sharm-el-Sheikh could easily become a model resort, and a credit to Egypt.

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