

Do Marine Protected Areas in the Red Sea Afford Protection to Megafauna?: A Reassessment Nearly a Decade On

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Abstract

Dugongs, sea turtles and sharks are threatened by gill nets worldwide. A Marine Protected Area (MPA) is one potential tool to reduce the impact of humans on these animals. We undertook a face-to-face survey to compare the proportions of fishers inside and outside MPAs who had observed these animals in their nets. We also assessed if the same fishers had collected and eaten turtles eggs. Forty-nine fishers living in Elba or Wadi El Gamal National Parks (NPs), two MPAs in Egypt's Red Sea, and 23 fishers living outside these MPAs were interviewed. We found similar proportions of fishers using nets irrespective of whether they lived inside or outside the MPAs. But a greater proportion of fishers living outside the MPAs had caught sharks, turtles and dugongs in nets and eaten turtle eggs. Nevertheless, the proportions of fishers living inside the MPAs who had caught sharks (76%), turtles (71%) and dugongs (20%) in nets were still high. Compared with 2006 data, there was little difference in the proportion of fishers living in Elba NP who had caught turtles in nets, but the proportion of fishers who had caught dugongs in nets was higher in the current study. One reason for this was that a greater proportion of fishers were using nets in 2013. Elba and Wadi El Gamal NPs are not providing comprehensive protection for dugongs, turtles and sharks. Given Egypt's MPAs are some of the oldest and best resourced in the Red Sea, it is unlikely that MPAs in other countries bordering the Red Sea are providing a better level of protection.

Keywords: Bycatch; Dugongs; Egypt; Fishing nets; Marine protected areas; Red Sea; Sea turtles; Sharks

Introduction

The plight of dugongs and sea turtles around the world is uncertain. Jackson et al. [1], for example, wrote that sirenians and sea turtles are functionally extinct in many coastal environments of the Caribbean. Marsh et al. [2] reported the collapse of dugong (Dugong dugon) populations in some sections of the Great Barrier Reef, Australia. Indeed, Marsh et al. [3] concluded that throughout much of its distribution, dugong populations have been severely impacted by humans. Common to most areas where dugong and turtle populations have declined is increasing human populations, hunting pressure, use of nets and habitat destruction [1,3].

Reef and pelagic species of shark have also suffered major population declines worldwide as a result of targeted fishing and bycatch [4,5]. Sharks, like dugongs, are particularly vulnerable to human disturbance because they are long lived, are slow to reach sexual maturity and produce few young [6]. Fortunately, a better understanding of the important role these apex predators play in ecosystems [4] and of their function in supporting specialised marine tourism activities has generated community support to conserve shark populations [7].

A number of methods have been proposed to counter declines in populations of marine megafauna. These include raising awareness of the threatened status of species, modifying fishing practices, developing a legal basis to protect species and developing international conventions to stop trade in their products [3,8]. Another approach is the establishment of Marine Protected Areas (MPAs) [9-13]. MPAs can reduce dugong, turtle and shark mortality by separating net fishing and other threatening processes from habitat used by these animals. Following recent tagging studies, Scott et al. [14] concluded that many existing MPAs encompass a large proportion of habitat used by sea

turtles. Scott et al. [14] also stated "Our findings constitute compelling evidence of the worldwide effectiveness of extant MPAs in circumscribing important foraging habitats for a marine megavertebrate."

Unfortunately, the establishment of MPAs is no guarantee that conservation objectives will be met [3,15,16]. MPAs may fail to achieve their intended objectives for two primary reasons i. threatening processes may be legally permitted in a MPA and ii. threatening processes may occur illegally due to a lack of compliance with MPA regulations. In terms of the former, such a scenario may occur when a MPA is managed solely as an IUCN VI category protected area that permits threatening processes such as net fishing [9]. In terms of the latter, scientists have used the term 'paper parks' to classify protected areas that largely only represent boundaries on maps. Such MPAs lack resources to enforce regulations [15,17] or to implement strategies to alleviate poverty of local communities, a major factor contributing to noncompliance of MPA regulations [18,19].

Yet what evidence is there that MPAs are not achieving their objectives in relation to megafauna? Although the intentional and accidental killing of these animals by humans has been documented

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Received July 11 2015; **Accepted** July 21 2015; **Published** July 30 2015

Citation: Rouphael AB, Marshall N, Noor N, El-Gawish S, Baha El-Din S, et al. (2015) Do Marine Protected Areas in the Red Sea Afford Protection to Megafauna?: A Reassessment Nearly A Decade On. J Coast Zone Manag 18: 411. doi:10.4172/2473-3350.1000411

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worldwide [1,3], with the exception of the Great Barrier Reef Marine Park [10,11,20] there is little reporting of such phenomena in proclaimed MPAs. In 2006, a study was undertaken by some of the authors of this study to assess whether MPAs in the Red Sea afforded protection to dugongs and sea turtles [21]. The aim of that study was to determine the proportion of fishers operating in Egypt's Elba National Park (NP), a combined terrestrial and marine protected area in the Red Sea, who had found dugongs and or turtles in their nets [21]. The authors reported that 80% and 9% of fishers had found turtles and dugongs, respectively, in their nets. Seven percent of fishers also believed that people still collected turtle eggs. The authors used the term bycatch to describe incidents of 'net entanglement' although it was not determined whether some fishers were intentionally targeting these animals.

The aims of this paper are to; i) compare bycatch and turtle eggs exploitation by fishers living in protected areas (e.g. NPs, MPAs) and unprotected areas, ii) compare net use and megafauna bycatch by fishers living in Elba NP between 2006 [21] and 2013 (this study), iii) confirm and extrapolate results of Rouphael et al. [21] to a larger area and finally to the whole Red Sea, and iv) discuss some of the limitations in improving management of megafauna in Red Sea MPAs. For convenience, in this paper Elba NP and Wadi El Gamal NP are collectively referred to as MPAs.

Methods

Study area context

The Red Sea

The Red Sea is a 2000 km long, narrow extension of the Indian Ocean between the latitudes 30°N and 12° 3'N. It is up to 2 km deep with an average depth of 491 m [22]. Coastal regions are characterised by low rainfall, not generally exceeding 180 mm/y⁻¹, and scant vegetation cover [23]. For these reasons, human populations along the Red Sea have remained sparse and centred on a few coastal cities and towns [24].

Egyptian Legal framework to protect megafauna

In Egypt, Law 102 is the primary legislation used to establish protected areas [25]. Article 2 of Law 102 states "It is forbidden to commit actions (deeds or activities or undertakings) which will lead to the destruction or deterioration of the natural environment or harm the biota (terrestrial, marine or fresh water) within protected areas". The level of protection offered by Law 102 is consistent with an IUCN Category Ia Protected Area [26], which offers the highest level of protection to megafauna [9].

Sea turtles, dugongs and sharks are also protected under Egyptian law outside protected areas. Egypt is a signatory party to several agreements providing protection to these fauna. These include the Convention on Migratory Species, which lists dugongs and turtles within its Annexes, and the Jeddah Convention, which includes a Regional Action Plan for the conservation of turtles and their habitat in the Red Sea [27]. In addition, Egypt is a signatory to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which will soon control trade in some shark and ray species.

The Nature Conservation Sector (NCS) of the Egyptian Environmental Affairs Agency (EEAA) is responsible for managing protected areas, environmental policy and interpreting conservation legislation in Egypt. The Red Sea Protectorate (RSP) is a sub-department under the NCS and EEAA and its staff are directly responsible for overseeing MPAs in Egypt.

Elba and Wadi El Gamal NPs

Two Egyptian MPAs, Elba NP and Wadi El Gamal NP, were involved in this study. Elba NP was proclaimed in 1986. Its southern boundary fringes North Sudan and is about 1300 km from Cairo, the capital of Egypt (Figure 1). The area is approximately 35,000 km², of which about 2,000 km² covers the marine environment. Its marine waters are characterised by fringing coral reefs, and large stands of the mangroves *Rhizophora* and *Avicennia*. A number of coastal villages are located in Elba NP [18,21]. The largest is Shalateen, with about 13,000 people [18]. Elba NP supports green (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) turtle nesting beaches [28,29] and is known dugong habitat [30]. There is a RSP office and protected area staff based in Shalateen.

Wadi El Gamal NP was declared in 2003. Situated between Ras Banas and the town of Marsa Alam, this NP covers approximately 7,400 km² of which about one third covers the marine environment (Figure 1). Wadi El Gamal NP is about 850 km from Cairo. Like Elba NP, Wadi El Gamal NP has mainland and island fringing reefs, and mangrove stands of *Avicennia*. Towns supporting fishing communities include Qulaan and Hamata [31]. Wadi El Gamal NP supports nesting beaches for green and hawksbill turtles [28,29], and is known dugong habitat [30]. There are marine-based tourism resorts and three RSP offices located along the coast inside the NP.

Survey method and administration

The field survey for this study was undertaken from 9 to 21 December 2013 at pre-selected coastal towns from Shalateen to Quesier (Figure 1). One of the authors (Dr. Elhalawani), a fluent Arabic speaker, led the field survey. Fishers were interviewed using a questionnaire, which consisted of three parts to cover the fishers: i) socio-economic aspects related to fishing areas and fisheries resources; ii) attitude, circumstances and experiences related to fisheries resources; and iii) personal perspectives of the protection of fisheries.

Fishers were asked to respond to each question using one of the following responses: yes or no or do not know. Examples of such closed-ended questions included "If you use fishing nets, have you ever accidentally caught a dugong in a net?" We deliberately used the word 'accidental' in this and similar questions to reduce the concern of fishers who might be fearful of reporting by catch of dugongs and other protected fauna in their nets (and to show respect and understanding that incidents may have indeed been accidental). Open-ended questions were also used to enable more detailed responses. Field staff were careful to ensure that fishers felt safe in admitting that they had accidentally caught dugongs or turtles. For example, we did not record the names of those interviewed. We did not distinguish between turtle and shark species so as to avoid difficulties in recalling with certainty species caught and exact time of capture. For similar reasons, we did not record information on the size or length of specimens caught. In terms of identifying where fishers fished we asked each where they lived and where they fished. In terms of the latter, the responses from fishers were often imprecise or not always offered. In terms of where they fished most actively we made the assumption that this would be closest to their homeport given the cost of fuel and need to get their catch to market due to limited or no refrigeration on vessels.

Approval to conduct the surveys was obtained from coast guard officials in Shalateen. Where practical, fishers were selected at random to ensure the representativeness of the sample and reduce the risk of non-independence among responses from fishers. The survey was pilot-tested to ensure that the survey was unambiguous and reflected

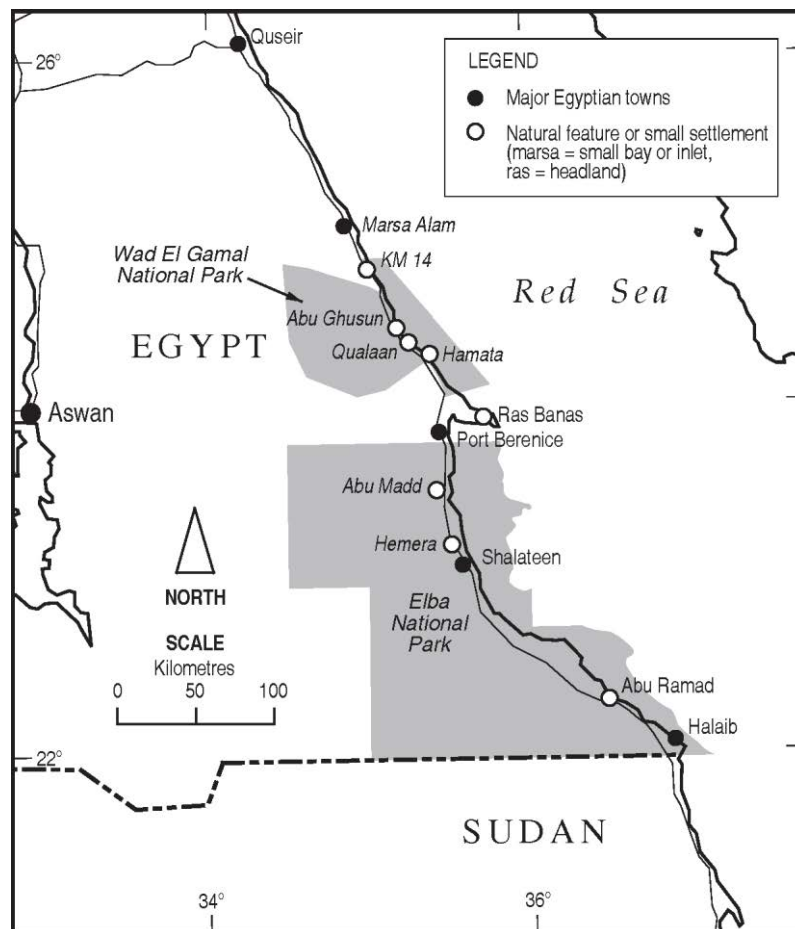


Figure 1: Elba and Wadi El Gamal National Parks, Egypt, and location of towns and other key features mentioned in the text.

local circumstances.

Seventy-two fishers, from twelve towns, were interviewed. Approximately equal numbers of fishers were interviewed in Elba NP (n = 27), Wadi El Gamal NP (n = 22) and outside the two MPAs (n = 23).

Analysis

For the first component of this study we used Chi-square (X^2) analysis to test for associations between the protected area status of the location where a fisher lived (MPAs versus unprotected areas) and the number of respondents who reported using nets and who had caught sharks, turtles and / or dugongs in nets. The specific hypotheses we tested were:

- i) There is no association between protected area status and the number of fishers using nets
- ii) There is no association between protected area status and the number of fishers who had caught sharks or turtles or dugongs in nets
- iii) There is no association between protected area status and the number of fishers who had exploited turtle eggs

For the analyses described above, fishers interviewed within

Elba NP and Wadi El Gamal NP were pooled and compared with respondents living outside these MPAs. Only the 2013 data were used to test the hypotheses listed above. With the second component of this study, the comparison of the Elba NP 2006 results with the 2013 results was descriptive, rather than inferential. This was because slightly different questions were used in both studies and, consequently, the raw data were not directly comparable.

Results

Compare bycatch and turtle exploitation between MPAs and unprotected areas

Ninety-two percent of fishers living outside the MPAs and seventy-six percent living inside the MPAs used nets (Table 1). Almost all net fishers used nylon nets, but at least two fishers still used cotton nets. The proportion of fishers who used nets and lived inside the MPAs was not statistically different from those living outside the MPAs ($X^2 = 2.49$, $P = 0.11$, $df = 1$). That is, there was no evidence of an association between the proportions of fishers using nets and whether they lived inside or outside the MPAs.

Of those fishers using nets, most (>50%) had caught sharks, a pattern consistent for fishers living inside and outside the MPAs (Table

2). However, the proportion of fishers who had caught sharks in nets and lived inside the MPAs was statistically different from those living outside the MPAs ($X^2 = 3.91$, $P = 0.04$, $df = 1$). This suggests a greater proportion of fishers living outside the MPAs had caught sharks in nets compared with fishers living inside (Table 2).

Ninety-six percent of fishers living outside the MPAs and seventy-one percent living inside had caught turtles in nets (Table 3). The proportion of fishers who had caught turtles in nets and lived inside the MPAs was also statistically different from fishers living outside ($X^2 = 5.34$, $P = 0.02$, $df = 1$). Thus, a greater proportion of fishers living outside MPAs had caught turtles in nets compared with fishers living inside the MPAs.

Only 20% of fishers living inside the MPAs had caught dugongs in nets compared with 77% of fishers living outside (Table 4). Not surprising, there was a clear association between observations of dugongs in nets and whether a fisher lived inside or outside the MPAs ($X^2 = 26.1$, $P = 0.00$, $df = 1$). No fishers reported dolphins being caught in nets.

Of the fishers who were asked “have you ever eaten turtle eggs?”, a greater percentage of those living outside the MPAs said yes (82%) compared with those living inside (34%) ($X^2 = 14.65$; $P = 0.00$; $df = 1$). This finding was consistent for the question “Have you ever collected turtle eggs?”, with 69% of fishers living outside the MPAs saying yes compared with 26% of those living inside ($X^2 = 12.05$; $P = 0.00$; $df = 1$).

Compare net use and bycatch in Elba NP in 2006 versus 2013

In 2006, approximately 16% of fishers interviewed in Shalateen, the main fishing village in Elba NP, reported using nets [18]. In 2013, the percentage of fishers in Elba NP who reported using nets, at least some of the time, was 96%. Of these, 92% reported using nylon nets. Data relating to the use of nylon nets in 2006 was unavailable.

A slightly smaller percentage of all fishers interviewed in Elba NP reported turtles being caught in nets in 2013 compared with 2006 (74% versus 80%). In contrast, a higher percentage of fishers reported

	No	Yes
Inside	12 (24%)	37 (76%)
Outside	2 (8%)	21 (92%)

Table 1: The frequency (and percentage) of fisher living inside and outside MPAs who have used nets.

	No	Yes
Inside	10 (24%)	31 (76%)
Outside	1 (4%)	21 (96%)

Table 2: The frequency (and percentage) of net fishers living inside and outside MPAs who have caught sharks in nets.

	No	Yes
Inside	12 (29%)	29 (71%)
Outside	1 (4%)	21 (96%)

Table 3: The frequency (and percentage) of net fishers living inside and outside MPAs who have caught turtles in nets.

	No	Yes
Inside	33 (80%)	8 (20%)
Outside	3 (13%)	19 (77%)

Table 4: The frequency (and percentage) of net fishers living inside and outside MPAs who had caught dugongs in nets.

dugongs being caught in nets in 2013 (18%) compared with 2006 (9%).

Discussion

MPAs versus unprotected areas

Similar proportions of fishers living inside and outside the MPAs were using nets. This not only indicated that a major threatening process to marine megafauna was occurring inside at least two Egyptian MPAs, but the proportion of fishers using nets was the same both inside and outside MPAs. A gill net is probably the most destructive fishing apparatus in terms of bycatch of dugongs, turtles and other species [32]. However, cotton gill nets may not pose the same risk as nylon nets [33], the latter being introduced to the Egyptian Red Sea in the 1980s [34]. According to our study, nylon nets are now more commonly used in Egypt's Red Sea. Tun et al. [33] reported that dugongs in Myanmar waters were capable of breaking loose from cotton nets. It is unknown if dugongs are capable of breaking loose from the cotton nets used in Egypt. Even if cotton nets pose less risk to dugongs, few Egyptian fishers are still using them and some respondents in this study suggested that cotton nets are more expensive and difficult to find.

The threat of gill nets is recognised by Egyptian Non-Government Organisations (NGO). In 2009 the NGO known as the Hurghada Environmental Protection and Conservation Association led an attempt to ban all gill netting from Egypt's territorial waters in the Red Sea [18]. This was motivated to minimise bycatch and stop destruction of values, such as sharks, supporting marine-based tourism. However the attempt failed because of insufficient support from all stakeholders. Nevertheless, all forms of fishing are, in theory, illegal within Egyptian MPAs based on Law 102 and thus could be outlawed. But forcefully turning back the clock would not be easy or even ethical given many fishers are burdened with poverty or lack of alternative income generating opportunities [18].

While the use of net fishing was proportionally the same for fishers living inside and outside the MPAs, the same did not apply in relation to observations of megafauna entanglement in nets. Dugongs, for example, were much more commonly observed in nets by fishers living outside the MPAs. There are at least three potential hypotheses that might explain this. The first is that the density of dugongs was lower in the fishing grounds of the fishers living inside the MPAs compared with fishers living outside. This cannot be conclusively determined because there are no quantitative data on the density of dugongs in the Egyptian Red Sea [30]. The second hypothesis is that fishers living inside the MPAs are using different types of gill nets or setting nets in different habitats compared with those living outside the MPAs. This is unlikely, as we found no evidence for such behaviour. The third hypothesis is that more fishers living inside the MPAs are aware of the protected status of dugongs and were fearful of admitting observing dugongs and other protected fauna in nets. This would not be inconsistent with the findings of Kiszka et al. [35] and Silva [36] from locations outside the Red Sea.

Although a greater proportion of fishers living outside the MPAs had caught sharks, turtles and dugongs in nets, a dishearteningly high proportion of fishers living inside the MPAs had also observed these animals in nets. We found 76%, 71% and 20% of fishers living in the MPAs had caught sharks, turtles and dugongs in nets, respectively. The consequences of bycatch on populations of these animals in the MPAs and the potential to reduce bycatch are discussed later in the paper.

We also compared the proportion of fishers inside and outside the MPAs who had eaten and collected turtle eggs. These comparisons

are particularly insightful because, unlike bycatch, fishers cannot argue that collecting or consuming eggs is an accident as opposed to a deliberate act. We found that a greater proportion of fishers living outside the MPAs were collecting and eating turtle eggs compared with fishers living inside. We speculate that the presence of MPA staff may be deterring some fishers living inside the MPAs from undertaking these activities. However, further research is required to test this hypothesis. In many areas of the world, the simple presence of MPA staff has not necessarily lead to positive conservation outcomes in regards to turtles [37].

Elba NP 2006 versus 2013

The proportion of fishers in our study who admitted to having observed turtles in their nets was almost identical to that reported by fishers from Elba NP about ten years earlier [21]. In contrast, the proportion of fishers who had caught dugongs in this study (18%) was much higher than the 9% reported in the earlier study. One hypothesis to explain this is that fishing practices have changed since the earlier study. Whereas Marshall et al. [18] reported that only 16% of fishers in Elba NP used nets in 2006, our study indicated that nearly 100% used nets at least some of the time.

Effectiveness of Egyptian MPAs to protect megafauna

Egypt has six MPAs in the Red Sea, which are supported by hard-working and professional staff. However, as we described in this study, Wadi El Gamal and Elba NPs are not providing comprehensive protection to marine megafauna from fishing and other activities. The effectiveness of Egypt's other four MPAs at protecting megafauna has not been assessed or easy to predict. Without data, we can only offer a qualitative assessment of the other MPAs based on our current understanding of what is happening in Wadi El Gamal and Elba NPs, and what activities are permitted in MPAs under Egyptian policy and law.

The Northern Islands NP allows some fishing, but the intensity of net fishing and bycatch has not been quantified. In contrast, Ras Mohammed NP is closed to all forms of fishing and other extractive type activities throughout its boundaries [38]. Nabq Managed Resource Protected Area (MRPA), in the Gulf of Aqaba, has a network of no-take zones [38], but so called 'traditional artisanal fishing' is permitted in other zones [39]. Similarly, Abu Galum Protected Area, in the Gulf of Aqaba, also allows 'traditional artisanal fishing' under EEAA policy [39]. Not only is this policy inconsistent with the wording of Law 102, but the phrase traditional artisanal fishing has not been formally defined by the local authorities. Consequently it is difficult to determine who is allowed to fish in these MPAs under EEAA policy, and what fishing practices, such as netting, can or cannot be used. One reason why this term may not have been defined is that the adjective 'traditional', like 'artisanal', can lead to a false sense of security because it implies that an activity, in this case fishing, is ecologically benign. But this is not necessarily the case. Kwan [40], for instance, found that Indigenous hunting of dugongs in the Torres Strait had potential for over-harvesting and Hawkins and Roberts [41] reported impacts to Caribbean corals reefs from artisanal fisheries. More recently, Moore et al. [32] highlighted the widespread impact to marine mammals from artisanal fisheries.

One definition of the word 'tradition' is "the handing down of statements, beliefs, legends, customs etc., from generation to generation, esp. by word of mouth or by practice" [42]. This begs the question, is the use of fishing lines and nets made of nylon, or boats with outboard

engines consistent with the phrase 'traditional fishing' especially given the uptake of these tools in the Egyptian Red Sea may be as recent as the 1980s? If the answer is no, then most fishers are technically not allowed in Egyptian MPAs under the current policy [39] let alone under Law 102. Of further concern is that Indigenous or traditional fishers, like other fishers will readily adopt new tools, if affordable, to maximise their catch per unit effort [43]. Without a definition of traditional artisanal fishing, controlling unsustainable fishing practices in Egypt's MPAs will continue to be problematic. Until these and other issues are resolved, it will be difficult to predict how well Egyptian MPAs will afford long-term protection to dugongs, turtles and sharks.

Although it is clear individual dugongs, turtles and sharks are at risk from nets in at least two Egyptian MPAs, we do not know whether the scale of bycatch is having or has had a population level effect on these organisms in Egyptian waters. Factors that hamper this understanding are the lack of quantitative data on the abundance and distribution of these animals, and the lack of data on the number of adult females killed per year. What is certain however is that populations of some of these animals, especially dugongs, are sensitive to declines following the deaths of even a small number of adult females [3].

Effectiveness of Red Sea MPAs protecting megafauna

Over ten years ago there were 75 proclaimed and recommended MPAs in the Red Sea [44] and may have since increased. Theoretically this should bode well for biodiversity conservation in the Red Sea. However, outside Egypt, the level of protection Red Sea MPAs afforded dugongs, sea turtles and sharks remains unknown. We are unaware of similar studies in other Red Sea countries that have assessed the effectiveness of proclaimed MPAs in terms of protecting megafauna. For most Red Sea MPAs their IUCN protected area category, both declared and realised, are not generally published. Further, most appear not to have plans of management articulating the management objectives for dugongs, turtles and sharks or even describing threatening processes and potential mitigation. Without management plans and clearly articulated management objectives, it is difficult to manage MPAs strategically. Further, without management plans it is difficult for the public to hold MPA managers, conservation agencies and governments accountable for failures to achieve management objectives or, conversely, to recognise management successes.

It is reasonable to infer that Egypt's MPAs should afford some of the highest level of protection to megafauna in the Red Sea. Egypt has at long history of MPA management beginning with the establishment of Ras Mohamed NP in 1983 [39] and all Egyptian MPAs contain protected area offices and or coast guard stations. Professional and dedicated rangers support these MPAs. Further, Egypt has a solid legal foundation to protect these animals inside and outside MPAs [21,25,39]. Nevertheless, at least two of Egypt's MPAs are not affording comprehensive protection to marine megafauna. For this reason, it is unlikely that better levels of protection are being afforded megafauna in MPAs in other Red Sea countries, especially those currently experiencing civil conflict, or have negligible budgets for marine conservation and where there is increasing human populations in coastal environments.

Moving forward

Marsh et al. [3] noted that one of the first steps towards addressing the conservation needs of dugongs is 'problem recognition and definition'. Our study is that first step because it highlights the limitation of at least two MPAs to protect dugongs, turtles and sharks from nets in the Egyptian Red Sea. It confirms the conclusion of an earlier study

that Elba NP was not affording protection to dugongs and turtles due to the presence of fishers using nets [21]. The present study also confirms the earlier prediction by Rouphael et al. [21] that Elba NP may not be the only MPA in the Red Sea failing to achieve conservation objectives relating to dugongs, turtles and sharks.

Now that the risk of bycatch is known within some Egyptian MPAs, the next questions are 'does the Egyptian community want to stop bycatch in its MPAs and, if so, 'how to stop it? Answering the first question is not as straightforward as it first seems. Stopping bycatch in Egypt's MPAs, as in MPAs worldwide, will come at a political and monetary cost [45]. Political cost is associated with unpopular decisions, such as instructing fishers to end net fishing in MPAs. Without support from the broader Egyptian community, the Government may be unwilling to take such action. Monetary cost may include compensation to fishers who surrender their gill nets [46] and the cost needed to effectively monitor and enforce a regulation banning nets. There is also the potential cost to assist those fishers affected by a ban on netting to adopt fishing practises that pose less risk to megafauna, or to find alternative income generating activities.

An obvious answer to the second question is to try to avoid megafauna coming into contact with gill nets, either by excluding nets from all areas in MPAs or only from critical habitat. The latter would be similar to an approach adopted by Australian authorities in the Great Barrier Reef Marine Park [20]. Net exclusion areas might be a desirable compromise to a complete exclusion of nets, but will be difficult to implement successfully without long-term data on the abundance and distribution of dugongs, turtles and sharks. Such data are needed to identify critical habitat that can sustain populations of these animals. A further complication with this approach is that critical habitats for these organisms will not always overlap [13] and thus net exclusion areas might need to cover a large proportion of a MPA to be effective.

Lastly, this debate brings into question the utility of Government funded MPAs as the principle conservation mechanism to protect megafauna populations in the Red Sea. The current reliance on Government funded MPAs to deliver marine conservation objectives may need to be reviewed in light of this and other studies showing the limitation of MPAs when regulatory compliance and community support maybe lacking or where threatening processes, such as net fishing, are legally permitted in MPAs [9]. Such a review should be seen as a positive opportunity for agencies to improve MPA governance or trial other methods that may have a greater level of success in providing sustained protection of megafauna while minimising impacts to local fishing communities.

Acknowledgements

Comments from Marina Costa, Celia Gruenthal, Zaher Agwan, Yasser Said and two anonymous reviewers greatly improved this paper. Marina Costa generously provided shapefiles of Elba and Wadi El Gamal NPs. Colin Reeves created Figure 1. Islam Mohammad Elsadek and other colleagues from the Red Sea Protectorate helped during the planning stage of this study. Members of Nature Conservation Egypt, especially Mindy Baha El-Din, encouraged and helped facilitate this project. This work was funded by a small grant from the International Coral Reef Initiative (ICRI). Anne Caillaud, from the Great Barrier Reef Marine Park Authority, kindly assisted us with the administration of the grant transfer. Dr. Fouda is also thanked for his encouragement.

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