Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008
Session number 18

Ecological patterns and status of the reefs of Sudan

R. Klaus[1], J. Kemp[1], M. Samoilys[1,2], H. Anlauf[1], S. El Din[3], E.O. Abdalla[3], T. Chekchak[1]

1) Equipe Cousteau, 92 Avenue Kleber, 75116 Paris, France
2) CORDIO East Africa, P.O.BOX 24562, Karen 00502, Nairobi, Kenya
3) Red Sea University, Port Sudan, Sudan

Abstract. Sudan borders the western shore of the Red Sea, a sea recognised as being of global importance for marine biodiversity. A survey carried out during October / November 2007 provided the opportunity to assess the current status of the reefs, many of which have never previously been surveyed. Within the Sudanese Red Sea there is a pronounced biogeographical transition from reef communities that are characteristic of the northern Red Sea to those more representative of the southern Red Sea. Recreational and extractive use of resources is still moderately low however the condition of the reefs and the abundance of resources is highly variable. There are low abundances of several key families of commercial fin fish (particularly groupers and larger snappers) and invertebrate groups (particularly sea cucumbers and larger gastropod molluscs). There is also a conspicuous absence of sea urchins (*Diadema* spp. and *Echinometra* spp.) from many sites. The reefs of Sudan were impacted by previous coral bleaching events, although the extent of mortality was influenced by variability in community composition and local environmental conditions. The biogeographic trends within Sudanese waters and the variability in resource abundance and reef condition all have important implications for management planning.

Key words: Red Sea, sea urchins, coral bleaching

Introduction

The Sudanese Red Sea supports an extensive near-continuous fringing reef, a complex offshore barrier reef system, and numerous uninhabited islands. While some of the more accessible reefs, such as those in the vicinity of Port Sudan and Sanganeb Atoll, have previously been the subject of research (Head 1980, Merger & Schumacher 1985, Edwards & Head 1987, Reinicke et al. 2003), and others are renowned tourism dive sites (e.g. Sha'ab Rumi), many of the reefs have never previously been surveyed. More recent survey efforts focused on the establishment of two marine parks at Dungonab Bay and Mukawwar Island National Park (DBNP) (surveyed in 2002 and 2006) and Sanganeb Atoll Marine National Park (SMNP) (surveyed in 2006) (Fig. 1) improved the understanding about the current status of the reefal communities within these areas (Kemp et al. 2002, PERSGA/GEF 2004, APF 2006).

In 2007 a more geographically comprehensive habitat and biodiversity baseline survey was carried out on some of the un-surveyed reefs in the Sudanese Red Sea. The survey was part of the first phase of a larger programme which aims to link poverty alleviation and the protection of the environment of the Sudanese Red Sea through the implementation of Integrated Coastal Zone Management (ICZM). The ICZM programme, led by Equipe Cousteau, and is part funded by the European Commission in co-operation with a consortium of partners including the Higher Council for Environment and Natural Resources (HCENR) of the Red Sea State of Sudan, UNESCO, and PERSGA (The Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden). This paper presents the preliminary results from the baseline survey that will be used to assist the Government of Sudan to manage the anticipated developments in the coastal region.

Methods

During a four week boat based survey (October—November 2007) on board the MSY Elegante a survey team collected data on the habitats and biodiversity associated with coral reefs along the Sudanese Red Sea coast. The survey area spanned approximately 195 km of coast north to south, and extended approximately 75 km west to east, across 2° of Latitude (between 20°28'N and 18°45'N) and 1° Longitude (between 37°11'E and 38°10'E).

A combination of survey methods was adopted similar to those used elsewhere in the Red Sea and Gulf of Aden region to characterize and map the distribution and status of coastal and marine habitats and associated species assemblages. This paper considers the results of the detailed transect based surveys that were completed at 40 sites along the Sudanese coast. At each of these sites a team of surveyors completed a modified version of the Reef

Check survey protocol which included: (i) video transects to characterize the benthic cover (4 replicate 20 m transects); (ii) timed swims to record the diversity of hard coral species; (iii) belt transects to assess the abundance of key macro-invertebrates (4 replicate 20 m by 2m wide belt transects) and (iv) belt transects using an underwater visual census (UVC) method to record abundance estimates and / or species presence / absence data on indicator fish groups and fisheries groups (4 replicate 5 m belt transect counts, and timed swims). Data collected included: (i) Abundance of butterflyfishes and angelfishes (all individuals identified to species level), (ii) Abundance of groupers, snappers, emperors, parrotfish, (iii) Abundance of Napoleon wrasse and moray eels, and, (iv) Species richness of surgeonfish, triggerfish, damselfish, and wrasse.

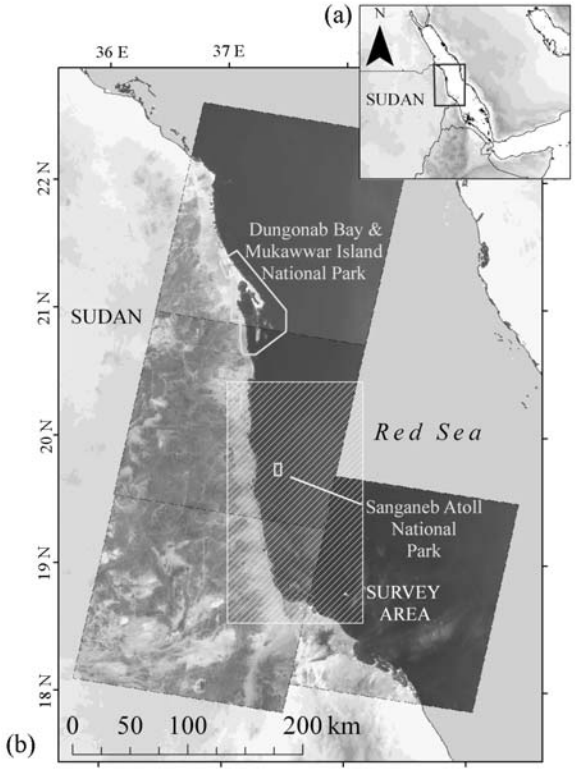

Figure 1: Map showing (a) the location of Sudan (Red Sea) and (b) The Sudanese Red Sea coast and the location of the existing marine protected areas at Dungonab Bay and Mukkawar Island National Park (DBNP) and Sanganeb Atoll Marine National Park (SMNP) and the 2007 survey area (hatched box).

Results

A total of 40 detailed transect sites were surveyed in 2007 and the key findings were as follows:

Benthos

Coral communities in the Sudanese Red Sea support more than 290 species, and transition between those communities characteristic of the northern/central Red Sea and those more typical of the southern Red Sea. Live hard coral cover on the fore reef slopes varied between 11% and 65% (Fig. 2a), and there were notable trends both north to south, and inshore to offshore, while more unusual high cover coral communities were found in sheltered shallow turbid areas. Reefs north of Port Sudan had a significantly lower cover of live stony corals, a higher abundance of both dead standing corals colonised by turfs or coralline algae, and rubble. The extensive mortality of corals on these reefs may of been due to a range of factors (e.g. coral bleaching, Crown-of-Thorns, *Drupella*), but is most likely due to coral bleaching during late 1998, as occurred on the around Dungonab (Kemp et al. 2002) and at similar latitudes on the reefs on the eastern Red Sea (DeVantier et al. 2000a, 2000b). By comparison, southern and offshore reefs supported higher live coral cover and healthy communities of bleaching susceptible species (e.g. *Acropora, Stylophora*), suggesting that these reefs may have avoided the major bleaching events of the past 10 years, most likely due to differences in the local environmental conditions.

Fishes

Pronounced north-south patterns in community structure were apparent, consistent with known patterns in Red Sea biogeography (Fig. 2b). Fish communities however also had very low abundances and diversity of lutjanids (snappers), lethrinids (emperors), serranids (groupers) and scarids (parrotfish) and other groups, which may be a result of overfishing, second-order coral mortality / bleaching effects, or a combination of both these factors (Fig. 2 c). Abundances of exploited species were particularly low in the Suakin archipelago.

Macroinvertebrates

Sea cucumber abundances were very low, suggesting that this group is heavily overfished. This is probably a recent development (within the past 6 to 8 years). Molluscs such as *Trochus* (*Tectis*), *Murex, Lambis* and *Strombus* were absent or present in very low abundance throughout the survey area, whereas *Tridacna* were common or abundant.

Sea urchins (*Diadema* spp. and *Echinometra* matthaei) were almost completely absent in the north and central parts of the survey area, and present only in very low densities in the southern area (Fig. 2 d).

Other Impacts and Threats

Coral diseases and sponge infestations were observed but these were not widespread, although incidents appear to have increased both within Sudan and the wider region in recent years (Klaus pers. obs.). Corallivores such as the Crown-of-Thorns starfish

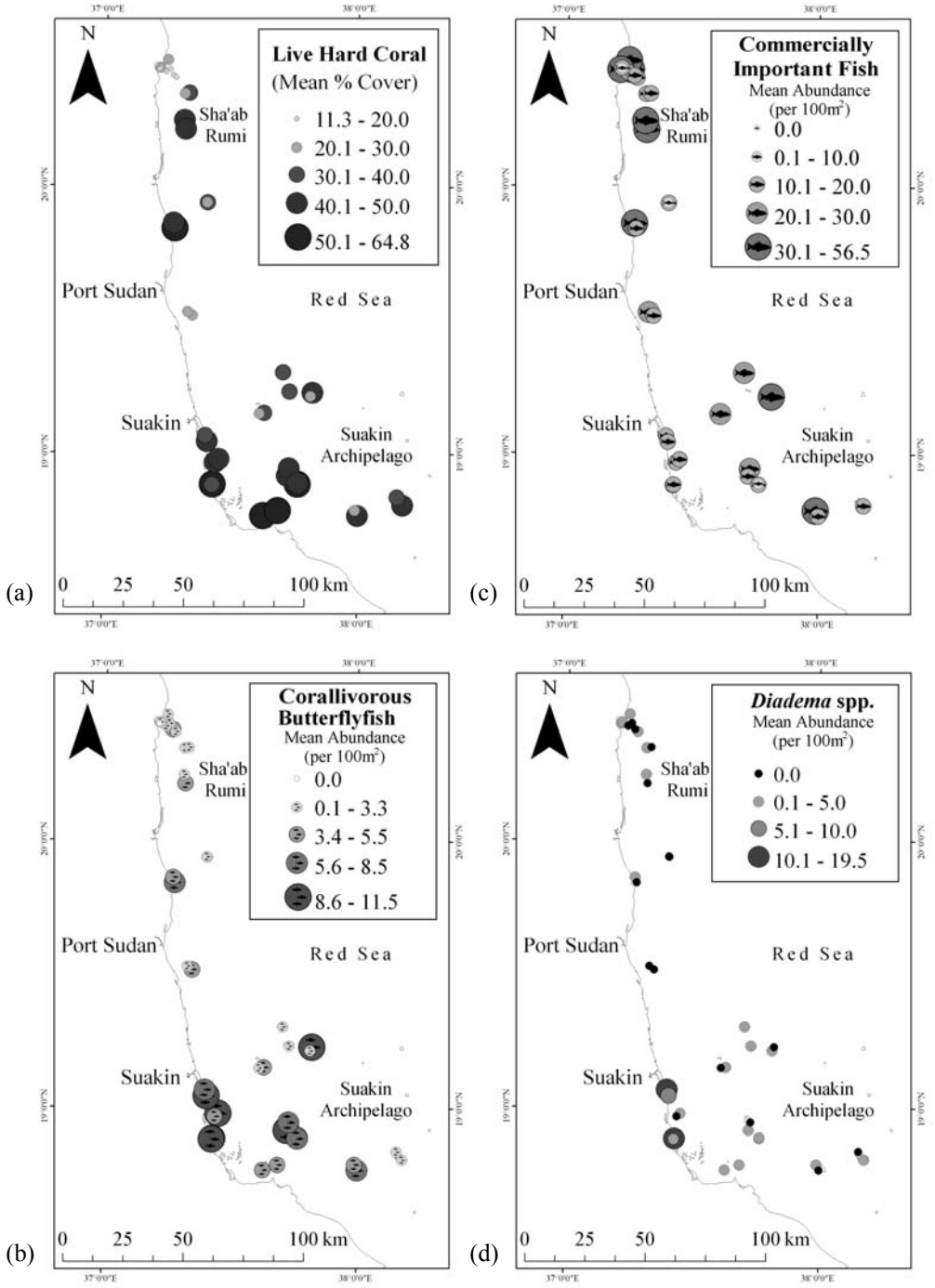

Figure 2: Maps showing some of the key findings from the 2007 survey (a) Mean percent live hard coral cover, (b) Mean abundance of corallivorous butterfly fishes (per 100m^2), (c) Mean abundance of commercially important fishes (per 100m^2) and (d) Mean density of *Diadema* spp. (per 100m^2)

(CoTs), *Acanthaster plancii* and *Drupella* spp. were found at most sites, numbers were generally low, and active outbreaks of CoTs were only found at two sites.

There were low abundances of commercially important fin fish (particularly groupers and large snappers) and invertebrates (sea cucumbers and gastropod molluscs).

Discussion

The composition of the benthic and fish communities found on Sudan's reefs reflects the influences of both the northern and southern Red Sea. Unusual, localized, 'geographically displaced' fish and coral communities may provide opportunities to understand the factors giving rise to biogeographic patterns in the region, and perhaps more widely (Kemp & Klaus, in prep).

The status of the coral communities on both the fringing and offshore coral reefs was highly variable, ranging from poor to good. Reefs to the north of Port Sudan had lower live coral cover and a higher abundance of both rubble and dead standing corals, colonised by turf and coralline algae, and the appearance characteristic of reefs that had been subject widespread coral bleaching event. Although there are few documented observations in the Red Sea during the severe 1997/1998 bleaching event that devastated large parts of the wider Indian Ocean, coral bleaching was observed on the reefs of northern Sudan at Dungonab (Kemp et al. 2002) and on Saudi Arabian reefs at similar latitudes in the eastern Red Sea in August-September 1998 (DeVantier et al. 2000a, 2000b). Corals on fringing and offshore reefs in the Dungonab area were observed to bleach in 1998, and the reefs were reported to be "*so bright white as to be visible from the shore",* while the weather conditions were "*calm and very hot*" (Andrea Bari [*of Dungonab Pearl Oyster Farm*], pers comm February 2002). The first systematic surveys in Sudan following the 1998 event were carried out along a 70 km section of coast in the Dungonab area to the north of Port Sudan in 2002 as part of the baseline surveys for the establishment of Dungonab Bay and Mukawwar Island Marine National Park (Kemp et al. 2002). By comparison, many reefs south of Port Sudan and offshore, showed little evidence of widespread impacts, still supported a high cover of live hard corals, including healthy communities of bleaching susceptible genera, suggesting that these reefs may have avoided exposure to the environmental conditions that caused coral bleaching and mortality on the reefs further north. The patterns in coral cover are reflected in the abundance of corallivorous butterfly fishes and other groups.

Other impacts included CoTs and *Drupella,* although these typically affected smaller patches of reef and their contribution to the spatial variability in the current status of Sudanese reefs was considered to be minor by comparison to the previous bleaching event. Minor outbreaks of CoTs have been recorded in Sudan since the 1970s, and they were present at low abundances throughout the areas surveyed (Kemp et al. 2002, PERSGA/GEF 2004, APF 2006, Cousteau 2007). The most severe outbreak observed during the three surveys undertaken between 2002 and 2007 extended across less than 200m of reef. The widespread coral mortality observed on the northern reefs was concentrated at depths of less than 10m, in contrast to coral mortality caused by CoTs outbreaks in, for example, Sinai, where outbreaks often begin at depths as great as 50m or more and, cause extensive coral mortality to similar depths (Salem 1999). *Drupella* was present at low densities throughout the survey area, and only observed at high densities in very specific habitats in Sudan (shallow areas of high density of *Stylophora* corals) (Kemp et al. 2002, 2003, APF 2006, Cousteau 2007).

Large snappers, groupers (*Epinephelus* spp. and *Plectropomus* spp.) and emperors (lethrinids) are taken by handline fisheries in Sudan. Their absence or very low abundance on most reefs suggests heavy fishing pressure. The low abundance and diversity of parrot fish is less easily explained since they are not targeted in local fisheries. Possible causes may be their dependence on healthy coral reef habitats and lag effects of coral bleaching on fishes (Graham et al. 2007).

The extremely low abundance of many commercially important species of holothurians, and the absence or low abundance of some exploited gastropods suggests that overfishing of these macro-invertebrate groups is widespread.

The complete absence of the common sea urchins (*Echinometra* spp. and *Diadema* spp.) from many reefs is a cause for concern, which reflects the trends recorded by the Reef Check programme (Hodgson and Liebeler 2002), where significant falls in abundance of *Diadema* were recorded on coral reefs of the Indo-Pacific, including the Red Sea, between 1998 and 2001. Historical data on distribution and density of sea urchins in the Red Sea, especially of the important species *Diadema setosum*, is limited, but abundances may be naturally low on some of the offshore deep water reefs. The absence of *D. setosum* from Sanganeb was repeatedly noted by Schuhmacher (1974, 1989) and Kroll, in Schuhmacher *et al. (*1995). The same authors did however note that *Diadema* "is abundant in the northern Red Sea, where it plays a major role in controlling reef development". Reef tops without urchins were, uncharacteristically for the Red Sea, overgrown with small macroalgae, a possible consequence of reduced grazing from both parrot fish and sea urchins. There is no immediately obvious reason for the absence of sea urchins as they were still common in some areas, primarily sheltered, relatively turbid inshore locations such as the large lagoon at Sha'ab Shubuk. These findings require further investigation.

The Future

Until recently, the Sudanese coast has remained

relatively unaffected by the coastal development activities taking place in other countries of the Red Sea. Anthropogenic influences are still mainly limited to a 70 km strip extending from Port Sudan to Suakin, where there are two major ports, oil refineries, a desalination plant, saltworks, power station, a shrimp farm and the new Red Sea Economy Free Trade Zone (although increased development has also recently begun to spread northwards from Port Sudan). The damage to coastal habitats due to construction within this strip is already extensive, and major industrial facilities have been sited with little or no regard to their potential negative environmental impact. Following the peace agreement which brought the war in the south of Sudan to an end, and the recent discovery of oil and gas reserves, rapid coastal development is likely to cause unprecedented economic transformation that will result in a surge in coastal development and associated risks.

Most of the coastal and offshore reef complexes are still relatively undisturbed by human pressures other than fishing. There is a small dive tourism industry, composed of between 8 and 10 boats operating out of Port Sudan and from Egypt. Further rapid development of tourism and other sectors is anticipated as more investors are attracted to Sudan. The increasing development will make the Sudanese coastline more attractive and accessible to the wider foreign and local public. The new coast road from Port Sudan to Egypt is nearing completion, making huge areas of previously relatively undisturbed coast easily accessible, and creating the opportunity for development to the north of Port Sudan but with all the associated risks to coastal habitats.

The focus of future development is likely to continue to be between Port Sudan and Suakin, and the coast between Port Sudan and the Dungonab Bay MPA. The results of this survey suggest that the reefs of Sudan are already suffering from overfishing and coral bleaching mortality, among other impacts. It is therefore of paramount importance that Sudan's designated Marine Protected Areas are given high priority, and that fisheries management plans be implemented. The need for effective planning, and a strategic approach which incorporates considerations of environmental sustainability, is urgent.

Conclusions

Sudan's 750 km long coastline and numerous uninhabited islands and offshore reefs are within the centre of marine diversity in the Red Sea. The country has two MPAs with great potential for UNESCO World Heritage status. Developments in and around Port Sudan are expanding, and the port in this city provides the only maritime access to a country that is otherwise land-locked. The ICZM Programme is uniquely situated to help mitigate future conflicts that may arise over natural resource use, distribution and over-exploitation. This survey is partly responding to the urgent need to provide decision makers with the tools and information necessary to manage the predicted development of the coastal area, whilst protecting its natural heritage.

Acknowledgements: This publication has been produced with the assistance of the European Commission. The contents are the sole responsibility of the authors and can in no way be taken to reflect the views of the European Union. Equipe Cousteau, founded by Captain Jacques-Yves Cousteau in France in 1982, is the sister organization to the Cousteau Society, a not-for-profit organization created in 1973 in the US.

References

African Parks Foundation (2006) Survey Report: Sudan Marine Parks Expedition 2006. Dungonab Bay and Mukkawar Island National Park & Sanganab Atoll Marine National Park. 2 volumes (121pp and 116pp). African Parks Foundation, Netherlands, 2006.

DeVantier, L., Turak, E., Al-Shaikh, K. and De'ath, G. (2000a) Coral communities of the central-northern Saudi Arabian Red Sea. *Fauna of Arabia* 18: 23-66.

DeVaniter, L., Turak, E., Al-Shaik, K. (2000b) Coral bleaching in the central northern Saudi Arabian Red Sea, August-September 1998. In Abduzinada, A., Joubert, E., Krupp, F. (Eds): *Proceedings of an international symposium on the Extent and Impact of Coral Bleaching in the Arabian Region. Riyadh (5th-9th February 2000)*: 110-127.

Edwards AJ & Head SM (Eds) (1987) *Red Sea*. Pergamon Press, Oxford, 441pp.

Mergner H & Schumacher H (1985) Quantitative Alalyse von Korallengemeinschaften des Sanganeb Atolls (mittleres Rotes Meer) I. Die Besiedslungs-Struktur hydrodynamisch unterschiedlich exponierter Auben-und Innenriffe. *Helgolander Wisenschaftliche Meeresuntersuchungen* 26:238-358.

Graham NAJ, Wilson SK, Jennings S, Polunin NVC, Robinson J, Bijoux J.P, Daw T.M (2007) Lag effects in the impacts of mass coral bleaching on coral reef fish, fisheries, and ecosystems. Conserv Biol 21:1291–1300

Head SM (1980). The Ecology of Corals in the Sudanese Red Sea. Ph.D. thesis. University of Cambridge.

Kemp J, Klaus R, Salem M, Awadalla Y, & Saleh B (2002) Survey of the Proposed Marine Protected Area at Dunganob Bay and Mukkawar Island, Sudan. PERSGA SAP Component 5 A Regional Network of Marine Protected Areas. 164p.

PERSGA/GEF (2004) Dungonab Bay–Mukawwar Island Proposed Marine Protected Area: Site-Specific Master Plan with Management Guidelines. PERSGA, Jeddah.

Reinicke GB, Kroll SDK, Schuhmacher H (2003) Patterns and Changes of Reef-Coral Communities at the Sanganeb-Atoll (Sudan, Central Red Sea):1980 to 1991. Facies 49:271-298

Salem, M. (1999) Management of fishing in the Ras Mohammed National Park, with special reference to the fishery for *Lethrinus nebulosus* (Forsskal, 1775). PhD Thesis, York. 272p.

Schuhmacher H (1974) On the conditions accompanying the first settlement of corals on artifical reefs with special reference to the influence of grazing sea urchins (Eilat, Red Sea). Proc of the 2nd Int Coral Reef Sym 1:257-367

Schuhmacher H (1989) Development of coral communities on artificial reef types over 20 years (Eilat, Red Sea). Proc 6th Int. Coral Reef Symp 3:379-384.

Schuhmacher H, Kiene W, and Dullo W (1995) Factors controlling Holocene reef growth: an interdisciplinary approach. Facies 32:145-188.