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Coral Reef Benthos and Fisheries in Tanzania Before and After the 1998 Bleaching and Mortality Event

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***Abstract*—**Surveys conducted in the 1980s and early 1990s indicated that coral reefs in Tanzania were being degraded by overexploitation and destructive resource harvesting practices, particularly dynamite fishing and the use of dragnets, with concomitant reduction in fish abundance. Despite reduction in dynamite fishing on most parts of the Tanzania coast, recent coral reef surveys (1999 and 2000) have indicated that live coral cover and the health of reef corals were further degraded by the 1998 coral bleaching event. The extent of coral mortality differed between areas and species. Although the relative contribution of some taxa such as acroporids and pocilloporids decreased on most reefs surveyed, there was no evidence of species extinction. Despite extensive coral mortality, there has been little evidence to suggest decline of reef fish abundance of commercial and artisanal fish catches. In many areas the dead reef structure has remained largely intact three years following the bleaching event. Coral recovery through growth of the surviving colonies and new coral settlement has been observed in all sites, but at different levels. The surviving *Montipora*, *Echinopora* and some *Fungia* were recovering faster than others in some sites. Studies in Mafia, Bagamoyo, Dar es Salaam and Tanga showed that pocilloporids had the highest number of recruits. Faster recovery will, however, depend on the level of natural and human disturbances in the near future. Appropriate reef management strategies, such as enforcement of existing regulations and establishment of more marine protected areas would help to prevent further coral reef degradation. Initiation of coral reef restoration programmes may also enhance the recovery process. Capacity building for coral monitoring/research and appropriate infrastructural support for coral reef ecosystem conservation would also bring noticeable improvement.

INTRODUCTION

Fringing and patchy reefs occur along much of the Tanzania coast (Fig. 1). Due to the narrowness of the continental shelf, the majority of the coral reefs are near-land, and as a result, the reefs are strongly subjected to human influences directly from land-based activities/processes as well as from unsustainable and destructive resource extraction practices (Bryceson, 1981; UNEP, 1989; Johnstone et al., 1998b). In 1998, coral bleaching and mortality occurred and resulted in further degradation of coral reefs in Tanzania (Mohammed et al., 2000; Muhando, 2001).

Coastal communities as well as coastal tourism depend heavily on coral reefs (Johnstone et al., 1998a). Furthermore, reef areas are widely used for fishing, particularly near coastal towns where finfish, shellfish, lobsters, octopus, mussels, ornamental and edible molluscs are collected for home consumption, sale to tourists and for export (Kudoja, 1985; Salvadori, 1985; Muhando, 1998; Johnstone et al., 1998b).

Environmental factors or ecological processes that impact negatively on coral reefs, whether originating from human disturbances or occurring naturally, deserve attention, as they may affect the ecology and the socioeconomic welfare of the

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coastal communities. Detailed and continuous information on the status of the coral reefs (and the entire coastal resource base) is a prerequisite to any development and conservation management process.

A number of coral reef surveys/studies have been conducted in Tanzania, though not consistently, since 1965. Most of the early studies were descriptive, and only a few dealt with the biology and ecology of reef organisms. Furthermore, only a few reef sites were studied, most of them located near urban centres or in the vicinity of university colleges. Some of the information from these studies has been used in coral reef management programmes, specifically in the establishment of marine protected areas.

This article synthesises the various findings from reefs surveys conducted before and after the 1998 El Niño-related coral bleaching event. It also attempts to quantify the magnitude of change on some reef benthos after 1998 and summarises the current status of coral reefs of Tanzania.

DATA COLLECTION

The coral reef environmental and resource information before the 1998 coral bleaching event was obtained/deduced from survey and research reports dating as far back as 1965. Most of the information on Pemba Island (Misali) and Unguja Island (Chapwani, Changuu, Bawe, Chumbe and Kwale) reefs (Fig. 1) was obtained from the Institute of Marine Sciences coral reef database, which was initiated in 1996. Information on the Dar es Salaam Marine Reserve (Mbudya and Bungoyo) reefs (Fig. 1) was based mainly on previous surveys (Hamilton, 1975; Kamukuru, 1997; McClanahan et al., 1999). Information in the Mafia Island Marine Park (Tutia, Mange and Juani) reefs was obtained from studies carried out by the Institute of Marine Sciences in collaboration with Frontier-Tanzania and Swedish scientists (Horrill & Ngoile, 1991; Öhman, 1999; Öhman et al., 1999). Information on Kilwa and Songo Songo (Pwayasi, Pwakuu, Jewe and Amana) and Mnazi Bay (Chamba cha Chumbo and Chamba cha Kati) coral reefs was deduced from Frontier-Tanzania survey reports (Darwall et al., 1996; Guard et al., 1998), while information on Tanga coral reefs was

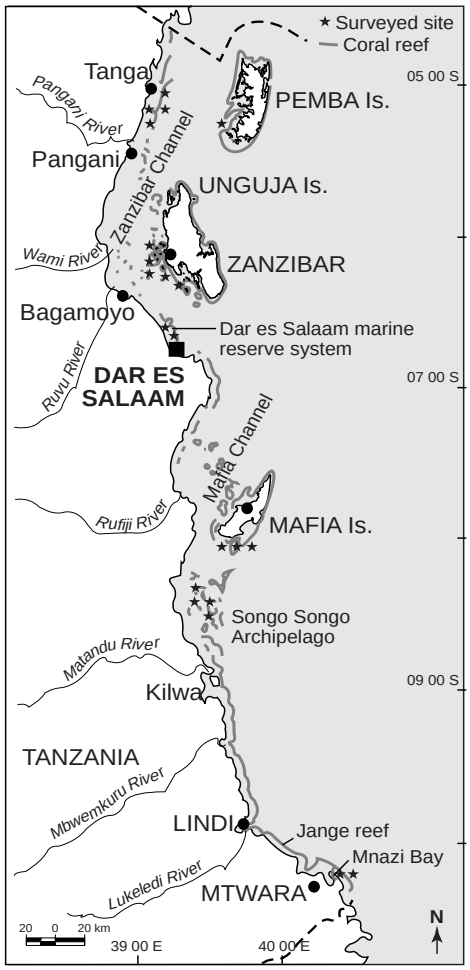


Fig. 1. Distribution of coral reefs along the Tanzania coast and location of surveyed sites

obtained from Tanga Coastal Zone Development and Conservation Programme library. Historical and research information on marine protected areas was obtained from various published and grey literature available at various libraries in Tanzania and Sweden.

The post-bleaching coral reef information was obtained during the 1999 countrywide coral reef surveys/monitoring programme sponsored by Coral Reef Degradation in the Indian Ocean, CORDIO project (1999–2001) and carried out by the Institute of Marine Sciences scientists (see Mohammed et al., 2000; Mbije, 2001). This monitoring programme targeted reef areas that were previously surveyed or studied before the

1998 coral bleaching event. At each site, the various benthic cover categories (as in English et al., 1994) were estimated using random (at least nine 50-m) and permanent (at least nine 10-m) transects. The line-intercept transect method (English et al., 1994) was used to estimate benthos on permanent transects and line-intercept point method was used on random transects (200 points in a 50-m transect at 25-cm intervals). Transects were set on the reef flat (1–5 m) and reef slope (5–15 m) parallel to the reef front. Macro-invertebrates were counted in a 50-m long x 2-m wide belt transect, while fish were counted in a 50-m long and 5-m wide belt transect on the reef flat and slope. Coral cover information before and after the bleaching event was obtained using similar methods, hence reef site data were compared without standardisation.

CORAL REEF BENTHOS AND FISHERIES BEFORE AND AFTER THE 1998 BLEACHING AND MORTALITY EVENT

The coral reef area in Tanzania is very extensive and only few areas have been surveyed and their status reported. A number of coral reef surveys aiming at describing or assessing different aspects of coral reef health and ecology have been conducted. Some of these studies include: Talbot (1965), Hamilton (1975), Hamilton & Brakel (1984), UNEP (1989), Ngoile (1990), Horrill and Ngoile (1991), Horrill (1992), Horrill et al. (1994a, b), Muhando (1995), Darwall et al. (1996), Kamukuru (1997), IMS-LGL Coral Monitoring project (1996–1998), Muhando et al. (1998a), Muhando et al. (1998b); Guard et al. (1998), McClanahan et al. (1999), Muhando (1999), Nzali (1999), Kangwe (1999), Kuguru (2002), Mohammed et al. (2000), Muhando & Francis (2000), Mohammed (2001), Mbije (2001), Muhando (2001).

Coral reef studies in the 1960s and 1970s reported high diversity and luxurious growth of corals and reef resources (Talbot, 1965; Ray, 1968; Hamilton, 1975). Although no complete baseline data on abundance and biodiversity exists, Misali coral reefs in Pemba, Tutia and Mange coral reefs in Mafia and Songo Songo archipelago reefs were ranked high in biological diversity and abundance of reef fish and corals. Other reefs such as Kunduchi reefs, the reefs off Zanzibar town, Menai Bay reefs, reefs in Msimbati and Mnazi Bay in Mtwara and in Tanga were ranked as having medium fish and coral diversity. Surveys in the 1980s and 1990s described a general degradation of the coral reef environment and its resources, mainly due to overexploitation and destructive resource harvesting methods, specifically dynamite fishing and dragnets (Kudoja, 1985; UNEP, 1989; Jiddawi & Muhando, 1990; Ngoile & Horrill, 1993; Muhando, 1995; Muhando & Jiddawi, 1998; Johnstone et al., 1998b; Wagner, 2000). Increase in coastal population, weak economy as well as unplanned coastal tourism and coastal construction have also contributed in coral reef degradation.

The unprecedented coral bleaching and mass mortality, which occurred between March and June 1998, resulted in substantial degradation of coral reefs in Tanzania (Muhando, 1999; Wilkinson et al., 1999; Muhando, 2001). The extent of bleaching and mortality differed between sites and species. *Acropora*, *Pocillopora*, *Seriatopora* and *Stylophora* were among the most affected genera. In some areas the coral cover of *Acropora cyntherea* (on Tutia reef) and *A. humilis* (on Chumbe reef) were reduced substantially (Muhando unpubl. data). This differential mass mortality of corals along the Tanzania coast brought about uncertainties as to the status of coral reefs reported before this event. In 1999, through the Coral Reef Degradation in the Indian Ocean (CORDIO) project, Sida/SAREC bilateral and regional marine science programmes and University of Dar es salaam, coral reef surveys aimed at assessing the extent of coral death, effects on reef macroinvertebrates and reef fish, and socioeconomic effects (tourism and fisheries) after the bleaching event were carried out on reef sites in Pemba Island, Unguja Island, Dar es salaam, Mafia Island, Mnazi Bay in Mtwara, Tanga coast and on the Songo Songo Archipelago (Mbije & Nur, in prep). Changes in live coral cover at different surveyed sites are summarised in Fig. 2. Although only few coral reef areas were surveyed, their wide geographical distribution gives a good representation of the current status of coral reefs in Tanzania.

Misali reefs on the west coast of Pemba

The live coral cover on Misali reefs in Pemba declined from 51–74 % to 7–17 % while the non-living substrate (rubble, rock or sand) increased from an average of 20 % in 1994 to 53 % in 1999 (Fig. 2). The relative cover of other benthic organisms such as fleshy and coralline algae, sponges and soft corals did not appear to have changed much after the bleaching event. Despite coral mortality, reef fish species richness and abundance was high compared to other areas that were less severely affected by the bleaching event (Fig. 3).

Unguja (Zanzibar) reefs

The extent of live coral cover on reefs around Unguja did not show significant decrease, except on Chumbe and Kwale reefs located south of Zanzibar Town, where the coral cover decrease from 51.9 to 27.5 % in 1999 and from 29.7 % in 1997 to 13.3 % in 1999, respectively (Fig. 2). Fleshy algae (mostly *Sargassum, Turbinaria* and *Dictyota* spp. and *Stypopodiun zonale)* increased from 8.8 to 18.4 % on Chumbe reefs and from 16.6 to 26.2 % on Kwale reef. Fleshy algal cover did not change on other sites on Unguja reefs. Despite low mortality of corals, Unguja reefs had the lowest density of fish compared to other reef sites in Tanzania (Fig. 3).

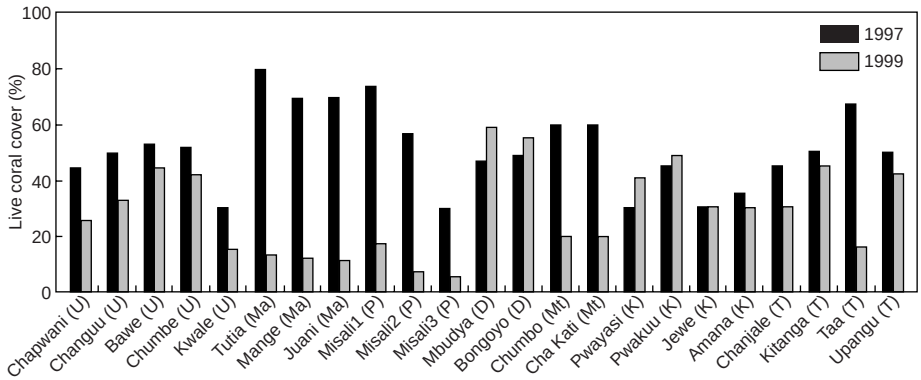


Fig. 2. Changes in live coral cover before and after the 1998 coral bleaching event at selected sites in Tanzania. U, Unguja Is.; Ma, Mafia Is.; P, Pemba Is.; D, Dar es Salaam; Mt, Mtwara; K, Kilwa/Songo Songo; T, Tanga. (Modified from Mohammed et al., 2000 and Muhando, 2001)

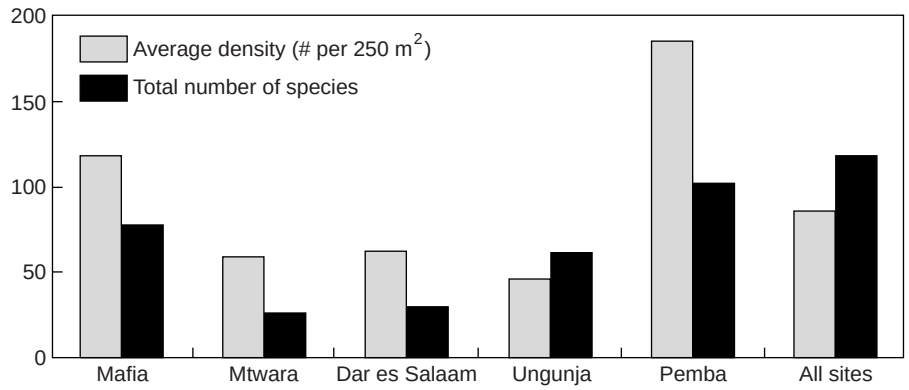


Fig. 3. Relative abundance (# per 250 m^2) and species richness of reef fish on selected reef areas in Tanzania. (Source: Mohammed et al., 2000)

Dar es Salaam Marine Reserve System reefs

The average live coral cover on reefs in Bongoyo Marine Reserve (inside the Dar es Salaam Marine Reserve System) in 1999 was estimated at 55 % (Mohammed et al., 2000) compared to 49 % in 1997 (Kamkuru, 1997) and 70 % in 1974 (Hamilton, 1975). Similarly, recent information on live coral cover for Mbudya Marine Reserve (Mohammed et al., 2000) suggests an increase from 47 % in 1997 (Kamukuru, 1997) to 59 % in 1999 (Fig. 2). With the exception of *Acropora*, other dominant hard coral species, *Montipora aequiturberculata, Galaxea clavus,* massive *Porites* and *Fungia* survived the bleaching event. *Montipora* was rapidly growing over the dead *Acropora* branches, increasing its dominance to 80 % of live hard coral in most areas. The fleshy algae and coralline algal cover was relatively low on both Mbudya and Bongoyo reserves. Corallimorpharian cover was estimated at 13 % on Bongoyo and 6 % on Mbudya in 1999 (Kuguru, 2002). Water visibility was generally low on these reefs because of the soft sediment (mud) deposition at the end of the reef slope. The fish species richness and abundance was the lowest in comparison with other surveyed reefs (Fig. 3).

Mafia reefs

The live coral cover at Tutia reef decreased from 80 % in 1991 to 15.1 % in 1999 while on Msumbiji and Utumbi reefs about 10 km apart (in Chole Bay) the live coral cover was about 30% in 1999. Fleshy algal cover increased substantially on Tutia reef from 1% in 1996 (pers. obs.) to (15 %) in 1999. The most abundant algal genera were *Stypopodium zonale*, *Turbinaria*, *Dictyota* and *Surgassum*. Abundance of soft corals on dead table *Acropora* (*Acropora cyntherea* and *A. hyacinthus*) was noticed on sites experiencing strong tidal currents on Tutia reef. As in Misali reef, the reef fish abundance was high (Öhman, 1999; Bergman et al., 2000; Öhman et al., 1999; Lindahl et al., 2001; Fig. 3) despite higher mortality of corals (Fig. 2). The water transparency on Mafia sites was higher than observed on other surveyed reefs.

Mnazi Bay reefs

Live coral cover on Chumbo (Chamba cha Chumbo) and Kati (Chamba cha Kati) decreased from 55 and 60 % in 1997 (Guard et al., 1998) to 28 and 42 % respectively. Most of the area was covered by rock substrate with high potential for coral settlement. The amount of dead coral was estimated to range from 9 % on Chumbo to 10 % on Kati reefs. The highest cover of sponges (22 %) was observed on Chumbo reef. However, coralline and fleshy algal cover was relatively low on all monitored sites in Mnazi Bay.

Tanga reefs

Results from four monitored reefs (Upangu, Taa, Chanjale and Kitanga) showed an average live coral cover decrease from 67 % in 1997 to 12.5 % in September 1999. The biggest decreases were associated with reefs with highest original cover. Invertebrate counts, including of sea urchins, have been relatively stable despite the increase in substrate for growth of filamentous algae. Reef fish counts have shown marked increase in siganids and other herbivores (Chris Horrill, pers. comm.)

Songo Songo archipelago reefs

Coral reef surveys on some coral reefs in the Songo Songo archipelago in March 2000 (N. Mbije and M. Nur of IMS, pers. comm.) revealed the live coral cover to range from 25–50 % compared to 20–55 % reported in Darwall et al. (1996), implying that coral mortality was lower here compared to Misali and Tutia reefs. Higher coral mortality was observed on reefs located offshore than on inshore reefs. No information exists on reef fish status from the Songo Songo area.

In summary, coral degradation was highest in areas previously described as excellent (e.g., Misali, Tutia). Invertebrate counts including those of sea urchins, sea cucumbers, sea stars, gastropods, bivalves, octopus and lobsters seemed relatively stable despite the increase in substrate for growth of filamentous algae. Ornamental shelled molluscs, sea cucumbers and other invertebrates of commercial importance were few, probably due to other reasons such as overexploitation (Johnstone et al. 1998b). Crown-of-thorns starfish (COTS),

Acanthaster planci, were encountered but at relatively low densities in all areas surveyed. The abundance of fleshy algae (*Sargassum*, *Turbinaria*, *Ulva*, *Dictyota*, *Stypopodium zonale*, etc.) increased on Tutia reefs (Mafia), Kwale, and Chumbe (Unguja) but not in other sites. Corallimorpharian distribution and abundance appear to have increased on most reefs in Tanzania (Kuguru, 2002). Fish counts have shown marked increase in siganids and other herbivores, which may be due to one or a combination of increased food (Öhman et al., 1999) and/or cessation of dynamite fishing pressure (Chris Horrill, pers. comm.). According to Mohammed et al. (2000) herbivores contributed more than 50% of the reef fish population in most sites.

EFFECTS OF CORAL MORTALITY ON FISHERIES AND TOURISM

More than 90 % of the marine fish catch is landed by artisanal fishers (Jiddawi, 1998) and about 70 % of this catch is harvested on or adjacent to coral reefs (Ngoile & Horrill, 1993). It was therefore, expected that the mass mortality of reef corals would have negatively influenced coral reef-based fisheries (Bell & Galzin, 1984). However, the surveys conducted so far have revealed an increase in reef fish abundance and a small shift in composition in favour of herbivorous fish (Öhman, 1999). Fishermen in Tanga, Mafia and Mnazi Bay also observed a slight increase in catch landed in 1999 and 2000 compared to previous years. The increased catch, according to Tanga fishermen, was a result of cessation of dynamite fishery and was not associated with coral mortality.

There were fears that Misali coral reefs in Pemba may have lost its touristic value after the 1998 coral mortality (Muhando, 1999). However, most dive operators and fishers have indicated that most tourists and fishermen were unaware of the coral bleaching and mortality until they were told about it. The abundance of fish on reefs and the intact reef structure make dead corals to remain functionally interesting to fishermen and tourists. Coral reefs continue to play as crucial a role in the tourism and fisheries as they did before. Indeed, coral reef-dependent tourism is actually increasing in Zanzibar (Khatib, 1998b) and Mafia.

PROSPECTS FOR CORAL RECOVERY

Experiments on Unguja Island reefs have shown that coral settlement mainly occurs in crevices and under reef structures (Franklin et al., 1998; Muhando, 2001) indicating that successful settlement and growth of corals could be influenced by structural complexity of the reef. This implies that destructive activities (e.g. dynamite and dragnet fishing), which flatten the intact dead reef structures may not only enhance algal growth (Tanner, 1995; Done, 1992) but could also hinder successful coral settlement. Thus, efforts must be made to stop destructive activities on coral reefs.

Mohammed et al. (2000) and Muhando (2001) indicated that there was considerable regeneration or growth of surviving corals in all the surveyed sites. On Tutia and Mange reefs (in Mafia) and to a less extent on reefs in Mnazi Bay, surviving colonies of some coral genera (e.g. *Echinopora*, *Montipora* and *Merulina*) were observed growing fast and covering the dead parts of the colony and cementing together dead branches of *Acropora*. On some Dar es salaam reefs (Mbudya and Pangavini) species dominance has shifted in favour of *Montipora* species. Recovery through regeneration of surviving colonies is progressing well on all reefs.

New coral recruits (less than 5 cm canopy width) were scarce on most reefs that suffered high coral mortality in 1999 but more recruits were observed in 2000 and 2001 (Mohammed et al., in prep). *Pocillopora*, *Stylophora*, *Millepora* and encrusting *Montipora* were the dominant genera in Mafia and Misali while acroporid recruits were more numerous off Zanzibar Town reefs. It appears that coral recovery through settlement is occurring on all reefs but at different levels. More research is required to reveal patterns in reef coral recovery rate and the factors influencing it.

Some authors (e.g. Loya, 1976) considered the recovery of coral assemblages disrupted by natural disturbances to be mainly a function of time. While this could be true, it has been demonstrated that human activities can cause a permanent shift towards algae-dominated reefs or even coral extinction (Done, 1992; Glynn & De Weerdt, 1991). In these situations appropriate management can enhance recruitment and shorten the recovery time (Hughes, 1994). This is especially true where

destructive practices, such as dynamite fishing, dragnet fishing and coral mining, are still practised. Enhanced coral settlement and coral transplantation could play a role in encouraging faster recovery of reef corals in severely degraded areas (Franklin et al., 1998; Lindahl, 1998).

ANTHROPOGENIC THREATS TO CORAL REEF BIODIVERSITY

Tanzania coral reefs are still being subjected to anthropogenic and natural threats. Some of these include:

- Over-exploitation and over-crowding of fishermen, especially on reefs located near urban centres (Johnstone et al., 1998a; Muhando & Jiddawi, 1998), the use of scuba equipment in collecting sedentary marine resources (e.g. sea cucumbers, ornamental shelled molluscs, octopus and lobsters, and increased demand (due to population growth, tourism and overseas marketing) on certain marine resources (e.g., finfish, sea cucumbers and octopus);
- Destructive resource-harvesting techniques (e.g. dynamite fishing, dragnets, small meshed nets, etc.), which are still in use despite several efforts to halt them (Horrill & Makoloweka, 1998; Horrill & Kalombo, 1999);
- Domestic and sewage pollution, mainly limited to reefs located near major urban centres. This is considered to have had little effect on coral reefs so far, but vigilance is required (see UNEP, 1982);
- Coral mining for lime making, which continues in some areas (e.g., Mikindani, Jibondo, Mji Mwema, Dar-es-Salaam, etc.) (Solandt & Ball, 1999);
- Anchor damage from both fishing and tourist boats;
- Sedimentation and siltation as a result of unplanned land use practices (e.g. deforestation, agriculture, coastal construction), dredging, and dumping near coral reef areas. Beach erosion can resulted in reef degradation (Fay, 1992);
- Trade in live and dead coral and aquarium fish, which is just starting (As yet there is no indication of any negative impacts from these activities, but vigilance is required.).
- Use of small islands and sand banks by fisheries or tourism-related activities appear to interfere with breeding of turtles in some areas (Khatib, 1998a).

MANAGEMENT OF CORAL REEFS

The sustainable utilisation of coastal habitats and resources, including coral reefs, has been given considerable attention by the Tanzania government as reflected in the *Tanzania Environmental Policy*, *Integrated Coastal Management Strategy* of 2001, and various existing legislations. The establishment of marine protected areas managed by central government institutions, local governments or communities and nongovernmental organisations was identified as one of the options to ensure proper utilisation and conservation of the coastal resources. Most of the existing, proposed and potential marine protected areas aim at conserving coral reefs and other resources. There are about 11 declared marine reserves or conservation areas in Tanzania. It is encouraging that coastal communities are now becoming aware of the benefits of conservation and are participating in the enforcement of MPA regulations (e.g. in Mafia Island Marine Park).

RESEARCH AND MONITORING

At present only a few scientists in Tanzania conduct research on the coral reef environment and its resources, and mostly in short term projects. Clearly, more applied research is required. Although it is widely accepted that research and monitoring of the reef environment and its resources are important for generating management information, most reef areas (including marine protected areas) do not have consistent and continuous programmes. The common reason is lack of trained personnel, equipment and financial resources. The first attempt to monitor coral reefs was initiated on reefs off Zanzibar town (Chapwani, Changuu, Bawe, Chumbe and Kwale reefs) by the Institute of Marine Sciences (IMS) in 1996 with technical and financial support from CIDA (Canada). The second attempt was in Tanga region with technical support from IUCN in 1997. Besides these two initiatives, there is no organised

coral reef monitoring in other coastal towns. In 1999, with support from the Coral Reef Degradation in the Indian Ocean (CORDIO) project, coral reef monitoring (IMS group) was expanded to a total of 17 reef sites, covering six of the existing MPAs, namely Misali Island Conservation Area, Chumbe Marine Sanctuary, Bongoyo Marine Reserve, Mbudya Marine Reserve, Mafia Island Marine Park and Mnazi Bay Marine Park. The ambitious 1999 coral monitoring programme, however, could not be repeated in 2000 or 2001 due to lack of funds. After the end of the CORDIO project in December 2001, the future of coral reef monitoring is not clear, as there is no clear commitment on sources of funds for the coming years.

A number of factors need to be improved in the existing monitoring systems, e.g. training of monitors and improvement/optimisation of the methodologies applied. For instance, the monitoring techniques used by the IMS group and the Tanga group differ considerably and efforts to standardise results by carrying out calibration exercises are underway. However, without consistency and continuation of activities, the exodus of trained manpower from the country is inevitable.

To improve research and coral monitoring the following should be considered and/or improved:

- Development of a national coral reef policy followed by the establishment of a focal point/centre (within the existing institutions) to coordinate research and monitoring activities among nationals and foreign scientists. (Reports and data collected by foreign scientist are often not available to national institutions).
- Establishment of an officially recognised coral reef database at the national level.
- Initiation of coral reef monitoring work in all MPAs.
- Support by MPAs of the training of coral reef monitors and scientists.
- Calibration and/or standardisation of monitoring procedures and results to facilitate comparison.

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