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Coral Reefs and Their Management in Tanzania

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Abstract—Coral reefs are very important in Tanzania, both ecologically and socio-economically, as major fishing grounds and tourist attractions. Numerous fringing and patch reefs are located along about two-thirds of Tanzania's coastline. These reefs have been partially to severely degraded by human (primarily destructive fishing practices) and natural (particularly coral bleaching) causes. These immediate human causes have been brought about by various socio-economic root causes, particularly poverty and lack of proper management. After decades of human and natural impacts there has been only limited reef recovery. This paper presents a region-by-region analysis of trends in the condition of coral reefs in Tanzania in relation to the causes of damage.

While earlier approaches to management were aimed at non-use of coral reefs in marine protected areas (seldom achieved), recent approaches have aimed at integrated coastal management (ICM) (whether in programs or conservation areas), where zonation into core protected areas and multiple-use areas is based on participatory decision-making involving fishing communities and other stakeholders. Some management initiatives also involve communities in reef monitoring, restoration and ecotourism. This paper examines the management approaches and strategies implemented by various ICM programs, conservation areas and marine parks in Tanzania. It also provides recommendations for further research and coral reef management strategies.

INTRODUCTION

Coral reefs have high productivity and biodiversity and are regarded as keystone ecosystems (Hunter, 1996) in that they provide important ecological services that extend far beyond their area of coverage. Stemming from their ecological importance, coral reefs have great socio-economic importance in Tanzania. They are abundant with finfish, lobsters, prawns, crabs, octopuses, mollusks and sea cucumbers, thus supporting 70% of artisanal fish production in East Africa as well as being important for commercial fishing (Ngoile & Horrill, 1993; Jiddawi & Öhman, 2002). For coastal dwellers, fisheries are very important both as a source of food, supplying 90% of the animal protein they consume, and as a source of income, fishing often being their primary occupation. In addition, coral reefs are one of the major tourist attractions (Andersson, 1998). Coastal tourism brings foreign currency into the country and provides a livelihood for coastal people. Moreover, coral reefs help to prevent coastal erosion by mitigating strong wave action, thus protecting coastal assets.

Due to growing numbers of people living along the coast and the concomitant increasing demand for fisheries and other marine resources, there has been not only overexploitation, but also improper or destructive exploitation of these resources (Wagner, 1999; Horrill et al., 2000; Francis et al., 2001; Jiddawi & Öhman, 2002). These human pressures, combined with natural impacts,

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particularly coral bleaching, have led to significant degradation of coral reefs in Tanzania.

With the increased pressure on coral reefs and their resources, proper management becomes a key issue. Management of coral reefs, or any other resource, basically involves gathering adequate information through assessment and monitoring to make informed decisions or plans, formulating strategic plans, implementing those plans (including enforcement) and periodically evaluating them to improve the management process.

This paper describes the distribution of coral reefs in Tanzania, analyses the natural and human threats to coral reefs (from 1970 onwards), describes early approaches to management, which were largely ineffective (1970s and 1980s), outlines trends in reef condition as a consequence of threats that went basically uncontrolled (1980s onwards), portrays recent management initiatives and their impacts, both at the national and district/local level (1990s onwards), and finally provides recommendations for further research and management of coral reefs.

DISTRIBUTION OF CORAL REEFS IN TANZANIA

Coral reefs are located along about-two thirds (600 km) of Tanzania's continental shelf (Fig. 1), thus comprising a very significant resource. Fringing reefs and patch reefs predominate. These reefs are found along the continental shelf, which is 8–10 km wide along most of the coast (IUCN Conservation Monitoring Center, 1988). However, between Tutia (south of Mafia Island) and Songo Songo, it reaches a width of 35 km (Darwall & Guard, 2000). The islands of Zanzibar, Pemba and Mafia, as well as numerous small islands all along the coast, are for the most part surrounded by fringing reefs. Also an outer fringing reef runs along the eastern side of both the Mafia and Songo Songo archipelagos.

Fringing reefs of Tanzania are usually narrow and often consist primarily of a reef flat. The fringing reef system is broken by numerous, often extensive, mangrove stands (IUCN Conservation Monitoring Center, 1988). Also, coral development is hindered by turbid waters to the north of the vast Rufiji and Ruvuma rivers (since the coastal currents are predominantly northward) (Darwall & Guard, 2000). Reefs on the landward sides of offshore islands and patch reefs usually have good coral development, but often the reef slope does not extend below 10 m. On the contrary, reefs on the seaward sides of islands and patch reefs have extensive reef slopes (IUCN Conservation Monitoring Center, 1988), corals sometimes extending down to 25–30 m.

Along Tanga (Fig. 1), the northernmost region in Tanzania, there are 407 km of coastline (including bays, inlets and estuaries), of which 97 km are bordered by 41 distinct sections of coastal fringing reef. In addition, there are 55 patch reefs. In total, there are 376 km of reef edge in Tanga (Horrill et al., 2000). Moving southwards to Bagamoyo District in Coast Region, there are short stretches of fringing reef and a few offshore patch reefs near the town of Bagamoyo (G. Wagner & S. Semesi, unpublished data). Further south, there are a few patch reefs off the coast of Mbweni, near the boundary between Coast and Dar es Salaam Regions. In Dar es Salaam Region, there are sections of fringing reef, both north and south of the harbor, as well as eight reef-fringed offshore islands and a number of patch reefs.

Along the northern, eastern and southern sides of Unguja Island, one of the two main islands of Zanzibar, there is a fringing reef, which is interrupted by Chwaka Bay. In addition, there are reef formations near Mnemba, a small island to the northeast, Leven Bank to the north and Bedford Bank to the south. On the western side of Unguja, between Ras Nungwi and Menai Bay, there are a number of patch reefs and reef-fringed islands (Horrill et al., 2000; Mbije, 2001; Mbije et al., 2002; Bergman et al., 2000). Pemba, the second main island of Zanzibar, is estimated to have 1100 km of reef, representing 45% of the coral reefs of Tanzania. Coral growth has been observed as deep as 64 m (Horrill, 1992; Horrill et al., 2000).

In southern central Tanzania, there are numerous patch reefs and reef-fringed islands in Mafia and Songo Songo Archipelagos. Further south, along the entire coast of Lindi Region, there are virtually no patch reefs or offshore islands, though there are narrow fringing reefs along the mainland. Mtwara, the southernmost region of Tanzania, besides having fringing reefs, has several patch reefs and reef-fringed offshore islands.

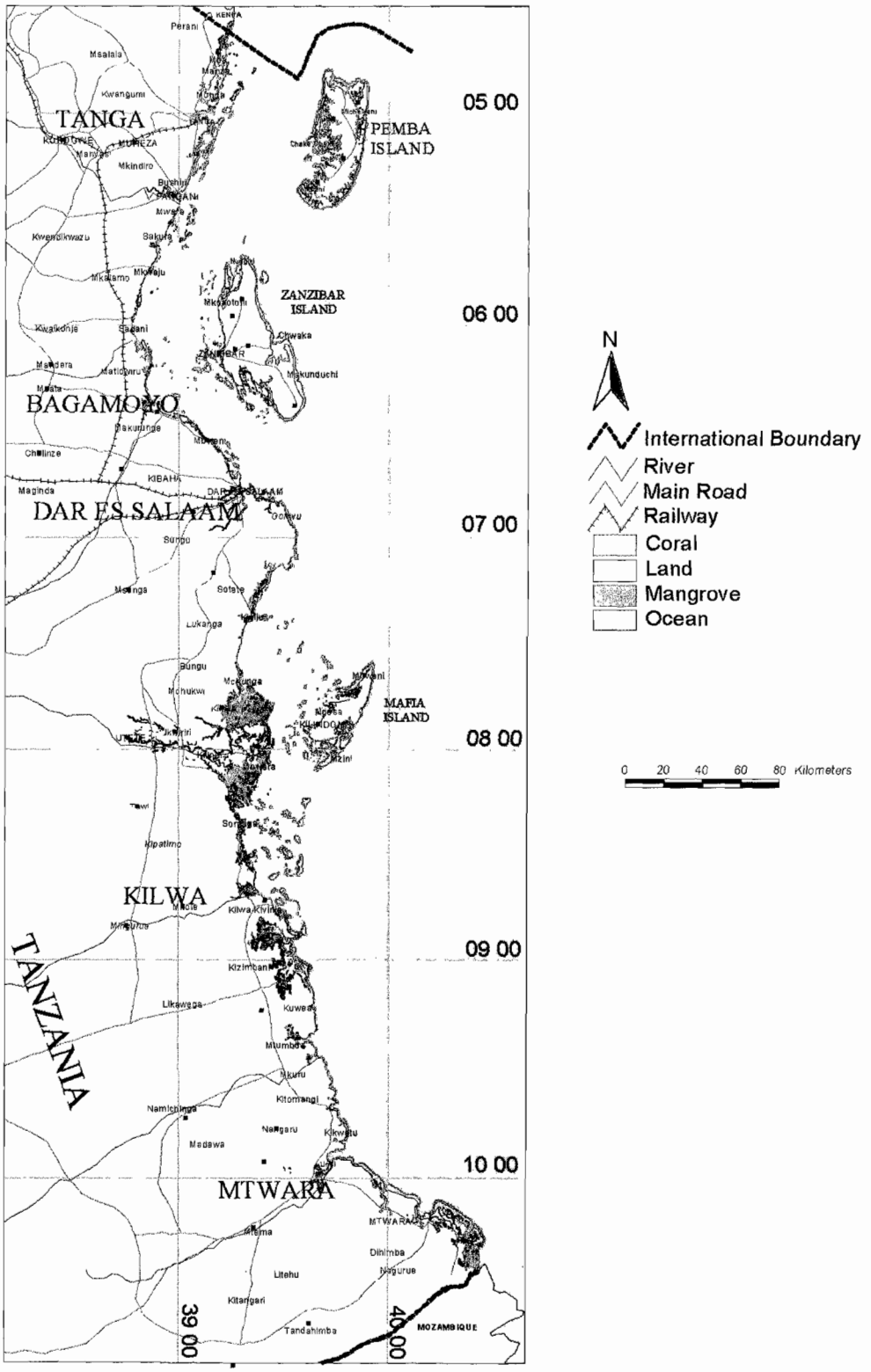

Fig. 1. The distribution of coral reefs in Tanzania

NATURAL AND HUMAN THREATS TO CORAL REEFS: 1970 ONWARDS

Natural threats

Natural impacts on coral reefs include storms, outbreaks of the crown-of-thorns starfish, and coral bleaching. Damage due to strong wave action during storms is common on exposed reefs all along the coast of Tanzania (Darwall & Guard, 2000), but there is no evidence that storm damage has changed over time. Occasional aggregations of the carnivorous crown-of-thorns starfish, *Acanthaster planci*, have been sighted at Tanga and Zanzibar (Ngusaru and Muhando, 1994) as well as Mafia (Choiseul & Darwall, 1996) though this predator has not, so far, posed a serious threat to coral reefs in Tanzania as has been recorded in other areas such as Australia (Veron, 1993).

Though coral bleaching has occurred at low levels periodically over the years, a major, worldwide bleaching event took place from March to May, 1998, which coincided with higher than normal seawater temperatures and increased rainfall (lower salinity) (Muhando, 1999). Coral bleaching was reported on all parts of the Tanzanian coast with variable severity. Bleaching was worse on reef flats than at deeper levels and was species-specific. In Zanzibar, *Acropora* was most affected, while a few corals such as *Diploastrea* and *Pachyseris* were seemingly unaffected. Some species of *Porites* were affected, while others were not (Wilkinson, 1998; Garpe & Öhman, 2003). It has been observed that surviving and dead corals were from different clones, which would indicate that genetic variation might influence bleaching tolerance (Öhman et al., 1999; Lindahl et al., 2001).

The 1998 coral bleaching event has had profound and long-lasting effects on the ecology of coral reefs. After the bleaching event, the dead corals were colonized by filamentous algae, and later by macroalgae and coralline algae. By January 1999, some areas showed the recruitment of small corals, while others were colonized by corallimorpharians and soft corals (Muhando, 1999; Muhando et al., 2002). A year after the event, a large proportion of the dead coral was still standing, but there was a change in fish community composition, with a 39% increase in fish abundance, particularly herbivorous fish, due to the growth of algae on the dead coral (Öhman et al., 1999; Lindahl et al. 2001). These findings indicated that reefs may uphold an abundant fish population as long as their architectural structure remains intact. Bergman et al. (2000) reported that branching structures accounted for 62% of the variation in juveniles of the reef fish *Pomacentrus sulfureus*. However, once the dead coral crumbles into rubble, with consequent loss of structural complexity, fish abundance is likely to decrease greatly.

Human threats

Little is known about the threats before 1970 but it is unlikely that human threats were very significant because the population pressure was low and exploitation was primarily by traditional means. However, with rising population pressure in the past three decades, coral reef resources have been increasingly utilized in a number of ways, particularly, for various types of fisheries, tourism and coral mining. Most of these uses have resulted in coral reef degradation due to either overexploitation or destructive/improper methods of exploitation. There are also other types of human threats, which do not involve the use of reef resources, but which have impacts on reef ecosystems, most notably pollution and excessive movement of boats and people (Wagner, 1998, 1999).

The greatest human impacts on coral reefs are related to destructive fishing practices (Wagner, 1998; Francis et al., 2001; Jiddawi & Öhman, 2002). By far the most destructive type of fishing is dynamiting, which has been practiced in Tanzania since the 1960s. In the 1980s and 1990s, dynamite blasts reached epidemic rates. In Mnazi Bay, Mtwara, 441 blasts were recorded over a two-month period in 1996, while in the Songo Songo Archipelago, 30 blasts were heard every three hours in one area and 100 blasts were recorded during one six-hour period at Mpovi reef (Darwall & Guard, 2000). Each blast of dynamite instantly kills all fish and most other living organisms within a 15–20 m radius (Guard & Masaiganah, 1997) and completely destroys the reef habitat within a radius of several meters, reducing it to rubble.

Moreover, dynamite fishing has a major impact on coral recruitment due to the removal of viable seed populations of corals (Nzali et al., 1998). With numerous blasts occurring daily on reefs all over the country over a period of several decades, the overall impact of dynamite fishing on coral reefs in Tanzania has been devastating. Reefs damaged by dynamite fishing take many decades to recover and some, in fact, may never recover (Guard & Masaiganah, 1997).

The use of seine nets around coral reefs is destructive in three ways. Firstly, fishermen sometimes hit the coral heads in order to scare fish out of hiding, known as the *Kigumi* technique, which has been particularly common on Pemba and the southwestern side of Unguja (Horrill et al., 2000). Secondly, the weighted net bottom hooks on corals while being dragged, causing breakage. Thirdly, the small-mesh size of seine nets results in the capture of many juveniles (Wagner, 1998). Poison (commonly an extract from the *Euphorbia* plant) was used for fishing as far back as 1900 and, although its use declined during the 1960s, it is still occasionally used today (Horrill et al., 2000). Spear fishing for octopus and the use of basket traps may also cause damage, if improperly undertaken. Other harmful activities related to fishing include the dropping of anchors and boat grounding (Wagner, 1999).

The catching of juveniles, the overexploitation of specific groups (e.g., mollusks and sea cucumbers) or species, as well as general overfishing, result in the depletion of fish stocks, alteration in species composition, disruption of food webs, and disturbance of the natural equilibrium of reef ecosystems (McClanahan et al., 1999; Wagner, 1999). For example, overfishing of the triggerfish (Balistidae), which normally control sea urchin populations (McClanahan & Shafir, 1990), results in proliferation of the latter, which are known to be bioeroders of reefs (McClanahan, 1988; Kamukuru, 1997).

Though highly destructive, the mining of live coral is another practice which is common in certain parts of the country, such as Mafia, Songo Songo and Mtwara (Dulvy et al., 1996; Darwall & Guard, 2000). Solandt & Ball (1999) reported that several communities in Mikindani Bay, Mtwara were almost entirely dependent upon coral mining for their income. In Mitengo Village, out of a population of 100 people, 50-75 men, women and children were involved in various stages of the lime industry. The most commonly mined coral is *Porites lobata*. Near Mikindani Bay, all *Porites* above a depth of 2 m have been removed. The negative impacts of coral mining include loss of reef habitat, loss of natural breakwaters with concomitant indirect loss of adjacent coastal habitats, and loss of the aesthetic value of the reefs for tourism (Dulvy et al., 1996; Darwall & Guard, 2000). Moreover, since coral mining simplifies the surface topography of reefs, there is also a reduction in microhabitat diversity that, in turn, results in a decrease in biodiversity.

While tourism is generally economically beneficial to the country (Andersson, 1998), it may have negative impacts on the environment, if unmanaged. Damage to corals can be caused by careless snorkeling and SCUBA diving as well as anchoring and grounding of tourist boats.

An indirect use of coral reefs is the establishment of seaweed farms in lagoons between coral reefs and sandy beaches, where conditions are ideal for algal growth (e.g., Paje seaweed farm, Zanzibar). While seaweed farming is thought to be relatively environmentally friendly, it has been reported in Unguja that this activity lowers bacterial production and has negative impacts on the diversity and abundance of intertidal organisms, including macrophytes, macrobenthos and meiobenthos such as nematodes (Olafsson et al., 1995; Horrill et al., 2000). Algal farming was also found to affect fish assemblages (Bergman et al., 2001). These impacts may have secondary impacts on coral reef communities in the vicinity, such as changes in species composition of fish and invertebrates.

In Tanzania, there are various types of pollution along the coast, which can affect coral reefs. The main centers of pollution are Dar es Salaam, Tanga, and Zanzibar town and, to a lesser extent, Mtwara, Lindi and Bagamoyo, where there are industrial, institutional, and domestic discharges; agro-chemical pollution; and construction activities. Phosphate levels in the water column were significantly higher at Changuu (Kuguru, 2002) and Chapwani (Johnstone & Suleiman, 1998) reefs, which lie in the path of water currents emanating

from Zanzibar town, than at Bawe, which is away from those currents. Though the impacts of pollution are much less away from the urban centers, deforestation and poor agricultural practices lead to increased sediment loads in coastal waters, which are detrimental to coral growth (Wagner, 1999; Francis et al., 2001). Moreover, commercial, high-speed boats operating between Zanzibar and Dar es Salaam stir up sediments, which may affect reefs along their paths as they approach these two harbors.

Socio-economic root causes leading to human threats

Although the human threats mentioned above are the immediate causes of coral reef degradation, these, in turn, have been caused by other socio-economic factors. In a causal-chain analysis, Francis et al. (2001) considered some of the main underlying root causes of coral reef degradation in Tanzania to be poverty, inadequate awareness amongst resource users, lack of general education and migration to coastal urban centers. As revealed through interviews held in Mbweni and Kunduchi, villagers (Wagner et al., 1999) considered the main underlying causes of environmental degradation to be poverty (34% of the interviewees), lack of enforcement (21%), lack of equipment for proper resource extraction (20%) (also related to poverty), lack of education, awareness and expertise (19%), overpopulation (10%), and greed (10%).

EARLY MANAGEMENT EFFORTS: 1970S AND 1980S

Based on a management proposal by Ray (1968), the Fisheries Act of 1970 designated eight marine reserves in which reefs were to be totally protected, namely, Chole Bay and Tutia Reef at Mafia Island (Darwall & Guard, 2000); Latham Island, east of Dar es Salaam; the Dar es Salaam Marine Reserve System; Maziwi Island; and Mwamba wa Mbwa, Mwamba Shundo and Fungu Mnyama in the Tanga coral gardens (Kamukuru, 1997). However, due to lack of capacity to actively manage these reserves, they became merely "paper" reserves (Bryceson, 1981). The Fisheries Act also outlawed dynamite fishing throughout the country. However, due to lack of enforcement, this destructive practice continued unabated.

The early approach to management was not integrated, but sectoral. There was serious overlap, often several departments being responsible for the same resource. In the marine reserves, the approach was protection, rather than sustainable use, but this protection was seldom enforced. Moreover, communities and local authorities were not consulted. Consequently, these early management efforts were ineffective and the impacts of human activities continued to accelerate as a result of increased human populations along the coast, which were accompanied by increased economic and social pressures.

TRENDS IN CORAL REEF CONDITION AS A CONSEQUENCE OF HUMAN AND NATURAL THREATS: 1980S AND ONWARDS

Following decades of degradation, primarily due to human impacts, numerous studies have been conducted to assess the condition of Tanzanian reefs. This section describes the trends in reef condition, which have differed greatly from region to region (Fig. 1), except for any trends that can be attributed to impacts of recent management initiatives, which are covered in the subsequent section.

Tanga

According to a rapid survey conducted in Tanga (Fig. 1) in 1987 (IUCN, 1987), most reefs, at that time, had only 20% live coral cover, while some areas had less than 10%. A more extensive survey in 1995 covering 58 reefs (Horrill, 1996; Horrill et al., 2000) showed that 12% of the reefs were completely destroyed, 12% in poor condition (0–25% hard coral cover), 52% in moderate condition (26–50% hard coral cover) and 24% in good condition (51–75% hard coral cover). Most of the damage to reefs north of the Pangani River was attributed to dynamite fishing (Horrill, 1997). Reefs adjacent to dense human populations had greater damage and lower abundance of commercially important fish species. Subsequently, 25% of the corals in Tanga were

bleached by the 1998 coral bleaching event (Wilkinson, 1998).

Bagamoyo

A survey of Mwambakuni, a large patch reef located 11 km northeast of Bagamoyo town (Fig. 1), conducted in 1999, showed a very high percent cover of rubble (up to 55% in some sites), which appeared to be primarily due to dynamite fishing, since the rubble consisted of small fragments of dead coral and many craters could be observed in the substratum. Dead coral, which was attributed mostly to coral bleaching, ranged from 1.3% to 17% (G. Wagner & S. Semesi, unpublished data).

Dar es Salaam

Pearson (1988) qualitatively observed that there had already been serious degradation due to dynamite fishing and anchoring on most of the fringing and patch reefs in Dar es Salaam. He also noted significant amounts of coral bleaching. Coral reef monitoring at selected sites at Mbudya and Bongoyo reefs, conducted during 1999 by Mohammed et al. (2000), indicated that there were 59.6% and 55.6% hard coral cover and 14% and 14.7% dead coral, respectively. However, Wagner et al. (2001), carrying out rapid assessment around the entire circumference of Mbudya Island, reported that 40–60% of the hard coral structures had died, which could be a result of the coral bleaching event of 1998. Substantial damage from dynamite fishing was also observed. At Pangavini (Mrema, 2001), there were two patches (northeast and southwest) with good coral cover (up to 80%), but the rest of the reef was primarily rubble (77.5%), due to extensive damage by dragging seine nets, dynamite fishing and storms. Fungu Mkadya was dominated by coral rubble (60%), probably mainly a result of dynamite fishing, with less than 5% hard coral cover (Bipa, 2000). At Fungu Yasin, there were patches of hard coral (32% cover) on the northwest side, but a large area on the southwest side was almost 100% rubble, which may be attributed to a combination of destructive fishing and coral bleaching (Peter, 2002).

Another indication of degradation is that sea urchin proliferation has been observed in the Dar es Salaam Marine Reserve System, with an average density of 2 individual/m^2, which could be a result of overfishing of the triggerfish (McClanahan et al., 1999). Kamukuru (1997) observed a significant negative correlation between hard coral cover and both sea urchin biomass and density in the Dar es Salaam reefs, indicating the impact of sea urchins as bioeroders.

Zanzibar: Unguja and Pemba Islands

The coral bleaching event of 1998 resulted in overall more than 60% of the scleractinian corals in Zanzibar (Fig. 1) showing signs of bleaching (Muhando, 1999). Wilkinson (1998) reported that, around Zanzibar town, 20–60% of the corals were bleached. However, 80–95% of the sensitive *Acropora* spp. were bleached at Chumbe, south of Zanzibar town.

Recent studies on reefs around Unguja showed that live coral cover ranged from 2% at Kichwani on the northeast coast to 78% at Pange on the west coast (Bergman & Öhman, 2001). It was generally highest on the reefs near Zanzibar town on the western side, except for Chapwani. The reefs on the southwestern side of Unguja near Menai Bay generally had lower live coral cover (12–29%), which can be attributed to the rampant use of destructive fishing methods. Mnemba (northeast) and the eastern fringing reefs had 11% coral cover or less, due to their exposure to strong wave action (Horrill et al., 2000). Coral generic diversity was highest at Chumbe on the west coast, followed by Mnemba (Mbije, 2001; Mbije et al., 2002). Results of coral reef monitoring (Mohammed et al., 2002), using the Line Intercept Transect method (English et al., 1994) along permanent transects, showed good recovery following the 1998 coral bleaching event. At Chapwani and Changuu near Zanzibar town, hard coral cover fell slightly from 1994 to 1999 and then rose to around 50% in 2002, which is actually somewhat higher it was before the 1998 bleaching event. At Chumbe, hard coral cover dropped from approximately 50% in 1994 to 25% in 1999 and then rose in 2002 to almost match the level of 1994.

According to Horrill et al. (2000), along the western coast of Pemba Island, the fringing reef had between 21 and 60% coral cover, with damage

due to destructive fishing practices being observed. The eastern fringing reef had not more than 15% coral cover, which could be due to its exposure to strong wave action. The highest live coral cover was found in Misali Island on the western side of Pemba, attaining 75% on the northern side and 53% on the eastern side. Misali also had high species richness (40 coral genera). Coral reef monitoring at Misali indicated that, while hard coral cover decreased from over 50% in 1994 to less that 10% in 1999, due to the coral bleaching event of 1998; between 1999 and 2001, there was a slight increase in coral cover to approximately 10%, as well as an increase in macro-algae and sponges (Mohammed et al., 2002).

Mafia Archipelago

The outer fringing reef at Mafia (Fig. 1) was reported to be in good health in 1995, with some damage caused by wave action. Two large, sheltered, shallow (less than 10 m) bays of Mafia Island, Chole and Jujima, had extensive growth of corals (Darwall & Guard, 2000). However, the bleaching event of 1998, caused 80–100% coral death in Mafia Marine Park, more than 95% death at Tutia, 80–90% death of *Acropora* at Kinasi Pass into Chole Bay and 100% death of *Acropora* on reefs in Chole Bay (Wilkinson, 1998). At Msumbiji and Utumbi reefs in Chole Bay, total live coral cover dropped to 30% in 1999 (Mohammed et al., 2000). Coral reef monitoring (Mohammed et al., 2002) indicated that, from 1999 to 2001, hard coral cover decreased in Chole Bay at Msumbiji (from 30% to 25%) and Utumbi (from slightly above 30% to just below 30%), but increased at Tutia from approximately 15% to 20%. At all three sites, macro-algae increased, while dead coral and soft coral decreased. In 11 sites examined by Garpe & Öhman (2003), overall, the substratum was dominated by dead coral (49%) and algae (25%), with only 14% live hard coral cover.

Lindi

During the 1980s and 1990s, coral reefs throughout the Songo Songo Archipelago, Kilwa (Fig. 1) were extensively damaged above a depth of 10 m, primarily by dynamite fishing, though below that level, the reefs were abundant with coral growth and fish. Shallow reefs, however, were almost completely destroyed (Guard & Masaiganah, 1997). Mpovi and Amani reefs near Kilwa Kivinje, which had previously been very productive, were later reported to have large areas of rubble, poor coral cover and low abundance and diversity of fish (Hanaphy & Muller, 1997). The reefs with the least degradation are those that are adjacent to deeper waters such as Poiasi and Pwajuu patch reefs and the outer fringing reef, where dense coral growth extends down to 30 m. The northwestern reefs of the Songo Songo Archipelago have low coral diversity due to high sediment emanating from the Mohoro River (Darwall & Guard, 2000). In a survey of 13 patch reefs in the Songo Songo Archipelago (Darwall et al., 1996), average hard coral cover (live + dead) was found to range from 25 to 55% and the average proportion of hard coral that was alive generally ranged from 70 to 95%.

In a recent rapid assessment of reefs around Kilwa Masoko (Ngoile et al., unpublished data), Mwamba Songo at Songo Mnara and Msangamla Bay at Kilwa Kisiwani were observed to have good biodiversity and fair hard coral cover (62 and 26%, respectively), though considerable damage due to coral bleaching and destructive fishing practices was also noted. South of Songo Mnara, the remaining coast of Lindi is lined by a narrow fringing reef with poor coral development.

Mtwara

In Mnazi Bay, before the 1998 coral bleaching event, the outer reef had an average hard coral cover of 40%, with less than 5% damage. Inside the Bay, there was considerable variability, where some reefs had an average hard coral cover of 60% with little damage, while other reefs averaged only 10% coral cover with extensive damage, mainly due to dynamite fishing (Guard et al., 1998a; Darwall & Guard, 2000). As a result of the 1998 bleaching event, 15–25% of corals bleached in Mnazi Bay, with 50% survival of the corals after bleaching (Wilkinson, 1998). At Matenga and Kati, live coral cover dropped from 55 and 60% in 1997 (Guard et al., 1998b) to 28 and 42% in 1999, respectively (Mohammed et al., 2000).

RECENT MANAGEMENT INITIATIVES AND THEIR IMPACTS: 1990S TO PRESENT

Within the last decade, a more practical approach has been taken to coastal zone management, i.e., considering the coast as a multiple-use zone, integrating the need for environmental conservation on the one hand and sustainable use and development on the other (UNEP, 1989). Thus, in 1993, a resolution was passed on Integrated Coastal Zone Management in East Africa (Darwall & Guard, 2000). The recent approach adopted in Tanzania has been basically that of the widely known Integrated Coastal Management (ICM), which is a continuing process of involving all stakeholders, who are either using or managing a coastal area, in planning and on-going management. This new approach minimizes damage, makes resource use sustainable and maximizes long-term economic and social benefits. ICM also mitigates resource use conflicts (Talbot & Wilkinson, 2001) by bringing different resource users together for consultation and joint decision-making.

At the national level, the Ministry of Natural Resources and Tourism instituted the Marine Parks and Reserves Act No. 29 of 1994, which formulated a management framework emphasizing community involvement in conservation and placed all marine protected areas in Tanzania under the Marine Parks and Reserves Unit. This unit has taken a number of measures to stop destructive fishing practices and have also constructed mooring buoys near some reefs, such as in the Dar es Salaam Marine Reserve System, so that fishing and tourist boats can tie up to these buoys, thus preventing anchor and boat grounding damage to the reef.

In 1997, the National Environment Management Council (NEMC) established the Tanzania Coastal Management Partnership (TCMP) in collaboration with the University of Rhode Island and the United States Agency for International Development (USAID). TCMP has been making efforts to influence government policy related to coastal environmental issues and their management and to provide accurate, up-to-date information to stakeholders and policy makers. In addition, they have been offering support to programs, projects and marine parks working at the district and local levels, through enhancing awareness, providing training and holding frequent retreats, which bring together representatives from these local programs for information sharing and consultation.

Efforts of TCMP towards influencing policy culminated in April 2003 with the launching of the National Integrated Coastal Environment Management Strategy (United Republic of Tanzania, 2003a), which addresses issues related to coral reefs in several ways. It calls for the conservation and restoration of critical habitats (including coral reefs) and for the establishment of Special Area Management Plans (SAMPs) in such coastal habitats of high economic interest and/or with substantial environmental vulnerability to natural hazards. Since TCMP is a partnership, which will not last indefinitely, the Strategy also makes provisions for the role that TCMP has been playing to be taken up within the Tanzanian government by the Integrated Coastal Management Unit (ICMU) within NEMC, though this Unit is yet to be formed.

The issue of dynamite fishing has also been tackled at the national level. In 1998, representatives of key institutions all over the country attended a 'National Workshop to Wage War Against Dynamite Fishing' in order to develop a coordinated national action plan to combat this destructive practice. The navy and marine police combined forces with local programs throughout the country, which resulted in a significant reduction in dynamite fishing (Horrill & Makoloweka, 1998). However, within the last couple of years, there has again been a slight increase in the occurrence of dynamite fishing in some parts of the country such as Tanga and Dar es Salaam.

Environmental Impact Assessment (EIA), an important management tool, is required by The Marine Parks and Reserves Act (1994), The Tanzania Investment Act (1997) and the new Mining Act (1998), before new development projects can be implemented. Development permits are issued by the National Environment Management Council (UNEP, 2001).

Tanga Coastal Zone Conservation and Development Program (TCZCDP)

TCZCDP was established in 1994 to ensure the sustainable use of coastal resources in the three coastal districts of Tanga Region (Muheza, Tanga and Pangani) in northern Tanzania (Fig. 1, Table 1). It operates on a collaborative, participatory approach between government agencies and local resource users such that villagers are involved in making decisions and implementing them (Horrill & Makoloweka, 1998). While the program deals with other marine habitats as well, its key interventions in terms of coral reef conservation have been joint patrols to enforce fisheries regulations, rotating closure of reefs to replenish fish stocks and allow for reef recovery, the testing of fish aggregating devices and mariculture options as potential alternatives to inshore fisheries and gear exchange program (Horrill et al., 2000; Horrill et al., 2001).

By 2001, a number of positive trends had been observed including reduction in destructive fishing practices, stabilized or increased fish catches, increased fish densities, rapid recovery of corals after the 1998 bleaching event and reappearance of triggerfish resulting in reduced populations of sea urchins (Horrill et al., 2001).

As of 2003, positive trends are continuing in the six management areas established by TCZCDP. Generally (though with some exceptions), hard coral cover remained stable in closed reefs of management areas that started recently (2000/2001) and actually increased in some of the older management areas, where it rose from 32% (± 14%) in 1998 to 51% (± 3%) in 2003. By contrast, in open reefs, coral cover generally decreased considerably in recently established management areas, e.g., it decreased from 20% (±2%) to 11% (±2%) in one management area; but it remained stable in old management areas (TCZCDP, unpublished).

Marine Environmental Protection Program (MEPP) and the Rural Integrated Support Program (RIPS)

In 1994, MEPP was initiated for Lindi and Mtwara districts (Fig. 1), facilitated by RIPS. This program has included seaweed farming, patrols for dynamite fishing, a village credit revolving scheme to enable fishermen to buy conventional fishing gear, and the production of media materials to enhance environmental awareness (Darwall & Guard, 2000).

Chumbe Island Coral Park (CHICOP)

The Chumbe Island Coral Park and Environmental Education Centre, established on the western side of Zanzibar Island (Fig. 1, Table 1) in 1992, is managed by a private company. In 1994, CHICOP was gazetted as a marine protected area (Horrill et al., 2000). The Centre strictly implements total protection of the reef. The only human activities allowed are tourism and research. Many studies have been conducted on this reef as well as regular monitoring (Mohammed et al., 2000, 2002; Muhando et al., 2002). Coral reef rehabilitation has been carried out there, which has had significant positive impact (Muhando, 2003).

Mafia Island Marine Park (MIMP)

MIMP, located in Mafia Island (Fig. 1, Table 1), was gazetted in 1995 as the first marine park in Tanzania (Darwall & Guard, 2000). One of the guiding principles for MIMP management strategy is the adoption of an integrated, multiple-user approach. The park has been divided into core, specified-use and general-use zones. Their broad management strategies are to conserve biodiversity and ecosystem processes, to promote sustainable resource use, to ensure community participation in management, to develop ecotourism, to promote community education and information sharing, to develop under-utilised resources, to conserve the cultural resources of Mafia Island and to develop monitoring and research (United Republic of Tanzania, 2000). One of the early accomplishments of MIMP was the virtual elimination of dynamite fishing by patrolling with a speedboat fitted with a water canon (Mambosho, 1998). Regular monitoring has been conducted on a few reefs ((Mohammed et al., 2000, 2002). In collaboration with MIMP, Garpe & Öhman (2002) carried out a comprehensive study describing both fish and benthic communities.

Table 1. Summary of some recently established marine protected areas in Tanzania

Name Year established	Area	Monitoring/ assessment	Major management strategies / activities
Tanga Coastal Zone Conservation and Development Program 1994	Tanga Region	Regularly, every 6 months	• Collaboration: government agencies and resource users • Patrols: fisheries regulations • Zonation: closed/open reefs • Gear exchange
CHICOP 1994	Chumbe Island, Zanzibar	Every 2–3 years	• Strict protection • Tourism • Research
MIMP 1995	Part of Mafia Island	Irregular	• Community participation,communication • Conserve biodiversity and ecosystem processes • Zonation: core, specified and general use • Patrols: fisheries regulations • Sustainable resource use • Develop ecotourism
Menai Bay Conservation Area 1997	Menai Bay	Irregular	• Elimination of destructive fishing • Control of overfishing· • Ecotourism
Misali Island Conservation Area 1998	Misali Island, Pemba	About every 2 years	• Zonation into core and multiple-use areas • Sustainable fishing and ecotourism
MBREMP 2000	Mnazi Bay and Ruvuma Estuary, Mtwara	Baseline conducted 2003	• Participatory planning and management • Sustainable resource use and livelihoods • Capacity building • Monitoring and evaluation
KICAMP 2001	Kino-ndoni, Dar es Salaam	Irregular	• Land/water use planning • Education, communication · • Community development • Research and monitoring
Bagamoyo ICM Program 2001	Bagamoyo	Baseline conducted 2003	• District/village involvement • Action plan focuses on only a few specific issues • Control destructive fishing
Mnemba Island Conservation Area 2003	Mnemba Island	Not started	• Management plan being developed

Menai Bay Conservation Area

The Menai Bay Conservation Area, located in Zanzibar (Fig. 1, Table 1), was gazetted in 1997 (Sichone, 1998). The main reef management strategies are the elimination of destructive fishing methods and control of overfishing (Horrill et al., 2000). Some of the fishing camps are closed seasonally, which to a large extent results in seasonal closure of a few reefs. There is also community involvement in ecotourism, which takes some pressure off the fisheries.

Marine Action Conservation Tanzania (MACT)

MACT is a non-governmental organization (NGO), which began patrolling for dynamite fishing in Dar es Salaam in 1997. In 1998, MACT and the University of Dar es Salaam involved the Kunduchi Fishing Village community in restoring coral reefs in the Dar es Salaam Marine Reserve System. About 500 coral fragments were transplanted in five dynamited sites on Mbudya Island reef (Wagner et al., 1999). Amongst the 342 coral fragments that could be relocated, *Galaxea* sp. showed greater survival (100% complete survival) than *Porites* sp. (55.7% complete survival, 13.9% partial survival) (Wagner et al., 2001).

Since 1999, ecotourism, combined with restoration, has been an on-going activity in the Dar es Salaam Marine Reserve System, as an alternative income-generating project for the community (Wagner et al., 2001). This combination provides economic benefits to the community and also motivates them to restore their ecosystems. Active restoration has facilitated the recovery of dynamite-blasted sites and has ensured higher coral species diversity in comparison with control sites (not transplanted), which either showed no natural recovery during the same period, or were overtaken by a mono-specific stand of *Montipora* spp.

Misali Island Conservation Area

The Misali Island Conservation Area, established in 1998, is aimed at establishing a financially self-sustaining marine and terrestrial protected area at Misali Island, Pemba (Fig. 1, Table 1), based on fishing and ecotourism (with community involvement) as the main activities (Hamad, 1998). Several assessments have been conducted on the island as well as monitoring approximately every two years (Mohammed et al., 2002). The Conservation Area has a core protected area, where no extractive use is allowed, as well as a general multiple user zone (Francis et al., 2002).

Mnazi Bay-Ruvuma Estuary Marine Park (MBREMP)

MBREMP, located in Mtwara (Fig. 1, Table 1), was the second marine park in Tanzania, which was officially established in 2000, but which was not effectively launched until 2002. It covers 650 km^2, of which 200 km^2 is marine, including islands, coral reefs and mangrove forests. The project has four components: participatory planning and protected area conservation and management, sustainable resource use and livelihoods, capacity building and project monitoring and evaluation (United Republic of Tanzania, 2003b).

Kinondoni Integrated Coastal Area Management Program (KICAMP)

KICAMP, launched in Dar es Salaam in May 2001 (Table 1), has four major components: surveys, research and monitoring; education, communication and information; land and water use planning; and community development (Kinondoni Integrated Coastal Area Management Program, 2001). The program has involved the local community in all aspects. An important aspect of the research and monitoring component is community-based monitoring of several aspects of the environment, including coral reefs, though it has been conducted somewhat irregularly.

Though it has only been operating for a short time, KICAMP has already made an impact in enhancing the community's awareness of marine issues and in creating a feeling of ownership of the coral reefs and other habitats.

Bagamoyo ICM Program

District ICM Action Planning was launched in Bagamoyo District (Fig. 1, Table 1) in 2001. TCMP collaborated with the district office, villages and wards in a participatory process of issue identification and analysis. Destructive fishing practices, including those that are damaging to coral reefs, were selected as a priority issue. Since only a baseline assessment of coral reefs has been conducted, it is too early to assess any possible impacts on the reef environment, but the program is already creating awareness amongst resource users.

Mnemba Island Conservation Area

Mnemba Island Conservation Area, located on the northeast side of Zanzibar Island, was established in 2003. It has a core area, which is fully protected,

while the remaining area is for multiple use. Since this is a very new program, there is very little information available on it.

CONCLUSIONS

Several of the recent management initiatives in various parts of Tanzania have already had significant positive impact on the coral reef environment in terms of the reduction of harmful fishing practices, coral recovery or regeneration and a return to equilibrium on the part of some associated reef organisms (e.g., recovery of fish populations and reduction in sea urchins). The resource users, particularly fishing communities have been involved, to an increasing extent, in managing their resources and, in addition their environmental awareness has been enhanced. However, there are still on-going threats which have not been completely eliminated such as dynamite fishing and other destructive forms of destructive fishing. Coral bleaching is another threat, which may cause increasing damage to coral reefs and which is of growing concern to coral reef managers.

INFORMATION GAPS AND RECOMMENDATIONS FOR FURTHER RESEARCH

The main geographical areas for which there is little information, and where research needs to be done include Pemba, Bagamoyo, the coastal area between Dar es Salaam and Mafia, and Lindi. Moreover, areas that have already been surveyed need to be re-examined and monitored more regularly over a longer period in order to assess trends over time.

Research on coral reefs in Tanzania needs to cover a wider range of topics such as genetics, physiology, nutrient dynamics, ecological processes, species interactions and associations, autecology of specific species, coral recruitment patterns, detailed taxonomic work, biogeography, connectivity among reefs, socioeconomics and fisheries. In addition, the ecological impacts of sedimentation caused by high-speed boats needs to be investigated, in particular, to determine the critical speeds and appropriate routes for boats to follow.

MANAGEMENT RECOMMENDATIONS

All forms of destructive fishing and overfishing must be eliminated, in a multifaceted approach, including enhancing environmental awareness, instilling a feeling of ownership of the environment amongst fishing community members, participatory planning, empowering fishermen to obtain environmentally friendly gear and vessels, creating supplementary and alternative sources of income to take the pressure off fisheries resources, and enforcing laws and regulations adequately. Moreover, since sea urchins have been found to occur in high abundance in areas like Dar es Salaam (up to 6000 kg/ha, Horrill et al., 2000), as recommended by McClanahan (1998), keystone species such as the red-lined triggerfish, which controls sea urchin populations, should be protected.

For severely degraded reefs, mere protection is insufficient. Deliberate human intervention is required in order to facilitate the recovery of reefs in a reasonable length of time and to ensure coral species diversity. Local fishermen can be trained to do reef restoration at low cost. Moreover, the combination of ecotourism and restoration, which is promoted by Marine Action Conservation Tanzania (MACT) in Dar es Salaam, should also be carried out elsewhere, since this combination provides economic benefits to the community, as an alternative income-generating project and, at the same time, motivates them to restore their ecosystems (Wagner, 2003). It is recommended that there be a conscious and deliberate shift from the mainstream, mass tourism towards ecotourism, where there is mutual benefit amongst three components: ecosystems, tourists, and the local communities.

Other recommendations include the construction and obligatory use of mooring buoys in strategic positions near coral reefs and islands, which could prevent the impacts of boat grounding and anchoring on reefs. The movement of speedboats, both large and small, should be regulated with respect to speed as well as direction and distance from coral reefs. The development of sewage disposal systems must give full consideration to the sensitive character of coral reef ecosystems. Coral mining must be eliminated,

while at the same time finding alternative building materials and alternative sources of income. Indigenous knowledge of the environment and resource management should be tapped. In addition, there needs to be vigilant, regular and widespread monitoring of coral reefs in terms of habitat characteristics, biota and ecological processes as well as natural threats, such as coral bleaching and outbreaks of the crown-of-thorns starfish. Involving fishermen in monitoring coral reefs, as has been done successfully in Tanga for many years and as has been started in Bagamoyo and Dar es Salaam, should be carried out elsewhere, not only as a means of increasing manpower for collecting more data, but also as a way of enhancing the awareness of fishermen and motivating them to protect their reefs.

Finally, integrated coastal management programs and marine protected areas should be expanded and strengthened, or established where they do not exist, so that the entire coastline of Tanzania is zoned and taken care of in an appropriate way. Such programs need to also address the underlying root causes of environmental degradation, which are basically socio-economic issues.

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