Approaches to Coral Reef Monitoring in Tanzania

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ABSTRACT

Coral reef monitoring (CRM) in Tanzania started in the late 1980s. The main objective was to assess the extent of damage caused by the use of destructive resource harvesting practices, mainly dynamite and drag-nets. The derived information formed the basis for setting up of legislation (control) measures and monitoring of further changes on reef health. Coral reef monitoring has contributed substantial descriptive information and has raised awareness of coastal communities and managers. Analysis of CRM data over the years has provided information on the dynamics of reef health, for example coral cover and composition, and fish and macro-invertebrate abundances. Experience has shown that there are more factors that degrade coral reef now than before. The contribution of natural factors (e.g., coral bleaching events, algal and corallimorpharia proliferation, crown-of-thorns predation) has become more apparent and these factors are acting synergistically with chronic human induced factors such as destructive resource harvesting practices (dynamite and dragnets), mining of live corals, trampling and anchor damage. In order to keep pace with increased reef problems, the Institute of Marine Sciences, Zanzibar, has modified its monitoring protocols. The main emphasis is now on biodiversity changes. Reef corals are now monitored at genus level instead of growth forms alone. Reef macro-invertebrates (sea urchins, sea cucumbers, gastropods) include more sub-groups than before. Coral recruitment (young corals less than 10 cm diameter) is now monitored at genus level. Analysis of the coral monitoring data takes into consideration resilience concepts such as functional redundancy. The improved coral reef monitoring approach will complement community-based monitoring which is being practiced countrywide in Tanzania. This paper discusses critical issues in the past coral reef monitoring program and describes modifications adopted by the Institute of Marine Sciences. Complementarities with community-based coral reef monitoring are also discussed.

APPROACHES TO CORAL REEF MONITORING IN TANZANIA

1. INTRODUCTION

The livelihood of many costal communities in Tanzania depends completely or partially on the artisanal fishery in inshore waters (UNEP, 1989; Muhando and Jiddawi, 1998; Johnstone et al. 1998b; Ireland et al. 2004). Reef-based fisheries contribute about 70 % of artisanal fish catch (Muhando and Jiddawi, 1998; Wagner, 2004). Reef-based tourism is

Obura, D.O., Tamelander, J., & Linden, O. (Eds) (2008). Ten years after bleaching - facing the consequences of climate change in the Indian Ocean.CORDIO Status Report 2008. Coastal Oceans Research and Development in the Indian Ocean/Sida-SAREC. Mombasa. http//:www.cordioea.org

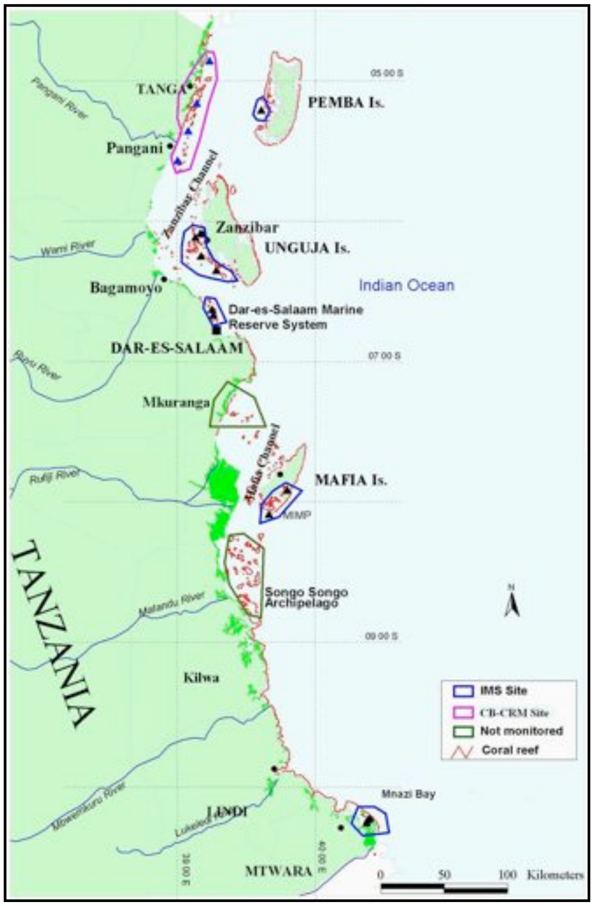


Figure 1. The distribution of coral reef monitoring sites in Tanzania.

increasingly becoming a major contributor to the economy (TCMP, 2001) and there is an increasing trend of use and extraction of natural products from reef organisms, some of which are of medicinal value (Scheuer, 2006). Besides playing a crucial role in biodiversity preservation, coral reefs provide protection for coastal zones. However, the importance of coral reefs and their proximity to the coast make them vulnerable to abuse and degradation from human activities such as over-fishing, destructive fishing, pollution by sediments, nutrients and toxic chemicals, coral mining and shoreline development, and unregulated tourism (Bryceson, 1981; Johnstone et al., 1998a, 1998b; Muhando et al., 2004). As in other parts of the world (Wilkinson, 2004; Souter and Linden, 2005), coral reefs in Tanzania are at risk from many threats including those enhanced by global climate change, e.g., coral bleaching, and Crown-of-thorns-starfish, algal and corallimorpharia proliferation (Muhando et al., 2002; Muhando and Mohammed 2002; McClanahan et al. 2007a, 2007b).

Taking into consideration the importance of coral reefs and the proliferation of stress factors, it is imperative to be aware continuously of the condition of coral reefs. Monitoring the ecology of the reefs and the socioeconomics of people dependent on them is the only way to understand the extent of use, nature and causes of the damage, and to identify ways to address threats. Monitoring provides the essential information required to make management decisions and determine whether or not the decisions are working (Wilkinson et al., 2003, Malleret-King et al., 2006). This paper considers the two main approaches to coral reef monitoring (CRM) that have conducted continuous data collection since the mid 1990s and outlines some of the benefits, challenges and lessons learned from these programmes. This analysis is used to present modifications to monitoring protocols that are being undertaken to improve the quality and usefulness of information derived from CRM in Tanzania.

2. CORAL REEF MONITORING METHODS AND INDICATORS

Coral monitoring in Tanzania started in the late 1980s. Two systems evolved: SCUBA based coral reef monitoring undertaken by academic staff, graduate students and technical staff from IMS (high tech) (Mohammed et al., 2000, 2002) and community based coral reef monitoring (low tech) (Horrill et al., 2001; Wagner, 2004). Both systems were based on internationally recognized protocols developed in Southeast Asia (English et al, 1994). Reef benthos (live coral cover, coralline algae, soft corals, sponges, fleshy algae, non-biotic cover) were assessed using Line-Intercept method, while reef fish and macro-invertebrates (lobsters, clams, gastropods, sea urchins,

Table 1. Comparison of reef benthic categories measured by IMS and TCZCDP.

	Scuba based coral reef monitoring (IMS)	Community based coral reef monitoring (TCZCDP)
Object type	Benthic objects (object id)	Benthic objects (object id)
Live hard corals (HC)	*Acropora*, branching (ACB) *Acropora*, encrusting (ACE) *Acropora*, submassive (ACS) *Acropora*, digitate (ACD) *Acropora*, tabulate (ACT) Coral, branching (CB) Coral, encrusting (CE) Coral, foliose (CF) Coral, massive (CM) Coral, submassive (CS) Coral, mushroom (CMR) Coral, *millepora* (CME) Coral, *heliopora* (CHL)	Matumbawe hai (MH) (Live hard corals)
Partly dead corals		Matumbawe yaliyokufa kidogo (MKK) (partly dead corals)
Bleached corals		Matumbawe hai maeupe (MHM) (Bleached corals)
Soft corals (SC)	Soft coral (SC)	Matumbawe laini (ML) (soft corals)
Sponges (SP)	Sponges (SP)	Spongi (SP) (Sponges)
Coralline algae (CA)	Coralline algae (CA)	
Algae (AL)	Algal assemblage (AA) Algae, Halimeda (HA) Algae, Macroalgae (MA) Algae, Turf algae (TA)	Mwani (MN) (All Algae)
Others (OT)	Seagrass (SG) Zoanthids (ZO) Clam (CLAM) Corallimorpharian (RH) Others (OT)	Majani (MJ) – (sea grass) Wengineo (WG) (Others)
Substrate (SU)	Sand (S) Silt (SI) Rock (RCK) Rubble (R) Dead coral (DC) Dead coral with algae (DCA)	Mchanga (MC) – (sand) Mwamba (MW) – (rocky surface) Matumbawe yaliyokufa (MK) (Dead corals)

Table 2. Fish recording template for Community based coral reef.

Category name	Description
Chafi	Family: Siganidae
Chewa	Family: Serranidae
Changu	Family: Lethrinidae and some members of Lutjanidae
Chazanda	*Lutjanus argentimaculatus*
Kangu wadogo	Selected members of Scaridae and Labridae
Kangu wakubwa	Selected members of Scaridae and Labridae
Kangaja	Family Acanthuridae: Members of the genus *Ctenochaetus* and *Acanthurus*, except *A. triostegus*,
Kolekole	Family Carangidae
Kitamba	*Plectorhinchus sordidus*, *P. playfairi*, *P. flavomaculatus*.
Kidui	Family Balistidae
Kipepeo	Family Chaetodontidae
Mlea	*Plectorhinchus gaterinus*, *P. orientalis*
Mwasoya	Family Pomacanthidae: Members of the genus *Pomacanthus* and *Plygoplites* only
Mkundaji	Family Mullidae
Haraki	*Lutjanus bohar*
Tembo	*Lutjanus fulviflamma*, *L.lutjanus*, *L. ehrenbergii*
Mbono	Family Caesionidae

sea cucumbers, sea stars, crown-of-thorns-starfish) were assessed using belt transects.

The community based coral reef monitoring (CB-CRM) method was first applied by the Tanga Coastal Zone Conservation and Development Program (TCZCDP) in 1996 and it extended to Dar es Salaam, Bagamoyo and Mkuranga. Efforts are underway to introduce it in Songosongo archipelago (Fig. 1). Scuba based monitoring was started in 1994 by the Institute of Marine Sciences (IMS) in Zanzibar. Coral reefs off Zanzibar town, Misali in Pemba, in Mafia Island Marine Park in Mafia and in Mnazi Bay, Mtwara are monitored using this technique (Fig. 1). There were differences in categories recorded by the two systems: TCZCDP grouped all live hard corals as one category "Matumbawe Hai", while Institute of Marine Sciences CRM Team had 13 categories representing Acropora and Non-Acropora growth forms (Table 1).

All algal types were grouped as one category "Mwani" in TCZCDP while coralline algae were separated from turf, macro-algae, *Halimeda* and other algal assemblages by IMS. Counting of coral recruits (less than 10 cm canopy width) was only done by IMS from 1999. Macro-invertebrates recorded in community and Scuba based monitoring were similar and included lobsters, clams, gastropods, bivalves, sea cucumbers, sea urchins, sea stars, and Crown-of-thorns starfish. Community based monitoring emphasized more on fished groups and paid less attention to other reef fish groups (Table 2). A calibration attempt between the two systems was carried in Tanga in 2004. Pairs of TCZCDP and IMS monitors assessed benthic cover, counted macro-invertebrates and fish in the same transects (twelve 20m transects in Mwamba Taa and Mwamba Makome reefs in Tanga and six 50 x 5 m belt transects for fish (Muhando, 2004 Unpubl). Comparisons revealed both systems provided the same estimates of live coral

Table 3. Comparison (Paired sample t test) for reef benthic cover results between Community (TCZCDP) and Scuba based coral reef monitors (IMS).

Benthic category	t	df	p	Difference between IMS and TCZCDP
Hard coral	0.70	12	0.4963	Not significant
Bleached corals	*	*	*	Extremely significant - Not observed by IMS team
Coralline algae	*	*	*	Extremely significant - Not observed by TCZCDP team
Algae	1.41	12	0.1855	Not significant
Soft coral	7.37	12	< 0.0001	Extremely significant (TCZCDP > IMS)
Sponge	0.44	12	0.6650	Not significant
Other Organisms	3.03	12	0.0105	Significant (IMS > TCZCDP)
Dead coral	0.98	12	0.3112	Not significant
Substrate	1.36	12	0.2003	Not significant

cover (Table 3). However, there were differences in algal cover and soft coral cover, mainly due to the fact that some community based monitors did not distinguish these categories from corallimorpharia and sea anemones. With more education and awareness, community based monitoring is expected to provide more or less the same results as currently contributed by the IMS coral reef monitoring team.

3. CONTRIBUTION OF THE PAST CORAL REEF MONITORING PROGRAMS

Coral reef monitoring contributed extensive and useful information on the intensity and trends of damage to reefs, including coral degradation after the 1998 coral bleaching and mortality event (Muhando, 1999; Mohammed et al., 2000, 2002; McClanahan et al., 2007b). Reef locations and coral species that suffered high mortality were identified. Local knowledge on coral reef environment and resources has improved, especially where community based coral reef monitoring was practiced (Horrill et al., 2001). Better understanding among the communities was noted when monitoring results were disseminated by trained monitors who were themselves community members.

After reading and understanding CRM reports, ICM managers became more aware of environmental processes and resource dynamics (Muhando, 2006). This understanding raised their hunger for further information on factors driving the observed changes. Resource protection efforts increased as a result of awareness derived from coral reef research and monitoring programs (e.g. Obura, 2004). Furthermore, information contributed to international forums has become more representative, elaborate and detailed than before CRM (see. CORDIO reports 1999, 2000, 2002, 2005 and Status of Coral Reefs of the World: 2002, 2004).

Scientific knowledge on biodiversity, especially of coral and reef fish species has improved tremendously, specifically after the introduction of underwater photography (Johnstone et al., 1998a). The use of local names is becoming more popular than English names as images of reef environment and organisms are presented to local communities. This has raised the need for developing standardised Kiswahili names of reef organisms. Coral reef monitoring has raised issues that require detailed research. For example, commercially important reef macro-invertebrates such as lobsters, sea cucumbers, octopus and ornamental gastropods occurred in lower numbers than anticipated in most reefs (Mohammed et al., 2000, 2002). This may be due to local growth and/or recruitment overfishing, changes in settlement and recruitment processes, or even habitat destruction in larval source reefs, which could be a nearby reef or a number of distant reefs. Studies on larval connectivity are urgently required to reveal larval dispersal processes of the reef invertebrates, including that of the notorious coral predator, the crown-of-thorns starfish.

4. LESSONS LEARNT FROM THE PAST CORAL REEF MONITORING PROGRAMS

There are lessons and challenges learnt from the CRM programs so far. Some of these are mentioned below:

a) Statistical power analysis on coral reef monitoring data revealed that a minimum of 140 transects was required in order to detect 10 % change, and that the on-going sample sizes of 12 – 24 random transects can only detect changes larger than 30%. Low power of detection is contributed mostly by high environmental variance, a characteristic of most coral reef environment. The variance between monitors was generally low, indicating that monitors were well trained and calibrated. With this high level of environmental noise, community based monitoring may not easily discriminate impacts, such as those contributed by human activities versus those from natural impacts.

b) The selection and grouping of reef indicators (categories) were probably not optimum for Tanzanian reef management needs. Feedback from some ICM managers at district level indicated that some parameters, e.g., habitat complexity and environmental forcing variables are not well represented in the ongoing monitoring programs. Factors like nutrient dynamics, fishing pressure and sedimentation levels, were not measured.

c) Change in coral reef biodiversity is not captured in the current coral reef monitoring programs as reef benthic and macro-invertebrate categories are restricted to growth forms and broad taxon groups. It is not possible to deduce change in coral species richness or isolate species tolerant to degradation forces in the current coral reef monitoring database.

d) Administration and coordination of coral reef monitoring outputs at national level is still not optimal. Currently there is no strategic plan for coral reef monitoring at the national level, nor is there a national centralized database. Capacity building (personnel and equipment) for monitoring is not coordinated and lacks continuity among institutions. There is also a problem of loss of trained coral reef monitors, often through promotion to higher levels of responsibility. The recently established National Coral Reef Task Force and the on going discussions on developing a National Coral Reef Strategic Plan are expected to contribute to the solution of this situation.

e) CRM monitoring programs are characterised by inconsistent financial support leading to interruptions. There are also inadequate procedures of tracking data and reports from individual projects by visiting scientists, denying access to potential management information.

f) Dissemination of CRM data and information is far from optimum. When available, coral reef monitoring reports are not timely and widely distributed at national level. Some managers were not aware of the biennial Status of Coral Reefs of World reports (2002, 2004) nor of the CORDIO Coral Reef Status reports (1999, 2000, 2002 and 2005).

g) CRM Reports were not optimally used by ICM managers. Some local managers had problems understanding scientific terminology and implication of changes in the monitored indicators, hence could not translate data into management options.

In conclusion, the current CRM program has increased awareness, enhanced conservation efforts and contributed knowledge on coral reef environment, resources and associated factors and processes. However, the current CRM effort is low, inconsistent and unable to detect changes at satisfactory levels. Hence it should be improved taking into consideration current management needs, field conditions and participation of scientists, local communities and other unutilized resources, including recreational divers.

5. SOME OF THE NECESSARY ACTIONS TO IMPROVE CORAL REEF MONITORING IN TANZANIA

Improvements in coral reef data collection (Scuba and community based techniques), analysis and dissemination information is necessary to guide sustainable development and conservation efforts. The following need to be considered carefully:

i. Ecological and socio-economic monitoring of coral reefs should be part of a larger ICM programme of activities. Results need to be integrated, linked and associated with other coastal ecosystems and socio-economy of coastal communities and vice versa.

ii. Existing CRM programs need to be reviewed and improved to solve ICM issues by:

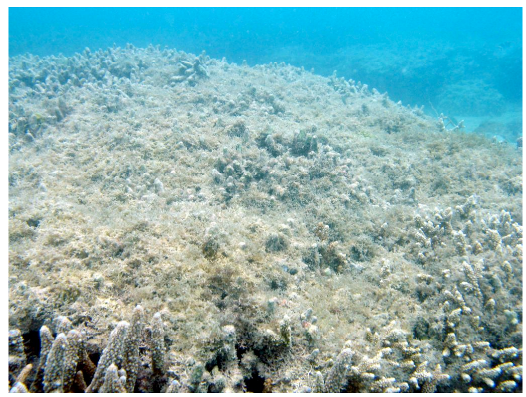
- Increasing change detection level by improving sampling designs and increasing sampling efforts
- Determining the optimum (better) combination of CRM protocols to meet the requirements than is currently done, e.g., by adding photo quadrats and recent technologies, including video transects
- Including biodiversity change indicators, e.g., coral genus and/or functional groups based on the morphology (Bellwood et al., 2004) instead of current growth forms (English et al., 1994).
- Preparing better illustrations (in Kiswahili) to improve data capture and information dissemination among local communities and others.
- Including coral recruitment and/or recovery indicators in community based monitoring
- Identifying as part of the coral reef monitoring program important environmental and human indicators, e.g. water temperature, nutrients, sedimentation, chlorophyll, fishing intensity, land-based sources of pollution, etc.

iii. In consultation with Central Govt, Local authorities, Regional CRTF, GCRMN, ICM programs, donors, etc., secure stable funding sources. CRM program should include continuous capacity building, of personnel and equipment.

iv. Continuous active participation of community based monitors and scientists in environmental awareness and education

6. MODIFICATIONS ADOPTED BY SCUBA BASED MONITORING TEAM AT IMS

In order to complement what can be assessed by community based monitors and to keep pace with increased threats to reefs such as loss of biodiversity, change in species composition, proliferation of algae (Figs. 2a and 2b) and corallimorpharia, and crown-of-



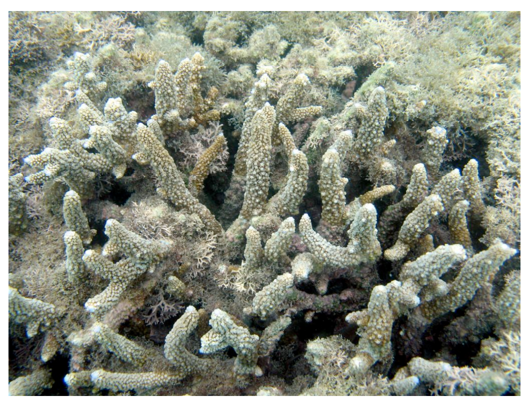


Figure 2a and 2b. Algal proliferation on Bongoyo coral reefs just north of Dar es Salaam. Impacts of eutrophication and sedimentation.

Table 4: The modified Reef benthos template for Scuba based coral reef monitoring at Institute of Marine Sciences, Zanzibar.

Object type	Benthic objects (object id)	
ACROPORA	*Acropora* branching (ACB) *Acropora* digitate (ACD) *Acropora*encrusting (ACE)	*Acropora*tabulate (ACT) *Acropora* submassive (ACS)
NON-ACROPORA	*Acanthastrea* (Acan) *Alveopora* (Alve) *Astreopora* (Astr) *Blastomussa* (Blas) *Caulastrea* (Caul) *Coscinarea* (Cosc) *Cyphastrea* (Cyph) *Diploastrea* (Dilp) *Echinophyllia* (Echph) *Echinopora* (Echpo) *Euphyllia* (Euph) *Favia* (Favia) *Favites* (Favit) *Fungia* (Fung) *Galaxea* (Gala) *Gardineroseris* (Gard) *Goniastrea* (Gonia) *Goniopora* (Gonio) *Halomitra* (Halo) *Herpolitha* (Herp) *Hydnophora* (Hydn) *Leptastrea* (Lepta) *Leptoria* (Lepto) *Lobopyllia* (Lobo)	*Merulina* (Meru) *Millepora* (Mill) *Montipora* (Monti) *Montastrea* (Monta) *Mycedium* (Myce) *Oulastrea* (Oula) *Oulophyllia* (Oulo) *Oxypora* (Oxyp) *Pavona* (Pavo) *Physogyra* (Physo) *Platygyra* (Platy) *Plerogyra* (Plero) *Pleiastrea* (Plei) *Pocillopora* (Poci) *Podabacia* (Poda) *Porites* branching (Pobr) *Porites* massive (Poma) *Psammacora* (Psam) *Seriatopora* (Seri) *Stylophora* (Styl) *Symphyllia* (Symp) *Synarea* (Syna) *Turbinaria* (Turb) *Unid-Corals* (Co-ot)
CALCAREOUS ALGAE	Coralline algae (CA)	
S-CORAL	Soft corals (SC)	
SPONGES	Sponges (SP)	
CORALLIMORPHARIA	Corallimorpharia (RH)	
ALGAE	Algal Assemblage (AA) *Halimeda* (HA)	Macroalgae (MA) Turf algae (TA)
OTHERS	Zoanthids (ZO) Clams (CLAM)	Seagrass (SG) Others (OT)
SUB_1	Dead coral (DC) Rock (RCK)	Dead coral with algae (DCA) Rubble R
SUB_2	Sand (S)	Silt (SI)

Figure 3. Crown-of-thorns-starfish infestation on Tanzania coral reefs .

thorns starfish predation (Fig. 3), IMS has modified its Scuba based CRM protocols. The main emphasis is now on biodiversity changes. Reef corals are now monitored at generic level instead of growth forms alone (Table 4). Reef macro-invertebrates (sea urchins, sea cucumbers, gastropods) include more sub-groups than before. Coral recruitment (young corals less than 10 cm corals) is also monitored at generic level based on the list in Table 4. Training and practice in the new system started in April 2006 and was repeated in May 2007 with funding from the Coral Reef Targeted Research and Capacity Building Project (www.gefcoral.org). Continuous training and calibration is part of the ongoing Coral Reef Targeted Research project activity at the Institute of Marine Sciences. Other recommended actions mentioned above will be considered at a later stage. In the near future a user friendly (and modified) manual for community based monitoring is under preparation to guide and harmonize various groups involved.

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