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Participatory monitoring of changes in coastal and marine biodiversity

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This study reports results obtained from participatory monitoring conducted in Tanzania in two types of keystone ecosystems, mangrove forests and coral reefs. The report also analyses participatory monitoring as an effective tool in environmental conservation and management. Participatory monitoring data collected from three mangrove areas subjected to different levels of human impacts, low, moderate and high, clearly indicated the effects on mangrove basal area and species diversity. Participatory coral reef monitoring clearly showed degradation due to human impacts in one are and definite positive trends over time due to management interventions in another area. Participatory monitoring produces large amounts of informative data in a short time at low cost. Moreover, it has profound positive impact on the participants in terms of enhancing their environmental awareness, creating a feeling of "ownership" of the environment and motivating them to protect and restore the ecosystems they monitor. However, in order for participatory monitoring to be successful, there should be proper selection of participants, adequate training and on-going supervision by experts.

[Key words: Participatory monitoring, coastal/marine, keystone ecosystems, biodiversity**]**

Introduction

For monitoring to be beneficial, it should be aimed at improving environmental management. Monitoring facilitates informed decision-making and strategic planning in management. Management basically involves gathering adequate information through assessment and monitoring to make informed decisions or plans, formulating strategic plans, implementation of those plans (including enforcement) and periodic program evaluation to improve the management process, where the latter is intimately linked to on-going monitoring of the environment.

The important aspect of environmental monitoring is to detect changes or trends over time, with respect to biomass, biodiversity or ecological processes. These may be either negative trends due to human activities or natural disasters or positive trends due to effective management interventions, e.g., protection and restoration. However, for monitoring to be effective, it should be done frequently enough and on a long-term basis in order to differentiate "noise" (stochastic, cyclic and dynamic variations) from "signal" (precipitous change in a definite, usually undesirable, direction)[1].

Generally, we think of biodiversity as having three main components: species diversity, ecosystem diversity and genetic diversity[2]. Species diversity takes into consideration both species richness, or number of species, and the evenness of the abundance of those species. Conserving ecosystem diversity is concerned with ensuring that at least a few representatives of all types of ecosystems persist. Ecosystems vary with respect to their physical and chemical properties, species composition, biomass, density, structural characteristics, spatial and temporal variations, food webs, ecological processes and stability. Conservationalists, however, do not have an agreed upon list of ecosystems to preserve, as is the case with species. Genetic diversity is the diversity of genes within species. This diversity is very important in allowing species to adapt and evolve to changing conditions, especially in this period of global climate change.

Often researchers concentrate primarily on species diversity and neglect ecosystem and genetic diversity. Actually, if ecosystems are monitored, species diversity is automatically monitored at the same time, since one of the characteristics of an ecosystem is its assemblage of species. Thus, focussing on monitoring

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ecosystems enables us to gain a very good understanding of overall trends in biodiversity.

In order to maximize efforts, it is often strategic to select keystone ecosystems to monitor instead of attempting to monitor all ecosystems in an area. Keystone ecosystems may be defined as ecosystems that provide important ecological services that extend far beyond their area of coverage[3]. Such services include the provision of breeding, nursery and feeding grounds; protection; and export of large quantities of organic matter. Keystone ecosystems are usually characterized by high productivity, high biodiversity, and rapid nutrient recycling. As a consequence of the important roles played by keystone ecosystems, a small impact on these ecosystems, either negative or positive, can have a large impact on the surrounding environment. In other words, changes in keystone ecosystems cause multiplicative changes in surrounding ecosystems.

Thus, it is very cost effective to select keystone ecosystems as monitoring targets. Monitoring these, gives a good indication of the health of other ecosystems in the vicinity. This does not mean, however, that other ecosystems should be neglected, since some threatened or endangered species are found far away from such ecosystems. Nevertheless, if resources for monitoring are limited, they should be invested in keystone ecosystems. Generally, the most important keystone ecosystems in the Indian Ocean are mangrove forests, coral reefs and seagrass beds, since they are found along the coastline of most of the countries in the region.

Participatory monitoring means involving resource users or stakeholders who have some interest in the habitats or biota being monitored. Such participants may be members of the communities who live in the vicinity of the ecosystems and who may or may not make use of the resources they provide. Others may include tourists, hoteliers, SCUBA divers and dive operators. Participatory monitoring has several advantages over conventional monitoring carried out by only scientists. First of all it greatly increases the manpower involved and thus facilitates the collection of large amounts of data in a short time. Another advantage is with respect to economics; participants often do not need to be paid because they consider that they are monitoring their own resources. Or, sometimes they may require minimal amounts as compensation for their time. Yet another advantage is that when participants monitor ecosystems from which they derive resources, it enhances a feeling of "ownership" of those ecosystems and, consequently, they become motivated to protect and conserve them. However, the disadvantage of participatory monitoring is that the reliability of the data produced may sometimes be questionable. Identifications of organisms are not always accurate, particularly with respect to some taxonomic groups. Moreover, identification is often not to species level, but rather, to the level of genus, family or even phylum.

This study reports results from participatory monitoring conducted in two types of keystone ecosystems, mangrove forests and coral reefs, which are very important in Tanzania. Mangrove forests cover 108,138 ha along the coast of mainland Tanzania[4] and coral reefs are located along about two thirds (600 km) of Tanzania's continental shelf[3] (Fig. 1). This report also analyses the benefits of participatory monitoring, points out some of the limitations involved and gives recommendations for mitigating difficulties encountered, so that participatory monitoring can, indeed, become an effective tool in environmental conservation and management.

In keeping with the theme of the Workshop on Coastal and Marine Biodiversity of the Indian Ocean held in Goa, India, 12-15 December 2003, participatory monitoring can be considered as a powerful tool to not only assess and explain the diversity, distribution and abundance of marine life, which is the mandate of The Census of Marine Life; but also to motivate the community participants to conserve the natural environment and its biodiversity.

Methodology

Study sites

Participatory monitoring of mangrove forests has been conducted in selected study sites in several regions/districts of Tanzania, namely (from north to south), Tanga, Bagamoyo, Dar es Salaam, Rufiji, Kilwa and Mtwara, from 2002-2003 (Fig. 1). In all of these areas only initial monitoring sessions (baseline) have been conducted so far; therefore, no trends can be reported over time, but comparisons can be made among mangrove areas. However, for the purpose of this paper, data is only presented from three contrasting areas: a relatively pristine area (Rufiji), an area closer to the large urban centre of Dar es Salaam (Bagamoyo) and an area on the outskirts of Dar es Salaam itself, which has been subjected to substantial

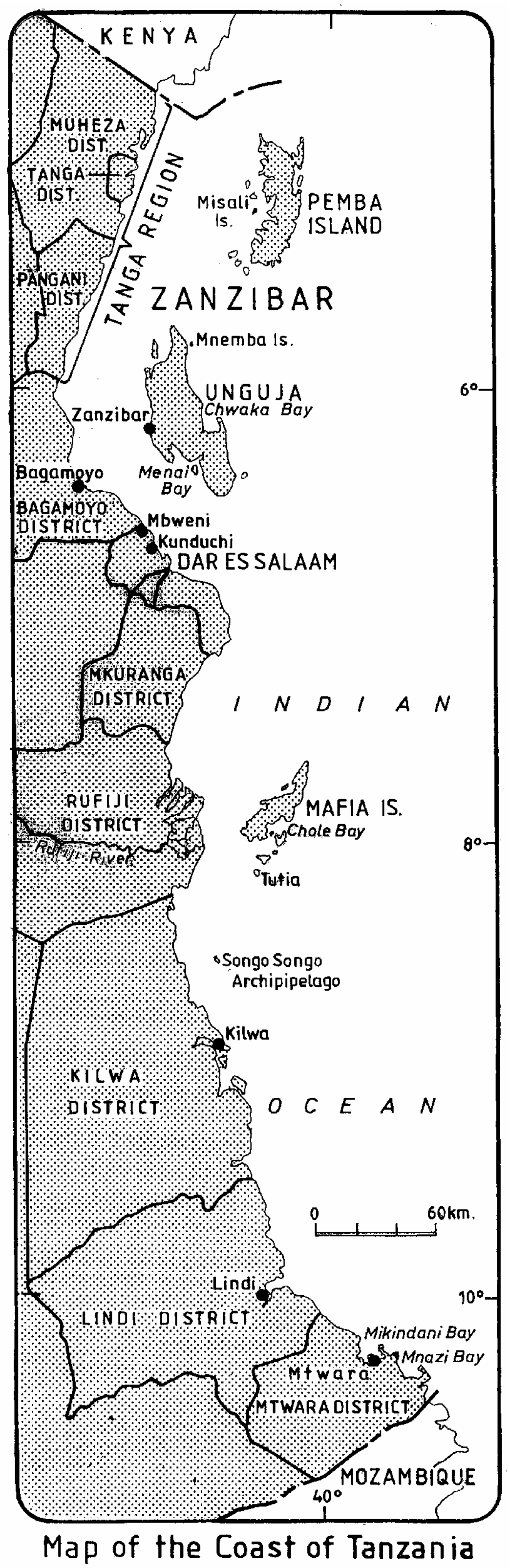

Fig. 1—Map of the coast of Tanzania

human impacts. Coral reefs have been monitored through the participatory approach only in Dar es Salaam, where only initial baseline measurements have been taken, and Tanga, where participatory monitoring has been carried out every six months since 1997.

Training and supervision of participants

Participants were trained in the field by demonstrating the methods, step by step, including, randomly selecting and permanently marking the plots/transects, taking measurements and recording data. Each participant was given a chance to practice all steps before data collection commenced. In the case of mangroves forests, such training required only one or two days, whereas, for coral reefs, several days were required.

There was on-going supervision during fieldwork. Field trips commonly involved a senior scientist and four junior scientists; four member of staff from the MPA, ICM program or district office concerned with the area; and 8-12 villagers from the surrounding area who were familiar with the ecosystem. This large group was divided into four teams, with one scientist and one program/district staff member present in each team in order to ensure close supervision.

Field methods

Internationally recognized scientific techniques[5] recommended by the Australian Institute of Marine Science (AIMS) were used. This was done to facilitate linking the data collected with other scientific studies carried out in the area and to enable information sharing from country to country. Moreover, GPS readings were recorded for almost every plot or transect monitored so that data could be fed into a GIS database.

In mangrove forests, 5 × 5 m plots were marked randomly along transects perpendicular to vegetation types. Within each plot, mangrove plants were counted by species and classified by three maturity categories (seedling, sapling and tree). The heights of seedlings and the girth at breast height (GBH) of saplings and trees were recorded. Stumps were also measured and counted by species as an indication of cutting pressure, though this is an additional variable not mentioned in the AIMS methodology. Benthic macrofauna were also monitored in some sites by counting them according to major taxonomic groups in random, 0.25 × 0.25 m quadrats. After counting crabs and other organisms on the surface, the substrate within the quadrat was dug out to a depth of 15 cm and passed through a 2 mm mesh sieve to extract infauna, which were then identified and counted.

On coral reefs, the Line Intercept Transect (LIT) method was used to record major benthic lifeforms (hard coral, soft coral, algae, sponge, etc.) and non-living substrate categories (sand, rubble, rock) along 10 m transects. Motile macro-invertebrates found on the surface of the substrate were identified and counted, according to major groups, in 2 × 10 m belt transects.

Data analysis

The data recorded through participatory monitoring in mangrove forests was analyzed to obtain information on species diversity (i.e., the species richness component or number of species), the density (calculated as the number of individuals of each species per unit area) and basal area of each species (calculated as the total area of tree trunks of each species per unit area, using the GBH measurements) as well as ecosystem maturity and regeneration capacity (based on the relative abundance of the trees, saplings and seedlings). The level of degradation due to cutting pressure was also ascertained. Data recorded on coral reefs gave percent cover of major benthic lifeforms and non-living substrate categories as well as the density of motile macro-invertebrates by major taxonomic group. The percent cover of rubble and dead coral provided important information on the extent of reef damage.

Results and Discussion

Mangrove forests

Rufiji

At Kifuma in Rufiji, total basal area of all species was 1261 $cm^2/25\ m^2$ plot (Fig. 2). *Sonneratia alba* and *Avicennia marina* were the dominant species. In terms of density, apart from a very high number of seedlings of *A. marina*, there was good representation of seedlings, saplings and trees of six other species (*Bruguiera gymnorrhiza, Ceriops tagal, Heritiera littoralis, Rhizophora mucronata, S. alba* and *Xylocarpus granatum*) and minor representation of *Lumnitzera racemosa* (Fig. 3). The number of stumps found at Kifuma was negligible, though some stumps were found in other areas of Rufiji. This very high basal area and high diversity of mangrove species can be explained by the fact that the Rufiji Delta is the largest mangrove complex in eastern Africa, consisting of 48,030 ha and is quite far from Dar es Salaam and other urban centres. The human population in and around the delta is very sparse, thus human impacts are low, which also explains the low cutting pressure. Moreover, there is relatively good management of the area by the Mangrove Management Project.

Bagamoyo

In Bagamoyo, the basal area of mangroves was 753, 744 and 631 $cm^2/25\ m^2$ plot at Chengeni-Bwanakozi, Ruvu-Mtailend and Ruvu-Chenipembe, respectively (Fig. 4). At Chengeni-Bwanakozi, only three species were found. *Rhizophora mucronata* was dominant in terms of density (Fig. 5), while *Sonneratia alba* was dominant in terms of basal area (Fig. 4) due to the presence of a few trees of large size. There are no seedlings or saplings of *S. alba* present, showing that this species may decline in the future. A few stumps of *Ceriops tagal* and *R. mucronata* were observed. Ruvu-Mtailend was dominated by *Avicennia marina* in terms of both basal area (Fig. 4) and seedlings (Fig. 6). There were also significant numbers of *A. marina* stumps. Ruvu-Chenipembe was dominated by *A. marina*, both in terms of basal area (Fig. 4) and density (Fig. 7), with *Heritiera littoralis* and *Xylocarpus granatum* also being important. There was also significant density of stumps of all three dominant species.

Bagamoyo is about 80 km from the large urban center of Dar es Salaam, but the suburbs of Dar es Salaam extend to within about 40 km of Bagamoyo. Thus, there is a huge demand for various resources that can be obtained from mangrove forests, particularly charcoal, firewood and building poles. Although the Mangrove Management Project and the Bagamoyo District office attempt to regulate mangrove exploitation, there is inappropriate exploitation of the resources, resulting in low mangrove abundance and diversity in comparison with the relatively pristine forest of Rufiji. Thus, not only better protection, but also restoration efforts are required to return the Bagamoyo mangrove forests to their original state.

Dar es Salaam

At two sites on the outskirts of Dar es Salaam, Mbweni and Kunduchi, the basal area of mangroves was 85 and 64 $cm^2/25\ m^2$, respectively (Fig. 8), as

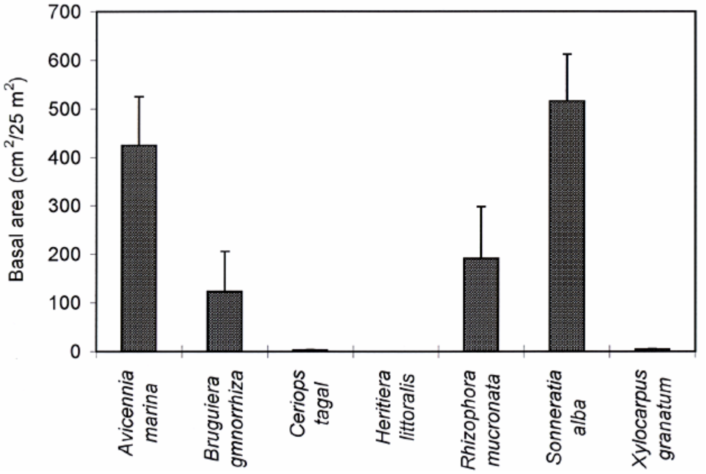

Fig. 2—Basal area (mean + standard error) of mangrove species at Kifuma in Rufiji.

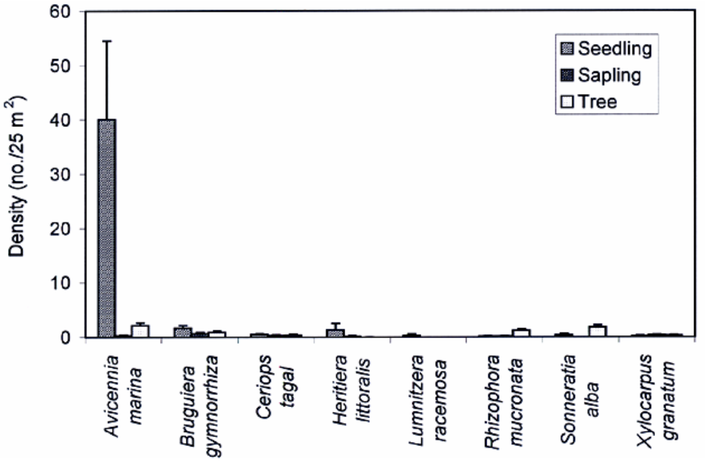

Fig. 3—Density (mean + standard error) of various maturity categories of mangrove species at Kifuma, Rufiji.

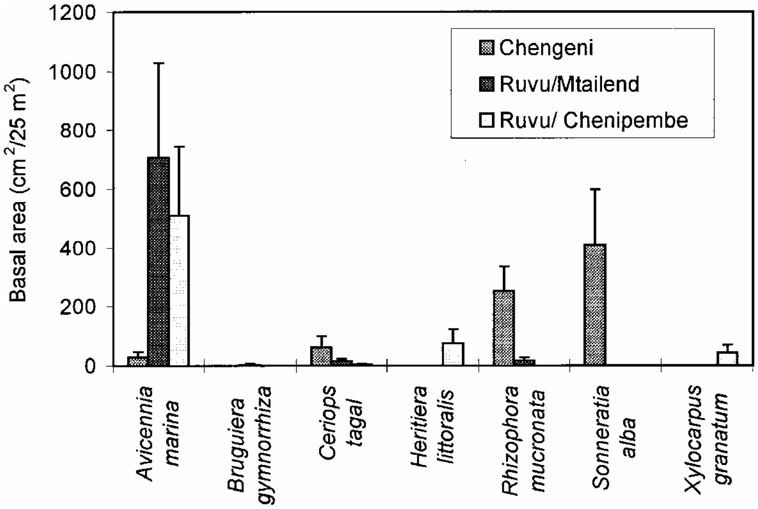

Fig. 4—Basal area (mean + standard error) of mangrove species at three sites in Bagamoyo.

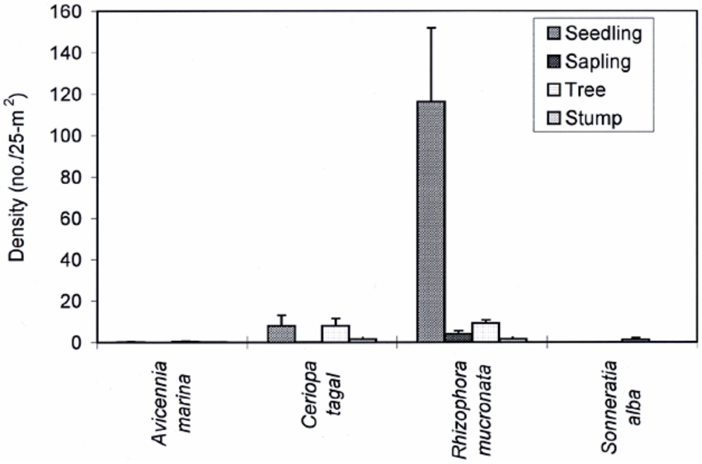

Fig. 5—Density (mean + standard error) of various maturity categories of mangrove species at Chengeni kwa Bwanakozi, Bagamoyo.

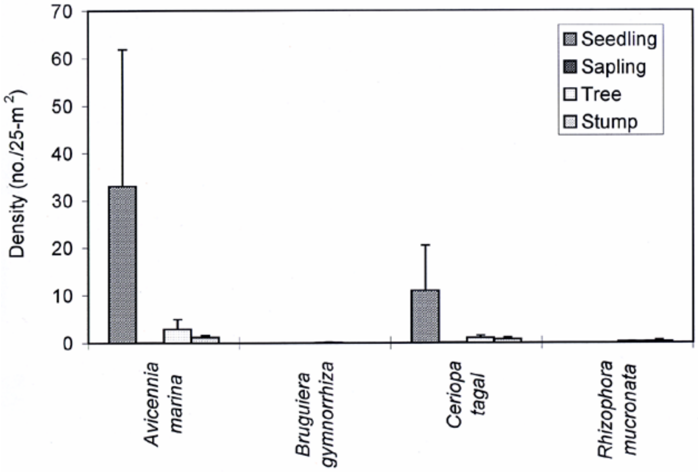

Fig. 6—Density (mean + standard error) of various maturity categories of mangrove species at Ruvu kwa Mtailend, Bagamoyo.

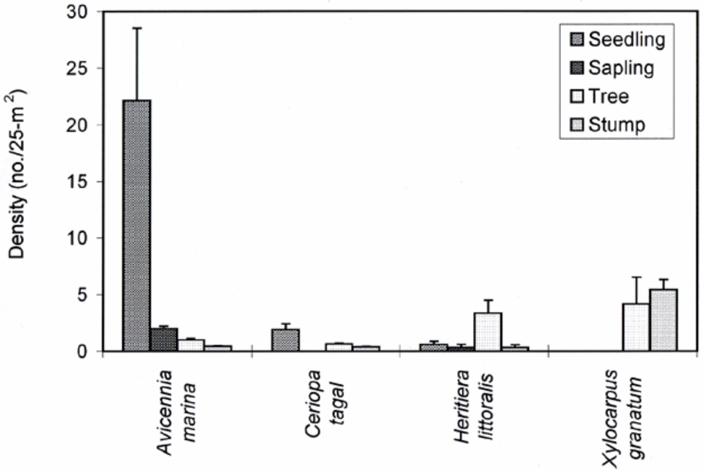

Fig. 7—Density (mean + standard error) of various maturity categories of mangrove species at Ruvu kwa Chenipembe, Bagamoyo.

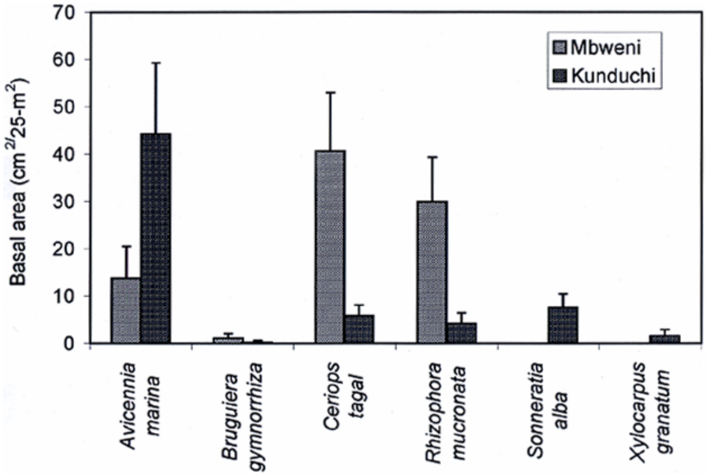

Fig. 8—Basal area (mean + standard error) of various mangrove species at Mbweni and Kunduchi, Dar es Salaam.

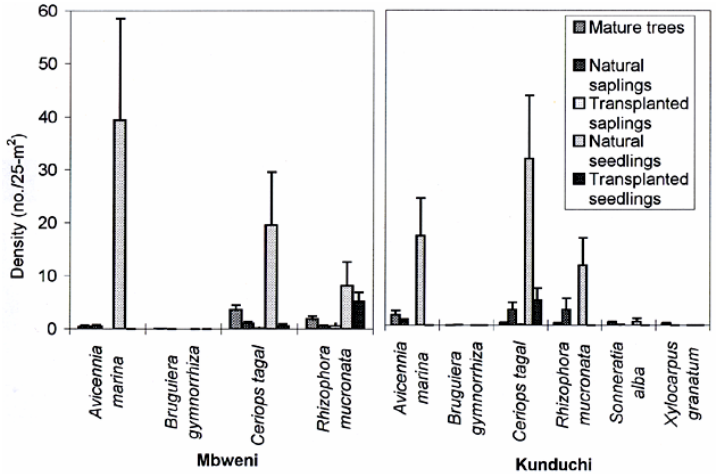

Fig. 9—Density (mean + standard error) of various maturity categories of naturally occurring and transplanted mangroves at Mbweni and Kunduchi, Dar es Salaam.

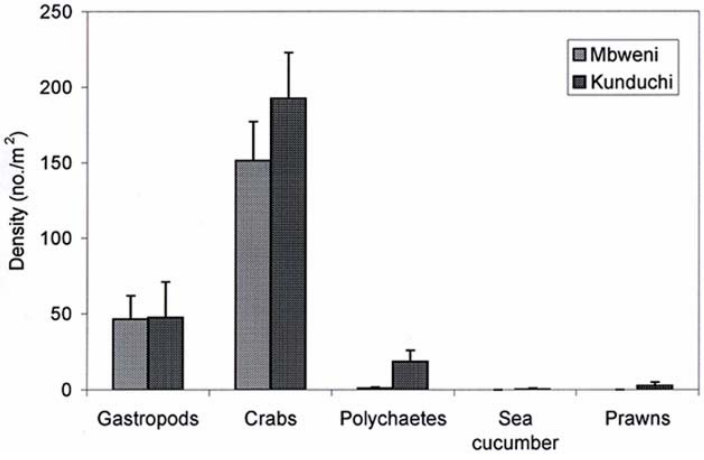

Fig.10—Density (mean + standard error) of benthic macrofauna in Mbweni and Kunduchi mangrove forests near Dar es Salaam.

recorded during participatory monitoring conducted in 2002. Mbweni was dominated by *Ceriops, Rhizophora* and *Avicennia* and had a particularly high density of *Avicennia* seedlings (Fig. 9). There was also considerable density of *Rhizophora* seedlings and saplings that had been transplanted by villagers residing in the area. In fact, thousands of seedlings have been transplanted since 1998. This restoration effort is likely to show significant positive impact on the forest in the near future. Kunduchi was dominated by *Avicennia*, in terms of basal area (Fig. 8) and had a high density of natural seedlings of *Ceriops, Avicennia* and *Rhizophora* (Fig. 9). There was also a significant number of seedlings of *Ceriops* that had been transplanted by the villagers. The dominant groups of macrofauna at both sites were crabs and gastropods (Fig. 10).

The results obtained from this participatory monitoring are very similar to those obtained through a scientific study conducted by Akwilapo[6] who used the same plot method in 2000 and recorded 62 $cm^2/25\ m^2$ in Mbweni. Since the area was being fairly well protected during the two-year period between that study and this study and since some of the seedlings transplanted by the community had reached the sapling stage by 2002, the slight rise from 62 to 85 $cm^2/25\ m^2$ is to be expected. Moreover, with respect to benthic macrofauna, Akwilapo[6] recorded a total of 260 individuals/m^2 in Mbweni during the rainy season and a total of 178 individuals/m^2 during the dry season. This participatory monitoring, conducted at the completion of the rainy season when the dry season was commencing, recorded 201 individuals/m^2. In both studies, crabs were dominant, followed by gastropods, with very few other organisms present. Thus, the findings of this study were remarkably similar to those of Akwilapo[6], verifying that participatory monitoring can produce nearly accurate and reliable data when there is proper training and supervision.

Since Mbweni and Kunduchi mangrove forests are right on the outskirts of Dar es Salaam, they have been subjected to constant human pressures for many years. There has been extensive harvesting for firewood, charcoal and building poles. Moreover, sections of these forests have been cleared for the construction of saltpans and houses. Thus, the participatory monitoring showed extremely low mangrove basal area and low species diversity in Dar es Salaam sites in comparison with Rufiji, and even in comparison with Bagamoyo. Thus, though there have been some restoration efforts carried out, more efforts in replanting a greater variety of mangrove species is required. However, since Rufiji is a mature forest consisting mainly of large trees, mangrove density is low and there are few seedlings. Mbweni and Kunduchi, on the other hand, show good density of seedlings, including those that have been transplanted, indicating good potential for recovery. Recently Mbweni and Kunduchi mangrove forests were monitored a second time. Although these data have not yet been analyzed, we expect a significant increase in both density and basal area, since cutting has been almost regulated and many of the seedlings transplanted have grown into saplings.

Coral reefs

Dar es Salaam

Participatory monitoring of coral reefs, involving local fishermen, started recently in Dar es Salaam. However, the process for selecting the fishermen was not thorough, the training period was quite short and the fishermen have not yet had much experience in monitoring. Fisherman X, nevertheless, learned the techniques of monitoring fairly quickly and recorded five benthic categories along transect one at Mbudya Island (Fig. 11), with rubble being the dominant category (70%) and hard coral only having 16% cover. Fisherman Y, on the other hand, was very slow at learning to differentiate the various categories and had trouble recording. He recorded only three benthic categories along exactly the same transect, with rubble dominating at 61%, hard coral being 38% and dead coral being almost negligible (Fig. 11). The actual monitoring report was based only on transects done by the fishermen who were considered as being the most accurate, with results as shown in Fig. 12. Rubble was by far the dominant benthic category at 70%, with only 16% hard coral cover. There is a plan to re-select some new fishermen for monitoring and to re-train others.

The high percent cover of rubble at Mbudya Island can be attributed to many years of dynamite fishing, combined with coral bleaching. Though there has been a reduction in dynamite fishing in recent years, complete elimination of this destructive practice has been difficult due to the influx of fishermen from many other areas and the lack of facilities for regular patrols. Following the worldwide coral bleaching event of 1998, the resultant dead coral remained

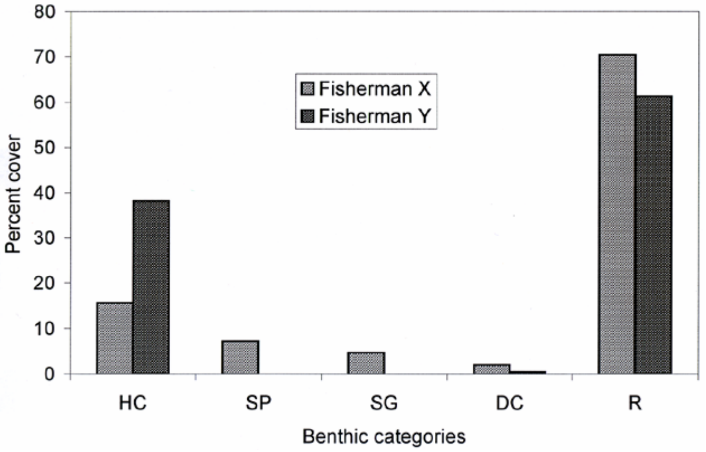

Fig. 11—Percent cover of benthic categories recorded by fishermen X and Y along the same transect at Mbudya coral reef, Dar es Salaam. (HC = hard coral, SP = sponge, SG = seagrass, DC = dead coral, R = rubble).

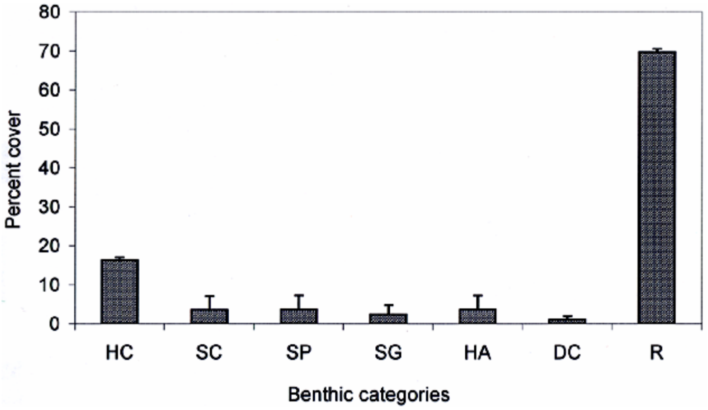

Fig. 12—Percent cover (mean + standard error) of various benthic categories on Mbudya coral reef, Dar es Salaam. (SC = soft coral, HA = Halimeda (algae); other abbreviations explained in Fig. 11).

structurally intact for almost two years, but has now crumbled into rubble, particularly branching *Acropora* sp., thus contributing substantially to the high percent cover of rubble observed.

Tanga

In contrast with Dar es Salaam, coral reef monitoring has been conducted by local fishermen in Tanga, in northern Tanzania, regularly every six months for the past several years, facilitated by Tanga Coastal Zone Conservation and Development Program (TCZCDP). The fishermen have had on-going training and years of experience. The fishermen have been monitoring benthic cover, motile macro-invertebrates and fish populations. Thus, data generated by these village monitors has proven to be accurate and very informative on changes that have occurred in the coral reef environment over time.

A major strategy of TCZCDP has been to completely close certain reefs to fishing and other activities, in consultation with the fishermen, and allowing other reefs to remain open for fishing, though the types of fishing practices used are carefully controlled. The participatory monitoring has shown that, in the closed reefs[3], hard coral cover increased from 32% (± 14%) in 1998 to 51% (± 3%) in 2003. In the open reefs, coral cover remained stable over the same time period. The coral bleaching event of 1998 had caused significant reduction in coral cover and had led to a great increase in sea urchins, which act as bioeroders on reefs. However, participatory monitoring showed that the triggerfish, one of the main predators of sea urchins, reappeared soon after the management interventions, resulting in a reduction in sea urchins in some of the managed areas.

Calibration of the TCZCDP monitors was carried out by coral reef scientists from the Institute of Marine Science in Zanzibar(IMS)[7]. In general, the results recorded by the TCZCDP fishermen and the IMS scientists were very similar. Statistical analysis showed no significant difference in results recorded by the two teams for the following categories: hard coral, algae, sponge, dead coral and non-living substrate. The IMS team recorded significantly more coralline algae, while the TCZCDP team recorded more bleached coral, though both of these categories were observed in very small quantities. In recording motile macro-invertebrates in belt transect, there were no significant differences in numbers recorded by the two teams for all groups except starfish. Fish identification by the two teams, to the level of family or group, was identical. However, the fishermen recorded slightly higher fish densities than did the scientists. Perhaps the fishermen were actually more accurate, because they are more experienced at spotting fish. On the other hand, of course, the scientists were able to record more taxonomic detail than the fishermen.

Assessment of the effectiveness of participatory monitoring

The participatory monitoring reported in this study has produced very valuable and useful information that can guide environmental managers[3, 4]. For example, these studies have identified areas that require ecosystem restoration. The results obtained seem very plausible since they can easily be explained in terms of destructive human activities, on the one hand, and positive management interventions, on the other. Moreover, the results are compatible with the few scientific studies that have been conducted in the same areas. Unfortunately, no scientific studies have been conducted in the same areas of Rufiji and Bagamoyo with which comparisons could be made. Nevertheless, when scientists are included as part of the team in participatory monitoring, as was the case in the studies reported in this paper, proper supervision of data collection is ensured and the results can be considered accurate and reliable, as though they were recorded by scientists. It is only when training and supervision is inadequate, as was the case of the coral reef monitoring in Dar es Salaam, that the results are not reliable.

In addition, participatory monitoring has greatly increased the manpower involved and has resulted in the collection of large amounts of data in less time and at low cost. For example, in some mangrove areas five scientists have been able to train and supervise a team of 12 villagers and 4 district staff members to record data in about 150 plots in five days. If such data were to be recorded by scientists, it would take a long period of time and would be uneconomical. Another advantage of participatory monitoring that has been observed in this study is that, while gathering data, discussions with the participants, particularly elders, can provide very useful information, i.e., indigenous knowledge, about past trends in the ecosystems, in terms of species diversity and abundance, as well as the causes of those changes over time, whether due to human activities or natural causes, etc.

However, probably just as important as the valuable information provided by the participatory monitoring is the profound impact it has on the participants. Though, this aspect is difficult to assess quantitatively, by working with the participants for a period of time, ranging from a few days to several years, it has become obvious that involvement in participatory monitoring has considerably changed their attitudes and level of awareness. Depending on how long they have been involved in monitoring, the participants have developed a feeling of "ownership" of the ecosystems they have assessed. This has motivated them to endeavor to protect their environment and restore it, where it has become degraded. For example, if anyone is seen cutting mangroves, those that have participated in monitoring become deeply disturbed and immediately report the issue to village or district authorities so that action can be taken. Also, former dynamite fishermen have been converted into coral reef protectors and restorers.

Experience with this study has shown that participatory monitoring is much easier to implement in mangrove forests than in coral reefs. If villagers are carefully selected, one or two days of training is sufficient for them to become fairly accurate and efficient in monitoring mangrove forests. Most villagers can already identify mangroves to species level and the techniques for taking measurements are easily grasped. Achievement of accuracy and efficiency in coral reef monitoring, on the other hand, requires repeated training and considerable experience. Nevertheless, it is possible to achieve such proficiency in coral reef monitoring, as well, as has been proven by the success of coral reef monitoring in Tanga.

Conclusion

The following conclusions can be made based on this study:

- Participatory monitoring can produce accurate and informative data if there is proper selection of monitors, adequate training and on-going supervision.
- Participatory monitoring has a profound positive impact on the participants in terms of:
  - Enhancement of environmental awareness,
  - Creation of a feeling of "ownership" of their environment, and
  - Motivation towards protection and restoration of ecosystems surrounding them.
- Participatory monitoring greatly increases the manpower available and provides large amounts of data in a short period of time.
- Participatory monitoring is very cost effective, since participants usually require little or no payment.
- The time and effort involved in training participants to carry out monitoring in mangrove forests is less than for coral reefs.

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