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Calibration of Community-based Coral Reef Monitoring Protocols: Tanzanian Case Study

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Abstract—Coral reef monitoring (CRM) has been recognised as an important management tool and has consequently been incorporated in Integrated Coastal Area Management (ICAM) programmes in the Western Indian Ocean (WIO). Community-based coral reef monitoring (CB-CRM), which uses simplified procedures suitable for local conditions, was introduced in Tanzania in 1996. Despite its widespread use, the method has not been calibrated and the validity of merging CB-CRM results with those gained using other techniques has not been determined. In this study, CB-CRM protocols adopted by the Tanga Coastal Zone Conservation and Development Programme (TCZCDP) were tested against SCUBA-based coral reef monitoring (SB-CRM) as practiced by the Institute of Marine Sciences, University of Dar es Salaam. Calibration showed no significant differences in measuring percent cover of live hard corals, sponges, dead corals and substrata (non-biotic cover). However, CB-CRM monitors recorded higher soft coral and lower fleshy algal cover. Larger differences were observed in deeper (>6 m) transects. Counts of sea cucumbers, clams, gastropods and bivalves categories were not significantly different. However, CB-CRM underestimated the abundance of sea urchins, starfish and younger macro-invertebrates in crevices or under overhangs. There were no differences in the identification of reef fish categories but CB-CRM recorded slightly higher reef fish densities than SB-CRM. If properly trained, CB-CRM monitors can generate results that are comparable to those obtained from SB-CRM on shallow reefs. Although a powerful tool which engenders community involvement and a sense of ownership in the sustainable use of coastal resources, CB-CRM has limitations of which managers need to be aware.

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INTRODUCTION

Concern over the worldwide degradation of coral reefs due to various natural and anthropogenic factors (Jackson *et al*., 2001; Hughes *et al*., 2003; McClanahan *et al*., 2007; Hoegh-Guldberg *et al*., 2007) has highlighted the need for effective coral reef management programmes in Tanzania (Makoloweka *et al*., 1997; Verheij *et al*., 2004; Muhando, 2008). The declaration of marine protected areas (parks, reserves, conservation areas) and, more recently, collaborative management areas (Christie *et al*., 2002; Verheij *et al*., 2006; Wells *et al*., 2007), among others, have constituted attempts to protect and conserve the Tanzanian coral reefs from human damage (UNEP, 1989; Johnstone *et al*., 1998a; Johnstone *et al*., 1998b; Muhando and Francis, 2000; Horrill *et al*., 2001; Verheij *et al*., 2006; Samoilys *et al*., 2007).

Effective implementation of integrated coastal management (ICM) programmes is dependent on information gained from ecological and socio-economic monitoring and research (McManus *et al*., 1988; Wilkinson *et al*., 2003). Ecological monitoring of coral reefs using protocols described in English *et al*., (1994) was first instituted in Tanzania by the Institute of Marine Sciences (IMS) in 1994 using self-contained underwater breathing apparatus (SCUBA) (Mohammed *et al*., 2000, 2002; Muhando, 2008). Although SCUBA-based coral reef monitoring (SB-CRM) yields detailed results, the method is relatively expensive (Wilkinson *et al*., 2003; Muhando, 2009) and was found inadequate for ICM in developing countries (Makoloweka and Shurcliff, 1997; Horrill *et al*., 2001). Instead, community-based coral reef monitoring (CB-CRM), based on English *et al*., (1994) and Reef Check (Hodgson and Liebeler, 2002) protocols, was introduced in the Tanga Coastal Zone Conservation and Development Programme (TCZCDP) in 1996 (Horrill *et al*., 2001; Verheij *et al*., 2004) and later adopted by the Kinondoni Integrated Coastal Area Project (KICAMP) (Wagner, 2004). CB-CRM is executed by trained local fishers and fisheries officers, with scientists as supervisors, as practiced in the Philippines (Uychiaoco *et al*., 2005). CB-CRM is more popular than SB-CRM, mainly because it is cost effective and enhances the education of local communities, their environmental awareness and their stewardship of natural resources (Hill and Wilkinson, 2004; Subade *et al*., 2008). More Tanzania coastal district ICM programmes, e.g., Bagamoyo, Kilwa, and Mafia, have introduced the CB-CRM protocols.

Despite the wide use of this recognised technique, its reliability and comparability have not been tested against data gained from methods such as SB-CRM. Cross-calibration was considered necessary to raise the confidence of information users, especially ICM managers, in CB-CRM data. In this study, cross-calibration was conducted in a joint venture by the Tanga Coastal Zone Conservation and Development Programme (TCZCDP) and the Institute of Marine Sciences with the objectives of: i) establishing whether results obtained by CB-CRM and SB-CRM are comparable, elucidating sources of error and ii) recommending modifications for improvement in the CB-CRM protocols.

MATERIALS AND METHODS

The CB-CRM protocols are fully described by Horrill *et al*., (2001), Verheij *et al*., (2006), and Samoilys *et al*., (2007), while the SB-CRM protocols are described by Mohammed *et al*., (2000) and Muhando (2008). The coral reef categories used in the calibration are listed in Tables 1-3. The calibration exercise was conducted on Taa and Makome reefs, Tanga (Fig. 1).

Similarities and differences between the CB-CRM and SB-CRM protocols

The CB-CRM team recorded all the live hard corals in one category, 'Matumbawe hai', while the SB-CRM team used the 13 coral growth forms listed in Table 1. The five algal groups in the SB-CRM records were grouped as one category, 'Mwani', in the CB-CRM. Categories such as soft corals, sponges, seagrass, sand, and rock were common to both groups. Three further categories in the SB-CRM method, dead coral, dead coral with algae and rubble, were lumped in one category, 'Matumbawe yaliyokufa' (dead corals), in the CB-CRM. Categories such as silt

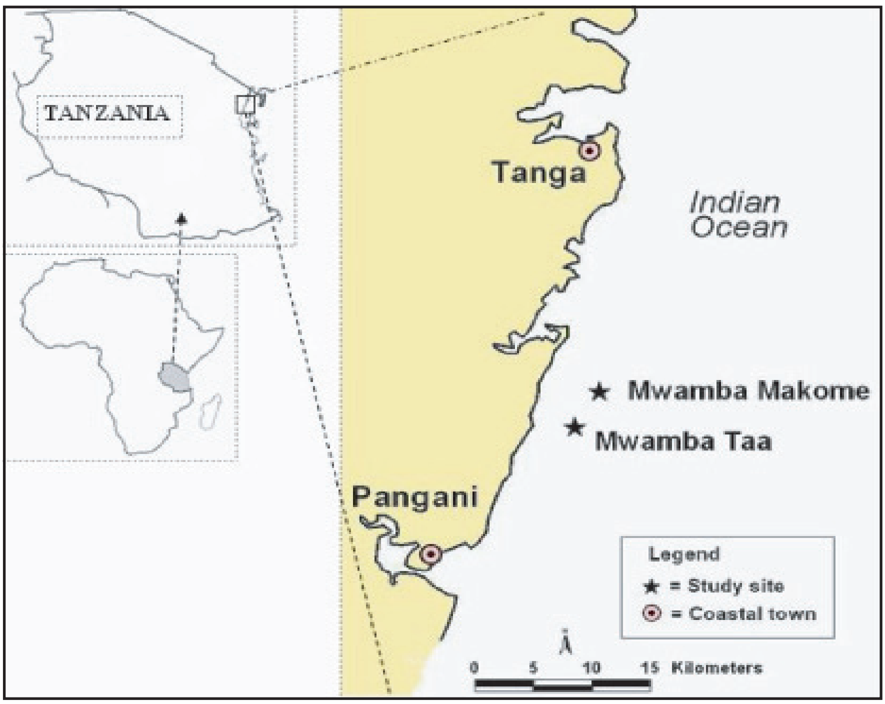

Fig. 1: Map of the Tanga coastline and location of the study sites.

Table 1. Coral reef benthic categories used in the SB-CRM, CB-CRM and calibration process.

	SB-CRM	CB-CRM	CALIBRATION
GENERAL DESIGNATION	BENTHIC CATEGORIES		
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 coral
		Matumbawe yaliyokufa kidogo (MKK)	Partly dead coral
		Matumbawe hai maeupe (MHM)	Bleached coral
Soft corals (SC)	Soft coral (SC)	Matumbawe laini (ML)	Soft coral
Sponges (SP)	Sponges (SP)	Spongi (SP)	Sponge
Algae (AL)	Coralline algae (CA)	Mwani (MN)	Algae
	Algal assemblage (AA) Algae, *Halimeda* (HA) Macroalgae (MA) Turf algae (TA)		
Others (OT)	Seagrass (SG)	Majani (MJ)	Seagrass
	Zoanthids (ZO) Clam (CLAM) Corallimorpharian (RH) Others (OT)	Others (OT)	Other organisms
Substratum (SU)	Sand (S)	Mchanga (MC)	Sand
	Silt (SI)		
	Rock (RCK)	Mwamba (MW)	Rock
	Rubble (R) Dead coral (DC) Dead coral with algae (DCA)	Matumbawe yaliyokufa (MK)	Dead coral

(which represented sediment stress), zoanthids, clams and corallimorpharians (mostly *Rhodactis*) were not recorded in the CB-CRM programme. Partially dead coral ('Matumbawe yaliyokufa kidogo') and bleached corals ('Matumbawe meupe') in the CB-CRM had no equivalent categories in the SB-CRM monitoring system.

Important macro-invertebrate categories such as lobsters, clams, gastropods, sea cucumbers, starfish,

Table 2. Coral reef macro-invertebrate categories used in the SB-CRM, CB-CRM and calibration process.

PHYLUM	SB-CRM	CB-CRM	CALIBRATION
Crustacea	Lobsters	Kamba koche (Lobsters)	Lobsters
Mollusca	Clams	Nyera (e.g. *Tridacna*)	Clams
	Gastropods	Nyale (e.g. *Lambis*)	Gastropods
	Bivalves	Makome (Shells)	Bivalves
		Pweza (Octopus)	Octopus
Echinodermata	Crown-of-thorns starfish (COTS)	Matokambe (COTS)	COTS
	Sea urchins	Ufuma macho Ufuma mawe Ufuma moto Ufuma bondo	Sea Urchins
	Starfish	Kiti cha pweza or Tawangwe (starfish)	Starfish
	Sea cucumbers	Jongoo bahari	Sea cucumbers

Table 3. Fish recording template for CB-CRM.

Category designation	Description
Chafi	Family Siganidae
Chewa	Family Serranidae
Changu	Family Lethrinidae and some Lutjanidae
Chazanda	*Lutjanus argentimaculatus*
Kangu wadogo	Selected smaller members of Scaridae and Labridae
Kangu wakubwa	Selected larger members of Scaridae and Labridae
Kangaja	Family Acanthuridae: Species of the genera *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,* and *P. orientalis*
Mwasoya	Family Pomacanthidae: Only species of the genera *Pomacanthus* and *Pygoplites*
Mkundaji	Family Mullidae
Haraki	*Lutjanus bohar*
Tembo	*Lutjanus fulviflamma*, *L.lutjanus, L. ehrenbergii*
Mbono	Family Caesionidae

sea urchins and crown-of-thorns starfish were included in both the CRM programmes. However, the community monitors divided sea urchins (‘Ufuma’) into four categories: ‘Ufuma macho’ (*Diadema setosum*), ‘Ufuma mawe’ (*Echinometra mathaei*), ‘Ufuma moto’ (*Diadema savignyi*) and ‘Ufuma bondo’ (*Echinothrix diadema*). Molluscs were subdivided into clams, gastropods, bivalves and octopus (Table 2). Octopus were only recorded by the community monitors. SB-CRM monitors counted macro-invertebrates in 2 x 20 m long belt transects, while this was done in wider but shorter 5 x 10 m plots in the CB-CRM. The number of fish categories recorded by the SB-CRM group was far too detailed (Mohammed *et al*., 2002) for use in the CB-CRM (Table 3), the latter also being biased towards commercial reef fish species.

Routine CRM monitoring in both protocols involved the use of randomly-set, line-intercept transects (LITs) within permanent marked plots.

Reef benthos and Macro-invertebrates: A 20 m measuring tape was laid over the reef and attached with iron stakes to ensure that all monitors followed the same transect line. Live coral cover, coralline algae, soft corals, sponges, fleshy algae and non-biotic cover (Table 1) were assessed using the line-intercept transect (LIT) method (English *et al*., 1994) by eight CB-CRM monitors and three SB-CRM monitors. Similarly, macro-invertebrates such as lobsters, clams, gastropods, sea urchins, sea cucumbers, sea stars and crown-of-thorns starfish (Table 2) were counted in 2 x 20 m belt transects after recording the reef cover. Unlike the SB-CRM monitors, the CB-CRM monitors dived up and down to identify and record the benthos and count macroinvertebrates. This procedure was repeated on eight transects: four at Mwamba Taa (at 1 m and at 6 m) and four at Mwamba Makome (at 4 m and at 9 m). The CB-CRM monitors recorded data using Kiswahili names, while the life-form categories of English *et al*., (1994) were retained in the SB-CRM .

Reef fish: Reef fish were counted in four 5 x 50 m belt transects, set between two parallel 50 m ropes set 5 m apart at the lower end of the reef slope. Fish counts were undertaken 10 minutes or more after setting the transects and between counts to allow fish to resume normal behaviour. The reef fish counted included commercially and ecologically important families or groups and were categorised in 17 groups, conveniently adopted from the CB-CRM protocols (Table 3). The eight CB-CRM monitors, two at a time, counted fish with the SB-CRM monitors following about 1-2 meters below and to their rear.

The CB-CRM and SB-CRM reef benthos and macro-invertebrate data were tested for differences using the Student’s two-tailed t-test. Reef fish densities were compared by calculating the percentage difference in each category. The performance

Table 4. Comparison (Student's two-tailed t test) of benthic reef cover recorded by the SB-CRM and CB-CRM monitors.

Benthic category	T	df	p	Difference between SB-CRM and CB-CRM
Hard coral	0.70	12	0.4963	Not significant
Bleached coral	*	*	*	Significant - not observed by SB-CRM team
Coralline algae	*	*	*	Significant - not observed by CB-CRM team
Algae	1.41	12	0.1855	Not significant
Soft coral	7.37	12	< 0.0001	Significant (CB-CRM > SB-CRM)
Sponge	0.44	12	0.665	Not significant
Other Organisms	3.03	12	0.0105	Significant (SB-CRM > CB-CRM)
Dead coral	0.98	12	0.3112	Not significant
Substratum	1.36	12	0.2003	Not significant

of the CB-CRM team in identifying categories was evaluated by estimating the number of categories they recorded relative to those by the SB-CRM monitors. Performance in counting reef fish was evaluated by estimating the Pearson correlation coefficient and similarity of counts (by category) between the monitoring groups.

RESULTS

Calibration of CB-CRM

Reef benthic cover

There was no significant difference between the CB-CRM and SB-CRM records of hard coral cover, sponges, dead coral or reef substrata (non-living components) (Table 4). However, CB-CRM monitors recorded a higher cover of soft corals and lower cover of 'other organisms'. The SB-CRM team recorded no bleached coral and the CB-CRM group reported no coralline algae. CB-CRM monitors were more at ease in water <6 m deep and less so in deeper water; correspondingly greater differences were observed between the groups in transects on deeper reefs.

Comparison of results revealed that CB-CRM overestimated the abundance of soft corals due to their misidentification of corallimorphs, zoanthids, sea anemones and turf algae. Whitish/pinkish coralline algae were incorrectly recorded as bleached coral by CB-CRM monitors.

Macro-invertebrate densities

While no lobsters, octopus, and crown-of-thorns starfish were observed, sea urchins ('Ufuma') were the dominant macro-invertebrate recorded in the transects (Table 5). The density of sea cucumbers, clams, gastropods and bivalves recorded by the CB-CRM and SB-CRM monitors was not significantly different (Table 5). However, CB-CRM monitors counted fewer sea urchins and starfish than the SB-CRM monitors (Table 5), especially on the deeper transects.

Table 5. Comparison (Student's two-tailed t test) of macro-invertebrate counts recorded by the SB-CRM and CB-CRM monitors.

Category	t	df	p	Difference between SB-CRM and CB-CRM
Sea urchins	2.21	8	0.045	Significant (SB-CRM > CB-CRM)
Sea cucumbers	1.66	8	0.162	Not significant
Starfish	2.74	8	0.031	Significant (SB-CRM > CB-CRM)
Crown-of-thorn-starfish	-	-	-	Not observed
Gastropods	*	*	*	Not significant
Bivalves	*	*	*	Not significant
Clams	*	*	*	Not significant
Octopus	-	-	-	Not observed
Lobsters	-	-	-	Not observed

Reef fish densities

The total fish count showed that CB-CRM recorded higher fish densities (42.1 fish per 250 m^2) than the SB-CRM monitors (34.6 fish per 250 m^2). Identification of the reef fish categories was similar, with the CB-CRM group identifying 12 and the SB-CRM group 11 of the seventeen pre-selected fish categories (Table 6). 'Changu' (Lethrinidae and some members of Lutjanidae) were recorded only by the CB-CRM monitors. Differences in counting were notable amongst the 'Chafi' (Siganidae), with CB-CRM monitors recording densities of these fish 1450% higher than SB-CRM monitors (Table 6). Other categories recorded in higher densities by the CB-CRM monitors included: 'Mbono' (Caesionidae) (325%), 'Kangu l' (large Scaridae and Labridae) (205%), 'Kipepeo' (Chaetodontidae) (76.2%), 'Mkundaji' (Mulidae) (56.3%) and 'Kidui' (Balistidae) (50%). On the other hand, they recorded lower densities of 'Chewa' (Serranidae) (-30%), 'Mlea' (-25%) and 'Kangu s' (small Scaridae and Labridae) (-19%). CB-CRM and SB-CRM counts of 'Mwasoya' (Pomacanthidae) were identical. Neither group of monitors recorded 'Chazanda' (*Lutjanus argentimaculatus*), 'Kolekole' (Carangidae), 'Kitamba' (*Plectorhinchus sordidus*, *P. playfairi*, *P. flavomaculatus*), 'Harak' (*Lutjanus bohar*) or 'Tembo' (*Lutjanus fulviflamma*, *L. lutjanus*, *L. ehrenbergii*) (Table 6).

Reef fish identification by individual CB-CRM monitors was generally good. Over 75% of the monitors were able to identify >80% of the fish categories recorded by the SB-CRM group (which comprised the control) (Table 7); two monitors were 100% accurate in their fish identification. However, most reported one or more categories in addition to those targeted observation is always more useful as it generates data specific to the management of fisheries problems (Labrosse *et al*., 2002).

Table 6. Density of reef fish recorded per 250 m^{-2} by the SB-CRM, CB-CRM monitors and the mean difference (%) for each fish category counted.

Name		CB-CRM	SB-CRM	% difference
Chafi	Siganidae	1.107	0.071	1450
Chewa	Serranidae	0.25	0.357	-30
Changu	Lethrinidae and some Lutjanidae	1	0	-
Chazanda	*Lutjanus argentimaculatus*	0	0	0
Kangu l	Large Scaridae and Labridae	2.179	0.714	205
Kangu s	Small Scaridae and Labridae	11.18	13.79	-18.9
Kangaja	Acanthuridae (*Ctenochaetus* spp. and *Acanthurus* spp. except *A. triostegus*)	13.79	13	6.0
Kolekole	Carangidae	0	0	0
Kitamba	*Plectorhinchus sordidus*, *P. playfairi*, *P. flavomaculatus*	0	0	0
Kidui	Balistidae	0.107	0.071	50
Kipepeo	Chaetodontidae	7.679	4.357	76.2
Mlea	*Plectorhinchus gaterinus*, and *P. orientalis*	0.214	0.286	-25
Mwasoya	Pomacanthidae (*Pomacanthus* spp.and *Plygoplites* spp.)	1.321	0.786	2
Mkundaji	Mulidae	0.893	0.571	56.25
Haraki	*Lutjanus bohar*	0	0	0
Tembo	*Lutjanus fulviflamma, L.lutjanus, L. ehrenbergii*	0	0	0
Mbono	Caesionidae	2.429	0.571	325
	Total	**42.14**	**34.57**	**21.9**
Total fish categories		**17**	**12**	**11**

The reef fish calibration undertaken in this study revealed that the identification of reef fish categories did not pose any problems. However, on average, CB-CRM monitors recorded higher densities than their SB-CRM counterparts (by about 22%; Table 6a). A similar calibration study in the Philippines yielded greater variation and higher fish abundance in CB-CRM than SB-CRM (Uychiaoco *et al*., 2005). Such biases may be attributable to the greater area view covered in CB-CRM as the monitors are positioned above the SCUBA divers. Taking this into consideration, the 22% error (Table 6) probably falls within tolerable levels (Carr *et al*., 2002). An error >50% would overestimate the fish stocks and may wrongly encourage managers to allow more fishing. Analysis of the performance of the CB-CRM monitors in fish identification and counting graded six out of the eight as good to very good. Such calibrations are important to maintain the quality of the CB-CRM datasets (Gaudian *et al*., 1995). In this study, it was recommended that the quality of the data would be improved by excluding data from the two poor fish monitors.

CONCLUSIONS

This study has shown that CB-CRM is useful in monitoring coral reef benthic cover. Modifying or removing confusing categories, the use of illustrative underwater guides and frequent calibration should further improve the method. CB-CRM is depth-dependant and is most effective in shallow water; hence additional strategies are needed in deeper or more complex coral reef habitats. The method of counting coral reef fish adopted in the CB-CRM was simple and convenient and should be effective in marine protected area (MPA) management. A CB-CRM manual describing indicator categories would be a useful reference for monitors, and would provide reef managers a tool to assist in the interpretation of reef data.

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