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Ecological Effects of the Crown-of-Thorns Starfish Removal Programme on Chumbe Island Coral Park, Zanzibar, Tanzania

C.A. Muhando[1] and F. Lanshammar[2]

1 Institute of Marine Sciences, Zanzibar
2 Chumbe Island Coral Park, Zanzibar

Abstract. Data on reef benthos has been annually collected on Chumbe, Bawe and Changuu reefs close to Zanzibar, Stone Town, since 1992. The data shows that the El Niño in the Indian Ocean in 1997/1998 reduced the coral cover on most reefs with up to 30%. After the El Niño, a slow recovery was noticed until a major Crown-of-Thorn Starfish (COTS) outbreak occurred in 2002/2003 followed by a dramatic decrease in live *Acropora* cover. Only one of the reefs shows an exception – the protected Marine Sanctuary on the western side of Chumbe Island. When the first COTS were seen, the park management immediately initiated an on-going COTS removal programme, which has had a significant positive impact on the reef recovery. On the protected reef, the percent cover of live coral is back on the same level as before the bleaching event. Manual COTS removal programmes are often seen as a waste of time and resources, as their impact are often short term. But the results from this study argue that in a relatively small reef area it is a viable option for maintained or increased reef health and for improving recovery prospects of coral after large natural disturbances.

Key words: COTS, coral mortality, Zanzibar

Introduction

The crown-of-thorn starfish (COTS), *Acanthaster planci*, belongs to the family of *Acanthasteridae*, class *Asteroidea* (starfishes), in the phylum of *Echinodermata*. It is a coral predator causing great damage to coral reefs worldwide when in outbreak condition, e.g. Guam: Chesher 1969; Great Barrier Reef: Pearson & Endean 1969; Japan: Yamaguchi 1986). Their preferred prey is *Acropora* sp. (Endean and Cameron 1990; Pratchett 2001).

Previous records show that Crown-of-thorns-starfish outbreaks were rare events in Tanzania (UNEP 1989). The first reported COTS case occurred in 1988 and only one reef (Pange) was affected (UNEP 1989). Smaller incidences occurred in 1996/97 on Changuu reef, Zanzibar (Mohammed et al., 2000). A serious outbreak started in 2002 on a few reefs close to Zanzibar and then expanded to infest more that 60 % of Tanzania reefs by 2006 including Tanga, Zanzibar, Pemba, Songosongo, Mafia and Mnazi bay reefs (Obura et al. 2004; Mohammed et al. 2005; Obura 2005; Ussi 2008). Unlike in preceding years, the 2002-2006 outbreaks were wide spread and have persisted for a much longer period. Up to now (2008) the Crown-of-thorns-starfish threat has not completely disappeared. Repeated outbreaks have been reported in Zanzibar, Tanga and recently in Mikindani Bay, Mtwara. Such prolonged and frequent Crown-of-thorns-starfish outbreaks are unprecedented in Tanzania. It is not clear whether or not these outbreaks are linked to climate change, overfishing, eutrophication or a combination of all these factors or even just a natural fluctuation in the population.

Instead of waiting for natural processes to control the numbers of Crown-of-thorns-starfish, Chumbe Island Coral Park Ltd. (CHICOP), the managing company of the Chumbe Reef Sanctuary established in 1994, introduced a removal program in 2004 as a way of averting loss in live coral cover. The Sanctuary is relatively small, about 1 300 m long and 300 m wide and the company has trained park rangers stationed on the island at all times. Unlike in other parts of Tanzania (Tanga, Dar es Salaam, and on reefs off Zanzibar town), the removal programme in Chumbe was started immediately after the outbreak; it was consistent and long term.

The impact of Crown-of-thorns-starfish appeared to be enormous and there was an urgent need to carry out assessments more widely. Aside from their potential to cause widespread coral destruction, selective feeding by *A. planci* causes differential mortality among coral species and can exert a major influence on coral community structure (Potts 1981, Moran 1986, Birkeland & Lucas 1990, Pratchett,

2001). One way of revealing Crown-of-thorns-starfish impact is through the analysis of long term trends in live coral cover against the corresponding Crown-of-thorns-starfish outbreaks and other mortality factors. This type of data in Tanzania has been collected annually through existing coral reef monitoring programs, e.g. Scuba based coral reef monitoring at Institute of Marine Sciences (Mohammed et al. 2000, 2002; McClanahan et al., 2007a; Muhando, 2008) or Community Based coral reef monitoring such as the programme existing in Tanga (Horrill et al. 2001). Alternatively, COTS removal programmes offer an ideal scenario to reveal the impacts when sites where COTS are collected are compared with uncontrolled areas. In this study the Crown-of-thorns Starfish Removal Programme on the protected reef on Chumbe has been studied to reveal its ecological impacts on live Acroporids and non-Acroporids by comparing benthic data with data from other unprotected nearby reefs. The specific objectives of this study were: i) to analyse coral reef monitoring data collected by Institute of Marine Sciences and to establish trends in live coral cover of *Acropora* and non-*Acropora*, ii) compare coral cover changes between reefs where the population of Crown-of-thorns-starfish was controlled (individuals continuously removed) and sites where there was no removal programs.

Material and Methods

This study was conducted on three nearby (14-16 km) reefs: Chumbe, Bawe and Changuu reefs, located on the west coast of Unguja Island (Figure 1). A consistent and long term Crown-of-thorns-starfish removal program was initiated on the Chumbe Reef Sanctuary (no-take) reefs in 2004. Bawe and Changuu reefs were not protected from Crown-of-thorns-starfish impact in any way. Data on live coral cover of *Acropora* and non-*Acropora* from 1994 to 2008 was obtained from the Institute of Marine Sciences coral reef monitoring database. Reef benthos (*Acropora*, non-*Acropora*, soft corals, calcareous algae, fleshy algae, sponges, dead corals, etc) was recorded using Line-Intercept Transect (LIT) method. The density of macro-invertebrates including Crown-of-thorns-starfish were also recorded. Additional density information was obtained from other researchers in the study area (e.g., Ussi 2008). Important environmental factors likely to influence large scale coral mortality, such as SST were recorded using Tid-Bit Stowaway temperature loggers since 1997. Two major intersession events occurred: the 1998 coral bleaching event (Muhando 1999; Mohammed et al. 2000; Wilkinson et al. 1999) and the 2002-2006 Crown-of-thorns-starfish infestation (Ussi 2008). Impacts of these events on coral reefs were reviewed from various studies conducted in the study areas.

Crown-of-thorns-starfish removal on the Chumbe reef was carried out by resident park rangers while snorkelling. Chumbe reef is relatively shallow and rangers used handmade wooden sticks and recycled rice bags to carry out the removals. All removed Crown-of-thorns-starfish were counted, measured and then buried on the beach sand.

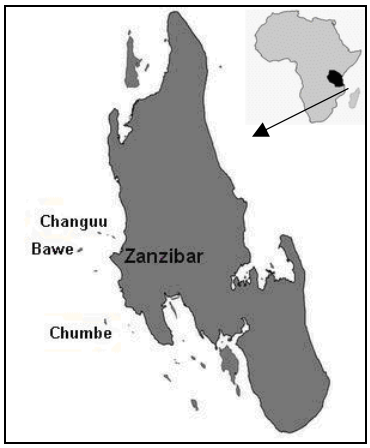

Figure 1: Map showing the study area of Zanzibar, Tanzania

Results

Coral cover

The reef benthic data shows that all studied reefs had around 50-60% total live coral cover back in the early 1990's (Figures 2a 2b and 2c). The first decrease of *Acropora* cover was noticed on Changuu in 1996 when the first isolated COTS outbreak took place (Figure 2a). Since then *Acropora* have not recovered due to long term presence of COTS and Changuu reef is now dominated by *Porites (*mostly *P. cylindrica*, *P. rus* or *Synarea rus*) and *Galaxea astreata*. Only a slight decline in *Acropora* occurred in Bawe as a result of the 1998 coral bleaching, which was mild compared to the bleaching that took place on Chumbe (Figure 2c; Muhando 1999). On Bawe, *Acropora* cover remained stable at about 21 % until Crown-of-thorns-starfish outbreak in 2003. Since then the *Acropora* cover has declined steadily down to 1-2 % in 2007 and 2008 (Figure 2b). The impact of the 1998 El Niño related increase of seawater temperatures about 2-3 ^{o}C above average (Muhando, 1999) was highest on Chumbe, where around 50% of all corals bleached and up to 90% of *Acropora* species bleached (Muhando, 1999; Mohammed et al., 2000) with total mortality of about 30% (Figure 2c). Unlike in other sites where *Acropora* abundance has substantially declined, the removal program at Chumbe prevented COTS destruction resulting in steady recovery of *Acropora* and non-*Acropora*. Figure 2d shows an

overview of the *Acropora* cover on all three reefs from 1992-2008.

Trends in non-*Acropora* cover in unprotected areas showed no significant change during both 1998 bleaching and Crown-of-thorns-starfish outbreak (Figs. 2a and 2b). Some species of *Montipora* and *Echinopora* were noticed to immediately colonise the dead *Acropora* framework, while *Porites rus* and *Galaxea astreata* and few other species were less affected by bleaching (Muhando 1999; McClanahan 2007b) and COTS predation.

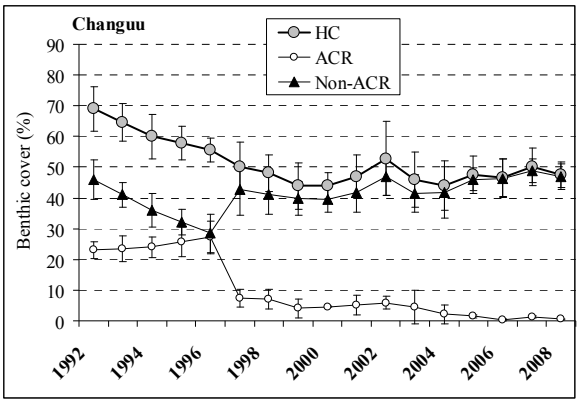

Figure 2a: Trends in live cover (%) of *Acropora* (ACR), non-*Acropora* (Non-ACR) and total live coral cover (HC) on Changuu reef from 1992 until 2008

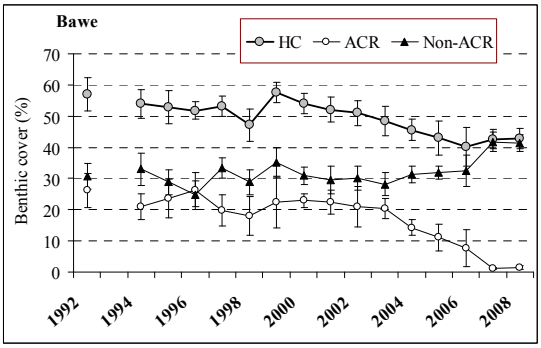

Figure 2b: Trends in live cover (%) of *Acropora* (ACR), non-*Acropora* (Non-ACR) and total coral live cover (HC) on Bawe reef from 1992 until 2008

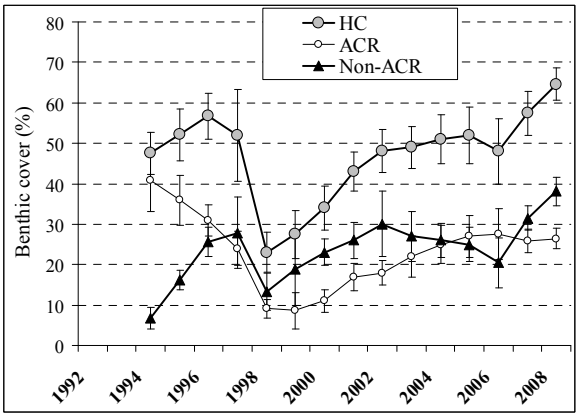

Figure 2c: Trends in live cover (%) of *Acropora* (ACR), non-*Acropora* (Non-ACR) and total live coral cover (HC) on Chumbe reef from 1994 until 2008

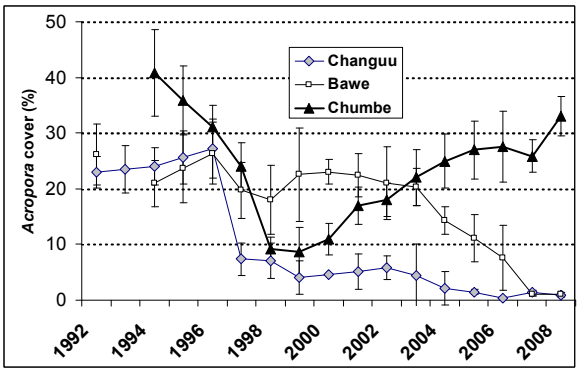

Figure 2d: An overview of the *Acropora* cover on all three reefs from 1992-2008.

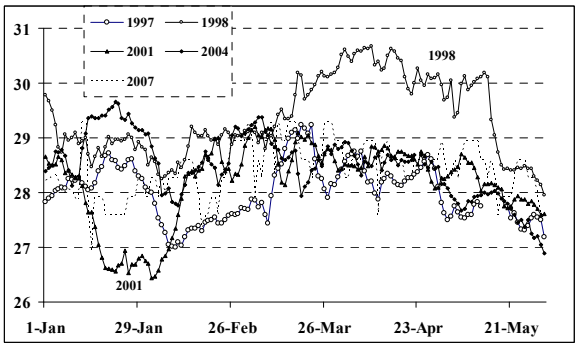

Figure 3: Daily mean seawater temperature (SST) for the months of January-May off Zanzibar town. Elevated seawater temperature in March-April 1998 was associated with coral bleaching and mortality.

Chumbe COTS removal programme

Since the programme started in 2004 a total of 118 collection days have taken place and more than 3,000 COTS have been removed inside the marine park (Figure 4), keeping the densities of COTS to almost zero at all times. Highest number of Crown-of-thorns-starfish removed per month was in January-March 2005 when 661 COTS were collected within the approximately 0.4 km^2 large MPA.

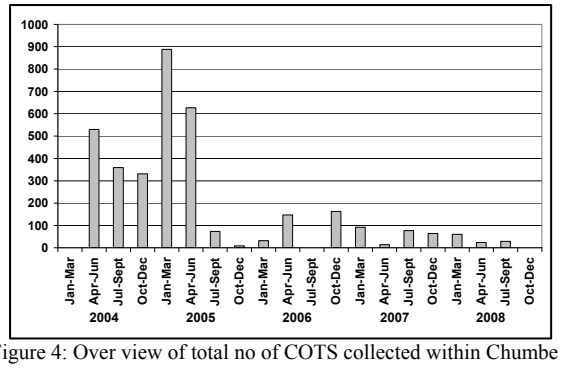

Figure 4: Over view of total no of COTS collected within Chumbe reef sanctuary since 2004

Discussion

Significant changes in *Acropora* cover were linked to the 1998 coral bleaching event (Figures 2b and 2c; Wilkinson et al., 1999) and infestation of Crown-of-thorns-starfish (Figure 2b). This study confirms that the 1998 coral bleaching event and the outbreak of Crown-of-thorns-starfish had more negative impact on *Acropora* when compared with non-*Acropora*. Regeneration of *Acropora* after the bleaching event was halted by outbreak of Crown-of-thorns-starfish, among other degradation factors in unprotected reef areas, while it flourished well in Chumbe where the removal program kept the Crown-of-thorns-starfish density on a low, in addition to other management actions. On the other hand, the removal program didn't have obvious impact on non-*Acropora* corals, at least in the studied areas.

Long term coral reef monitoring data can be useful in linking causes and impacts with natural and human induced disasters on coral reefs. In this study fast decline in *Acropora* was linked to coral bleaching event and Crown-of-thorns-starfish outbreaks. However, non-*Acropora* (as a group) did not show clear links. Such selective mortality has already been demonstrated elsewhere, e.g., McClanahan et al., (2007b) for bleaching and Pratchett (2001) for COTS. *Acropora* seem to be defenceless, easily accessible, palatable, high nutritional value, convenient structure (firm grip against wave actions) and few aggressive/defensive symbionts (Endean and Cameron 1990; Pratchett 2001) and all of the above mentioned features make *Acropora* an ideal target for COTS predation.

When compared to previous outbreaks in 1988 (UNEP 1989) and 1997 (Mohammed et al. 2000), the recent Crown-of-thorns-starfish population outbreak was unprecedented widespread and persisted for longer period. Its persistence and duration appears to suggest a significant environmental change towards favourable conditions for COTS. It is not clear at this stage whether or not this is an indirect impact of climate change (global warming).

Crown-of-thorns-starfish removal program has demonstrated that exclusion of predators can be an effective strategy in enhancing recovery after natural disasters (e.g., El Niño). Unlike in Bawe and Changuu reefs where no clean up action took place, the demise of *Acropora* in Chumbe was rescued. On the other hand, results suggest that non-*Acropora* corals were much more stable. Such differential coral mortality caused by selective feeding habits has a direct influence on reef structure (McClanahan et al. 2007b). In the unprotected study areas the coral composition has changed in favour of *Porites rus* (Synarea), branching *Porites* (*P. cylindrica*) and *Galaxea astreata*. High abundance of Corallimorpharia was noticed on the reef flat and reef slope, covering the dead *Acropora* plates and rubbles (Muhando et al., 2002). *Acropora* is no longer the dominant coral genera today in many unprotected reefs, e.g. Bawe and Changuu. Reef fish that depend directly on *Acropora* for their replenishment are likely to decline as a result (Garpe et al. 2006). The impact of these changes to ecosystem functions requires special research attention.

This study has demonstrated the need to encourage coral predator removal programs, specifically Crown-of-thorns-starfish, as one of the management options to achieve increased coral cover. The removal methodology used was inexpensive and convenient only for shallow water reefs. The use of SCUBA divers is however necessary in case of deeper reefs, though it will increase operation costs. Part of Chumbe success was the decision to initiate the removal at early stages of outbreak along with the continuous monitoring of the reef. Removal programs in Dar es Salaam (Wagner 2004) and in Tanga were not successful because COTS removal was initiated well after significant damage to coral ecosystems occurred. Thus, COTS management requires effective institutional (approving and sponsoring) mechanisms to be in place for making prompt decisions regarding removal programs. Unlike in unprotected areas, the overall management actions within the MPAs also contributes to improved reef health and productivity in the face of human impacts (Russ et al. 2003; McClanahan and Mangi 2000)

Prediction knowledge of when and where *A. planci* outbreaks will occur is still lacking. This is essential to improve future control and increase the chances of success from removal programs. Furthermore, research is also needed to determine factors influencing dynamics of Crown-of-thorns-starfish. For example, a hydrodynamics studies found that due to the interaction of tidal, gravity and wind flows, some areas within the reef retained higher numbers of larvae than others (Black and Moran 1991). Surveillance of these locations, which may be correlated with initial recruitment of *A. planci*, could provide an 'early warning' strategy for monitoring and controlling future outbreaks of this starfish on reefs (Black and Moran 1991). The main long term objective of research at this stage in the western Indian Ocean, is to find out what factors and processes that favour these out-breaks of COTS populations so they can be dealt with and the problem can be avoided before it even occurs.

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