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Resource degradation of the sea cucumber fishery in Zanzibar, Tanzania: a need for management reform

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Abstract – This study assessed the Zanzibar sea cucumber fishery using a multidisciplinary approach. Data was collected by (i) interviewing various groups of actors in the fishery and reviewing management documentation and legislation, (ii) by monitoring catches and (iii) through a visual census of coastal sea cucumber populations in areas open and closed to fishing. The fishery showed clear signs of being unsustainable with high fishing effort, and weak formal and informal management institutions. The fishery operation was characterised by an intricate cross-scale structure with both fishers and sea cucumber products being transported across national borders. The visual census of commercial sea cucumber stocks at three sites open to fishing around Zanzibar showed low densities across the range of sea cucumber value groups including low value species. Furthermore, the diversity of commercial sea cucumber species was lower in fished reefs than on a protected reef. The poor status of the sea cucumber populations was confirmed by the perception of an overfished resource by the interviewed actors active in the fishery. This was also depicted by the paucity of high value species, and high representation of low value and newly commercialised species in fishers catch. We conclude that the current state of Zanzibar's sea cucumber populations is compromising the fisheries self-replenishment and existence and that the fishery is in urgent need of a complete management reform.

Key words: Bêche-de-mer / Fisheries / Overfishing / Holothurians / Echinoderms / Trepang / Western Indian Ocean

1 Introduction

During the past decades it has become apparent that many stocks of fisheries resources around the world have collapsed as a result of overfishing (e.g. Pauly et al. 2002). Especially highly commercial species have suffered, and harvest of less commercially valuable species have followed in their place (Pauly et al. 1998). The reasons for these collapses are complex (Cochrane 1999), and include for instance institutional weakness (Stephenson and Lane 1995), complex governance issues (Jentoft and Chuenpadgee 2009), narrow approaches focussing on regulations and ignoring cultural and normative factors (de la Torre-Castro and Lindström 2010), and ecological uncertainty (Ludwig et al. 1993). The lack of basic knowledge on ecological life histories of many invertebrates, together with sessility or low motility, makes them particularly vulnerable to overfishing (Perry et al. 1999). Belonging to this category of resources are Aspidochirotid sea cucumbers, which are harvested to produce the commercial high-valued beche-de-mer (also known as trepang) – the dried body wall of the sea cucumber traded and consumed in Asia (Conand 1990; Conand and Byrne 1994). Predominantly Chinese communities cherish this item as a delicacy, health tonic and aphrodisiac, and its status as a trade commodity in the central Indo-Pacific was well established during the 18th century (MacKnight 1976). The fishery and trade has since then spread and intensified and today beche-de-mer is a common export commodity from many Western Indian Ocean countries (Conand and Muthiga 2007; Conand 2008; Ochiewo et al. 2010), as well as in many other tropical and developing regions (Toral-Granda et al. 2008; Purcell 2010a).

In Zanzibar (Tanzania, East Africa), local people do not recognise sea cucumbers as food items, instead the fishery for sea cucumbers was introduced for export of beche-de-mer and is a source of income for the actors involved (Jiddawi and Öhman 2002). The fishery also provides national revenue from export taxation. It is difficult to state when the sea cucumber fishery in Zanzibar commenced. Intensification of Asian markets demand in Africa took place at the beginning of the second millennium (Sheriff 1987) and records of marine products commerce have been reported since the 18th century, along with the establishment of small Chinese communities (Gilbert 2004). According to the interviews in this study, the contemporary exploitation of the product gained momentum when

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the Chinese immigrants pushed the fishery in Unguja island (the largest island in the island group commonly referred to as Zanzibar) in the late 1960s for own consumption and export. The fishery and its market have since then developed and the sea cucumber fishery in Zanzibar has been documented as high valued and under increasingly high fishing pressure (Coleson and Jiddawi 1996; Jiddawi and Öhman 2002). However, no systematic studies of sea cucumber stocks or ecology have been performed.

Zanzibar's coastal communities rely heavily on the marine environment for subsistence and income (Jiddawi and Öhman 2002; de la Torre-Castro 2006), with about 85% of the coastal population living on less than one US dollar per day (Ruitenbeek et al. 2005; de la Torre-Castro 2006). Despite an increasing research attention on the marine resources in Zanzibar many fish stocks that provide elements of subsistence are declining (Jiddawi and Öhman 2002; de la Torre-Castro and Rönnbäck 2004). The Department of Fisheries and Marine Resources (DFMR) is the "government institution, which is directly responsible for day-to-day fisheries management in Zanzibar" (The Fisheries Act 2005). Even though formal institutional structures are in place, and perceived as robust and well designed (Ruitenbeek et al. 2005), performance of formal management in the coastal fishery in Zanzibar is strongly influenced by normative and coastal institutions (de la Torre-Castro & Lindström 2010), and the general poverty situation (de la Torre-Castro 2006).

Aspidochirotid sea cucumbers are generally detrivorous and provide important ecosystem functions through bioturbating behaviour and by regenerating nutrients through feeding (Uthicke and Klumpp 1998; Uthicke 1999). Therefore overfishing of sea cucumbers likely reduces ecosystem productivity (Wolkenhauer et al. 2010). Artisanal fishing can deplete stocks already after a handful of years, and recovery is generally slow and dependant on many factors for which there is limited information (Friedman et al. 2010). The many examples of sea cucumber overfishing (Toral-Granda et al. 2008; Purcell 2010a), together with prevailing Allee effects (Levitan and Petersen 1995; Bell et al. 2008), major knowledge gaps in ecology (Conand 1990; Uthicke et al. 2004a), and unpredictable recruitment (Uthicke et al. 2009), suggest that a precautionary management approach is appropriate for this fishery. However, this is often not the practice (Purcell 2010a), and for example, depicted in mainland Tanzania where authorities have placed a moratorium on exports of sea cucumbers due to overfishing (Mgaya and Mbaga 2007). Fisheries closures due to overfishing, or concerns of overfishing, are common (Friedman et al. 2008; Purcell 2010a), and emphasises the high vulnerability to fishing.

In this study we investigated the sea cucumber fishery on Unguja Island in Zanzibar. First, we approached fishing methods, fishers' organisation and formal and informal management by interviewing actors in the fishery. In this part of the study, we also established the livelihood importance of the resource by evaluating the level of dependence on the activity, and the involvement of different actors in the fishery. Second, we performed catch monitoring to assess the species and value distribution in fishers catch. Third, we assessed the status of sea cucumber populations for species with a commercial value using visual census of coverage and density along the seascape, and estimated the effects of the fishery by sampling in a no-fishing protected marine park as well as in fished areas. This fishery lacks baseline data so we analyzed the results by taking into consideration the perceptions among interviewed actors in the fishery.

2 Methods

2.1 Interviews with fishery actors

Fishing methods and the organization of the fishery were addressed by using semi-structured interviews. The interviews were conducted from October 19 to December 31, 2007 in eight different sites (Mkokotoni, Mazizini, Fumba, Unguja Ukuu, Nungwi, Mtende, Uroa and Chwaka villages) (Fig. 1). The sites were selected trying to cover most parts of the island and based on information of where the fishery was active.

All groups of actors involved in the local fishery were interviewed: fishers (n = 72), middlemen (n = 15) and traders (n = 5) as well as senior management officials (n = 8) and local monitoring agents (n = 15) (referred to as beach recorders or "Bwana dikos" in Kiswahili, see de la Torre-Castro 2006). All the large export traders located in Zanzibar urban area and most of the local market middlemen were interviewed. Fishers were selected randomly while living in the villages.

The interviews were conducted in Swahili (with the assistance of a translator) but some management officials and export traders were interviewed in English. All interviews were semi-structured (Kvale 1996; Denscombe 1998) and provided material for qualitative and quantitative analysis. The answers for the quantitative analysis were categorised into answer groups (e.g. "positive", "negative" or "unsure") to perform further analysis. In addition to the interviews, informal discussions with fishers and middlemen were also conducted. These were, along with observations, used in particular to approach the clandestine diving activity in the fishery.

The interviews focused on the way the fishery is operated, management (i.e. both formal institutions such as formulated laws and regulations sanctioned by government agencies or authorities, and informal institutions such as community level practices and codes of conduct not formally established as laws but that may provide a sustainability function for the fishery), and social-ecological aspects of the fishery following de la Torre-Castro et al. (2007). In particular, the aim with the interviews was to provide understanding of the fishery structure and chain of actors involved, the fishing methods and scales and areas of operation, management perception and awareness of the legislation, perception of fishery changes over time and finally the reasons to be a sea cucumber fisher and possible livelihood alternatives. The interview form is available upon request.

Parallel to the interviews literature and policy documentation were collected from the Department of Fisheries and Marine Resources (DFMR) and the Department of Environment, and analysed to identify current legislation and management of the sea cucumber fishery.

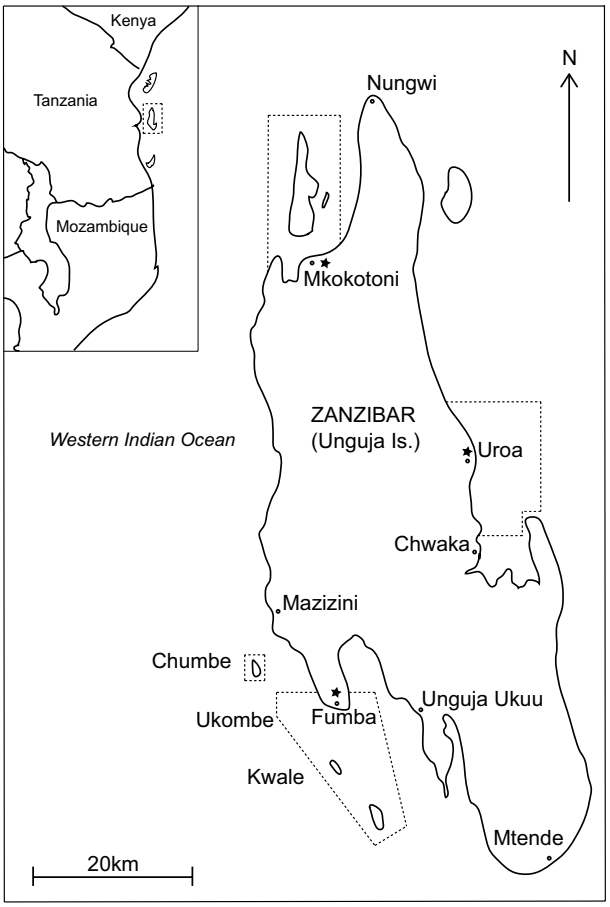

Fig. 1. Study area Unguja Island (Zanzibar, Tanzania) 6° 8′ 0″ S, 39° 19′ 0″ E. Interviews were conducted in villages indicated by a filled circle. Catch assessment and visual census of stock were carried out in villages marked out with a star ⋆. The areas outlined with dotted lines adjacent to the villages marked with a star indicate where visual census of sea cucumber populations were performed. Note that Chumbe is not included in the Fumba area but it was used for the comparison of species richness with Ukombe and Kwale reefs that were sampled inside the Fumba area.

2.2 Catch monitoring

Daily catch data was collected in the landing locations in three selected sites (Fumba, Mkokotoni and Uroa villages) (Fig. 1) between June 23 and August 23, 2009 during approximately two weeks in each site. Species, quantity and fishing effort (number of fishers and time spent fishing) was recorded. On occasions, catch and effort data was also collected cooperating with the trade middleman (person buying local catches for further distribution and/or processing) as a key-informant. The species value was recorded as the purchasing price offered by the middlemen to fishers at point of landing. Length measurements of *Holothuria scabra* were collected from all individuals found in the catch at the site Fumba. This species was used for analysis as it was regularly observed in catch in this location and its body wall is relatively rigid reducing measurement variability (Purcell et al. 2009).

2.3 Visual census of commercial sea cucumber stocks

The condition of the commercial sea cucumber stock was investigated using a visual census of sea cucumber populations during June 23, to August 23, 2009 in the coastal areas around three villages i.e. Mkokotoni, Fumba, and Uroa (Fig. 1). These specific sites were chosen because they have an active fishery and the geographic location provides fishery information from different sites around the island. Stocks where sampled using two techniques at different scales: a broad-scale assessment using manta tows, and a fine-scale assessment using swimming (or walking) line transects. Manta tows were performed following methods outlined in English et al. (2003) and covered 300×2 m (measured using a handheld GPS) at depths between 0.5–8 m, targeting reef and lagoon areas. Manta tows provide a suitable spatial scale to sample at when assessing commercial sea cucumber populations (Uthicke and Benzie 2000; Purcell et al. 2009), but may under-estimate some species due to their ecology (e.g. diurnal behaviour) (Shiell and Knott 2008). Stocks were also surveyed using line transects covering 40 × 1 m by swimming or walking in shallow areas. Transects specifically targeted reef or soft benthic areas in places where manta tows were not suitable, e.g. shallow reef areas and muddy lagoons. The smaller sample area allowed the surveyor to turnover rocks and dig in sand to find cryptic or burying species (Purcell 2010b).

Sea cucumber populations were also assessed in the reef areas of Chumbe Coral Park that is a private-run marine park protected from fishing since 1994 (Riedmiller 1998). Chumbe provides a reference site for comparison of commercial sea cucumber assemblage to the nearby reefs Ukombe and Kwale that are open to fishing, but under locally developed regulation since 1994 (e.g. restriction of fishing camps to exclude outsiders, local monitoring programmes) (Ngaga et al. 1999). These three reefs are located approximately 5 km apart, and on similar SW aspect. Each site was sampled at the same effort (n = 12) with the manta tow method described above. Species diversity between the three reefs was assessed using a comparison of a cumulative unique species count, and Shannon-Wiener diversity index (H') (Peet 1974). The order of transects for the cumulative species count for each reef was simulated with permutations (n = 20) using R 2.10.0 to calculate a mean cumulative number of species per sample size and reef.

3 Results

3.1 The fishery operation

The general structure of the domestic fishery trade system followed a "Fisher - Middleman - Trader" chain, similar to that described by Conand (1997), and in nearby Kenya (Ochiewo et al. 2010).

Fishing was conducted using three methods: gleaning, breath hold diving and scuba diving. We estimate that there were at least 800 fishers regularly participating in the fishery. Gleaning was generally undertaken by women collecting benthic fauna in intertidal seagrass areas, and the latter two diving-methods were generally undertaken by men in deeper areas both on soft bottoms and in reef areas (Table 1). The fishers

Table 1. Outline of the sea cucumber fisher types in Zanzibar.

Type	Gleaning	Breath hold diving	Scuba diving
Range	Intertidal	Intertidal - Subtidal	Subtidal
Depth	<1m	1-10m	10-50m
Target area	Near shore shallow areas	Local fishing grounds (but may be more mobile)	Mobile, Zanzibar wide, Mafia, Pemba, mainland Tanzania and other countries of WIO
Equipment	Buckets, baskets, bags, to collect catch	Mask, fins, mesh bag to collect catch, drag buoy, often use boat and sometimes speargun to catch octopus and fin fish	Boat (engine), rustic gear (single regulator, no bcd, wetsuit is rare), mesh bag to collect catch
Representation	Many	Fewer	Few (concentrated to a few villages/sites)
Demography	Mostly women, but men and children too	Men	Young men

Table 2. Recorded economic value range per individual at point of landing for species and groups of species (local name) in Zanzibar 2009.

Species group	Species	Value range (TZS)	Value category
Pauni	*Holothuria nobilis, H. fuscogilva (cf), H. "pentard"* *	300-20000	High
Spinyo baba	*Theleonota ananas*	4000-8000	High
Barangu	*Holothuria lessoni*	500-7000	High
Myeupe	*Holothuria scabra*	150-4000	High
Nanasi	*Holothuria spinifera*	1000-2000	Medium
Spinyo mama	*Theleonota anax*	1000-2000	Medium
Tairi	*Stichopus herrmanni, Stichopus sp.***	100-1500	Medium
Kijini	*Actinopyga miliaris*	1500	Medium
Dole	*Bohadschia atra, B. vitiensis****	150-1000	Medium
Barangu mwamba	*Holothuria fuscopunctata*	500	Medium
Sankude	*Stichopus sp.***	200-300	Low
Tambi	*Bohadschia maculisparsa, B. subrubra****	150-200	Low
Mbura	*Actinopyga mauritiana, A. echinites, A. lecanora*	100-200	Low
Kichupa	*Holothuria atra, H. leucospilota, H. coluber*	20-150	Low
Shirimeni	*Holothuria isuga*	50-200	Low
Disera	*Actinopyga capillata*	100	Low

* See Uthicke et al. 2004b for phylogeny of teatfish complex and Conand 2008 with regard to *H."pentard"*. ** The Stichopus varieties are part of a cryptic species complex that is under cur rent taxonomic review (Byrne et al. 2010). *** The Bohadschia varieties are also part of a cryptic species complex under taxonomic review, identification is difficult and scientific names may change (personal communication Maria By rne). There is some confusion regarding the Dole and Tambi groups but processors report that Dole has a higher recovery rate to marketable product. 1 USD = 1 355 TZS, 1 EUR = 1 854 TZS (2010/03/02)

landed the catch either in the village or in designated landing sites for mobile divers. The middleman purchased the catch live from the fishers and generally performed the first stage of processing by boiling and storing the animal in salt before selling it to the exporting traders. These traders performed the final drying stage of the processing to marketable product. A fisher could occasionally be a middleman as well, purchasing catch from other fishers and selling it wet or boiled to traders. There were also examples of traders that purchased wet sea cucumbers directly from fishers, thereby eliminating the middleman role. Middlemen frequently gave credit or equipment to fishers, which create an informal agreement structure important for both actors, i.e. fishers (obtained cash when needed) and middlemen (securing future catch and loyalty in return for credit).

The divers fished at depths down to 50 m with poor training and worn-out equipment (no buoyancy control device, old regulators, rusting steel tanks were observed). The diving fishers were opportunistic and harvested in areas based on experience and hearsay, both in nearby fishing grounds and in distant waters requiring days at sea. The high mobility of the divers was a recent feature of the fishery as a result of near shore overfishing as indicated in interviews.

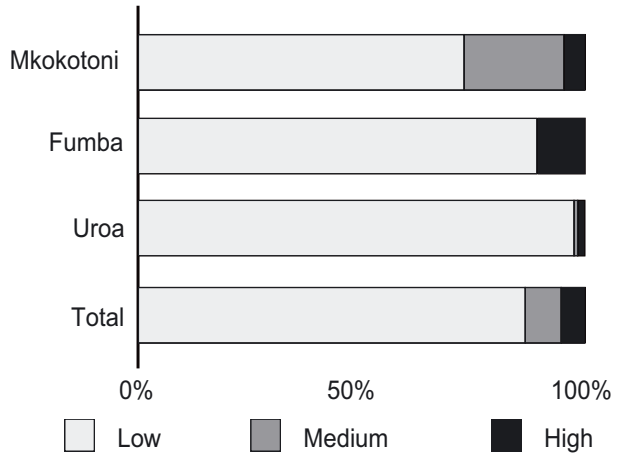

Fig. 2. Catch composition according to commercial value group (low, medium and high) from the areas surrounding the villages presented. See Table 2 for key to which species are included in each value category.

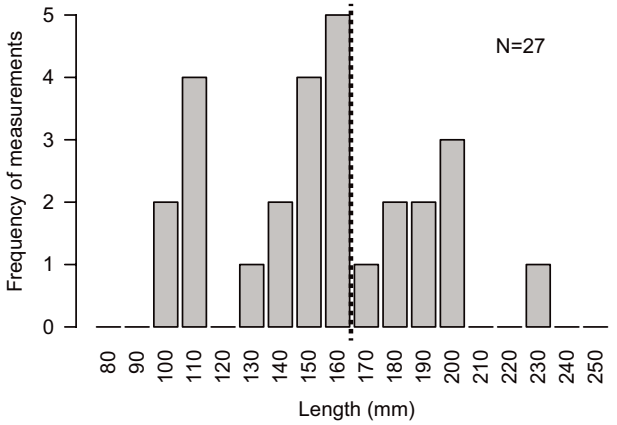

Fig. 3. Length frequency distribution with 10 mm intervals of *Holothuria scabra* recorded in fishery catches in the village of Fumba during July 22–30, 2009. The dotted line is the size at sexual maturity (160 mm; e.g. Conand 1993).

3.2 Management and perceptions of the fishery

The sea cucumber fishery was included in the broader "fish" section in The Fisheries Act of 1988 and the revised Fisheries Act of 2005 of Zanzibar, but was not specifically mentioned as a separate fishery. There were no sea cucumber fishing licenses but according to The Zanzibar Constitution 1984 Order, a legal supplement to the Zanzibar Government Gazette, the fishery was managed by a length restriction of 100 mm for "Holothuriodea". The existence of this formal length restriction was, however, only known to 50% (four out of eight) of the interviewed DFMR senior management officials, by 7% (one out of 15) of the interviewed local monitoring agents ("Bwana dikos"), by 13% (two out of 15) of the middlemen and by 3% (two out of 72) of the fishers. None of the respondents (management officials, monitoring agents, middlemen or fishers) that were aware of the restriction could account for the specific length. Traders were required to purchase an annual license. There was no restriction on the number of export licenses.

Out of the interviewed fishers, 28% described an awareness of informal management (i.e. community level arrangements or practices that are not established and passed as formal laws). The interviewees mentioned agreements such as "*not allowed to collect during night*", "*only collect large sea cucumbers*", or more general restrictions such as "*not allowed to destroy environment*", "*only fish during NE monsoon*", "*foreign collectors must pay [to the] village committee*", "*other villagers not allowed to collect*". 20% of the fishers said that the arrangements were not being followed in conduct. A quarter (28%) of the fishers said that they couldn't consider stopping sea cucumber fishing, while ca. 60% of the interviewed fishers said that they could agree to an occasional or seasonal closure (three months or up to a year).

Almost all of the fishers and middlemen (94% and 92% respectively) answered that it was harder to find most species today than when they first engaged in the activity, emphasising a dramatic decline in the status of the resource. In addition, 93% of the interviewed middlemen wanted access to capital to employ fishers or to invest in equipment such as motors, boats, diving gear etc., to rent to fishing teams to increase the effort in the fishery. In a similar manner, 76% of the fishers said that they want equipment such as motors, boats, diving gear, protective shoes etc. to improve their activity.

When approached with the question of what the fisher would do if the opportunity to fish sea cucumbers was lost, nearly one quarter (24%) indicated that they would struggle to find another source of income. Out of the remaining 76%, 55% stated that the alternative was another type of marine resource extraction (finfish, octopus, lobster or seaweed farming), 19% mentioned land based activities such as farming or firewood collection, 23% mentioned small businesses and 4% mentioned education as an alternative.

3.3 Catch assessment

A total of 2030 animals caught by 347 fishers were counted in catch. The value range of recorded species groups is summarised in Table 2. The catch per unit effort (CPUE) was ca 1.1 individuals h^{-1}, estimated from the mean reported time spent fishing by interviewed fishers (5.3 h). The majority of the catch consisted of low value species (Fig. 2), with local names species groups "Kichupa" (*Holothuria atra, H. leucospilota* and *H. coluber*), "Mbura" (*Actinopyga lecanora, A. mauritiana* and *A. echinites)* and "Sankude" (*Stichopus* sp.) being the most common. Length frequency distribution of caught *Holothuria scabra* showed that the majority of the measured animals are harvested before its estimated length of maturity (160 mm; Conand 1993) (Fig. 3).

3.4 Commercial sea cucumber stock status

The visual census of sea cucumber stocks covered a total area of 16 ha of benthos using 269 manta tows (including Chumbe) and 258 line transects. Sea cucumbers of any commercial value (low, medium or high) were only found in approximately 45% of the manta tow replicates and about 15% of

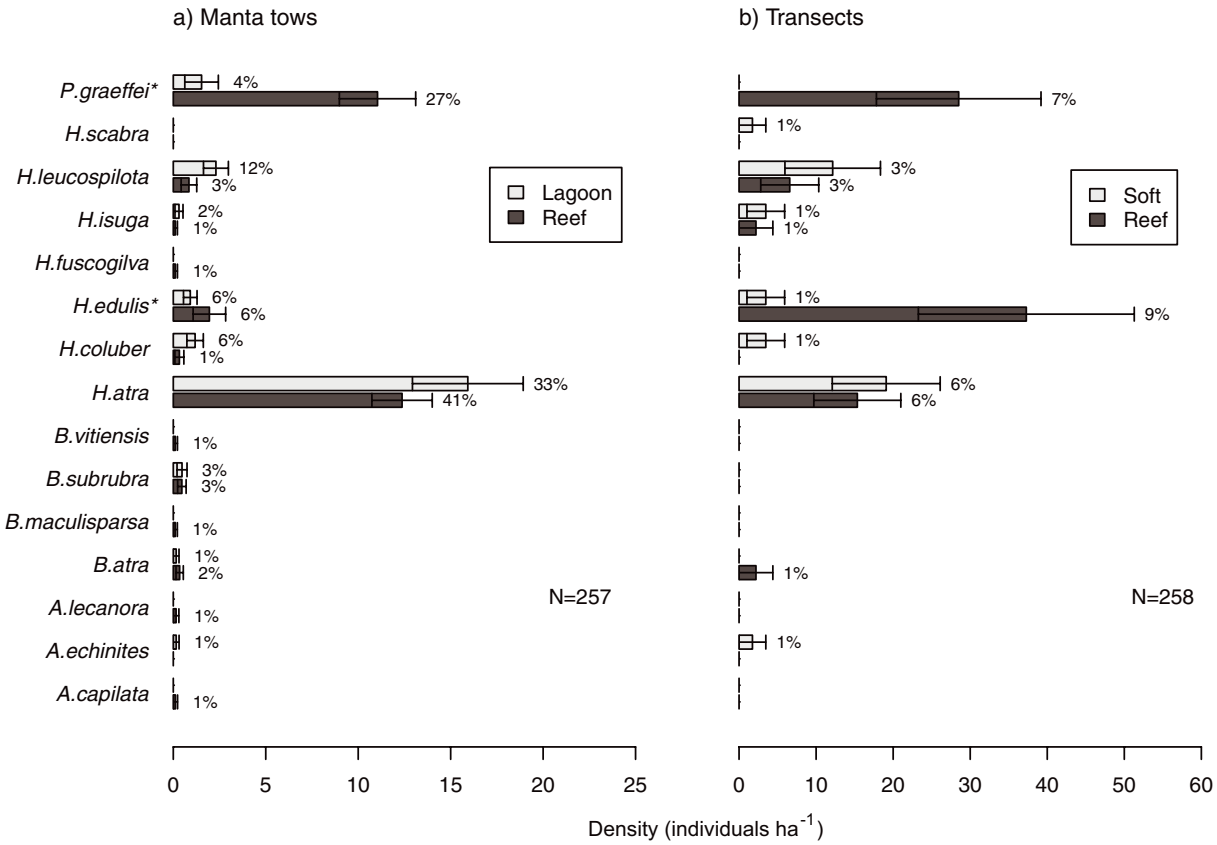

Fig. 4. Mean density of no. individuals ha^{-1} in the three surveyed sites in Zanzibar. Tails are ± SE. Percent numbers above bars represent occurrence in the total amount of transects for that environment and method. a) 300 m × 2 m Manta tows targeting reef environments (n = 148) and lagoon environments (n = 109). b) 40 m × 1 m Transects targeting reef benthos (n = 114) and soft benthos (n = 144). * *P. graeffei* and *H. edulis* are not harvested in Zanzibar.

the line transects in areas open to fishing. The survey revealed a striking paucity of high value species and very low coverage and densities of medium value species using manta tow method and line transect (Fig. 4a,b). The low value species *H. atra* was the most commonly recorded species. *Pearsonathuria graeffei* was also regularly found in reef environments. This species is not fished in Zanzibar but is commercial in other places (Rasolofonirina et al. 2004; Kinch et al. 2008a). Only one animal of the high value species *Holothuria scabra* was found in transects targeting suitable soft benthos areas yielding a very low occurrence and density. No other species of medium or high value were recorded using this method. Results from the manta tow method were pooled into value groups (low, medium and high; Table 2) for each site and reveals the striking scarcity of commercial medium and high value species groups in village fishing grounds, both in terms of occurrence and recorded density (Fig. 5).

The Shannon-Wiener diversity index (H') was found to be higher in the protected site Chumbe (H' = 1.73) than in the fished reefs Ukombe (H' = 1.04) and Kwale (H' = 0.50). On Ukombe reef some individuals of *H. atra* were recorded, which increases this reef H'-value as the index includes an abundance measure. The cumulative species count shows nearing asymptotes for Ukombe and Kwale, whereas Chumbe has a steeper slope and an increasing trend at the same sampling effort (Fig. 6), which highlights a less diverse commercial sea cucumber assemblage in the reefs open to fishing. In addition, Chumbe reef was the only site where the high value species black teatfish, *H. nobilis* (1.2 individuals ha^{-1}), and the medium value species *S. herrmanni* (9 individuals ha^{-1}) and *T. anax* (2.5 individuals ha^{-1}) were recorded in this study, along with a ten times higher density for the medium value species *B. atra* (5 individuals ha^{-1}) compared to the sampled areas open to fishing. This emphasises the positive protection effect from fishing on the commercial sea cucumber assemblage in Chumbe despite its small size (300 m × 1100 m).

4 Discussion

4.1 The fishery operation and management

The fishery includes men, women and children and operates using different modes of collection and effort. For example, women collect sea cucumbers in intertidal areas during the low tide while the highly mobile (men) breath hold and scuba divers target offshore areas, villages with no resident divers, and even waters in other countries in the region with high effort. None of the harvesting activities are monitored or controlled. The mobile divers and the reported connections within the Zanzibar commerce structure from other

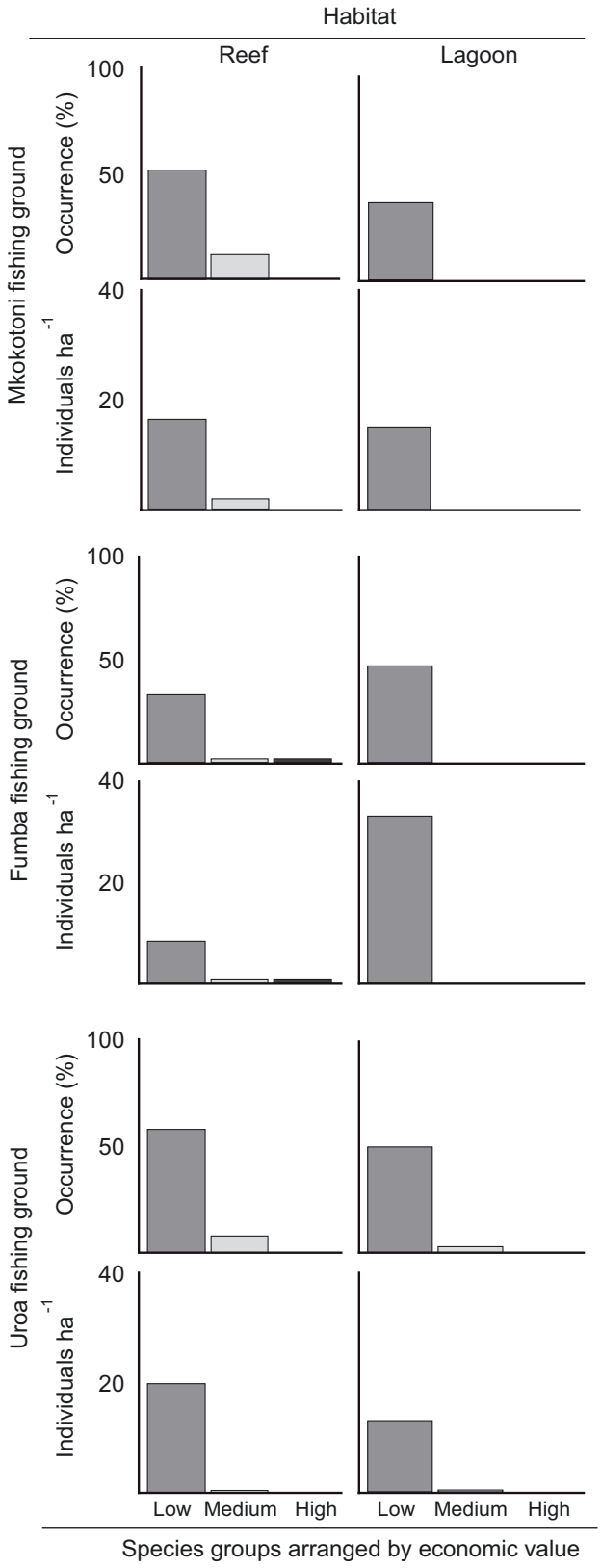

Fig. 5. Pooled occurrences (% of records in transects) and densities (individuals ha^{-1}) of high, medium and low commercial value sea cucumber species in reef and lagoon environments using manta tow assessment method. For key to which species are included in each value category please refer to Table 2.

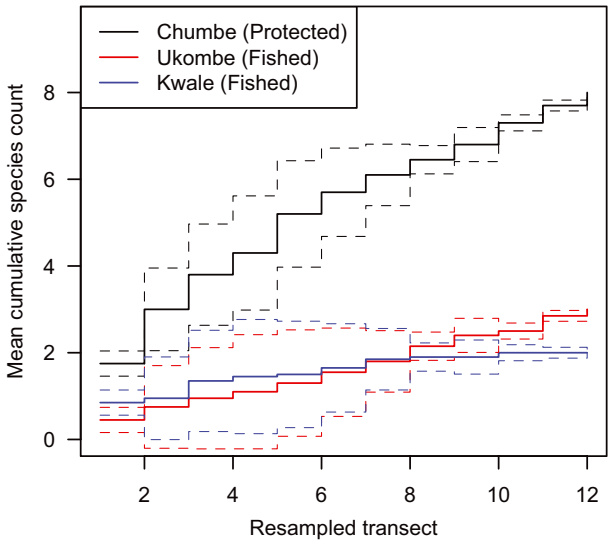

Fig. 6. Cumulative commercial sea cucumber (Holothuroidea: Aspidochirotida) species richness for the protected Chumbe, and fished Ukombe and Kwale reefs (see location in Fig. 1) sampled with manta tows (n = 12). The order of transects was simulated with permutations (n = 20). Plotted data is the mean increment increase in species per transect for simulated combinations of sampled transects. Dotted lines are 95% confidence interval. The slope and asymptotes of the cumulative curves illustrate that Chumbe reef, which is protected from fishing, has higher diversity in commercial sea cucumbers.

areas in the region suggest an intricate cross-scale and cross-border structure. During the study smuggled batches of sea cucumbers from Tanzania mainland were observed at trader's facilities (mainly medium and high value species *H. scabra*, *S. herrmanni*, *T. ananas*, *T. anax*, and the three teatfish varieties), which indicates that Zanzibar could be a regional exit point for legally and illegally fished sea cucumbers. Zanzibar reportedly also receives migratory fishers, middlemen and trading agents from mainland after the closure there. Reportedly the migrating fishers set up camps to harvest in areas around Zanzibar. The scales (e.g. Cash et al. 2006) of sequential exploitation in the fishery include both spatial (geographical area and depth), temporal (day and night, throughout the year) and species range (targeting an array of species). Reported problems with the influx of fishers, other than competition for resources, included environmental degradation in camping areas where firewood is collected to prepare the sea cucumber products and for cooking.

The current formal management is insufficient to control the fishery, both in terms of lack of regulation and lack of implementation. The weak formal management capacity is illustrated for example by the paucity of formation of rules and laws. In addition, our findings illustrate that there are some existing informal arrangements in the sea cucumber fishery that can support management. However, few of the fishers are aware of them and they are not customary as norms of behaviour, hence, they provide a weak instrument for sustainability. To design management and institutional structure to control the fishery the structures and scales of the fishery operation are important to identify (Lee 1993; Holling 2001; Folke et al. 2007). Given the regional trading structures,

bridging institutional structures, and coordinated management between the involved areas and countries is needed. Regional approaches towards management of invertebrate exports are being explored and encouraged in the South Pacific to address similar cross-scale reasons (Friedman and Chapman 2008). Additionally, effort to control the sea cucumber trade at a "higher" policy level is pursued via the possible trade protection under the Convention on International Trade in Endangered Species Wild Fauna and Flora (CITES) (Bruckner et al. 2003). A major constraint for CITES listing is that the taxonomy for many commercial sea cucumbers has not been resolved (Massin et al. 2009), the slow formation of regulation in relation to the rapid progress of fishing (Berkes et al. 2006), and the apparent lack of monitoring and enforcement at the local fishery level as illustrated in this study.

Management based on an ecosystems approach is prescribed for sea cucumber fisheries (Purcell 2010a), as it recognises humans and society as integral in the fishery system, thereby capturing the complexity of the sea cucumber ecology and beche-de-mer trade under its framework. Interviewed fishers seemed positive to shorter seasonal closures of the fishery in order to increase catches. However, the efficiency of maintaining healthy stocks through shorter closures is questionable as a management measure (Purcell 2010a). The role of the international trader is to facilitate the transport of the animal from the ecosystems to the recipient markets, while making a profit. Through this role the traders perform a key function in the trade system linking the world market to the local fishery system and the ecosystem. In Zanzibar, the traders are not under control today but their linking function is indeed important to acknowledge in management (Crona et al. 2010). The manager's responses in discussions showed awareness of a degraded and declining fishery. The fact that decisions are not being made, or that those that are made are not being communicated or enforced, may be due to a mismatch between the normative, cultural and regulative institutions (de la Torre-Castro and Lindström 2010). The environmental policy for Zanzibar (1997) concurs with this finding and states that a constraint in performance of management of the coastal zone is the "lack of comprehensive institutional arrangement that provides mechanism for interagency intersectoral cooperation and collaboration". Management officials also mention lack of funds and resources as a determinant in conducting socio-economic or stock assessment and developing management strategies (jointly with communities or otherwise).

4.2 The fishery as a livelihood

Fishers were paid for their catch at landing sites and the middlemen or traders then processed the catch into products, thereby earning the added value in the market. That traders perform processing to final product is common and reduces the potential for fishers to add value of their catch (Friedman et al. 2008). Price varied markedly for price at point of landing with observations of 85–94% price differential for similar catch in different locations (Table 2). Hence, local fishers (mainly women gleaners) are exploited for profits and do not get a reasonable market price for their catch. This situation is not unique to the Zanzibar sea cucumber fishery, but has been observed in Asia (Choo 2008) and Kenya (Ochiewo et al. 2010), as well as in other marine resources trade structures like commercial seaweed farming (Brycesson 2002). Most importantly, such inequalities hinder poverty reduction (Walmsley et al. 2006), and reduce the sustainability of the fishery even further. This issue is worsened by the reliance on sea cucumbers among those involved in the fishery, with about one quarter of the fishers arguing that they would struggle to find alternatives at all. This scenario is similar to that noted in nearby Kenya (Ochiewo et al. 2010). The interviewed fishers mention other marine resources, agriculture and firewood collection as alternatives to harvesting sea cucumbers, illustrating that the activity to fish sea cucumbers is part of a societal conduct of natural resource use rooted in a society with few market-based alternatives and poverty (Anderson and Ngazi 1998; de la Torre-Castro 2006). The narrow range, and deteriorated status, of alternativesamong the fishers in Zanzibar, suggests that it will be difficult to change conduct or implement restrictions to allow recovery of the fishery and that it will affect communities ability to support themselves.

4.3 Catch and resource status

The low awareness of the length restriction (100 mm) among all actors in the fishery is probably one of the clearest examples of the poor performance of current management. However, the matter is worsened even further as the length restriction is smaller than the known body size of sexual maturity of any commercial sea cucumber species (Conand 1993). The results from the catch monitoring manifests that sea cucumbers smaller than estimated length at sexual maturity, and legal length, is indeed being harvested. The lack of sustainability is also depicted by the ambition among fishers and middlemen to increase effort despite the awareness that the fishery is declining.

Historical CPUE values are not available for trend analysis of catches. Instead, this study focussed on perceptions of fishery trends among fishers, rather than asking them for historical catches in numbers, which is laden with uncertainty. The modest CPUE recorded (1.1 animals h^{-1}) illustrates the reported dramatic decrease in catches by almost all of the interviewed fishers (94%). Catches were generally handled negligent and left on sand or in sun for longer periods, degrading the body walls and reducing the quality of the product. Simple measures such as improving handling of catch and processing (through training) can provide added value to the catch. In particular *Stichopus* varieties suffer from "degenerating" body wall tissue and improper handling can reduce the value of the product by 20–30% (Ram et al. 2010). The *Stichopus* varieties noted in catch are part of a cryptic species complex (Byrne et al. 2010). *Holothuria isuga* was frequently recorded as a low value species in the fishery. This species has previously been noted in New Caledonia (Purcell et al. 2009) and on One Tree Reef in Australia (H. Eriksson pers. obs.), however it is not encountered as a commercial species in the main taxonomic surveys in the region (as compiled by Conand and Muthiga 2007). In addition, the high value teatfish variety *Holothuria* sp. "pentard" (e.g. Conand 2008), that

Table 3. Fishery status summary following indicators in Friedman et al. (2008).

Indicator	Results	Conclusions
Presence of breeding groups	Low densities and coverage levels of coastal commercial sea cucumber stock with no aggregates of medium or high value species recorded.	Stock depletion, replenishment of stock constrained *
Fishing gear used	Both "traditional" hand collection at low tide by women and children and breath hold and scuba diving by men in organised fishing teams. The diving teams are highly mobile and travel far from nearshore overexploited areas. High effort required to find commercial sea cucumbers of any value.	Diving teams illustrate nearshore stock depletion, high effort, lack of regulation leading to overexploitation
Sea cucumber abundance	Low abundance and coverage levels of commercial sea cucumbers recorded.	Stock depletion, replenishment of stock constrained, high effort
Ratio of species abundance	Predominantly low value or newly commercialised species, with absence of high value species and very low abundance of medium value species, in both catch and water.	Stock depletion, unsustainable development of the fishery, high effort
Size of sea cucumbers	The majority of catch is often smaller than estimated size at sexual maturity. In addition, the length restriction placed on the fishery is ecologically irrelevant and not followed in conduct.	Stock depletion, reduced "per-piece" earnings for fishers, replenishment of stock constrained
Profit to fishers	Fishers are exploited for profits not getting a reasonable earning of their catch. A woman in Fumba receives ca 10% of what a man in Mkokotoni gets for similar catch.	The resource is not benefitting fishers to its full potential, market works arbitrarily with functional anomalies

* Arguably breeding success may occur for some species in the protected Chumbe Coral Park, however, such "spillover" effects into the fished areas are unknown.

has not yet been described as a species, and the recently described *Actinopyga capillata* (Rowe and Massin 2006), were also recorded in catch, emphasising that the fishery is targeting species not yet (or recently) described to science. Phylogenetic work is needed to resolve the nomenclature of the species found in the catch in Zanzibar.

The degraded state of the resource due to the fishery is partly illustrated by the paucity of high value species and low densities of medium value species, as well as by the higher diversity of commercial sea cucumbers in the protected Chumbe site than in the fished sites Ukombe and Kwale. Here numerous fishers were observed daily, whereas at Chumbe local rangers patrolled the area (employed by the Chumbe Coral Park administration), and no fishers were present. The additional species found in Chumbe were generally of a higher commercial value. The result of a reduced diversity is in line with studies using Chumbe as an example in addressing macro benthos assemblage differences between protected and open areas (McClanahan et al. 1999; McClanahan and Arthur 2001).

The ability of sea cucumber populations to self-replenish is greatly compromised in reduced densities and may lead to population demise (Bell et al. 2008). Indeed, recovery may take decades despite protection (Uthicke et al. 2004a), which should promote precautious conduct and management (Perry et al. 1999; Friedman et al. 2008). The low densities and coverage levels of commercial species found in this study indicates that few shallow water spawning aggregates remain intact around the coast of Zanzibar today and that management reform is urgently needed. Unfortunately, the knowledge gap in ecology prevents reliable predictions of the future status of this fishery (Conand 1990; Uthicke et al. 2004a; Uthicke et al. 2009). Further ecological research is required to understand species-specific life history and to assist in fisheries management. For instance, deep-water stocks were due to logistical reasons not assessed in this study.

4.4 Summarising the need for change

The Zanzibar sea cucumber fishery has passed all indicators (i.e. presence of breeding groups, fishing gear used, sea cucumber abundance, ratio of species abundance, size of sea cucumbers and profit to fishers as outlined by Friedman et al. 2008) that should, in the presence of adaptive management systems, trigger a change in management involvement (Table 3). This is also confirmed by the generally negative perception of the status of the resource and weak management as described by fishers, middlemen, and management officials. Our findings illustrate that the contemporary sea cucumber fishery and trade system in Zanzibar resembles the historic one with a strong international market influence, "Patron-client" structures and reciprocal agreements and roving bandits-style sequential exploitation as outlined by Schwerdtner Máñez and Ferse (2010). We propose that the fishery has reached the current point of depletion because of i) the strong influence by the world market, linked to the ecosystem via the traders, that introduced the fishery and then facilitated development to the current high effort and shift to low value species with depletion of high value species, ii) the fishery is institutionally marginalised lacking both formal and informal regulation and control and iii) the long time that the fishery has been operating in this manner, which in turn has also led to iv) the fishery becoming recognised and established as an important source of income among communities with few alternative livelihood options, and v) the ecology of these organisms making them particularly vulnerable towards fishing.

5 Conclusion

It is unlikely that the commercial sea cucumber stock size will increase, or the fishery performance will improve, under the current weak management regime, since it fails to provide dialog or restriction in effort despite an awareness of an

overexploited fishery. At best the fishery will remain at similar levels as today, because of geographical in-accessibility or embedded complexity in the ecology of some species restricting harvest. Based on the results in this study a sea cucumber fishery management reform is urgently needed for stocks to regain and eventually maintain their potential to contribute to the village economies and functioning of the coastal ecosystems. However, restrictions of effort must be strongly anchored in co-management schemes including resource-users and taking the existing normative and cultural institutions in consideration. Otherwise the likelihood of failure is very high as shown in attempts to regulate other fisheries in Zanzibar (de la Torre-Castro and Lindström 2010). To successfully implement control and enhance sustainability we conclude that management requires a better fit to the geographic scale of the fishery (e.g. regional cooperation) and increased participation by fishery actors to address the elements that structure the fishery today, such as: extensive scales (spatial, temporal and species range), lack of formal and informal regulation and control, market anomalies (black market, unfair prices etc.), dangerous and high effort scuba diving, and unsatisfying processing. All of which need attention to promote sustainability, safety, fairness and performance in the fishery.

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