Strengthening capacity to sustainably manage sea cucumber fisheries in the western Indian Ocean

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Background

There has been an active sea cucumber fishery in the western Indian Ocean region (WIO) for about a century. Because sea cucumbers in the WIO are solely harvested for the export market, the fishery generates foreign exchange and constitutes an important means of income generation for local communities. However, the increase in coastal populations, the high demand for beche-de-mer (processed sea cucumber) from Asian countries, the ease of collection in shallow coastal waters, and the introduction of scuba, have all combined to cause overfishing of this valuable resource. Despite the importance of sea cucumbers, information on their biology and ecology — which is crucial for management — is scarce from the WIO.

In October 2005, the Western Indian Ocean Marine Science Association, through the Marine Science for Management (MASMA) grant, provided funding for a regional sea cucumber project led by the Wildlife Conservation Society and the University of Reunion (Conand et al. 2006). A multi-disciplinary team contributed to different aspects of the research, and consisted of scientists from the Universities of Dar-es-Salaam, Reunion and Sweden, the Institute of Fisheries and Marine Science (IHSM) in Madagascar, the Kenya Marine and Fisheries Research Institute, and the Seychelles Fishing Authority.

The project began in 2006 with the production of a comprehensive regional review (Conand and Muthiga 2007), and culminated in a regional workshop that was held in Mombasa, Kenya. The main components of the project included: species inventories and distribution studies; assessing the effectiveness of marine protected areas (MPAs) in managing sea cucumbers; studies on the reproductive biology of key commercial species; studies on the socioeconomics and management of the fishery; and training in the taxonomy and biology of sea cucumbers. Although the project focused mainly in Kenya, Madagascar, Reunion, the Seychelles and Tanzania, the similarities and differences in the biodiversity and fisheries within these countries were expected to generate information that was of relevance to other countries in the region. This paper provides a summary of the deliberations, key research findings, and main recommendations for effectively managing the sea cucumber fishery in the WIO.

Main research findings and management recommendations

Species inventories and the effects of marine protected areas

About 250 species of sea cucumbers are reported in the WIO (Richmond 1997; Samyn and Tallon 2005; Conand and Muthiga 2007) but comprehensive surveys have only been carried out in Kenya, Reunion and the Seychelles (Table 1). As several new species have recently been described (Rowe and Massin 2006; Thandar 2007) and taxonomic studies continue in the region, it is expected that species diversity will increase in the future. Information from historical sources collected during the review and from surveys carried out during the study revealed that at least for the commercial species, densities were very low except in deeper waters, in marine protected areas, and in remote sites, which questions the viability of these populations. More detailed surveys were recommended in each country given the pressure to harvest new stocks of species whose biology and ecology is unknown, such as the case with *Holothuria notabilis* and *Stichopus horrens* in Madagascar (Rasolofonirina 2007).

MPAs promote biodiversity and are used for fisheries management in the WIO region. The project studied the effects of MPAs on sea cucumber population dynamics and reproduction in Kenya and Tanzania. Results indicate that MPAs have a positive impact on species diversity and abundance in the Mombasa Marine Park and reserve in Kenya (Orwa 2007), which validates a previous study in the MPAs and fished sites of Malindi, Watamu, and Kisite-Mpunguti (Muthiga and Ndirangu 2000). In addition, results of the reproductive output of

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Table 1. Sea cucumber diversity in some countries of the western Indian Ocean.

Country	No of species	Main taxonomic references	Comment
Kenya	44 (10 genera)	Humphreys 1981; Muthiga and Ndirangu 2000; Samyn 2003	*Holothuria arenacava*, a new species, has not been reported elsewhere *H. coluber* a new record for Kenya
La Reunion	21 (9 genera)	Conand 2003 Rowe and Massin 2006	*Actinopyga capillata* a new species also reported in Rodrigues
Madagascar	125	Cherbonnier 1988 Massin et al. 1999	*Holothuria naso, H. notabilis* and *Stichopus horrens* are new records
Seychelles	35	Clark 1984	*Holothuria* sp. Pentard still under taxonomic investigation
Tanzania	23 (Pemba Is)	Samyn 2003	Limited taxonomic work has been carried out

Table 2. Breeding seasons of some sea cucumber species in the western Indian Ocean.

Species	Location	Reproductive pattern	Reference
*Actinopyga echinites**	Reunion, (21° S)	Annual, spawning January–February and April–May	Kohler et al. in press
Holothuria arenacava	Mombasa, Kenya (4°S)	Annual, spawning March– May	Muthiga 2006
*H. fuscogilva**	Shimoni, Kenya (4° S)	Annual, spawning December–April	Muthiga and Kawaka in press
H. fuscogilva	Maldives (7° S)	Annual, spawning March– May	Reichenbach 1999
*H. leucospilota**	La Saline, Reunion (21° S)	Annual, two spawning peaks (February & May)	Gaudron et al. 2008
*H. leucospilota**	Mombasa, Kenya (4°S)	Annual, spawning March– May	Kawaka 2008
*H. notabilis**	Toliara, Madagascar (23° S)	Annual, spawning November–December	Rasolofonirina pers. comm.
*H. scabra**	Vanga, Kenya (4° S)	Biannual, spawning major event November–December and minor event May–September	Muthiga et al. 2009
H. scabra	Toliara, Madagascar (23° S)	Annual, spawning November–April	Rasolofonirina et al. 2005
H. scabra	Kunduchi & Buyuni, Tanzania (6° S)	Biannual, spawning August–September and December–January	Kithakeni and Ndaro 2002
*Stichopus horrens**	Toliara, Madagascar (23° S)	Annual, spawning January–March	Rasolofonirina pers. comm.

* = Results from the regional project

the high-value *Holothuria scabra* and the low-value *H. leucospilota* demonstrate the impact of fishing effects. Individuals of *H. leucospilota* were larger, had significantly larger gonads and higher fecundity in the fully protected Mombasa marine park than in the partially protected marine reserve (Kawaka 2009). Studies in Tanzania indicate that seasons (dry and wet) and fishing pressure influence both fecundity and spawning peaks in *H. scabra*, with fishing pressure having a negative effect on body sizes and fecundity (Mmbaga 2009). Area closures and reduced fishing pressure were effective in enhancing reproductive output and potentially increasing densities of sea cucumbers in the region.

Reproductive biology and management implications

Studies were untaken on the reproductive biology of *Actinopyga echinites* and *Holothuria leucospilota* in La Reunion, *H. fuscogilva* and *H. scabra in Kenya*, *H. notabilis*, and *Stichopus horrens* in Madagascar, and *H. scabra* in Tanzania (Table 2). The research on this project increases the number of studies on the reproductive biology of sea cucumbers in the region from 4 to 11 (Table 2). The main mode of reproduction is sexual, although asexual reproduction through fission has previously been reported in *H. atra* (Conand 2004) and *S. chloronotus* (Conand et al. 2002) in La Reunion. Species closer to the equator (~ 4–7°S) either displayed a biannual pattern with two spawning periods (*H. scabra*) or an annual pattern with a single extended spawning period (*H. arenacava*, *H. leucospilota* and *H. fuscogilva*). Farther from the equator (~21–23°S), species exhibited annual patterns with a single extended spawning period (*H. scabra, H. horrens* and *H. notabilis*) or two short spawning periods (*Actinopyga echinites* and *H. leucospilota*).

Reproductive patterns were not necessarily species specific. For example, *H. scabra* displayed a biannual pattern closer to the equator (Muthiga et al. 2009; Kithakeni and Ndaro 2002) and an annual pattern at higher latitudes (Rasolofonirina et al. 2005). On the other hand, *H. fuscogilva* not only exhibited an annual pattern closer to the equator in this and previous studies (Muthiga and Kawaka in press; Reichenbach 1999; Ramofafia et al. 2000), but has also been reported to have an annual pattern at higher latitudes (Conand 1993). In general, spawning in the studied species coincided with the warmest months of the year in the WIO. However, because the warmest temperatures also coincided with the highest light intensities and highest ocean productivity, experimental studies would have to be carried out to ascertain the main cue for the onset of gametogenesis and spawning in individual species. Studies from the regional project not only contribute to the knowledge of reproductive patterns of the most commercially valuable sea cucumber species in the world (*H. scabra* and *H. fuscogilva*), but also assist in reevaluating the factors that affect reproduction in tropical marine invertebrates.

The project provided information on reproductive parameters that should assist countries in improving the management of their fisheries. For example, information is now available on size at sex maturity and on spawning seasons, which will enable fisheries officers in the WIO to set size limits and seasonal closures (Table 3). Overfishing has reduced population densities. In areas where individuals may be too far apart to successfully reproduce, restocking programmes are recommended for most WIO countries. Mariculture is already being piloted in Madagascar (Rasolofonirina et al. 2004; Eeckhaut et al. 2008), and several other countries in the WIO have shown an interest. Research findings from

Table 3. Possible management interventions based on the reproductive season and size at sexual maturity of commercial species in the western Indian Ocean.

Species	Country	Management interventions
Holothuria scabra	Kenya	Closures November–December, minimum size of 16 cm
H. scabra	Tanzania	Closures December–January, minimum size 16.8 cm
H. scabra	Madagascar	Closures November–April, minimum size 22 cm
H. fuscogilva	Kenya	Closures December–March, minimum size 1167 g or 32 cm
H. notabilis	Madagascar	Closures August–December, minimum size 20 g or 9.5 cm
Actinopyga echinites	Reunion	Closures December–January, minimum size 50 g
Stichopus horrens	Madagascar	Closures November–March, minimum size 170 g, 25 cm

(gutted weight = g; length in cm)
Source: see Table 2 for citations

the project will provide baseline scientific data on reproduction, which is needed for mariculture and restocking programmes.

Fisheries management and legislation

In total 32 sea cucumber species are harvested throughout the WIO (Conand and Muthiga 2007), with Madagascar having the highest number of species harvested (30 species). Five main species — *Holothuria fuscogilva*, *H. scabra*, *H. nobilis*, *Thelonata ananas* and *Actinopyga miliaris* — are harvested in most countries. The sea cucumber fishery is mainly artisanal (except in the Seychelles), contributing to the livelihoods of many households (De la Torre-Castro et al. 2007). Several factors indicate that sea cucumber fisheries are severely stressed:

- catches in most countries have declined between 40% and 80% over recent decades (Conand and Muthiga 2007; Conand 2008);
- abundances of commercial species are low;
- fishers indicate that species of high commercial value have become increasingly scarce;
- the length of fishing trips has increased; and
- sexually immature individuals and species of low commercial value are being harvested.

An analysis of legislative and regulatory instruments governing the management of sea cucumber fisheries indicates that most countries (Kenya, Tanzania, La Reunion and the Seychelles), have national fisheries legislations that partly address the sea cucumber fishery (Table 4). The analysis also shows that sea cucumber fishery management plans are lacking everywhere in the WIO except in Madagascar (the largest producer of beche-de-mer in the WIO) and the Seychelles. Fisheries catch monitoring programmes were present in nearly all countries but were often unreliable due to poor collection and storage of catch and export data (Conand and Muthiga 2007). In addition, except in the Seychelles where a system of logbooks was established in 1999, catch statistics are rarely collected at the species level.

Management regulations and interventions include seasonal closures, area closures, size limits, gear restrictions, licensing, restocking, education and extension, and research. At present, most countries have area closures in the form of MPAs that were established for biodiversity conservation and fisheries management. Gear restrictions are also widely used, mainly the prohibition on scuba and the licensing of fishers. To date, no restocking of overexploited sea cucumber populations is taking place although the first-ever trade company, Madagascar Holothurie SA, has been created in Madagascar, working with non-governmental organisations (NGOs) in a mariculture programme (Eeckhaut et al. 2008; Robinson and Pascal 2009). In most WIO countries, therefore, a lack of targeted management and ineffective or poorly implemented regulations reduces the contribution of this valuable resource to the fisheries sector.

Summary and recommendations

Thirty-three participants from Kenya, Madagascar, Mozambique, Sweden and Tanzania attended the final regional workshop. Participants included managers of fisheries and MPAs, NGO representatives, university lecturers, and scientists with a stake in managing marine resources in the region. The workshop drew on the knowledge gained through the regional sea cucumber project, including the regional review (Conand and Muthiga 2007), several scientific publications produced through the project (see list below), as well as other relevant information from the collective experiences of investigators and participants. The regional workshop served as a forum to enhance awareness among relevant institutions in the WIO about sea cucumbers. Relevant identification and scientific documents were provided to participants, and a field trip served to develop skills in sea cucumber field methods. The workshop also served to enhance networking and coordination among participants, which is crucial to the continued work on sea cucumbers that is needed in the WIO.

Workshop participants acknowledged that sea cucumber fisheries in the WIO are under severe pressure, that national institutions lack capacity, and that poor monitoring systems and enforcement programmes compound the management of this fishery. Participants involved in conservation, fisheries and research resolved to assist their national institutions in developing management programmes (where such programmes currently do not exist), and explore ways to enhance the effective management of this fishery. The following recommendations are relevant (in differing degrees) for each country in the WIO:

1. Develop and implement appropriate stock assessment and monitoring programmes for sea cucumbers. These may use existing structures within fisheries authorities or work in partnerships with local research and educational institutions, NGOs or local communities. Catch and trade statistics should be collected at the species level wherever possible, and management and archiving of data should be improved.
2. Continue research on the biology, fisheries and trade of commercial sea cucumbers in WIO countries. Studies on growth, mortality and recruitment are crucial for fisheries management, and there should be continued efforts to

Table 4. Sea cucumber fisheries management interventions in selected areas of the western Indian Ocean.

	Kenya	Reunion	Tanzania	Seychelles	Madagascar	Mozambique	Zanzibar
Legislation							
Sea cucumber fisheries	present (artisanal)	partly present	partly present	partly present	present	present	present
Policy	partly present	partly present	partly present	present	present	partly present	partly present
Management plans	absent	partly present	absent	proposed	present	absent	absent
Monitoring frameworks	partly present (catch data)	present	partly present	partly present	present but unreliable	partly present	partly present
Socio-economic data collection	partly present	absent	partly present	partly present	present	no information	partly present
Regulations and other interventions							
Seasonal closures	absent	absent	absent	absent	partly present	absent	absent
Area closures (for fisheries and marine organisms)	present	present	present	present	present	present	present
Size limits	absent	absent	present but not enforced	absent	absent	present	present but not enforced
Restocking programme	absent	absent	absent	no information	absent	absent	absent
Stock assessment	absent	partly present	absent	present	present	present	absent
Gear restrictions (scuba)	present	present	present	absent	present	present	absent
Licences (fishing and trading)	present	present	present	present	present	present	present
Education and extension	absent	absent	absent	no information	present	absent	absent
Research	partly present	present	partly present	partly present	present	partly present	absent
Mariculture and other interventions							
Willingness to adopt	absent	absent	absent	absent	present	absent	absent
Marketing	absent	absent	absent	present	absent	absent	absent
Organisation of fishers (collectors, traders)	absent	absent	partly present	absent	absent	absent	absent
Processing (level and quality)	absent	absent	absent	present	absent	absent	absent
Quality assurance	absent	absent	absent	absent	absent	absent	absent

update species inventories and resolve taxonomic challenges.

3. Improve the capacity for management including increasing resources for surveillance, enforcement and training. In particular, capacity is required in the inspection of the trade, data collection and monitoring, and the use of scientific information to implement management interventions.
4. Develop sea cucumber-specific management plans, including specific regulations such as regulations on gear use, size limitations, seasonal and depth closures, and total allowable catches. At present, some high-value species are severely overexploited and total bans may be needed. Management plans should: a) be based on the best available scientific information; b) take into account best practices and the precautionary principle of fisheries management; and c) involve stakeholders during their development and implementation.
5. Train communities in harvesting and processing beche-de-mer in order to improve the quality and reduce the inefficiencies of current systems.
6. Develop mariculture programmes as alternative livelihood options as well as for commercial and restocking purposes.
7. Integrate the use of MPAs within the suit of tools for management of the sea cucumber fishery.

Despite the challenges discussed above, there is increasing interest in improving the management of fisheries in the WIO. Concerns about food security, global climate change and trade, and biodiversity conservation have increased the pressure for governments to better manage coastal and marine resources. Given that the incidence and severity of these challenges vary according to the conditions within each country, the solutions need to be tailored to the specific context within which the challenges occur. The above recommendations are, therefore, generic but if appropriately implemented they should assist in addressing some of the development and management goals of countries in the WIO region.

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