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PREFACE

Sea cucumbers (Holothurians) are a group of marine invertebrates that are harvested worldwide in tropical and subtropical countries. Over the past decades, a significant increase in the demand for sea cucumber has led to an explosion in exploitation often resulting in population declines in many producing nations. Because of the importance of sea cucumbers as a source of livelihood for many artisanal fishers from developing countries and as a globally traded product, much interest has been generated for information on their biology, ecology and fisheries management.

Although management agencies and fishing communities have recognized that sea cucumber fisheries are in trouble worldwide, attempts at management have been largely unsuccessful due to several factors including: 1) the vulnerability of sea cucumbers to harvesting, 2) the artisanal nature of the fishery that prevents fisher communities from using alternative coping mechanisms and 3) the institutional and socio-economic barriers to management.

Sea cucumber production has been declining in nations of the Western Indian Ocean in the last ten years. The reasons for the decline include: 1) a lack of ecological information for understanding species life histories, 2) a lack of understanding of the socio-economic realities of the fishery and 3) inadequate monitoring and enforcement of fishery regulations.

The Western Indian Ocean Marine Science Association (WIOMSA) as part of its aim to serve the information needs of resource managers and communities for the sustainable management of marine resources in the WIO, approved a 'Regional Sea Cucumber Project' in 2006. This review was prepared as the baseline study of the project and aims to provide a comprehensive synthesis of the current state of knowledge on sea cucumbers in the WIO. The information used in the review comes from many sources including journal articles, theses and dissertations, and reports on all aspects of sea cucumbers in the region. Although the report focuses on the five countries (Kenya, La Reunion, Madagascar, Seychelles, Tanzania) that are involved in the project, a brief description of the status of sea cucumbers in other countries of the WIO is also included.

It is hoped that this review contributes scientific information that will support management efforts of sea cucumbers in the WIO and also serve as a useful reference for scientists and students interested in echinoderms in general and sea cucumbers in particular.

CHAPTER 1

INTRODUCTION

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General Introduction

Sea cucumbers (holothurians) are a poorly understood coastal resource, despite their long history of exploitation for consumption by oriental populations (Conand 1990, 2004a; Lovatelli *et al.* 2004; Bruckner 2006). The most valuable sea cucumber product is the dried body wall that is marketed as beche-de-mer (trepang or hai-som). Whilst the high demand for sea cucumbers has resulted in overexploitation in the main producing nations, there remains a lucrative market for the product worldwide, leading to expansion into new fishing grounds. Interest for sea cucumber fisheries has increased recently because the fishery has features including; the sedentary behavior of sea cucumbers, the high value of the product, the low cost of processing and the huge international market, that enable the development of artisanal and community based fisheries. These charactereistics also make sea cucumbers very vulnerable to overexploitation and unfortunately, this has occured in many producing nations (Lovatelli *et al.* 2004 ; Bruckner 2006).

Interest in sea cucumber fisheries management first developed in the tropical Pacific, through the Secretariat of the Pacific Community (SPC), with the production of several publications including the Beche-de-mer Information Bulletin (BDM) (SPC 1990 to 2007) and a handbook for sea cucumbers (Anonymous 1994). The BDM Bulletin continues to publish contributions on various subjects on sea cucumbers every six months. More recently, several developments have also occurred at the global level including; a meeting organized by the Food and Agricultural Organisation (FAO) in China (ASCAM 2003) on the fisheries, management and aquaculture of sea cucumbers (Lovatelli *et al.* 2004), and a Convention on International Trade in Endangered species (CITES) meeting in Malaysia (Conand 2004b ; Bruckner 2006). Both these meetings were crucial in highlighting the conservation and management challenges of the global sea cucumber fishery. In addition, information on sea cucumber aquaculture is becoming increasingly more available with the publication of numerous scientific papers and the production of a manual on the culture of the high-value sea cucumber *Holothuria scabra* (Aguda 2006). Recently, an international meeting has been suggested by FAO in collaboration with the Darwin Initiative in the Galapagos to produce Technical guidelines for sustainable management of sea cucumber fisheries. Taxonomists from several countries have also formed the Aspidochirote Working Group (AWG), to exchange ideas, organize programmes and tackle the numerous problems that still exist on the taxonomy of sea cucumbers, through the Partnerships for Enhancing Expertise in Taxonomy (PEET) (http://www.uog.edu/marinelab/peetcukes/index.html). This increase in attention on sea cucumbers may result in more effective management and conservation of sea cucumber fisheries.

The sea cucumber fisheries of the Western Indian Ocean and the MASMA Programme

Coastal fisheries provide an important source of food and income for communities in the Western Indian Ocean (WIO) (McClanahan and Pet-Soede 2000; Cesar *et al.* 2002). However, the increasing need for finfish and other marine products is leading to overexploitation and habitat degradation hences losses of biodiversity and ecosystem services (McClanahan and Sheppard 2000; de la Torre-

Castro and Rönnback 2004 more references). Partly due to the opening up of international trade to China and to the decline in the finfish fisheries in the inshore waters of the WIO, interest has developed in alternative and valuable fisheries, such as sea cucumbers, in order to divert fishing pressure away from traditional fisheries and to improve incomes of coastal communities.
Currently, sea cucumber fisheries in the WIO are artisanal (Figure 1.1) and are characterised by poorly informed management despite their long history in the region as evidenced by narratives of complex trade routes to China (Gilbert 2004). Except for a general review of the management systems in three countries of the WIO (Marshall *et al.* 2001), no regional level analysis has been undertaken. Renewed interest in this fishery as well as the development of aquaculture has resulted in several studies on the biology and ecology of sea cucumbers (Rasolofonirina and Conand 1998; Muthiga and Ndirangu 2000; Conand 2001, 2004a, 2006a, 2006b; Rasolofonirina *et al.* 2004; Aumeeruddy and Skewes 2005; Aumeeruddy *et al.* 2005; Conand *et al.* 2005 ; Samyn *et al.* 2005; Muthiga 2006).

The problems associated with the sea cucumber fishery has generated an urgent need for knowledge on the biological aspects of the resource as well as impacts on the livelihoods of coastal communities by several fisheries agencies in the region. To this end, a regional interdisciplinary research project was proposed in 2006 and received funding from the Western Indian Ocean Marine Science Association (WIOMSA) through the marine science for management (MASMA) program (see Conand *et al.* 2006 for details).

Figure 1.1. Sea cucumbre processing in Madagascar (a) and Tanzania (b)

a) Multispecies exploitation of sea cucumbers in SW Madagascar (Photo: Conand)

b) Drying and packing sea cucumbers in Tanzania (Photo: Mmbaga)

Scientists from five countries, Kenya, La Reunion, Madagascar, Seychelles and Tanzania are currently collaborating in the regional project. The Project was initiated at a start-up workshop in Mombasa in 2006, where the concept of a regional review was discussed as well as common methodologies for the project (Muthiga and Conand 2006). The socio-economic aspects of the Project were further defined during a workshop in Dar-es-Salaam (de La Torre-Castro *et al.* 2007). This review provides a summary of the current status of knowledge on sea cucumbers in the five countries and is intended to serve as a preliminary tool with a view to contributing knowledge on sea cucumbers in the region. It is hoped that the review will guide and facilitate identification of research and management actions since the sustainability of this highly valuable resource ultimately depends on how well this resource is managed.

Knowledge on the biology and ecology of sea cucumbers in the Western Indian Ocean

Some studies on sea cucumbers have been conducted in several countries in the WIO but there has been limited analysis of information relevant for fisheries management in individual countries and no regional level analysis. Previous studies have included some taxonomic work indicating a rich and diverse population of holothurians ; Cherbonnier (1988) for Madagascar, Humphreys (1981) for Kenya, Clark and Rowe (1971) for the Indo-Pacific distribution. More recent taxonomic studies include Richmond (1997), Conand (1999), Massin *et al.* (1999), Samyn and Berghe (2000), Samyn *et al.* (2001), Conand and Mangion (2002), Conand (2003), Rowe and Richmond (2004), Samyn (2004), Samyn *et al.* (2005), Conand *et al.* (2005), Pouget (2005) and Samyn *et al.* (2006). In the Seychelles, an FAO funded project focused on resource assessment and distribution of sea cucumbers (Aumeeruddy and Skewes 2005; Aumeeruddy *et al.* 2005).

The biology of some commecial species has been studied to some limited extent in Kenya (Muthiga and Ndirangu 2000; Muthiga 2006), Madagascar (Rasolofonirina 2005 ; Rasolofonirina *et al.* 2004, 2005), La Reunion (Conand 1996, 2003, 2004c ; Conand *et al.* 1997; 2002; Conand and Mangion 2002; Mangion *et al.* 2004: Uthicke and Conand 2005b) and Tanzania (Kithakeni and Ndaro 2002). In addition, Hamel *et al.* (2001) provide a synthesis of the biology of *Holothuria scabra* (sandfish), the most important commercial species in the region. Some limited information is also available on other species of commercial value including *H. nobilis, H. fuscogilva* and species of *Actinopyga, Stichopus* and *Thelenota* (Conand 1990, 1999; Muthiga and Ndirangu 2000). Given that the WIO region has more than 100 species of sea cucumbers (Clark and Rowe 1971) and at least 20 species are of commercial value, it is apparent, that more information is needed, especially knowledge on reproduction, recruitment, growth and mortality that are crucial for fisheries management, as recommended by FAO (Lovatelli *et al.* 2004) and CITES (Conand 2006b ; Bruckner 2006).

Information on the ecology of the main commercial species is also important for fisheries management, yet very little ecological work has been carried out in the region. For example the importance of different ecosystems (coral reefs, sea grasses, mud flats) for different stages during the life history of commercial species and how changes in these ecosystems affect sea cucumber populations is not clear. Information on the habitats of juveniles that is necessary for understanding recruitment is also lacking (Shiell 2004). Factors that control population densities including predation and causes of sea cucumber mortality are difficult issues which have also received very little attention.

Unfortunately despite the potential importance of sea cucumbers to the livelihoods of coastal communities, few studies have taken the socio-economic aspects of the fishery into account. This is especially important because the characteristics of the fishery seem to vary from country to country and with different world zones (Conand 2006a). In addition, the conservation implications (Bruckner 2006) and the impact of Marine Protected Areas have also not been addressed. De la Torre-Castro *et al.* (2007) present a conceptual model of sea cucumber resource dynamics. The model encompasses multiple scales and considers the main structures of the sea cucumber fishery in terms of ecosystems used as fishing and collection grounds, resource users and other actors involved in the fishery, e.g. the fishers themselves, the middlemen and the importers, the links between actors, villages and countries and the associated management initiatives at different scales. This framework seems promising when analyzing the sea cucumber fishery from a holistic perspective considering both social and ecological interactions. The results generated from this conceptual model should provide knowledge and management advice for the sustainability of the fisheries in the WIO and should be easily adaptable for other developing nations.

Knowledge on the management of sea cucumbers in the Western Indian Ocean

There have been some basic analysis of the sea cucumber fisheries (Figure 1.1) and management systems in some countries of the region (Horsfall 1998; Muthiga and Ndirangu 2000; Marshall *et al.* 2001; Rasolofonirina *et al.* 2004; Mbaga and Mgaya 2004; Aumeeruddy and Skewes 2005, Uthicke and Conand 2005a) indicating rapidly developing and unregulated fisheries with some showing signs of over-exploitation. Catches have been declining over the last 10 years, and fishers are reported to be catching smaller and reproductively immature individuals in some countries (Muthiga and Ndirangu 2000). Conand (2001) has also modeled five levels of the sea cucumber fishery-system that should provide a framework for the analysis of the fisheries management programs of WIO countries.

It is difficult to make a thorough assessment of the fisheries of the WIO at the present time however, because of inconsistencies and poor collection and storage of catch statistics in most countries. Nonetheless, the annual production trends of beche-de-mer of countries in the WIO are available from the FAO fishery statistics (FAO 2004). Conand (2006b) compiled these for the decades (1994-2003; Table 1.1), for area 51 which encompasses the WIO, and FAO area 57 the Eastern Indian Ocean (EIO) as well as the world total (excluding Japan and Korea PR that report fresh captures rather than the dried product; see Conand 2001). Although there are some problems with the FAO statistics partly due to the failure of countries to report accurately and consistently to FAO, some general observations can be made from this data. The sea cucumber production trends indicate that: (1) the decadal mean tonnage in the WIO accounts for about a third of the worlds total, showing the importance of this production to the global trade despite under-reporting; (2) the annual production varied widely in each country and has generally been declining; (3) the highest producing nations, Madagascar and Tanzania show boom and burst features with high production in the mid-to late 80s and dramatic declines of more than > 100% by 1998 (Madagascar) and 1999 (Tanzania); (4) within the WIO, the countries with a mean production over 100t, ranked by decreasing decadal mean tonnages are Madagascar, Tanzania and the Maldives; (5) several countries that are reported to produce beche-de-mer such as Seychelles are not currently reporting to FAO making regional comparisons tenuous.

There is a growing recognition within the fisheries authorities of the WIO that sea cucumber fisheries although valuable, are poorly managed hence several regulatory and policy interventions have recently been initiatied in Kenya (Muthiga and Ndirangu 2000; Beadle 2005), Madagascar (Rasolofonirina *et al.* 2004) and Tanzania. Only Seychelles has carried out a comprehensive survey and stakeholder analysis leading to regulation of Total Allowable Catch quotas for sea cucumbers (Aumeeruddy and Skewes 2005).

Table 1.1. Annual beche-de-mer production (tonnes) in the Indian Ocean, for the last decade. Data from FAO (2004)

Table 1.1: Sea cucumber production by countries and fishing areas in tonnes and %												**(data from FAO 2004 B76)**	
Country	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**m (11 y)**	**% m/WT**
Egypt	-	-	-	-	-	-	20	139	2310	527	15	602,2	4,0
Madagascar	5400	5400	5400	5400	1446	1500	1500	1500	500	500	500	2640,5	17,5
Maldives	66	94	145	318	85	54	205	226	191	239	182	164,1	1,1
Tanzania	1591	1460	1644	1527	1800	189	372	340	65	75	10	824,8	0,2
Kenya	41	55	15	41	38	15	30	13	68	27	28	33,7	0,2
Yemen	102	-	-	-	-	1	- -		14	10	380	101,4	0,7
Mozambique	0	6	54	7	2	8	12	11	10	4	1	10,5	0,1
**area 51*	*7200,0*	*7015,0*	*7258,0*	*7293,0*	*3371,0*	*1767,0*	*2139,0*	*2229,0*	*3158,0*	*1382,0*	*1116,0*	*4377,2*	*29,1*
Indonesia	548	227	269	338	630	689	903	697	649	870	360	561,8	3,7
Sri Lanka	92	100	150	272	203	170	145	90	150	170	280	165,6	1,1
Malaysia	-	-	-	-	-	-	- -	-		-	-	-	-
**area 57*	*640,0*	*327,0*	*419,0*	*610,0*	*833,0*	*859,0*	*1048,0*	*787,0*	*799,0*	*1040,0*	*640,0*	*727,5*	*4,8*
World total	**16246**	**15556**	**17590**	**15295**	**13613**	**12596**	**16020**	**11964**	**15243**	**18578**	**13017**	**15065,3**	**100**
**area 51* and *57: mean for 11 Y, by area* and *country*													

Conclusion

Sea cucumbers are a group of marine invertebrates that are fished and traded in many countries of the WIO (Conand xx). Culture of some species has also recently commenced in Madagascar (Rasolofonirina *et al.* 2004). Over the last decade, production trends have been decreasing with the highest decreases registered by the largest producers (Conand 2006b). Because of the high value of sea cucumbers, their potential as an alternative resource and as a globally important traded commodity, much interest in improving the fisheries management of this resource has been generated in the WIO region. WIOMSA (through the MASMA program), as a part of its mandate to build management capacity and hence contribute to the sustainability of marine resources has provided funds to carryout a regional study in five countries in the region (Conand *et al.* 2006). This is the first review of the current knowledge on sea cucumbers, their biology, ecology and fisheries management in Kenya, La-Reunion, Madagascar, Seychelles and Tanzania conducted under this project. Information on sea cucumbers is drawn from more than 140 publications and reports starting with a general overview (Chapter 1) and then country comparisons (Chapter 2 – 6). It is hoped that this report will serve as a useful source of information and references to fisheries managers, researchers, students and stakeholders interested in sea cucumber management and research.

Acknowledgements

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Literature cited

Anonymous (1994) Sea cucumbers and beche-de-mer of the Tropical Pacific. A handbook for fishers. SPC, Noumea, Handbook 18. 51pp

Aumeeruddy R, Skewes T (2005) Resource assessment of the holothurian populations in the Seychelles SPC Bêche-de-mer Inf Bull. 21: 19-21

Aumeeruddy R, Skewes T, Dorizo J, Carocci F, Coeur de Lion F, Harris A, Henriette C, Cedras M (2005) Resource assessment and management of the Seychelles sea cucumber fishery. FAO Project Number: TCP/Seychelles/2902(A), November 2005. 49 pp

Beadle R (2005) Management, conflict and compliance: The case of the Kenyan sea cucumber (Echinodermata: Holothuroidea) fishery. M.Sc thesis in Tropical Coastal Management University of Newcastle upon Tyne

Bruckner AW (ed) (2006) The proceedings of the technical workshop on the conservation of sea cucumbers in the families Holothuridae and Stichopodidae. NOAA Technical Memorandum 44, 239 pp

Cesar H, Pet-Soede L, Westmacott S, Mangi S (2002) Economic analysis of coral bleaching in the Indian ocean – Phase II. In: Linden O, Souter D, Wilhelmsson D, Obura D (eds). Coral Reef Degradation in the Indian Ocean. Status Report 2002. Kalmar, pp 251-262

Cherbonnier G (1988) Echinodermes: Holothurides. Faune de Madagascar. ORSTOM 70, 292 pp

Clark AM, Rowe FWE (1971) Monograph of the shallow-water Indo-West Pacific echinoderms. Bath, England, Pitman Press.

Conand C (1990) The fishery resources of Pacific island countries. Part 2: Holothurians. FAO Fisheries Technical Paper, Rome, No. 272 (2): 143 pp.

Conand C (1996) Asexual reproduction by fission in *Holothuria atra* : variability of some parameters in populations from the tropical Indo-Pacific. *Oceanologica Acta* 19(3): 209-216.

Conand C (1999) Manuel de qualité des holothuries commerciales du Sud-Ouest de l'Océan Indien. PRE/COI: 39p.

Conand C (2001) Overview of sea cucumber fisheries over the last decade - what possibilities fora

durable management ? In : Barker (ed) Int. Echinoderms 2000. Swets and Zeitlinger, pp 339-344
Conand C (2003) Les Echinodermes de La Réunion. In: Conand C, Chabanet P, Gravier-Bonnet N (eds) Biodiversité du milieu récifal réunionnais: échinodermes, poissons et hydraires Rapport au Conseil Régional. Annexe 1 :129 pp.
Conand C (2004a) Present status of world sea cucumber resources and utilisation: an international overview. In: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds). Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463:13-23
Conand C (2004b) Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES):conservation and trade in sea cucumbers. SPC Bêche-de-mer Info Bull 20:3-5
Conand C (2004c) Suivi de la population scissipare de Holothuria atra d'un récif frangeant de l'Ile de La Reunion (Ocean indien) SPC Bêche-de-mer Info Bull 20: 22-25
Conand C (2005) Commercial sea cucumbers and trepang markets, in fisheries and aquaculture. In: Encyclopedia of Life Support Systems (EOLSS), UNESCO, EOLSS Publishers, Oxford, UK, [http://www.eolss.net] [Retrieved November 6, 2005]
Conand C (2006a) Sea cucumber biology, taxonomy, distribution, conservation status. In : Bruckner AW (ed) The proceedings of the CITES workshop on the conservation of sea cucumbers in the families Holothuriidae and Stichopodidae. NOAA Technical Memorandum 44, pp 33-50
Conand C (2006b) Harvest and trade: utilization of sea cucumbers; sea cucumber fisheries; current international trade; illegal, unreported and unregulated trade; bycatch; socio-economic characteristics of the trade in sea cucumbers:. In : Bruckner AW (ed) The proceedings of the CITES workshop on the conservation of sea cucumbers in the families Holothuriidae and Stichopodidae. NOAA Technical Memorandum 44, pp 51-73
Conand C, Mangion P (2002) Sea cucumbers on La Reunion Island fringing reefs: diversity, distribution, abundance and structure of the populations. SPC Bêche-de-mer Info Bull 17 : 27-32
Conand C, Dinhut V, Quod JP, Rolland R (2005) Eléments pour l'inventaire des holothuries de Mayotte, sud-ouest océan indien S.P.C. Bêche-de-mer Info Bull 22 :19-22
Conand C, Muthiga N, Aumeeruddy R, De la Torre Castro M, Frouin P, Mgaya Y, Ochiewo J, Rasolofonirina R (2006) A three year regional project on sea cucumbers in the south-western Indian ocean : national and regional analyses to improve management S.P.C. Bêche-de-mer Info Bull 23 : 11-15
de la Torre-Castro M, Rönnback P (2004) Links between humans and sea grasses- an example from tropical East Africa. Ocean Coastl Mngt 47: 361-387
de la Torre-Castro M, Ochiewo J, Kithakeni T, Mbaga Y, Pinault M (2007) A framework addressing socioeconomics and management of the sea cucumber resources in the Western Indian Ocean considering multiple scales. SPC Bêche-de-mer Info Bull 25: 22-25
FAO (2004) Yearbook of fishery statistics. Rome
Gilbert E (2004) Dhows and the colonial economy of Zanzibar : 1860-1970. James Currey Ltd, England 176 pp
Hamel JF, Conand C, Pawson DL, Mercier A (2001) Biology of the sea cucumber *Holothuria scabra* (holothuroidea: echinodermata) and its exploitation as beche-de-mer. Adv Mar Biol 41:129-223
Horsfall IM (1998) Sea cucumbers of Tanzania, the salad days are over. Miombo 18: 4-5
Humphreys WF (1981) The Echinoderms of Kenya's marine parks and adjacent regions. Zoologische Documentatie 19:1-39
Kithakeni T, Ndaro SGM (2002) Some aspects of sea cucumber, *Holothuria scabra* (Jaeger, 1935) along the coast of Dar es Salaam. WIOJMS 1(2): 163-168
Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) (2004) Advances in sea cucumber aquaculture and management. FAO, Rome. Fisheries Technical Paper No. 463, 425 pp
Mangion P, Taddei D, Frouin P, Conand C (2004) Feeding rate and impact of sediment reworking by two deposit feeders *Holothuria leucospilota* and *Holothuria atra* on a fringing reef (Reunion Island, Indian ocean). In: München – Heinzeller, Nebelsick (eds) Echinoderms. Taylor and Francis, London, pp 311-317
Marshall NT, Milledge AH, Afonso PS (2001) Trade Review: Stormy seas for marine invertebrates: trade in Sea cucumbers, ceashells and lobsters in Kenya, Tanzania and Mozambique. WWF

IUCN. 70pp
Massin C, Rasolofonirina R, Conand C, Samyn Y (1999) A new species of *Bohadschia* (Echinodermata, Holothuroidea) from the Western Indian Ocean with a redescription of *Bohadschia subrubra*. Bull inst. Royal Sciences Belgique 69:151-160
McClanahan TR, Pet-Soede L (2000) Kenyan coral reef fish, fisheries and economics - trends and status after the 1998 coral mortality. In: Westmacott S, Cesar H, Pet-Soede L (eds) Amsterdam, Institute of Environmental Studies, Free University, pp 79-100
McClanahan TR, Sheppard CR, Obura D (eds) (2000) Coral reefs of the Indian Ocean: their ccology and conservation, Oxford University Press, New York
Mmbaga T, Mgaya Y (2004) Studies on sea cucumber in Tanzania and the gaps towards resource inventory and management In: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds.) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463, pp193-203
Muthiga NA, Ndirangu S (2000) Village based larviculture and stock enhancement of sea cucumbers (Echinodermata: Holothuroidea) on the Kenyan coast. Final Technical Report, Biodiversity Support Fund, 66pp
Muthiga NA (2006) The reproductive biology of a new species of sea cucumber, *Holothuria (Mertensiothuria)* arenacava in a Kenyan marine protected area: the possible role of light and temperature on gametogenesis and spawning. Mar Biol 149 (3): 585-593
Muthiga N, Conand C (eds) (2006) Regional sea cucumber project: Proceedings of the start-up workshop, Mombasa Kenya, 26–29 January 2006. 20pp. (on line www.wiomsa.org)
Pouget A (2005) Abundance and distribution of holothurians on the fringing reef flats of Mayotte. SPC Bêche-de-mer Info Bull. 21:22-25
Rasolofonirina R (2005) Reproduction et développement de l'holothurie *Holothuria scabra* à Madagascar (Holothuroidea : Echinodermata). Ph.D, ULB, Bruxelles. Summary in Beche-de-mer Info Bull 21:38-39
Rasolofonirina R, Conand C (1998) Sea cucumber exploitation in the Toliara region of south-west Madagascar. SPC Beche-de-mer Info Bull 10:10-13
Rasolofonirina R, Mara E, Jangoux M (2004) Sea cucumber fishery and mariculture in Madagascar: A case study of Toliara, south-west of Madagascar. In: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds.) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463, pp 133-149
Richmond M (1997) A guide to the seashores of eastern Africa and the Western Indian Ocean Islands. SIDA, 448 pp
Samyn Y (2003) Shallow-water holothuroidea (Echinodermata) from Kenya and Pemba Island, Tanzania. Std Afrotropical Zoology, 292 :158pp
Samyn Y (2004) Shallow-water holothuroidea (Echinodermata) from Kenya and Pemba Island, Tanzania Steven Simpson books, 158 pp
Samyn Y, Van den Berghe E (2000) Annotated checklist of the echinoderms from the Kiunga Marine National Reserve, Kenya. Part 1: Echinoidea and Holothuroidea. J East African Nat Hist 89:1-36
Samyn Y, Massin C, Muthiga NA (2001) A new species of holothuria (Aspidochirotida, Holothuriidae) from Kenya. Annals Sciences Zoologiques 285:101-110
Samyn Y, Van den Spiegel D, Massin C (2005) Sea cucumbers of the Comoros archipelago. SPC Bêche-de-mer Info Bull 22:14-18
Samyn Y, Van den Spiegel D, Massin C (2006) Taxonomie des holothuries des Comores. AbcTaxa Vol 1, 130 pp
Shiell G (2004) Questionnaire on the field observation of juvenile sea cucumbers. SPC Bêche-de-mer Info Bull 19:41
SPC Bêche-de-mer Information Bulletin No. 1 to 25 (also distributed as pdf files: www.spc.int/coastfish/)
Uthicke S, Conand C (2005a) Local examples of beche-de-mer overfishing: an initial summary and request for information. SPC Bêche-de-mer Info Bull 21:9-14
Uthicke S, Conand C (2005b) Amplified fragment length polymorphism (AFLP) analysis indicates importance of both asexual and sexual reproduction in the fissiparous holothurian *Stichopus chloronotus* (Aspidochirotida) in the Indian and Pacific Ocean. Coral Reefs 24:103–111

CHAPTER 2

SEA CUCUMBERS IN KENYA

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Introduction

Like many coastal fisheries along the Kenyan coast, the sea cucumber fishery is primarily artisanal and contributes to the livelihoods of fisher households (Muthiga and Ndirangu 2000; Marshall *et al.* 2001; Beadle 2005). Although the fishery has been in existence since the early 1900s (KNA Coast 1917-1925a) and there is no tradition of consuming sea cucumbers in Kenya, many species have local names, indicating the cultural identification of this fishery by the local communities. Sea cucumbers are currently collected either as by-catch by spear fishermen and other gleaners or by fishers that target only sea cucumbers using snorkel and mask or SCUBA equipment. The gear and boats are usually provided by dealers who purchase the processed product, while collectors at the landing beaches carry out the processing and drying. The local level dealers in turn sell their products to a few exporters based in the coastal capital of Mombasa who than export to Hong Kong.

Information on the trade and fishing of sea cucumbers is poorly documented and primarily consists of records from the National Archives, the Fisheries department, and recent assessments and studies by Muthiga and Ndirangu (2000), Marshall *et al.* (2001) and Beadle (2005). The start of the sea cucumber trade is thought to coincide with the influx of Asian nationals in the 1900s. For example, by 1918 there were fisheries concessions in Malindi, Mombasa and Kipini in northern Kenya (KNA Coast 1917-1925a). Concessions were granted for three to five years at a time and Chinese fishers and dealers dominated the trade. The death of a concessionaire meant his license ended but his family members and other interested parties could take up the concession. The fishery was considered so lucrative that Concessionaires fiercely protected their turf and poaching of others concessions 'nearly led to bloodshed' in the Wasini area in 1921 (KNA Coast 1917-1925b). Today harvesting is primarily done by a small number of fishers concentrated in a few villages in Lamu (northern Kenya) and Kwale (southern Kenya) districts. Forty species of sea cucumbers have been reported along the Kenyan coast and of these 17 species are currently harvested.

Despite the long history of the sea cucumber fishery in Kenya, the fishery has continued to evolve without much intervention from the management authority. Early records of management interventions include the removal of royalties in 1959 supposedly to encourage unrestricted collection to revitalize the trade (KNA Coast CA/21/29). The development of this fishery is further complicated by the lack of knowledge of stock size and the biology and ecology of target species or the impact of the fishery on local livelihoods and the Kenyan fisheries sector as a whole. Unlike marine finfish, there have been no large-scale assessments of the stocks of sea cucumbers along the Kenyan coast, although a few limited studies have been carried out on the taxonomy, biology and some aspects of the fishery (Muthiga and Ndirangu 2000; Samyn and Van den Berghe 2000; Marshall *et al.* 2001; Samyn 2003; Beadle 2005). These studies have raised concerns about the viability of this fishery especially as trade records indicate a rapid growth of the fishery from the 1960s to 1990s, but a sustained decline over the last ten years. It is unclear as to the cause of this decline and the lack of historical information makes it difficult to discern whether the peaks and troughs are due to stock depletions, gear improvements, global markets or other socio-economic factors impacting the coastal communities.

Overfishing of sea cucumbers is a management concern worldwide; because the fishery is highly valuable, there is increasing worldwide demand, and, the fishery is characterized by serial local depletions and migrations to new fishing areas (Conand 1990; Conand and Byrne 1993; Lovatelli *et al.* 2004). The sustainability of the fisheries future is further jeopardized by the slow recovery of sea cucumber populations (Uthicke 2004). Appropriate management measures are urgently needed to manage and restore sea cucumber stocks in Kenya, hence the involvement in the Western Indian Ocean Marine Science Association's (WIOMSA) Regional Sea Cucumber, Marine Science for Management (MASMA) project (Conand *et al.* 2006).

State of the resource

The distribution and abundance of holothurians is poorly studied along the Kenyan coast although a few surveys have reported the presence of species from Kiunga in the north (Obura *et al.* 1998; Samyn and Van den Berghe 2000; Samyn 2003) to Shimoni in the south (Anon 1994; Muthiga and Ndirangu 2000; Samyn 2003). Clark and Rowe (1971), the most comprehensive taxonomic monographs of echinoderms in the Indo-West Pacific, reported 67 species of holothurians for the western Indian ocean, 53 for east Africa and Madagascar, however, the number of species recorded in individual countries is not reported in this monograph.

At least two locations have been surveyed in detail, the Watamu Marine Park, Mida creek and adjacent areas, during the Bangor-Watamu expedition (Humphreys 1981) where 22 holothurian species were reported, and the Kiunga marine reserve where 23 species were reported (Samyn and Vanden Berghe 2000). A widespread survey that was carried along the Kenyan coast at 27 sites, from Mambrui in the north to Shimoni in the south (Muthiga and Ndirangu 2000), reported a total of 27 species including a new species *Holothuria arenacava* that was subsequently described by Samyn *et al.* (2001). The most detailed taxonomic publication of the holothurians of Kenya is currently Samyn (2003) and it includes the survey of the Kiunga marine reserve (Samyn and Van den Berghe 2000) as well as collections at nine other locations along the Kenyan coast. These combined surveys increase the total number of holothurians reported in Kenya to 10 genera and 44 species (Table 2.1). *Bohadschia cousteaui, B. similis, Holothuria (Metriatyla) albiventer, H. timana, H. erinacea, Opheodesoma grisea and O. mauritiae* are new records for Kenya (Samyn and Van den Berghe 2000; Samyn 2003) while Bohadschia atra (Massin *et al.* 1999) and H. *arenacava* are new species. Samyn (2000) also reported that *H. parva, H. pyxi*s and *Actinopyga plebeja* have been recorded by other authors as occuring in Kenyan waters.

The inclusion of *B. koellikeri* in the species list presented by Humphreys (1981) is queried by Samyn and Van den Berghe (2000) because the description of the specimen indicates that this sample was probably *B. subrubra*, however, Samyn (2003) was not able to verify the description since the voucher specimen could not be found at any of the museums where Humphreys deposited samples. In addition, Humphreys (1981) reported a sample of *Opheodesma* sp. collected from Ras Ngomeni and noted that it was probably *O. spectabilis*. If his identification is correct, this is a range extension from the western Pacific for this species, however again the voucher specimen could not be found (Samyn 2003). A re-examination of the voucher specimen for *Labidodemas semperianum* indicated that the sample was *L. pertinax* (Massin *et al.* 2004). In addition, *Bohadschia subrubra* (Figure 2.1) that is common in shallow reefs in Kenya, was recently redescribed by Massin *et al.* (1999).

Table 2.1. Holothurian species reported along the Kenyan coast by the main taxonomic surveys (Humphreys 1981; Muthiga and Ndirangu 2000; Samyn and Berghe 2000; Samyn 2003) arranged in systematic order. Humphreys (1981) was restricted to Watamu marine park and Mida creek, Samyn and Van den Berghe (2000) surveyed the Kiunga marine reserve. Muthiga and Ndirangu (2000) surveyed 27 sites between Mambrui and Shimoni, while Samyn (2003) combined the Kiunga survey and nine additional sites along the Kenyan coast.

	Humphreys 1981	Muthiga & Ndirangu 2000	Samyn & Van den Berghe 2000	Samyn 2000	Samyn 2003
SYSTEMATICS					
Sclerodactylidae					
Afrocucumis Africana	√		√		√
Holothuriidae					
Actinopyga echinites (Jaeger 1833)	√	√	√	√	√
Actinopyga lecanora (Jaeger 1833)		√		√	√
Actinopyga mauritiana (Quoy & Gaimard 1833)	√	√	√	√	√
Actinopyga miliaris (Quoy & Gaimard 1833)	√	√	√	√	√
Actinopyga plebeja (Selenka 1867)				*	
Actinopyga sp [1]	√				
Bohadschia atra Massin *et al*. 1999		√	√	√	√
Bohadschia cousteaui Cherbonnier 1954				√	√
Bohadschia koellikeri [2]	√				
Bohadschia marmorata (Jaeger 1833)	√	√	√	√	√
Bohadschia similis (Semper 1868)				√	√
Bohadschia subrubra (Quoy & Gaimard 1833)		√		√	√
Bohadschia vitiensis		√			
Labidodemas pertinax (Ludwig 1875)			√	√	√
Labidodemas semperianum [3] (Selenka 1867)	√			√	
Holothuria (Acanthotrapeza) pyxis Selenka 1867				*	
Holothuria (Cystipus) rigida (Selenka 1867)		√	√	√	√
Holothuria (Halodeima) atra Jaeger 1833	√	√	√	√	√
Holothuria (Halodeima) edulis Lesson 1830		√	√	√	√
Holothuria (Lessonothuria) pardalis Selenka 1867	√	√	√	√	√
Holothuria (Metriatyla) albiventer					√
Holothuria (Metriatyla) scabra Jaeger 1833	√	√	√	√	√
Holothuria (Metriatyla) timana					√
Holothuria (Mertensiothuria) arenacava [4]		√			
Holothuria (Mertensiothuria) fuscocinerea Jaeger 1833				*	
Holothuria (Mertensiothuria) hilla Lesson 1830	√	√	√	√	√
Holothuria (Mertensiothuria) leucospilota Brandt 1835	√	√	√	√	√
Holothuria (Mertensiothuria) pervicax Selenka 1867				*	
Holothuria (Microthele) fuscopunctata Jaeger 1833		√		√	
Holothuria (Microthele) nobilis (Selenka 1867)	√	√	√	√	√
Holothuria (Microthele) nobilis (sensu fuscogilva)		√			√
Holothuria (Platyperona) difficilis Semper 1868			√	√	√
Holothuria (Selenkothuria) erinacea					√
Holothuria (Selenkothuria) parva Lampert 1885				*	
Holothuria (Semperothuria) cinerascens (Brandt 1835)	√		√	√	√
Holothuria (Stauropora) fuscoscinarea (Jaeger 1833)	√		√		√
Holothuria (Stauropora) pervicax	√	√			√
Holothuria (Theelothuria) turriscelsa Cherbonnier 1980			√	√	√
Holothuria (Thymiosycia) arenicola Semper 1868			√	√	√
Holothuria (Thymiosycia) impatiens (Forskal 1775)	√	√	√	√	√
Pearsonothuria graeffei (Semper 1868)		√		√	√
Stichopodidae					
Stichopus chloronotus Brandt 1835		√		√	√
Stichopus herrmanni Semper 1868	√	√		√	√
Stichopus cf. Monotuberculatus (Quoy & Gaimard 1833)			√	√	√
Thelenota ananas (Jaeger 1833)	√	√		√	√
Thelenota anax H.L. Clark 1921		√		√	√
Synaptidae					
Opheodesoma grisea					√
Opheodesoma mauritiae					√
Opheodesoma sp	√				
Synapta maculata	√	√	√		√
Total number of species	**22**	**27**	**23**	**35**	**39**

*[1] According to Humphreys (1981) this specimen was probabaly A. echinites or A. miliaris. [2] This specimen of Bohadschia koellikeri (Humphreys 1981) was suggested to be B. subrubra however this could not be confirmed as the voucher specimen was not found (Samyn 2003). [3] This specimen of Labidodemas semperianum (Humphreys 1981) was confirmed to be L. pertinax (Massin et al. 2004). [4] Holothuria arenacava is no longer retained in the subgenus Mertensiothuria (Samyn and Massin 2003). *These species are recorded in Samyn (2000) as reported by other authors in Kenyan waters.*

Figure 2.1. The sea cucumber *Bohadschia subrubra* in the Mombasa marine protected area (Photo: Muthiga).

The Kenyan holothurian fauna is generally similar to the Indo-Pacific assemblage and except for H. arenacava that was found only in the Mombasa marine reserve, few species are restricted only to the Kenyan coast. In most groups, the majority of the species also occur in the Indo-Pacific with more than 80% of the assemblage belonging to the family Holothuriidae (Samyn 2003). According to Samyn (2003), an estimation of the expected number of species from species accumulation curves constructed during his surveys, indicate about 50 species at the asymptote, close to the number of species reported to date. Since sampling effort in the few surveys that have been completed along the Kenyan coast was variable and mainly concentrated on shallow reef environments, it is expected that the species richness estimate of holothurians on the Kenyan coast will increase as more as well as deeper sites are surveyed. In addition, there exist taxonomic queries due to morphological, biological and coloration differences in some species (for example *H. scabra* and *H. scabra* var versicolor, Conand 1986) that require additional studies to be resolved.

Figure 2.2. The common sea cucumber *Holothuria lecospilota* at Ras Iwatine, Mombasa marine protected area (Photo: McClanahan).

Sea cucumbers have been reported in a variety of habitats along the Kenyan coast including, sea grass beds (Muthiga and Ndirangu 2000; Samyn 2003), shallow water reef habitats including reef lagoons and reef flats (Humphreys 1981; Anon 1993; 1994; Obura *et al.* 1998; Samyn and Van den Berghe 2000; Muthiga and Ndirangu 2000; Samyn 2003) and in soft bottom channels and reef edges to a depth of 20m (Muthiga and Ndirangu 2000; Samyn 2003). Many species were commonly found on sandy patches between coral heads in reef lagoons (*B. subrubra*) or hiding under live coral heads (*H. leucospilota*; Figure 2.2), in shallow sea grass beds (*B. similis, O. spectabilis*), burrowed under coral rubble/blocks (*H. pardalis*) or sandy channels (*H. arenacava*), on reef flats (*H. atra*) or coarse sand at the base of reef edges (*T. ananas*).

The species distribution is variable and shows no geographic pattern along the coast although this could be due to a lack of adequate data (Figure 2. 3). The highest diversity of sea cucumbers was reported in reef lagoons and the lowest in sea grass beds. The most ubiquitous species were *Holothuria atra* and *H. leucospilota* that commonly occur in most coral reef habitats and at the fringes of sea grass beds throughout the Western Indian Ocean (Figure 2.4). *Holothuria arenacava* has currently been reported at only one site in the Mombasa marine reserve in a sandy-bottomed channel. Individuals of this species burrow just beneath the sand leaving a small part of their dorsal surface exposed, a behavior that is unusual in the subgenus Mertensiothuria (however note that the subgenus of this species has not been confirmed Samyn and Massin 2003).

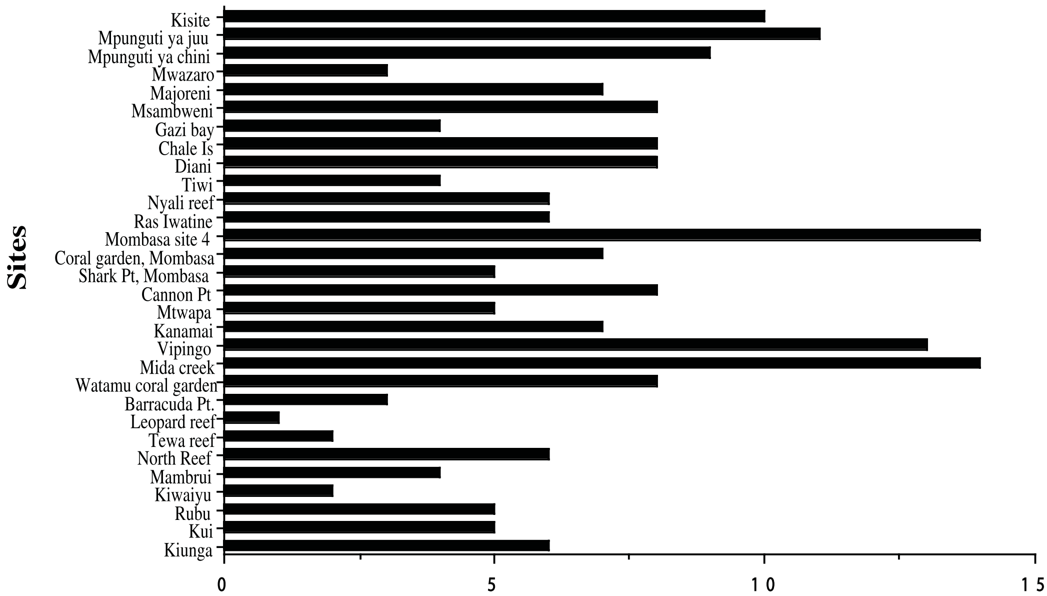

Figure 2. 3. The number of sea cucumber species recorded at different sites along the Kenyan coast (Adapted from Muthiga and Ndirangu 2000).

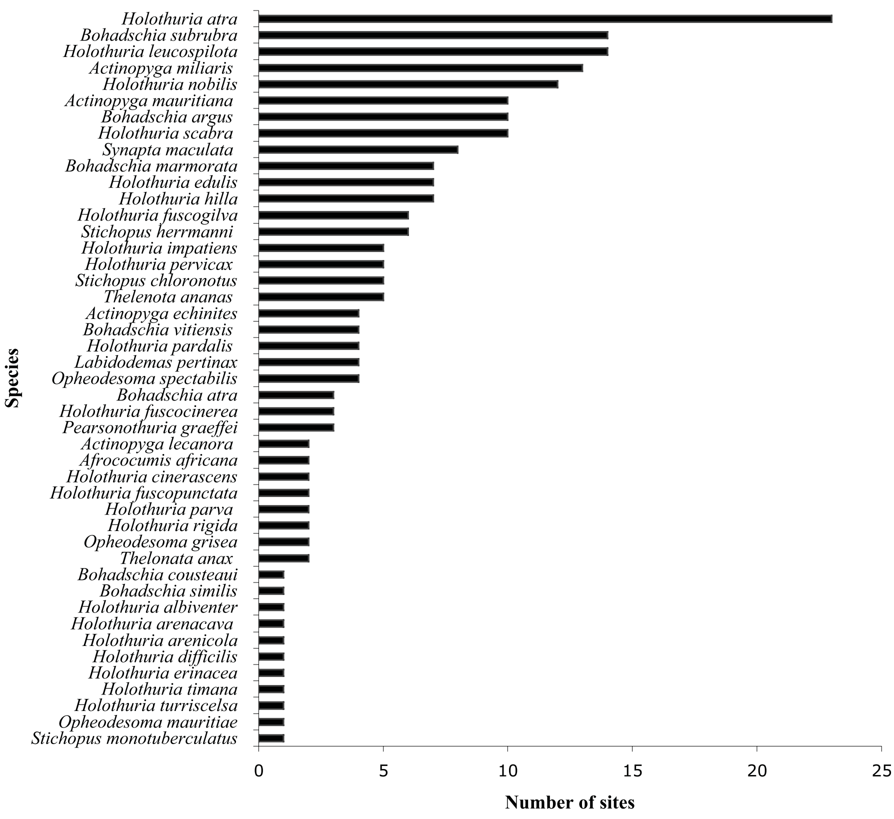

Figure 2. 4. The frequency of occurence of individual species of sea cucumbers at different sites along the Kenyan coast (Adapted from Muthiga and Ndirangu 2000).

The relative abundance of sea cucumbers was highly variable ranging between 0.7 to 14 indiv/200m^2 and averaging ~7indiv/200m^2 (Muthiga and Ndirangu 2000). The density of individual species was generally low (0.03 to 3 indiv/200m2) and also highly variable although *H. arenacava* was found in relatively dense aggregations of 19ind/200m^2. In general, the highest densities of sea cucumbers were found in shallow water habitats primarily reef lagoons (Figure 2. 5a) as well as in marine parks (Figure 2. 5b); however, the factors that control variability have not been sufficiently explored.

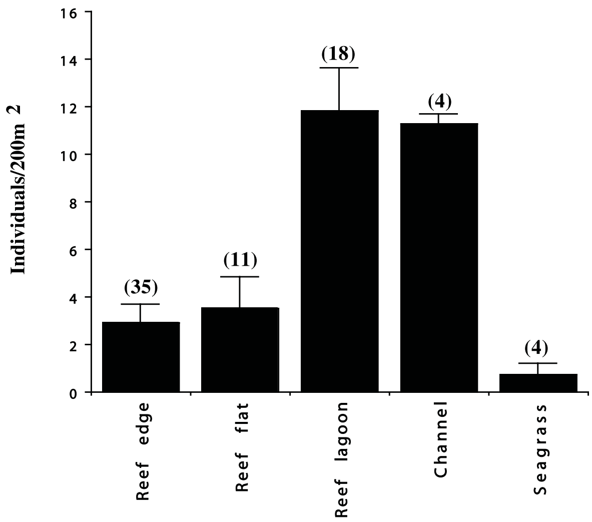

Figure 2.5. a) The average density (individuals/200m^2±SEM) of sea cucumbers recorded in different habitats along the Kenyan coast. The numbers in brackets indicates the number of belt transects sampled per site (Adapted from Muthiga and Ndirangu 2000).

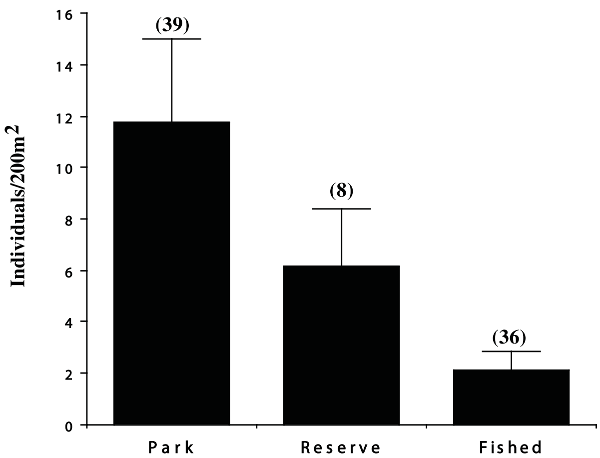

Figure 2.5. b) The average density (individuals/200m^2±SEM) of sea cucumbers recorded in sites under different management regimes along the Kenyan coast. Marine parks are no-take areas and marine reseves are under restrictions from use of destructive gears. The numbers in brackets indicates the number of belt transects sampled per site (Adapted from Muthiga and Ndirangu 2000).

Biology and ecology

Except for observations carried out while collecting sea cucumbers for taxonomic studies, little ecological and biological information is available on the holothurians along the Kenyan coast. The exception is a detailed study of the reproduction of *H. arenacava* in the Mombasa marine reserve (Muthiga 2006). Gonad index measurements of *H. arenacava* collected over a period of 13 months indicated a seasonal pattern of reproduction that maybe mediated by changes in light and temperature along the Kenyan coast. Gametogenesis commenced in July during the southeast monsoon and peaked in February-March towards the end of the northeast monsoon period (Figure 2.6. Although there was a high correlation between light and temperature with gonad index, gametogenesis commenced when seawater temperatures were still decreasing and light had started to increase indicating that light was more likely the cue for the onset of gametogenesis. Spawning was synchronized between males and females and occurred between March and May and there was no evidence of lunar periodicity. The sex ratio was skewed towards females with significantly more females than males in the population. The females were also significantly larger on average and had significantly larger gonads relative to body size than males. These life history strategies coupled with spawning during a discrete period when food availability for the planktonic larvae is available, may serve to increase the reproductive success of this species (Muthiga 2006).

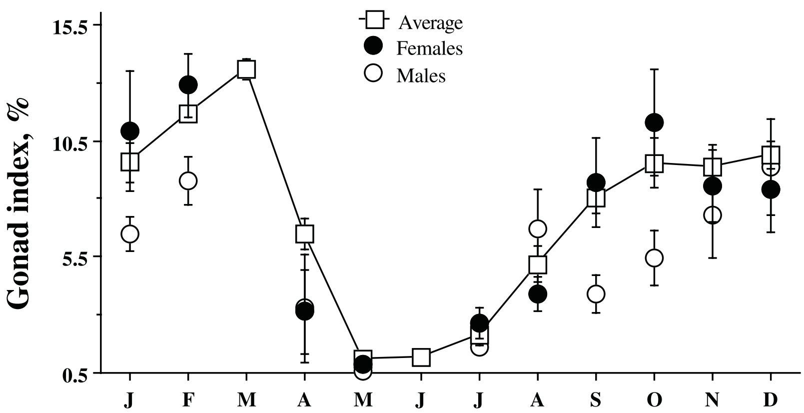

Figure 2.6. The annual reproductive pattern of *Holothuria arenacava* collected at the Mombassa marine reserve Kenya measured as the mean monthly gonad index (± SEM) of 20 individuals per month from 1997 to 1998 (Adapted from Muthiga 2006).

In many cases holothurians are reported to be deposit feeders and observations of the gut contents indicate that guts are predominantly filled with the surrounding substrate, for example the gut of *H. arenacava* consisted mainly of very fine sand (Muthiga 2006) while that of *H. atra* collected from sandy patches in the reef lagoon was composed mainly of sand (Samyn 2003). Individuals of *Synapta maculata* on the other hand occur amongst seagrasses and feed on organic matter attached to leaves of seagrasses and algae as well as the soft substrate (Samyn 2003). Observation of some holothurian species showed that feeding mainly occurred during the day, although some species such as *H. fuscocinerea* are nocturnal (Samyn 2003) while *Opheodesoma* sp. was reported as actively sweeping its tentacles over the mucus attached to live coral (Samyn 2003). *Holothuria arenacava* appears to feed during the day as feeding tracks were observed over the sand next to individuals. Feeding, however, did not show seasonal variability since the size of the gut did not change throughout the year (Muthiga 2006). Changes in food availability sometimes limit gonad growth in some holothurian species, the fact that this is not the case for *H. arenacava* indicates that this species is probably getting adequate amounts of nutrients for growth and reproduction throughout the year.

For many species with a seasonal reproductive pattern and planktonic larvae, recruitment onto the substrate follows within a short or longer period after spawning. The pattern of reproduction of *H. arenacava* on the Kenyan coast indicates that recruitment of this species could occur on a seasonal basis. Although recruitment of *H. arenacava* has not been investigated, recruits of marine invertebrates including the sea urchins *Echinometra mathaei*, *Diadema setosum and D. savignyi* (McClanahan and Kurtis 1991; Muthiga 2003; Muthiga and Jaccarini 2005), sea cucumbers (too small to identify; Muthiga 1996) and the oysters *Crassostrea cucullata* and barnacles *Balanus amphrite* (Ruwa and Polk 1994) have been reported between April and May on the Kenyan coast. This is the period towards the end of the northeast monsoon when seawater temperatures and phytoplankton concentrations are high along the Kenyan coast (McClanahan 1988) and is probably a period of enhanced larval development for many invertebrate species. The fact that seasonal recruitment around the same time of the year is common for some invertebrates species along the Kenyan coast indicates that this strategy maybe common throughout the east African coast since similar oceanographic and climatic conditions driven by the monsoonal system occur along this coastline (Bryceson 1982; McClanahan 1988). Further studies on holothurian reproduction and ecology in the western Indian Ocean are needed to test this hypothesis.

Management and Legal Framework

Kenya's fisheries are managed and regulated under the Fisheries Act Cap 378 of 1989 (revised in 1991) that also prescribes fisheries development and management measures including prohibition of areas, species and gear. The Fisheries Act in its subsidiary regulations refers to *"beche-de-mer"* especially *Echinoderms* of the class *Holothuroidea* and prescribes measures for managing this fishery including the payment of fishing and export licenses. The contents of the license to collect or trade in *beche-de-mer* should, but rarely includes; name and address of the licensee, area of collection and processing, and name of building (business premises / stores), plot number, and, the physical address of the sea cucumber trader.

Several other institutions in Kenya have jurisdiction over sea cucumbers including the Kenya Wildlife Service (KWS) established under the Wildlife Conservation and management Act Cap 376 (1989 amendment) that has jurisdiction over marine parks where collection is strictly prohibited. The management of sea cucumber resources within marine reserves where partial fishing is allowed, falls within the mandate of both the fisheries department and the KWS, however, there is no mechanism to allow the joint management of these resources in the reserves. The KWS and Fisheries Dept are currently negotiating a Memorandum of Understanding that will allow the development of a mechanism for joint management of marine resources within marine reserves. In addition, the Kenya Marine and Fisheries Research Institute (KMFRI), was established under the Science and Technology Act Cap 250 to provide scientific information for the management of fisheries resources including sea cucumbers. A few Non-Governmental Organizations and a number of Community Based Organizations are also involved in fisheries management along the coast of Kenya hence impact the management of sea cucumbers.

Despite a relatively strong management framework, the sea cucumber fishery is under threat of over-exploitation (Muthiga and Ndirangu 2000; Marshall *et al.* 2001; Beadle 2005). Information from the National Archives indicates that there was concern of over-fishing of sea cucumbers as early as the 1918 since orders commissioned by the Provincial Commissioner of Lamu became increasingly difficult to fill (KNA Coast 1917-1918). Currently, collectors and exporters are supposed to be licensed by the fisheries department annually and an export fee of 5% of *ad valorem* of the market price is also charged. Catch statistics are submitted in kilograms of dry weight to the district fisheries officers for compilation into the national statistics.

The historical and current production of sea cucumbers is difficult to accurately estimate in Kenya because statistic are inadequately collected and managed resulting in landing and export statistics that often fail to tally. Comparison between FAO data (FAO 2005), Fisheries department data (various sources) and reported Kenyan imports into Hong Kong show a variable and declining trend of production (Figure 2.7.). In general, the catches were fairly low in the early 1950s averaging between 3 and 12 metric tons, increased to ~80 metric tons between 1968 and 1995, except for a short period between 1979 and 1980 when catches were less than 10 metric tons and a spike to 225 metric tons in 1992. The production has averaged about 20 metric tons in the last 10 years. The fishery is concentrated in Lamu and Kwale districts and in 2003 Kwale district produced more than 80% of the catch although Lamu contributed 35% of the catch in 2004 (Fisheries statistics). Currently, the main beaches where sea cucumbers are landed on a daily basis and regular records are maintained include Vanga/Jimbo, Majoreni, Shimoni, Gazi, and Lamu. Minor landing beaches where fishing of sea cucumbers is done on a seasonal basis include Kilifi, Vipingo, Nyali, Mombasa, Tiwi, Diani, Msambweni, Kimbuyuni Ngomeni. Records of landings from these beaches are not collected on a regular basis by the Fisheries department.

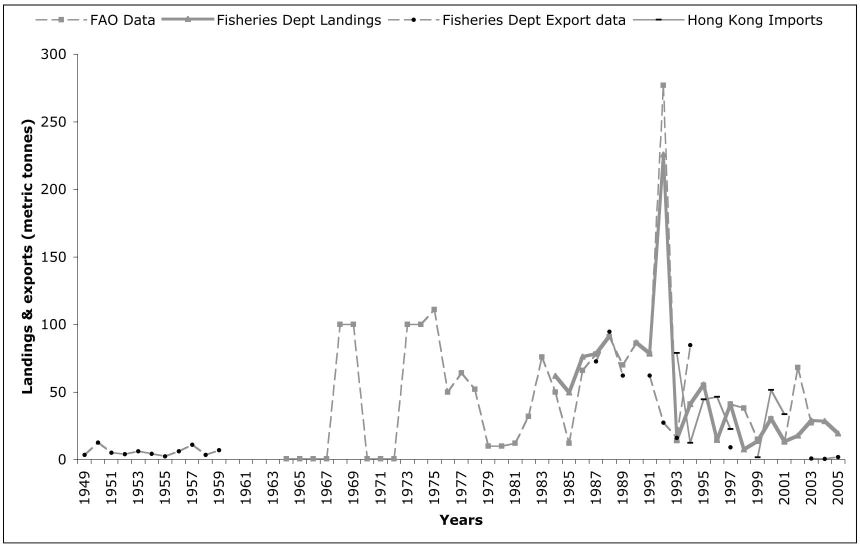

Figure 2. 7. Annual sea cucumber production on the Kenyan coast recorded as yearly dry weights of beche-de-mer (metric tons). Source: Fisheries department catch data, FAO (FISHSTAT) data and Kenyan imports into Hong Kong (Infofish Trade News).

Although more than seventeen species of sea cucumbers (Table 2.2) are harvested, the high value species *H. fuscogilva* dominates the catch. For example, the composition of the catch at Gazi and Shimoni, the main landing beaches in northern Kenya, consisted mainly of H. fuscogilva (49% and 63% respectively) followed by *A. miliaris* (17%) and *Bohadschia marmorata* (7 to 8%) at Gazi and *H. nobilis, Thelenota ananas* and *B. argus* (10 and 13%) at Shimoni (Muthiga and Ndirangu 2000). An increasing trend towards collection of the mid and low value species such as *A. mauritiana* were noted by several authors (Marshal *et al.* 2001; Beadle 2005) as well as the harvest of sexually immature individuals (Muthiga and Ndirangu 2000). Before the 1990s, skin diving was the main method of collection, however around 1991-92 SCUBA diving was introduced resulting in a dramatic increase in the catch. Cross border trade with Tanzania and other trade routes such as dhow trade to Yemen that are not recorded through the Kenyan customs office further complicate the catch statistics and it is estimated that possibly more than 50% of the production is unreported as indicated by large disparities between the Fisheries department statistics and the import statistics to Hong Kong (Marshall *et al.* 2001; Beadle 2005).

Table 2.2. The commercial species of sea cucumbers harvested in Kenya

Scientific name	Common name	Value	Local name
Actinopyga echinites	Deep-water redfish	Low	
Actinopyga lecanora	Stonefish	Low	Tambi
Actinopyga mauritiana	Surffish	Low	Kijino
Actinopyga miliaris	Blackfish	Low	Kijino mweusi
Holothuria atra	Blackfish	Low	
Holothuria edulis	Pinkfish	Low	
Holothuria fuscogilva	White teatfish	High	Pauni mweupe
Holothuria fuscopunctata	Elephant's trunk fish	Low	Ngoma
Holothuria nobilis	Black teatfish	High	Pauni mweusi
Holothuria scabra	Sandfish	High	Mchanga
Stichopus chloronotus	Greenfish	Low	
Stichopus herrmanni	Curryfish	Low	
Thelonata ananas	Prickly redfish	Medium	Spinyo
Thelonata anax	Amberfish	Low	Spinyo mama
Bohadschia argus	Leopard fish	Low	Gobore
Bohadschia marmorata	Chalkfish	Low	Kijino tambi
Bohadschia vitiensis	Brown sandfish	Low	

The sea cucumber fishery is considered a lucrative fishery (Marshal *et al.* 2001), yet little is know of its socio-economic impact on the coastal community. Muthiga and Ndirangu (2000) estimated that fishing effort at the main landing beaches ranged between 12 and 30 pieces/man /day (2 - 6kg/man/day) at Gazi and 20 and 24 pieces/man/day (4 - 4.8kg/man/day) at Shimoni in southern Kenya. Given that sea cucumbers fetch 0.14 to 2$ per piece (Beadle 2005) or between $2.5/kg for low value or unprocessed products and $10/kg for high value products (Marshall *et al.* 2001), this would potentially add a substantial income to the livelihoods of collectors. Both Muthiga and Ndirangu (2000) and Beadle (2005) noted the great interest the local communities had of this fishery.

Despite the high value of this fishery, and with the exception of yearly catch statistics, and data on licenses of collectors, traders and exporters, there are few records that indicate the level and type of intervention that the Fisheries department undertakes in this fishery. On the other hand, although the fisheries department encourages fishers not to collect small individuals, no size limit has been set although fishers apparently voluntarily enforce a size limit of 20cm (Beadle 2005). Muthiga and Ndirangu (2000) found that about 20% of the catch of *H. fuscogilva* and a smaller percentage (~ 5%) of *H. scabra* at Gazi were sexually immature (using Conand's (1981) and (1993) estimation of size at sexual maturity for *H. fuscogilva* and *H. scabra* respectively). Assuming that Conand (1981; 1993) estimates of sexual maturity will hold for these species on the Kenyan coast, the voluntary 20cm size limit may prove an effective management intervention for *H. scabra* that achieves sexual maturity at 16cm (body length) but not for *H. fuscogilva* that is not sexually mature until it attains a size of 32cm.

Other conservation measures include full protection of sea cucumbers in the marine parks by the KWS. This protection is effective since the abundance, species richness and sizes of sea cucumbers is higher in marine parks than in reserves and unprotected areas (Muthiga and Ndirangu 2000). In 2001, the Fisheries Department, sought to reduce the level of sea cucumber fishing effort by stopping the issuance of additional collectors licenses following the study by Muthiga and Ndirangu (2000) that reported the inadequate management and potential overfishing of this fishery. This was followed in 2003 by a ban of the use of SCUBA for the collection of sea cucumbers under Legal Notice No. 214, Part 2 (c), Cap. 378, in order to protect the breeding stock in deeper areas. Although catches have slowly increased since the ban, it is difficult to estimate the effectiveness of these interventions as no adequate monitoring system was put in place. However, given that it takes many years for stocks to recover, it is too early to evaluate the impact of these interventions in protecting the fishery. In addition, according to Beadle (2005) insufficient dialogue with fishers has led to poor compliance of the SCUBA ban.

A number of challenges are faced in the management of the sea cucumber fishery in Kenya. The challenges include first, the fact that fisheries have continued to be an open access resource in Kenya resulting in increased fishing effort and overexploitation of many fisheries (Ochiewo 2004). Second, is the inadequacy of knowledge on the biology and ecology of sea cucumbers, financial and other resources available to the Fisheries Department to undertake its functions especially enforcement and monitoring, as well as the development of aquaculture. Sea cucumbers are particularly suitable for harvest by local communities since they are sedentary and require low technology for collection and processing. This fact combined with poverty and the growing world demand has greatly increased the pressure on this fishery making it vulnerable to overexploitation. Although sea cucumbers are protected in the marine parks, this consists of only 5% of the inshore area, which is probably inadequate for replenishing over-exploited stocks. The lack of clarity in the management of the sea cucumber resources in the marine reserves that are adjudicated by both the Fisheries and KWS adds an additional level of complexity further reducing the effectiveness of managing this fishery. Finally, there is a lack of awareness amongst fishers of the specific regulations of this fishery (Muthiga and Ndirangu 2000; Beadle 2005), increasing dialogue and awareness of the fishery is critical to the improved management of this fishery.

There are strong indications; including reduced production, reduced sizes of valuable species, increased search time by fishers and increased proportion of less valuable species in the catch, and catches of sexually immature individuals, that the sea cucumber fishery in Kenya is overexploited and on the verge of becoming unviable (Muthiga and Ndirangu 2000; Marshall *et al.* 2001; Beadle 2005). Given the importance of this resource to local communities, there is therefore an urgent need to carry-out more detailed biological and socio-economic assessments to better evaluate the status of the sea cucumber stocks and the impacts of sea cucumbers on livelihoods, the barriers to effective management and the options for replenishment including culture and restocking as well as additional legislative protection of sea cucumbers in Kenya. Renewed interest of sea cucumbers has risen in the region and Kenya is now participating in the WIOMSA regional sea cucumber project. It is hoped that the comprehensive scientific information that will be accumulated under this project will assist in the improved management and sustainability of this resource.

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Literature cited

Anonymous (1993) Kenya Shimoni marine park expedition, 1992: Report on the distribution of habitats and species of Kisite Marine National Park and Mpunguti Marine National Reserve, Universities of York & Hull, United Kingdom

Anonymous (1994) Kenya Diani marine reserve expedition, 1993: Report on the distribution of habitats and species of the Diani coast, University of York and Hull, United Kingdom

Beadle R (2005) Management, conflict and compliance: The case of the Kenyan sea cucumber (Echinodermata: Holothuroidea) fishery. M.Sc thesis in Tropical Coastal Management University of Newcastle upon Tyne

Bryceson I (1982) Seasonality of oceanographic conditions and phytoplankton in Dar es Salaam waters. University Science Journal (Dar University) 8:66-76

Clark AM, Rowe FWE (1971) Monograph of the shallow-water Indo-West Pacific Echinoderms. Bath, England, Pitman Press

Conand C (1981) Sexual cycle of three commercially important holothurian species (Echinodermata) from the lagoon of the New Caledonian. Bull Mar Sci 31: 523-543

Conand C (1986) Les resources halieutiques des pays insulaires du Pacifique. Deuxième partie: Les Holothuries. FAO Doc Tech Pêches, 272 (2): 108 pp

Conand C (1990) The fishery resources of Pacific island countries. Part 2: Holothurians. FAO Fisheries Technical Paper No. 272 (2): 143 pp

Conand C (1993) Reproductive biology of the characteristic holothurians from the major communities of the New Caledonia lagoon. Mar Biol 116: 439-450

Conand C, Byrne M (1993) A review of recent developments in the world sea cucumber fisheries. Mar Fish Rev 55 (4): 1-13

Conand C, Muthiga N, Aumeeruddy R, de La Torre-Castro M, Frouin P, Mgaya Y, Mirault E, Ochiewo J, Rasolofonirina R (2006) A three-year project on sea cucumbers in the southwestern Indian Ocean: National and regional analyses to improve management. SPC Beche-de-Mer Information Bulletin 23: 11-15

FAO (2005) FAO Fishery Information Data and Statistics Unit. Databases: Capture Production 1950-2003. Rome: FAO, 2005 http://www.fao.org/fi/statist/fisoft/fishplus.asp

Government of Kenya (1985) Wildlife (Conservation and Management) Act, Cap 376 of the Laws of Kenya. Government Printer, Nairobi

Government of Kenya (1991) The Fisheries Act Cap 378 of the Laws of Kenya: Revised Edition (1991). Government Printer, Nairobi

Humphreys WF (1981) The Echinoderms of Kenya's marine parks and adjacent regions. Zoologische Documentatie 19: 1-39

KNA Coast (1917-1925a) Kenya National Archives Coast 1917-1925. Kenya government records

KNA Coast (1917-1925b) Kenya National Archives. Reel 69:2/638. Kenya government records

KNA Coast (CA/21/29) Kenya National Archives. Kenya Government records

Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) (2004) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463, 425 pp

Marshall NT, Milledge AH, Afonso PS (2001) Trade Review: stormy seas for marine invertebrates: trade in sea cucumbers, seashells and lobsters in Kenya, Tanzania and Mozambique, WWF/IUCN 69pp

Massin C, Rasolofonirina R, Conand C, Samyn Y (1999) A new species of *Bohadschia* (Echinodermata, Holothuroidea) from the Western Indian Ocean with a redescription of *Bohadschia subrubra* (Quoy & Gaimard, 1883). Bull de l'institut royal des Sci naturelles de Belgique 69: 151-160, 1pl

Massin C, Samyn Y, Thandar AS (2004) The genus *Labidodemas* (Holothuroidea: Aspidochirotida) revisited, with description of three new species and with re-positioning of *Holothuria (Irenothuria) maccullochi* Deichmann, 1958. J Nat Hist 38 (14): 1811-1847

McClanahan TR (1988) Seasonality in East Africa's coastal waters. Mar Ecol Progr Series 44: 191-199

McClanahan TR, Kurtis JD (1991) Population regulation of the rock-boring sea urchin *Echinometra mathaei* (de Blainville). J Exp Mar Biol Ecol 147: 121-146

Muthiga N (2006) The reproduction of a new species of sea cucumber, *Holothuria (Mertensiothuria) arenacava* in a Kenyan marine protected area: the possible role of light and temperature on gametogenesis and spawning. Mar Biol 149 (3): 585-593

Muthiga NA (2003) Coexistence and reproductive isolation of the sympatric echinoids *Diadema savignyi* Michelin and *Diadema setosum* (Leske) on Kenyan coral reefs. Mar Biol 143 (4):669-677

Muthiga NA (1996) The role of early life history strategies on the population dynamics of the sea urchin *Echinometra mathaei* (de Blainville) on reefs in Kenya. Ph.D dissertation, University of Nairobi, Kenya. 252pp

Muthiga NA, Jaccarini V (2005) Effects of seasonality and population density on the reproduction of the Indo-Pacific echinoid Echinometra mathaei in Kenyan coral reef lagoons. Mar Biol 146: 445-453

Muthiga N, Ndirangu S (2000) Village based larviculture and stock enhancement of sea cucumbers (Echinodermata: Holothuroidea) on the Kenyan coast. Final Technical Report, Biodiversity

Support Fund

Obura DA, Church J, Mwadzaya H, Muthiga N (1998) Rapid assessment of the biophysical and socioeconomic parameters of the Kiunga marine reserve Kenya. UNEP / FAO report

Ochiewo J (2004) Changing fisheries practices and their socioeconomic implications in south coast Kenya. Ocean & Coastl Mngt 47: 389-408

Ruwa RK, Polk P (1994) Patterns of spat settlement recorded for the tropical oyster Crassostrea cucullata (Born 1778) and the barnacle Balanus amphitrite (Darwin, 1854) in a mangrove creek. Trop Zool 7: 121-130

Samyn Y (2000) Conservation of aspidochirotid holothurians in the littoral waters of Kenya. SPC Beche-de-Mer Info Bull 13: 12-17

Samyn Y (2003) Shallow-water Holothuroidea (Echinodermata) from Kenya and Pemba Island, Tanzania Studies in Afrotropical Zoology Vol. 292, 158pp

Samyn Y, Van den Berghe E (2000) Annotated checklist of the echinoderms from the Kiunga marine national reserve, Kenya. Part 1: Echinoidea and Holothuroidea. J East African Nat Hist 89: 1-36

Samyn Y, Massin C (2003) The holothurian subgenus Mertensiothuria (Aspidochirotida: Holothuriidae) revisited. J Nat Hist 37(20): 2487 - 2519

Samyn Y, Massin C, Muthiga NA (2001) A new species of Holothuria (Aspidochirotida, Holothuriidae) from Kenya. Annls Mus R Afr Centr (Zool) 285: 101-110

Uthicke S (2004) Overfishing of holothurians: lessons from the Great Barrier Reef In: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel J-F and Mercier A (eds) Advances in sea cucumber aquaculture and management. FAO, Rome. FAO Fisheries Tech Paper 463:163-171

CHAPTER 3

SEA CUCUMBERS IN LA REUNION

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Introduction

La Reunion is a volcanic island from the Mascareignes archipelago. The area is 2512 km^2 and the highest point 3069 m. First visited by European navigators in the 16th century, the permanent settlements on this inhabited island, started during the 17th century. Development on Bourbon island (the first name of La Reunion) started with the Compagnie des Indes Orientales, through coffee and then sugar cane plantations. Reunion Is. became a French Department in 1946 and is presently part of the European Union. The colonial history explains the present ethnical diversity and the interbreeding of the population (now 775 000 inhabitants).

The economy of La Reunion is based on agriculture (mostly sugar cane), tourism and fisheries. Unemployement however, is high, at a rate of 32%. The low interest for exploitation of marine resources during the colonial times has changed and the main fishery is currently mostly focused on large pelagic species. The management of the coastal zone is also a priority with the need of preservation of the small reef areas which are now under increasing anthropic pressure (Conand 2002).

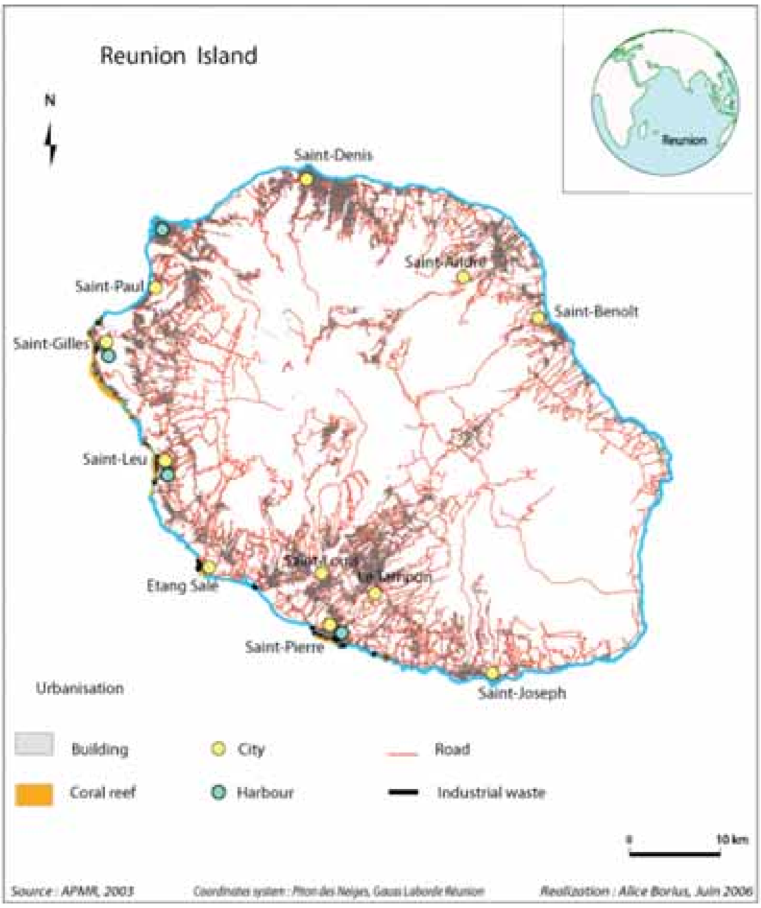

Figure 3.1. The main towns, harbors and coral reefs of Reunion Island.

History of exploitation of the resource

Holothurians have never been commercially exploited in La Reunion, because the reefs are so small that the sea cucumber resource would be depleted within a few days or weeks and also since the commercially valuable species are not abundant. Projects that have been presented to the local administration for the exploitation of sea cucumbers have always been discouraged because scientists rejected the proposal by using the rational of the precautionary principle.

Biology and ecology

The holothurians of La Reunion were poorly studied before 1995, but interest has risen since and a list of 21 species is now available (updated from Conand 2003 ; Table 3.1). The species are dominated by the order Aspidochirotida (20 species), including the new species *Actinopyga capillata* that has also been reported in Rodrigues, Mauritius (Rowe and Massin 2006). This is comparable with the number of species recently recorded for Rodrigues by Rowe and Richmond (2004). Several dendrochirotids and species of small body size that present challenging taxonomic problems have certainly been overlooked hence the species list will probably increase in the future.

Table 3.1 The sea cucumbers of La Reunion (Adapted from Conand 2003)

Aspidochirotida		
	Holothuriidae	
		Actinopyga echinites (Jaeger, 1833)
		Actinopyga mauritiana (Quoy and Gaimard, 1833)
		Actinopyga capillata (Rowe and Massin , 2006)
		Bohadschia vitiensis (Semper, 1868)
		Holothuria atra (Jaeger, 1833)
		Holothuria cinerascens (Brandt, 1835)
		Holothuria coluber (Semper, 1868)
		Holothuria difficilis (Semper, 1868)
		Holothuria hilla (Lesson, 1830)
		Holothuria leucospilota (Brandt, 1835)
		Holothuria nobilis (Selenka, 1867)
		Holothuria pardalis (Selenka, 1867)
		Holothuria pervicax (Selenka, 1867)
		Labidodemas pertinax (Ludwig , 1875)
		Pearsonothuria graeffei (Semper, 1868)
	Stichopodidae	
		Stichopus chloronotus (Brandt, 1835)
		Stichopus herrmanni (Semper, 1868)
		Stichopus monotuberculatus (Quoy and Gaimard, 1833)
		Thelenota ananas (Jaeger, 1833)
		Undetermined species 1
Apodida		
	Synaptidae	
		Synapta maculata (Chamisso and Eysenhardt, 1821)

Extensive benthic studies in Reunion started in the 70's, with emphasis placed on corals whereas other benthic invertebrates were rarely considered (Montaggioni and Faure 1980; Faure 1982). Sea urchins and holothurians had been observed for decades but qualified as "undesirable" given their high densities near some beaches of the west coast (Naim and Cuet, 1989). More recently, during the past 13 years, research at the Marine Ecology Laboratory (University of Reunion) has been orientated toward the biology and ecology of holothurians. The most relevant quantitative data on holothurian distribution can be found in Conand and Mangion (2002), and in the reports by Conand (2003) and Fabianek and Turpin (2005). However more data is needed for a better understanding of the structure and function of holothurian guilds in Reunion reefs.

Holothuria leucospilota and *H. atra*, are the dominant species of sea cucumbers in La Reunion. Most studies on these species were conducted in the Saint-Gilles/La Saline reef complex (Figure 3.1), which is the most important reef in Reunion, comprising ~40% of the reef surface (~9km long, 500m wide at for the widest section and < 2m deep). The back reef areas (dominanted by sandy bottoms) and inner reef flats (dominated by hard substrata) have been extensively sampled. The belt transect or quadrat methods have been commonly used in these studies. Conand and Mangion (2002) counted individuals on a 2x10m (20m2) belt transect. These authors plotted 6 stations on the 3 following sites: Toboggan, Planch'Alizés and Trou d'Eau. At each site, back reef and inner reef flats and outer reef flats were surveyed. Recently, Fabianek and Turpin (2005) have used 30 quadrats ($1m^2$) hapharzandly placed in each station. They surveyed 9 stations in 5 sites. Holothurians were identified, counted and sometimes measured and weighed.

Holothuria atra showed higher densities in the Saint-Gilles/La Saline reef (Figure 3.2) than H. leucospilota. The mean value in the reef was 0.68±1.67 ind.m^{-2}. *Holothuria atra* was also dominant in back reefs (1.44 ± 2.46 ind.m^{-2}). However the distribution of this species over the reef complex was highly heterogeneous. Maximum values of 5.1 ± 0.1 to 6.6 ind.m^{-2} have been recorded in Planch'Alizés back reef station (Fabianeck and Turpin 2005; Conand and Mangion 2002, respectively), whereas in the back reefs of Trou d'Eau and Grand Trou d'Eau (south part of the reef – Figure 3. 1) no individuals of *H. atra* were observed. In the inner reef flats, densities were less than 0.1ind.m^{-2}. No differences were found between the results from 2002 by Conand and Mangion (2005), nor by Fabianeck and Turpin (2005). Jaquemet *et al.* (1999) reported 4.8 ± 0.53 ind.m^{-2} (converted to m-2). Conand (2004) analysed data collected from 1993 to 2000 and concluded relatively stable densities over this long time period of 4.7 ± 0.3 ind.m^{-2}.

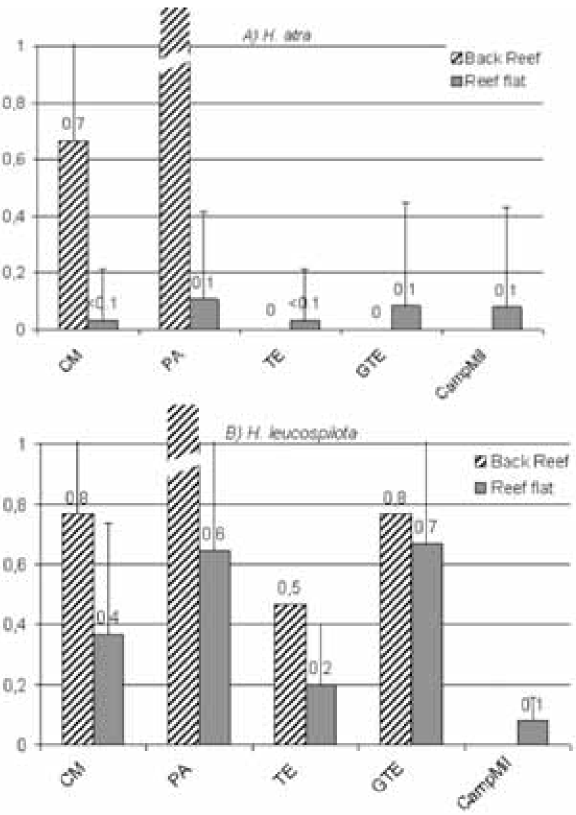

Figure 3.2. Density in La Saline back reef and inner reef flat areas of the two dominant holothurian species, *Holothuria atra* and *H. leucospilota*. Y axis : ind.m^{-2} ;x axis : stations (CM = Club Med, PA = Planch'Alizés, TE = Trou d'Eau, GTE = Grand Trou d'Eau, Camp Mil = Camp Militaire). A) *H. atra* ; B) *H. leucospilota* (From Fabianeck and Turpin 2005 unpublished).

Conand (1996) had noted the existence of populations of *H. atra* with different morphological and population parameters at the La Saline reef complex. Larger individuals and low densities of *H. atra* were predominantly found on the outer reef flats, while smaller individuals were found in back reef and inner reef flat stations, that were also characterised by high fission rates. Reproduction by fission could partly explain the high densities and relative stability in abundance over the years at La Saline. In contrast, *H. leucospilota* individuals were present in all back reef and inner flat stations, with total mean densities of 0.59 ± 0.38 ind.*m*-^{2}. Highest densities were in back reefs (mean 0.84 ± 0.38 ind.m^{-2} versus 0.39 ± 0.26 ind.m^{-2} in inner reef flats), with a maximum density of 1.4 ± 0.7 ind.m^{-2} in Planch'Alizés station (Figure 3. 2).

Other holothurian species have been observed in the field by several authors, but few reliable quantitative data are available. For example, *Stichopus chloronotus* showed a total mean density of 0.34 ± 0.69 ind.m^{-2}, with no individuals found in inner flats and a mean density in the back reefs of 0.78 ± 0.91 ind.m^{-2} (Fabianeck and Turpin 2005). Surpringly these figures are far lower than those presented by Conand *et al.* (1998) who found 3.7 ind.m^{-2} at Trou d'Eau station where the sexual reproduction and fission studies were carried out. *Actinopyga echinites* on the outer reef flat and *A. mauritiana* on the reef front are also frequently observed species (Conand and Mangion, 2002). Available data on length and / or biomass reported in several publications show vaiability between sites and populations (Table 3.2.). *Synapta maculata* is also very abundant on the different reefs.

Table 3.2. The average size (length, cm) and biomass (g, wet weight) of the dominant species of sea cucumbers reported in La Reunion.

Species	Total length (cm)	Total weight (g)	Station/reference
Holothuria leucospilota	18	321-770	Conand & Mangion (2002)
		80-700 (total weight) 26-318 (gutted weight)	Kohler, 2006
		411 ±183 (back reef) 318 ±199 (inner flat)	Fabianeck & Turpin (2005)
Holothuria atra	7 - 20	157 ± 53 (back reef) 41 ± 28 (inner flat)	Fabianeck & Turpin (2005)
		51-162	Conand & Mangion (2002)
Stichopus chloronotus		70.0 ±17.3	Conand *et al.* 1998
Actinopyga echinites	17	138 ± 80	Conand & Mangion (2002)
Actinopyga mauritiana	22	374 ± 85	Conand & Mangion (2002)
Synapta maculata		480	Conand & Mangion (2002)

This synthesis shows that standardized methods and replication of samples are needed for statistical interpretation of the distribution of holothurians in La Reunion. The information was focused on the most important coral reef (La Saline) of Reunion, but the other reefs will be sampled and environmental factors will be analysed (e.g. temperature, total organic matter, grain size) during the MASMA regional sea cucumber project to better understand the factors that affect the distribution and abundance of holothurian populations in coral reefs at Reunion island.

The nutrition of sea cucumbers has recently been an important goal for research in La Reunion, as sea cucumbers are a major component of the soft-bottom reefal communities (Conand and Mangion, 2002 ; Taddei, 2006). The nutrition of the dominant species, *H. atra* and *H. leucospilota,* was first investigated at two sites, one eutrophic and one oligotrophic (Mangion *et al.* 2004). A relation was established between the enrichment level of the sites and holothurian densities: holothurians are abundant (densities up to 3 ind.m^{-2}) in eutrophic areas whereas low densities characterize oligotrophic areas. *H. atra* and *H. leucospilota* consumed an average of 79.7 g dw.ind^{-1}.d^{-1} and 88.8 g dw.ind^{-1}.d^{-1} of sediment respectively, in both stations. A mixed population of both species in a eutrophic area is estimated to rework 82 kg dw.m^{-2}.y^{-1} (only 3 kg dw.m^{-2}.y^{-1} in the oligotrophic area). Although no significant difference in sediment organic matter was recorded between the stations, nevertheless the high densities found in the eutrophic area indicates a higher benthic production. Gut content analysis showed that the organic matter ingested from the sediment was used with 10% efficiency for both species. C / N ratio decreased along the gut showing organic matter degradation. This shows the ability of these holothurians to break down the organic matter from the sediment and to make it easily available for other organisms (Mangion *et al.* 2004).

A more detailed analysis of the nutrition of sea cucumbers has been focussing on the microbenthic communities that were assessed by measurements of chlorophyll a, phaeopigments, phospholipids and glycolipid content. Holothurians from the oligotrophic reference station appeared to discriminate soft bottom patches with high nutritional value. In contrast, no selectivity was observed in the eutrophic stations. *H. atra* also shows a significantly higher assimilation than *H. leucospilota*. Data suggest that efficiency of assimilation decreases with the eutrophication gradient. More recently, Taddei (2006) evaluated the role of the soft-bottom community during the transfer of matter and energy on reefs (Figure 3. 3). The holothurian biomass constituted a major element that could reach 7.92 gDW m^{-2} in the most productive areas. The soft-bottom components played a key role in catching the organic matter provided by the back-reef. This was influenced by the high hydro-dynamism, which modulated the loss of matter and energy of the reef. Losses were however, limited by the action of the holothurians, which stored organic matter such as biomass and probably enhanced local production.

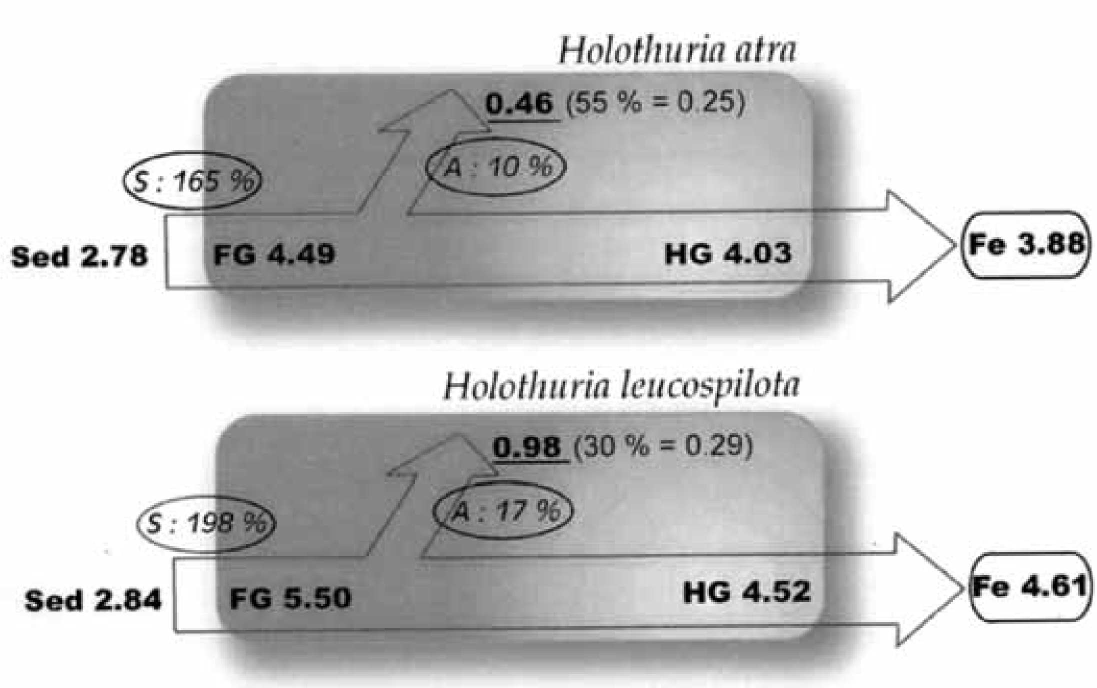

Figure 3.3. A schematic representation of the absorption of nutrients as sediments move through the gut measured as the carbon concentration (mg-1) in the sea cucumbers *Holothuria atra* and *H. leucospilota*. Sed: sediment under the tentacles; FG: foregut; HG: hindgut; Fe: faeces; S: selectivity for carbon; A: carbon absorption. The numbers 0.46 and 0.98 are the amount of carbon derived from living origin (in quantity and %) for *H. atra* and *H. leucospilota* respectively. (From Taddei 2006).

Sea cucumbers show two modes of reproduction: sexual and asexual by transverse fission. Sexual reproduction, the most common mode, has attracted far more attention, in many countries, for example in the South Pacific (Conand 2006a). Fission is observed in a few species mainly from the Aspidochirota. Several studies have been conducted in La Reunion on the reproductive biology of the main populations of Stichopus chloronotus, *H. atra* and *H. leucospilota*.

The reproductive biology (sexual and by fissiparity), population variations and genetics have been described for the fissiparous species *S. chloronotus* and *H. atra* (Uthicke *et al.* 2001; Conand *et al.* 2002; Uthicke and Conand 2005). *S. chloronotus* in La Reunion, exhibits two spawning seasons and does not differ from other populations previously studied on the Great Barrier Reef (Australia) (Fra nklin 1980 ; Uthicke 1997) . However, the population in La Reunion is quite unusual in terms of the high densities recorded (3.7 specimens / m^2), low average specimen weights and a sexual reproduction by fission (Conand *et al.* 1998). It should nevertheless be noted that spawning occurred in the warm season; it has recently been observed at Etang Salé site by Barrere and Bottin (2007); while fission occurs during the cool season (Conand *et al.* 2002). Amplified fragment length polymorphism (AFLP) analysis indicates the importance of both asexual and sexual reproduction in this holothurian in the Indian and Pacific Ocean. Although asexual reproduction is important for the maintenance of populations, large distance dispersal of sexually produced larvae provides the genetic link between populations (Uthicke and Conand 2005).

Figure 3.4. Fission in *Holothuria atra* (a) at 1 / 3 of the length from the mouth and *H. leucospilota* (b) at 1 / 5 of the length (Photo: Conand).

Holothuria atra, exhibits asexual reproduction through transverse fission (Figure 3.4a) that has been reported in several localities, from the south of Taiwan (Chao *et al.* 1994), to the reefs of New Caledonia (Conand, 1989) and the GBR in Australia (Harriot 1982; Uthicke 1997). In La Reunion, the characteristics of the different stages in fission and regeneration have been described. Asexual reproduction is seasonal on the back reef, with a higher fission rate during the cool season. Regeneration lasts about five to six months. Fission is much higher in the back-reef zones than on reef flats (Conand 1996), as is also the case in other mixed populations of this species, for example on the Great Barrier Reef (Uthicke 2001). The population that has been studied for a decade, showed stable density and weight distributions, and seems to have attained the optimum density in relation to the abiotic and biotic back-reef conditions, at a euthropic station of a Reunion Island reef (Conand 2004). These results can be extended to an assessment of mortality, which is compensated by fission. A more detailed study of environmental factors would allow a better understanding of the extrinsic causes of fission, as endocrinal mechanisms could also exist.

Fission in *H. leucospilota* (Figure 3.4b) has been described for the first time in La Reunion (Conand *et al.* 1997). The morphology and anatomy of the different stages of the regeneration is shown on Figure 3.5. The fission rates are much lower than for *S. chloronotus* or *H. atra*. Fission in *H. leucospilota* has now been observed on other reefs (Purwati and Luong-Van 2003). The reproductive cycle of *H. leucospilota* and *Actinopyga echinites* that is currently being studied on a monthly basis (Kohler 2006) will allow comparisons with other WIO countries to sek for regional wide responses.

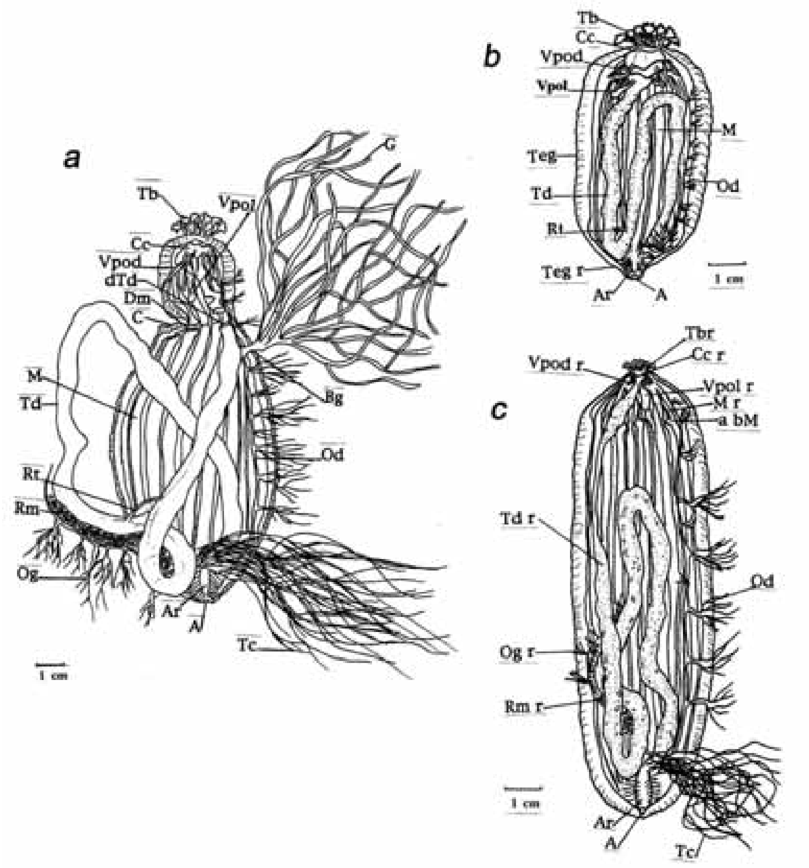

Figure 3.5. Schematic representation of fission in *Holothuria leucospilota*. Anatomy of a fissioning individual (a), and of individuals regenerating after fission, a posterior individual regenerating the oral end (b) and an anterior individual regenerating the anal end (c). (Adapted from Conand *et al.* 1997).

Recruitment is poorly studied for most species of sea cucumbers, particularly the tropical ones (Conand 1989; Shiell 2004a and b) although it is an important parameter for fisheries management. The different reproductive strategies may result in different patterns of recruitment. Species with a clear annual sexual reproduction may have a recruitment peak that should enable the finding of small recruits in the field; but this has proven to be very rare throughout the Indo-Pacific (Conand 1989 ; Shiell 2004b ; 2005). Recruitment is probably occasional and may not happen in the same area as the parental population as migration may occur during growth. In the populations of *S. chloronotus, H. atra* with high seasonal asexual fission rates, small recruits have been found, some originating from fission, but also some small normal individuals probably from sexual reproduction.

Growth and mortality patterns have not yet been studied in La Reunion, despite their importance for management; these studies are nevertheless very difficult to undertake for sea-cucumbers (Conand 1989 ; 1991 ; 2006a & b ; Lovatelli *et al.* 2004).

Management and legal framework

As there has never been a sea cucumber fishery on the tiny reefs of La Reunion, information on different aspects of socio-economy, threats, legislation and conservation of this resource are not available. However the conservation of the reefs was seen as an urgent issue (Conand, 2002) and a Marine Natural Reserve was created by decree N° 2007-236 of 21 February 2007 situated from Cap La Houssaye to Etang Salé along the eastern coast of La Reunion.

Literature cited

Barrère A, Bottin C (2007) Observations in situ de la reproduction sexuée de *Stichopus chloronotus* sur un récif frangeant de La Réunion (Océan indien). S.P.C. Bêche-de-mer Information Bull 25 : 37-38

Chao SM, Chen CP, Alexander PS (1994) Reproduction and growth of *Holothuria atra* (Echinodermata: Holothuroidea) at two contrasting sites in southern Taiwan . Mar Biol 119: 565 – 570

Conand C (1989) *Les Holothuries Aspidochirotes du lagon de Nouvelle-Calédonie : biologie, écologie et exploitation. Etudes et Thèses,* ORSTOM, Paris : 393 pp

Conand C (1996) Asexual reproduction by fission in Holothuria atra : variability of some parameters in populations from the tropical Indo-Pacific. *Oceanologica Acta* 19, 3: 209-216

Conand C (2002) Marine ecology of La Reunion : An overview of recent research. Ambio 31 (7-8) : 602-605

Conand C (2003) Les Echinodermes de La Réunion, Annexe 1 ;129 pp. In: Conand C, Chabanet P, Gravier-Bonnet N. Biodiversité du milieu récifal réunionnais: échinodermes, poissons et hydraires Rapport au Conseil Régional.

Conand C (2004) Monitoring a fissiparous population of *Holothuria atra* on a fringing reef on Reunion Island (Indian Ocean). S.P. C. *Bêche-de-mer Information Bull* 20: 22-25

Conand C (2006a). Sea cucumber biology: taxonomy; distribution; biology; conservation status. In: Bruckner AW (ed) 2005. The Proceedings of the Technical workshop on the conservation of sea cucumbers in the families Holothuridae and Stichopodidae. NOAA Technical Memorandum 44 : 30-46

Conand C (2006b) Harvest and trade: utilization of sea cucumbers; sea cucumber fisheries; current international trade; illegal, unreported and unregulated trade; bycatch; socio-economic characteristics of the trade in sea cucumbers:. In Bruckner AW (ed) In : The proceedings of the CITES workshop on the conservation of sea cucumbers in the families Holothuriidae and Stichopodidae. NOAA Technical Memorandum 44 :51-73

Conand C, Morel C, Mussard R (1997) A new case of asexual reproduction in holothurians: Fission in *Holothuria leucospilota* populations on Reunion island in the indian ocean. SPC Bêche-de-mer Information Bull 9 : 6p

Conand C, Jerome A, Dijoux N, Garryer J (1998) Fission in a population of *Stichopus chloronotus*, on Reunion island, Indian Ocean. SPC Bêche-de-mer Information Bull 10 : 15-23

Conand C, Mangion P (2002) Holothurians from La Réunion fringing reefs: diversity, distribution, abundance and population structure. SPC Bêche-de-mer Information Bull 17 : 27-33

Conand C, Uthicke S, Hoareau T (2002) Sexual and asexual reproduction of the holothurian *Stichopus chloronotus* (Echinodermata) : a comparison between La Réunion (Indian Ocean) and east Australia (Pacific Ocean). Invert Reprod Develop 41 (1-3): 235-242

Fabianek F, Turpin A (2005) Distribution des populations d'holothuries peuplant le récif de St Gilles / La Saline, à l'île de La Réunion. Unpubl. Report. MBPE, Univ. de La Reunion, 33 pp.

Faure G (1982) Recherche sur les peuplements de Scléractiniaires des récifs coralliens de l'archipel des Mascareignes (océan indien occidental). Thèse Université Aix-Marseille II, 206 pp.

Franklin SE (1980) The reproductive biology and some aspects of the population ecology of the holothurians *Holothuria leucospilota* (Brandt) and *Stichopus chloronotus* (Brandt). PhD Thesis, Univ. of Sydney : 253 p.

Harriot VJ (1982) Sexual and asexual reproduction of *Holothuria atra* Jäeger at Heron Island Reef, Great Barrier Reef. Australian Museum Memoir, 16 : 53-66.

Jaquemet S, Rousset V, Conand C (1999) Asexual reproduction parameters and the influence of fission on a *Holothuria atra* sea cucumber population from a fringing reef on Reunion Island (Indian Ocean). SPC Bêche-de-mer Information Bull 11 : 12-18

Kohler S (2006) Reproduction sexuée de *Holothuria leucospilota* à La Réunion. Unpubl. Report. MBPE. Univ. de La Réunion. 25 pp + annexes

Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) (2004) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463, 425 pp

Mangion P, Taddei D, Frouin P, Conand C (2004) Feeding rate and impact of sediment reworking by two deposit feeders *Holothuria leucospilota* and *Holothuria atra* on fringing reef (Reunion Island, Indian Ocean), Echinoderms. In : München - Heinzeller and Nebelsick (eds), Taylor and Francis Group, London, pp 311-317

Naim O, Cuet P (1989) Les platiers récifaux de l'île de la Réunion. Report AUR. Univ. de La Réunion, 303p

Montaggioni L, Faure G (1980) Les récifs coralliens des Mascareignes. Coll. Travaux Centre Univ. La Réunion. 151 pp

Purwati P, Luong-Van JT (2003) Sexual reproduction in fissiparous holothurian species, *Holothuria leucospilota.* SPC Beche-de-Mer bull 18: 33-38

Rowe FWE, Richmond M (2004) A preliminary account of the shallow water echinoderms of Rodrigues, Mauritius, western Indian Ocean. J Nat Hist 38 : 3273-3314

Rowe FWE, Massin C (2006) On a new species of *Actinopyga* Bronn, 1860 (Echinodermata, Holothuroidea) from the Indo-West Pacific. *Zoosystema* 28 (4): 955-961

Shiell G (2004a) Questionnaire on the field observations of juvenile sea cucumbers. SPC Bêche-de-mer Information Bull 19 : 41

Shiell G (2004b) Field observations of juvenile sea cucumbers. SPC Bêche-de-mer Information Bull 20 : 6-11

Shiell G (2005) Information on juvenile holothurian communicated by James DBJ. SPC Bêche-de-mer Information Bull 21 : 26-27

Taddei D (2006) Matter and energy transfers in soft-bottom sediments of an anthropogenic reef complex (La Réunion island, Indian Ocean. PhD La Reunion University.

Uthicke S (1997) Seasonality of asexual reproduction in *Holothuria atra*, *Holothuria edulis* and *Stichopus chloronotus* on the Great Barrier Reef. Mar Biol 129: 435-441

Uthicke S, Conand C, Benzie JAH (2001) Population genetics of the fissiparous holothurians *Stichopus chloronotus* and Holothuria atra (Aspidochirotida): a comparison between Torres Strait and La Réunion Mar Biol 139 : 257-265

Uthicke S, Conand C (2005) Amplified fragment length polymorphism (AFLP) analysis indicates importance of both asexual and sexual reproduction in the fissiparous holothurian *Stichopus chloronotus* (Aspidochirotida) in the Indian and Pacific Ocean.*Coral reefs*, 24 (1): 103–111

CHAPTER 4

SEA CUCUMBERS IN MADAGASCAR

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Introduction

Sea cucumbers and sea urchins are echinoderms that are exploited in Madagascar. Sea urchins are fished for local consumption and sea cucumbers for the preparation of 'trepang' that is mostly exported to Asian markets. Sea cucumber harvesting is a traditional and permanent activity in coastal regions of Madagascar, especially near coral reefs (Conand *et al.* 1997; Rasolofonirina *et al.* 2004). This activity developed increasingly from the early nineties.

The sea cucumber fishery is intensively carried out in the west coast of Madagascar (Rasolofonirina and Conand 1998; Figure 4.1). Fishermen collect various resources on the reef flat, during the low tide, such as shellfish, urchins, octopus and sea cucumbers (Rosa 1997; Salimo 1997; Rakotonirina 2000). Currently, more than thirty species are exploited. The harvested species, however, vary according to the market price, the international demand and their availability. *Holothuria scabra, H. fuscogilva, H. nobilis, Stichopus horrens Actinopyga miliaris* and *Thelenota ananas* are the main harvested species. *Holothuria notabilis* that was recently described for Madagascar (Massin pers. comm.) is also now intensively fished.

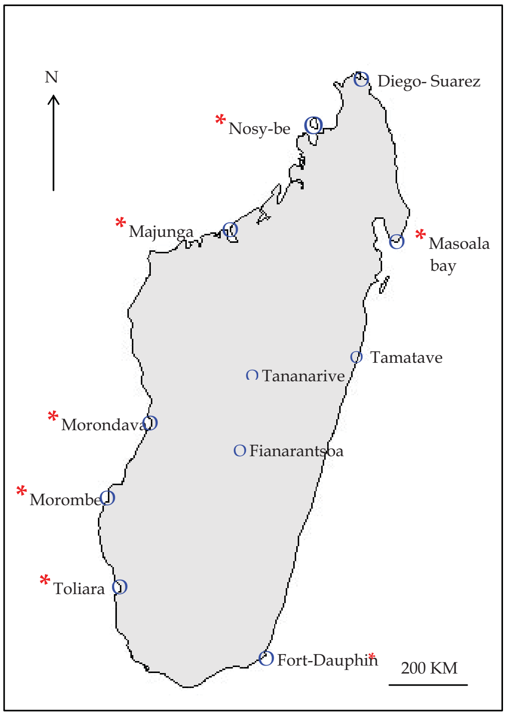

Figure 4.1. Sea cucumber fishing areas in Madagascar (*)

Since 1990 signs of over-exploitation of the sea cucumber resources were observed in Madagascar. The most important are: (1) the declining quality of the product, (2) the decrease in product size and consequently the prize, (3) the use of illegal equipment for harvesting (216 diving tanks were seized in 2002; L'express de Mada, N° 2 379), (4) intense competition between collectors (Conand *et al.* 1998), (5) the exploitation of fishing areas outside of Malagasy waters and (6) the collection of juveniles (Conand 1999). In May 2001, 110 Malagasy fishermen were arrested in the Seychelles for illegal exploitation of sea cucumbers (Madagascar Magazine, 3 May 2003). Because this over-exploitation of the sea cucumber resources not only affects the local economy and the environment, various actions have been undertaken in Madagascar since 1990 by scientists, professional organisations and government institutions to monitor the fishing, processing, fishery organisation, catches and marketing in many coastal villages of the country.

Biology and ecology

A comprehensive identification of the holothurian species of Madagascar was carried out by Cherbonnier (1988), as a long-term study that resulted in the description of 122 species (the highest number of species recorded in any country in the WIO), of which 47 were new to science (Table 4.1) and 5 led to the creation of two new genera; *Koehleria* and *Parathyone*. Rowe and Richmond (1997) also provided data for species from the islands of the Western Indian Ocean including Madagascar. *Bohadschia atra* a newly described species that is common in the western Indian Ocean, is a new record for Madagascar (Massin *et al.* 1999) as is *Holothuria notabilis* (Massin per. com).

Table 4.1. The new species of sea cucumbers described by Cherbonnier (1988) in Madagascar

Holothuriidae	**Phyllophoridae**
Actinopyga bacilla	*Cucumella decaryi*
Bohadschia mitsionsis	*Neothyonidium dissimilis*
Holothuria (Selenkothuria) bacilla	*Globosita murrea*
Holothuria (Selenkothuria) spinea	*Phyllophorus (Urodemella) oculus*
Holothuria (Selenkothuria) vittalonga	*Phyllophorus (Phyllonovus) anomalia*
Holothuria (Semperothuria) granosa	*Phyllophorus (Phyllophorella) contractura*
Holothuria (Thymiosycia) milloti	*Thyonidielle exigua*
Holothuria (Platyperona) crosnieri	*Lipotrapeza ambigua*
Holothuria (Platyperona) insolita	*Lipotrapeza incurva*
Holothuria (Mertensiothuria) albofusca	*Cladolabes pichoni*
Holothuria (Lessonothuria) duoturricula	
Holothuria (Cystipus) mammosa	**Synaptidae**
Holothuria (Metriatyla) fuligina	*Opheodesoma sinevirga*
	Leptosynapta geyserensis
Cucumariidae	*Leptosynapta tantula*
Pentacta verrucula	*Protankyra picardi*
Ocnus amiculus	
Ocnus tantulus	**Chiridotidae**
Koehleria unica	*Trochodota mira*
Athyone maculisparsa	*Trochodota vivipara*
Havelockia ferali	
Havelockia turrispinea	
Thyone carens	
Thyone comata	
Thyone crebrapodia	
Thyone guillei	
Thyone longicornis	
Thyone sineturra	
Thyone vadosa	
Parathyone incurva	

Studies on the biology and ecology of some commercial holothurian species have been carried out in different sites along the coast of Madagascar (Figure 4.1): (1) in the southwest coast by Mara *et al.* (1997); Rasoarinoro (1990); Rasolofonirina (1997) studied *Bohadschia vitiensis* and *Holothuria scabra versicolor*; Rasolofonirina *et al.* (2005); Rasolofonirina and Jangoux,

(2005) concentrated on *H. scabra*, (2) in the northeast coast by Be (2002), and (3) in the northwest by Rasolofomanana (2006). Most studies focused on the reproductive cycle and population dynamics of sea cucumbers. For example, Rasolofonirina *et al.* (2005) describe the gonad anatomy and tubule development of *H. scabra* in monthly samples of 30 individuals collected from November 1998 to April 2001 in Toliara. Results indicate that although gametogensis was synchronous within the gonads of individual sea cucumbers, it was not synchronous within the population. An annual reproductive cycle occurred with most individuals spawning between November and April during the warmest months of the year.

Studies on the bio-ecology of exploited species in the southwest of Madagascar: *Holothuria notabilis* (Figure 4.2a) which is presently the dominant species in the catch and *Stichopus horrens* (Figure 4.2b) the third ranked species, after *Holothuria scabra* are currently underway by the Institute of Fisheries and Marine Sciences (IH-SM) and Aqua-lab in Madagascar as well as biological studies mainly, feeding, growth and mortality of other species.

a) Holothuria notabilis

b) Stichopus horrens

Figure 4.2. Commercial species chosen for bio-ecology studies at the Institute of Fisheries and Marine Sciences (IH-SM) and Aqua-lab in Toliar. *a) Holothuria notabilis; b) Stichopus horrens* (Photos: Rasolofonirina).

History of exploitation of the resource

About thirty species of commercial sea cucumbers are reported in the main fishing areas in Madagascar (Table 4.2). While all these species are not collected in each fishing area, the number of harvested species increases with the resource availability and the market price.

Table 4.2. Species of sea cucumbers reported to be exploited in Madagascar

Species	Exploitation level			
	1920 (1)	1990 (2)	1996 (3)	2002 (4)
HOLOTHURIIDAE				
Actinopyga echinites (Jaeger, 1833)		+?	+	+
Actinopyga lecanora (Jaeger, 1833)			+	+
Actinopyga mauritiana (Quoy et Gaimard, 1833)		+?	+	+
Actinopyga miliaris (Quoy et Gaimard, 1833)			+	+
Actinopyga sp			+	+
Bohadschia marmorata (Jaeger, 1833)			+	+
Bohadschia subrubra (Quoy et Gaimard, 1833)			++	+
Bohadschia tenuissima (Semper, 1868)			+	+
Bohadschia vitiensis (Semper, 1867)			+	+
Holothuria scabra (Jaeger, 1833)		+	+++	+++
Holothuria scabra versicolor (Conand, 1986)		+	++	++
Holothuria atra (Jaeger, 1833)			+	+
Holothuria notabilis (Ludwig,1875)				+++
Holothuria excellens (Ludwig,1875)			+	+
Holothuria fuscogilva (Cherbonnier, 1980)		+	++	++
Holothuria nobilis (Selenka, 1867)		+	++	+
Holothuria edulis (Lesson, 1830)			+	
Holothuria hilla				
Holothuria sp1			+	+
Holothuria leucospilota (Brandt, 1835)			+	
Holothuria cinerascens (Brandt, 1835)			+	
Holothuria fuscopunctata				
Holothuria rigida(Selenka, 1867)				+
Holothuria arenicola (Semper, 1868)				
Holothuria impatiens (Forskal, 1775)				+
Pearsonothuria graeffei (Semper, 1868)			+	+
STICHOPODIDAE				
Thelenota ananas (Jaeger, 1833)		+	+	+
Thelenota anax (Clark)				
Stichopus chloronotus (Brandt, 1835)			+	+
Stichopus horrens (Selenka, 1867)			++	++
Stichopus hermanni (Semper, 1868)	+	+?	++	+
Stichopus naso			+	++

Source: (1): Petit 1930; (2): Rasoarinoro 1990; (3): Mara *et al.* 1997 ; Rasolofonirina 1997 ; (4) : Rasolofonirina *et al.* 2004. +: limited harvesting ; ++ : moderate harvesting; +++ : heavy harvesting ; ?: uncertain level of harvesting

An investigation of the abundance and distribution of the different exploited species was carried out in 1996 on the Toliara Great Barrier Reef (southwest of Madagascar) (Mara *et al.* 1997). The abundance of sea cucumbers (Table 4.3) was highly variable ranging from as low as 0.09kg/ha to as high as 6000kg/ha in different habitats. Seagrass beds yeilded the highest biomass (79%) followed by detrital ridges (20%) while outer flats had the lowest biomass (0.02%) in this study. *Holothuria notabilis* had the highest biomass and density with 6000 kg/ha and 60,000 individuals/ha in the sea grass habitat. This species was not exploited at the time of the study, but is now the most exploited species in the area and its biomass has decreased considerably.

Table 4.3. The biomass (kg/ha wet weight) of the dominant sea cucumbers in different habitats in Madagascar (Source: Mara *et al.*1997)

Species	Inner slope	Seagrass	Microatoll	Detrital ridge	Outer flat
Actinopyga echinites		0.018		1.125	
Actinopyga mauritiana				1.159	0.117
Actinopyga lecanora	0.09		0.299		
Bohadchia vitiensis	33.38	2.151			
Holothuria atra	2.617	0.618	3.7	0.884	1.316
Holothuria cinerascens				1 520	
Holothuria edulis	0.602	0.095	0.515		
Holothuria excellens	1.380	0.274	0.124		
Holothuria leucospilota	13.302	1.004	4.243	1.515	
Holothuria notabilis		6000			
Holothuria nobilis	0.1	0.046			
Holothuria scabra	0.298	3.774			
Holothuria s. versicolor	0.802	1.207			
Stichopus horrens	0.228	0.137	0.218	0.113	0.033
Stichopus variegatus	0.636	1.022	0.048		
Total	**53.44**	**6 010.3**	**9.15**	**1 524.80**	**1.47**
Percent	**0.70 %**	**79.09 %**	**0.12 %**	**20.07 %**	**0.02 %**

State of the fishery

There are seven main sea cucumber fishing areas in Madagascar (Figure 4.1) and the production is generally dependent on the resource availability and market price. The number of species collected increased from three in the 1920s to eight in 1990 and twenty-five in 1996 and 2002 (Table 4.2). It is difficult to gauge the exact level of production and export of sea cucumbers in Madagascar because catch and export statistics are poorly collected and managed. Nonetheless some data is available from the Statistics Services in Fishing and Marine Resource Office as well as the veterinary service office and several publications (Table 4.4). The earliest exports recorded from Madagascar were in 1920, about 40 metric tonnes of trepang from three species (Petit 1930). Exports then varied annually from 50 to 140 metric tonnes until the early 1990s when the harvesting of sea cucumbers greatly increased and resulted in the overexploitation of the resource. Trepang exports peaked between 1991 and 1994 at nearly 600 metric tonnes, which represents more than 6000 metric tonnes in fresh weight. Subsequently, trepang exports showed a significant decline (200 t in 2004) but a temporary explosion of exports was recorded in 2002 of about 980 metric tonnes of trepang. Although Madagascar reports production data to FAO, there is poor correspondence between the data from the Statistics Services in Fishing and Marine Resource Office and the data reported to the FAO (Conand 2006; Table 1.1).

Although about 30 species are harvested, a few species are intensively collected for artisanal or semi-industrial fishing: *Holothuria fuscogilva, Holothuria nobilis, Thelenota ananas and Actinopyga miliaris.* More recently, the discovery of healthy populations of *Holothuria notabilis* and *Stichopus horrens* (Figure 4.2.) has led to intense fishing pressure of these species.

Table 4.4. The production (recorded from fishers) and exports (from export statisitics) of trepang (t: tonne) from Madagascar.

Year	Production (t)	Exports (t)
1987		60.6
1988		119.4
1989		113.8
1990		202.6
1991		545.3
1992		423.2
1993		356.6
1994	1800	539
1995	1800	317.2
1996	1800	307.4 ; (340.5)[3]
1997	1800	(150.9)[1,2]; (331)[2]; (161.5)[3]
1998	482	322.5, (6.5)[2]
1999	512	326.6
2000	838	389.8
2001	851	355.2
2002	708	986.9
2003	669	204.5
2004	300	299.9

Sources: 1) Report SIR-PRH / MPRH (Inter-Regional Service of fishery); 2) Veterinary Service (COS) ; 3: Statistics Services in Fishing and Marine Resource Office.

Management and legal framework

The earliest exploitation systems for sea cucumbers in Madagascar were the traditional fishery that was characterised by gleaning and use of traditional gears and the familial fishery that was characterised by fishing in family groups including women and children. The increase in the international demand for trepang, scarcity of sea cucumbers in shallow waters and competition between collectors, has led to a shift to an artisanal or semi-industrial fishery that often requires motorised boats and specialized equipment for harvest. Currently, there are four levels within the fishery that require different management interventions; (1) the fishers that mainly glean in shallow waters or are employed in the semi-industrial fishery, (2) the collectors who buy sea cucumbers from various fishermen, process trepang and sell to operators, (3) the operators who buy the processed product and in turn sell to the exporter and (4) the exporter.

a) A landing beach near Toliar, SW Madagascar (Photo: Conand)

b) Samples of the catch of sand fish, *Holothuria scabra* (Photo: IH-SM)

c) Processing *beche-de-mer* in the NW Madagascar (Photo: Conand)

d) Processed *beche-de-mer* ready for market (Photo: Conand)

Figure 4.3. Sea cucumber fishing and processing activities in Madagascar

Currently, the sea cucumber resource and management problems in Madagascar are related to over-fishing, legislation and administration. This is evidenced by; the decline in traditional fishing, the increase in the harvest of small sized individuals (Conand 1999), the illegal exploitation by Malagasy ships in neighbouring countries (e.g. Seychelles), the employment of hundreds of illegal scuba divers to harvest sea cucumbers and intense competition between collectors or operators. Madagascar's sea cucumber fisheries are managed and regulated under several Fisheries regulations including: the Arrêté No. 525 of the 5th February 1975 that regulates the minimum legal size of capture to 11cm and processed trepang to 8cm body length, the Arrêté No. 4796/96 of 16th August 1990 on the sea cucumber fishery and processing and Ordinance No. 93-022 of 4 th May 1993 that prohibited the use of SCUBA for the collection of sea cucumbers.

While the legislation exists, it is not effectively applied or appropriate for all species exploited. For example, the minimum harvest size does not take into account size at sexual maturity of the various harvested species, neither does the legislation take into consideration the management requirements of the various players in the fishery. In addition, while the use of SCUBA is forbidden, enforcement is weak and harvesting using SCUBA is still commonly carried out in Madagascar. Apart from weak enforcement of regulations, there is also the problem of inadequate collection and management of catch statistics. This is partly due to exporters under-reporting to avoid paying the corresponding taxes, subsequently, the exact quantity of trepang that the country exports is unknown making management interventions tenuous. Implementation of sustainable management processes will only take place through collaboration between all the various participants in the fishing sector, from the fisherman to the exporter (Conand 2004).

Several programmes related to sea cucumbers have been undertaken in Madagascar in the last decade. At IH-SM, University of Toliara, a research project entitled "Study of the sea cucumber fishery and sustainable management" was initiated in 1995-1996. The research has provided important information on the status of exploitation and the marketing of sea cucumbers in the south-west of Madagascar and proposed recommendations for management (Mara *et al.* 1997). In addition, a component of the environmental programme of the Indian Ocean Commission (PRE / COI / UE) that is funded by the European Union (EU) and co-ordinated in Madagascar by the CN-MAD has supported the efforts of the Fishery Department and the various stakeholders in the sea cucumber fishery to improve management of the fishery. As part of this initiative, an association - National Association of Sea Cucumber Producers (ONET) was created in 1996, (Conand *et al.* 1998). Plans to study the current status of the sea cucumber resource, the accurate collection of production and export statistics, and the publication of a 'Product Quality Manual' (Conand 1999) as well as projects to experiment on sea cucumber farming are underway. A sea cucumber hatchery and farm has now been established in Toliara region with funding from Belgian Cooperation, (Conand 1997; Conand *et al.* 1998; Jangoux *et al.* 2001; Rasolofonirina *et al.* 2004).

Conclusion and recommendations

Madagascar currently has the highest production of sea cucumbers in the WIO, however, the fishery has experienced the boom and burst cycle typical of poorly managed sea cucumber fisheries in the world. Until the beginning of the nineties, the trepang production in Madagascar was more or less stable at the level of one hundred tonnes but showed a sharp increase to more than 5000t in the early 1990s. The production than decreased markedly probably due to the decrease of the traditional fishery that has slowly been replaced by the semi-industrial fishery and use of illegal gear. Although species of high commercial value are still in demand there has been a shift towards species of low commercial value.

The sea cucumber fishery plays an important role in the economy of coastal villages and the country as a whole. Exports of sea cucumbers had an estimated value of 3.1 million US$ in 2002 (official report) which represents about 2% of the total value of all marine resources in Madagascar. The management authorities and donors have recognized the value of this resource and the potential for poverty alleviation and more interventions have been initiated for the improved management and mari-culture of sea cucumbers in Madagascar. It is hoped that participation in the new WIOMSA funded regional sea cucumber research project will provide additional information to enhance the sustainable management of this highly valuable resource in Madagascar.

Literature cited

Be JJ (2002) Approche bio-écologique et analyse socio-économique de l'exploitation des holothuries Aspidochirotes (espèces commerciales) dans les trois parcs marins de la presqu'île de Masoala (nord-est de Madagascar). DEA, IH.SM, Université de Toliara, Madagascar

Cherbonnier G (1988) Echinodermes: Holothurides. Faune de Madagascar. ORSTOM 70, 292 pp

Conand C (1997) Gestion durable de la filière holothurie à Madagascar. Séminaire International sur les récifs coralliens, October 1997, Nosy-Be, Madagascar. 7pp

Conand C (1998) Overexploitation in the present world sea cucumber fisheries and perspectives in mariculture. 9th Int Echinoderm Conf : 449-454

Conand C (1999) Manuel de Qualité des Holothuries Commerciales du Sud-ouest de l'Océan Indien. Programme Régional Environnement. Commission de l'Océan Indien, Sécrétariat Général, 40pp

Conand C (2004) Present status of world sea cucumber resources and utilisation: an international overview In: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463 pp 13-23

Conand C (2006) Harvest and trade: utilization of sea cucumbers; sea cucumber fisheries; current international trade; illegal, unreported and unregulated trade; bycatch; socio-economic characteristics of the trade in sea cucumbers In: Bruckner AW (ed) The proceedings of the CITES workshop on the conservation of sea cucumbers in the families Holothuriidae and Stichopodidae. NOAA Technical Memorandum 44 pp 51-73

Conand C, Galet LN, Randriamiarana H, Razafitseheno G, De San M (1997) Sea cucumbers in Madagascar : difficulties in the fishery and sustainable management. SPC Bêche- de-mer Info Bull 9: 4-5

Conand C, De San M, Refeno G, Razafitseheno G, Mara E, Andrianjatovo S (1998) Difficulties and sustainable management of the sea cucumber fishery sector in Madagascar. SPC Bêche-de-mer Info Bull 10: 7-9

Jangoux M, Rasolofonirina R, Vaïtilingon D, Ouin JM, Seghers G, Mara E, Conand C (2001) A sea cucumber hatchery and mariculture project in Toliara, Madagascar. SPC Bêche-de-mer Info Bull 14: 2-5

Mara E, Rasolofonirina R, Rabesandratana H, Rakotoarinivo W, Ravelo I, Conand C (1997) Etude de la pêcherie aux holothuries et propositions de mesures d'aménagement dans le Sud-ouest de Madagascar. Report IH.SM / ONE / BM, Toliara. 40pp

Massin C, Rasolofonirina R, Conand C, Samyn Y (1999) A new species of *Bohadschia* (Echinodermata, Holothuroidea) from the Western Indian Ocean with a redescription of *Bohadschia subrubra* (Quoy & Gaimard, 1833). Bull de l'institut royal des Sci naturelles de Belgique 69: 151-160, 1pl

Petit G (1930) L'industrie des pêches à Madagascar. Faune des Colonies Françaises. Mart G et Colon (eds) 392pp

Rakotonirina JS (2000) Evaluation de l'activité de pêche à pied sur les platiers du récif frangeant entre Fiherenamasay et Tsifota (Région de Toliara, Sud-Ouest de Madagascar). DEA, IH.SM, Université de Toliara, Madagascar

Rasoarinoro J (1990) Approche bio-écologique et socio-économique des holothuries de recifs coralliens de Toliara (SW de Madagascar). DEA, IH.SM, Université de Toliara, Madagascar. 52pp

Rasolofomanana VL (2006) Contribution à l'analyse de l'exploitation des holothuries dans la baie de Ramanetaka, dans le cadre de la création d'une APMC aux îles Radama / Sahamalaza. Mémoire de Maîtrise des Sciences et Techniques de la mer et du Littoral. IH.SM, Université de Toliara, Madagascar

Rasolofonirina R (1997) Ecologie, Biologie et Exploitation de deux espèces d'Holothuries Aspidochirotes, *Bohadschia vitiensis* et *Holothuria scabra var versicolor* sur le Grand Récif de Toliara (Sud-ouest de Madagascar). Mémoire de D. E. A. en Océanologie appliquée. IH. SM, Université de Toliara 84pp

Rasolofonirina R, Conand C (1998) Sea cucumber exploitation in Toliara, region of south- west of Madagascar. SPC Bêche-de-mer Info Bull 10: 10-15

Rasolofonirina R, Mara E, Jangoux M (2004) Sea cucumber fishery and mariculture in Madagascar: A case study of Toliara, south-west of Madagascar In: Lovatelli C, Conand S, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463 pp133-149

Rasolofonirina R, Jangoux M (2005) Apparition et Développement des éléments squelettiques chez les larves et les juvéniles épibiontes de *Holothuria scabra*. Beche-de-mer Inf Bull 22 :6-10

Rasolofonirina R, Vaïtilingon D, Eeckhaut I, Jangoux M (2005) Reproductive cycle of edible echinoderms from the South-Western Indian Ocean. II: The sandfish *Holothuria scabra* (Jaëger, 1833). WIO J Mar Sci 4 (1): 61-75

Rosa JC (1997) Etude de la pêche à pied sur les platiers des récifs frangeants entre les villages de pêcheurs de Maromena, Befasy et Beheloka (Sud-Ouest de Madagascar). DEA, IH.SM, Université de Toliara, Madagascar

Rowe FEW, Richmond MD (1997) Echinodermata In: Richmond MD (ed) A guide to the seashores of Eastern Africa and the Western Indian Ocean Islands: Echinodermata. Department for Research Cooperation, SAREC pp 300-330

Salimo (1997) Etude de la pêche collecte à pied sur les platiers du Grand Récifs de Toliara (Sud-Ouest de Madagascar). DEA, IH.SM, Université de Toliara, Madagascar

CHAPTER 5

SEA CUCUMBERS IN SEYCHELLES

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Introduction

Sea cucumbers in Seychelles have been fished for more than a hundred years, with reports of beche-de-mer exports dating back to the late 1800's (Marguerite 2005). However the quantities fished were fairly low and it is only in the late nineties that the fishery has seen a rapid development. This is due to several factors, the main one being the high demand for beche-de-mer on the international market and higher prices offered for the product (Aumeeruddy and Payet 2004). The fishery has evolved from a collector-type; whereby fishers collect sea cucumbers on foot, to a more sophisticated one; where divers using SCUBA gear do most of the harvesting. This is due to the fact that stocks of the most valued commercial species have been over-fished in the shallow coastal areas, and the fishing grounds are much deeper. Today divers go down to 40 or even 50 metres to collect sea cucumbers.

A lot of fishers have entered the fishery during the last 8 years, and the fishery which was uncontrolled and unmanaged till then, has had to be put under management. The national fisheries authority (Seychelles Fishing Authority – SFA) put in place some management measures in 1999 in view of the local depletion of some species. These measures included a licensing system for fishing and processing sea cucumbers; a quota on the number of fishing licenses allocated each year, and a limit of 4 divers for each fishing license. Before this recent interest for the fishery, very little was known about the holothurians from Seychelles. A synthesis by Clark (1984) based on previous publications by Clark and Rowe (1971) who listed 115 Echinoderm species, detailed 151 species, including 35 sea cucumbers and gave some brief information on the ecology of the most common sea cucumbers. Other observations and reports that include information on sea cucumbers on Aldabra atoll have been published by Sloan (1982).

State of the resource

For a long period and until 1999, the sea cucumber fishery was unregulated because of its small size and low catch. No catch and effort statistics were collected and there was no information on the status of the stocks. With the increased fishing pressure in the late nineties, the SFA became concerned that there was a high risk of over-fishing or even stock depletion for certain species.. The first management measures introduced in 1999, made it a requirement for a licence for fishing and processing sea cucumbers. The license also made it mandatory for the licensees to provide data (catch, effort, exports) to the SFA.

The SFA was requested to do a stock assessment of the sea cucumber population to improve the management of the fishery since prior to that time very little information had been collected on sea cucumbers in Seychelles. The SFA subsequently requested and obtained funding from the FAO to carry out a resource assessment of the sea cucumber population. That project started in December 2003 and was completed in August 2005. Due to the large size of the Seychelles' EEZ, the stock surveys focused on the two main fishing grounds, the Mahé Plateau and the Amirantes which together represent a large area, with a total of 48,305 km2. The study area was stratified using a combination of bathymetry and substrate type in a GIS. The optimal allocation of sample sites was calculated based on the area of each stratum and estimates of sea cucumber density and variance (Aumeeruddy *et al.* 2005). A total of 246 sites were surveyed during the different research cruises, using a combination of SCUBA divers (98 sites) and towed video recording (148 of the deeper sites).

Twenty-three species of large sea cucumbers were recorded during the surveys although some individuals may be varieties or colour morphs of other species. The overall average density in the study area was 19.78 indiv / ha which equates to an estimated standing stock of 95.5million individuals (± 20.5million, 90% CI Confidence Interval). This corresponds to an estimated live weight of 98,578 t (± 21,194 t, 90% CI). The most abundant commercial species in the study area was the low value black lollyfish, *Holothuria atra* with an average density of 5.61indiv / ha and an estimated standing stock of 12,722 t (± 4,758 t, 90 % CI); being 28 % and 13 % of all commercial sea cucumbers in the study area by numbers and weight respectively (Figure 5.1 and 5.2). The next most abundant species was the black teatfish *H. nobilis* (1.98 indiv / ha), followed by the brown sandfish, *Bohadschia marmorata* (1.79 indiv / ha) and the tigerfish, *B. atra* (1.62 indiv / ha) (Aumeeruddy *et al.* 2005). However, the tigerfish had the highest stock weight of all sea cucumbers at 13,105 t (13.3 %), followed by lollyfish (12,722 t), brown sandfish (12,017 t) and black teatfish (11,589 t) (Figure 5.2).

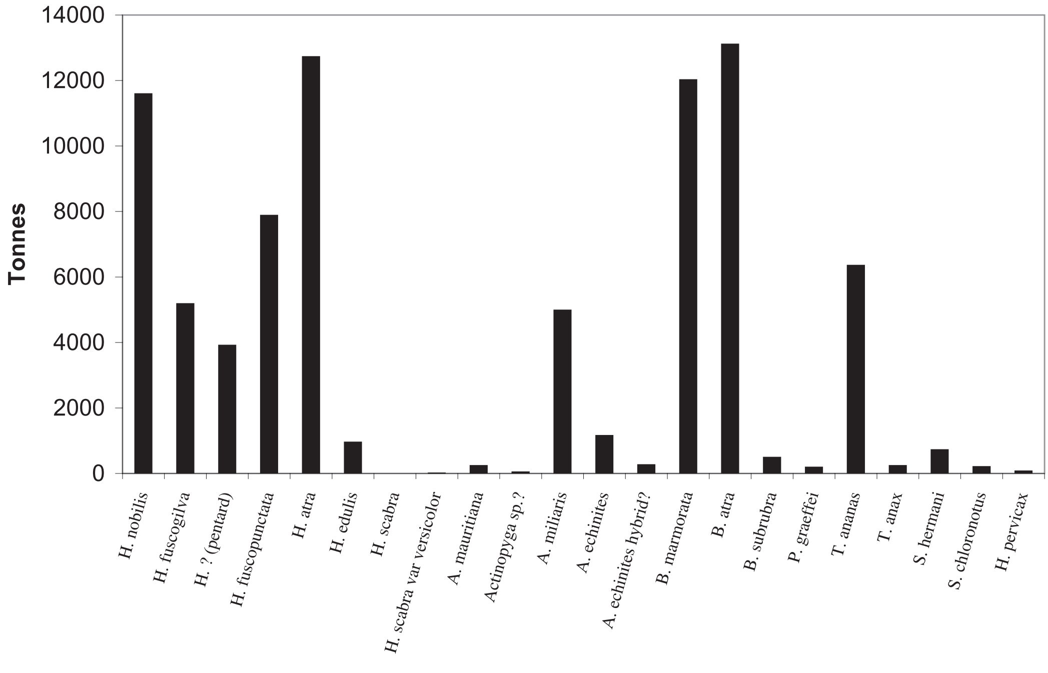


Figure 5.1. Mean density of sea cucumbers in the Mahé Plateau and the Amirantes (Adapted from Aumeeruddy *et al.* 2005).

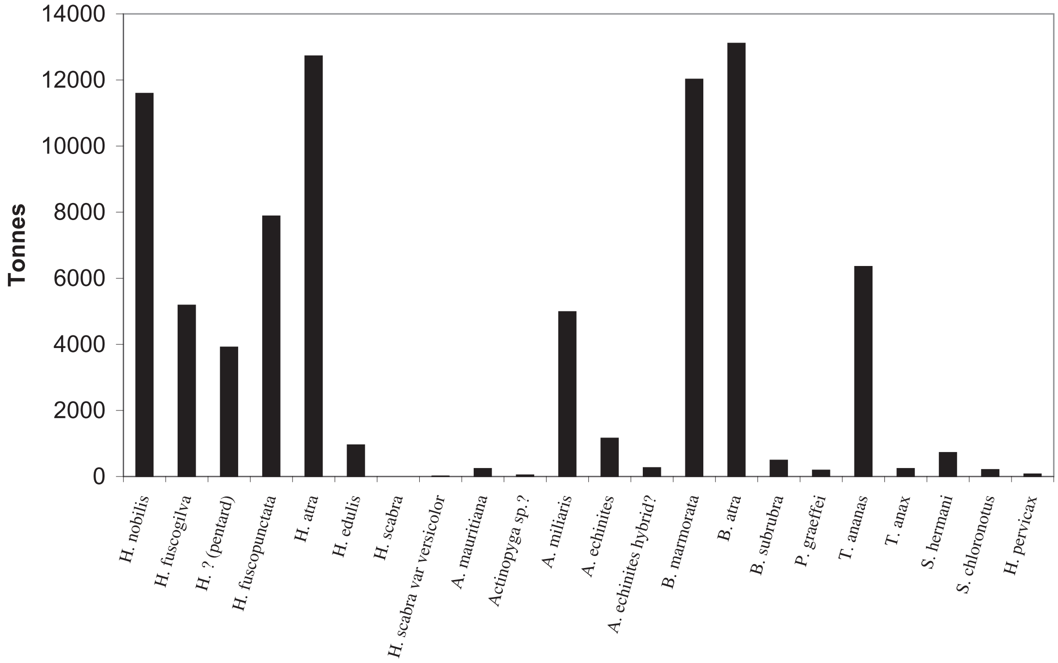


Figure 5.2. Estimated stock biomass of sea cucumbers in the Mahé Plateau and the Amirantes (Adapted from Aumeeruddy *et al.* 2005).

The estimated stock weight of high value sea cucumbers (black teatfish, white teatfish, prickly redfish; *H. nobilis, H. fuscogilva, T. ananas*) was 20,676 t (± 10,234 t, 90 % CI), being 21 % of all commercial sea cucumbers by weight. Unidentified sea cucumbers accounted for 16 % of the total population estimate. These animals were all from the deeper video transects and were difficult to fully identify due to low light conditions.

The highest density of commercial sea cucumbers was found in the shallow strata (<20m) while the deep strata (>50m) had the lowest density. The intermediate depth strata (20-50m) had an intermediate density of sea cucumbers but, due to its large size, had the bulk of the overall standing stock (61.2%) (Figure 5.3).

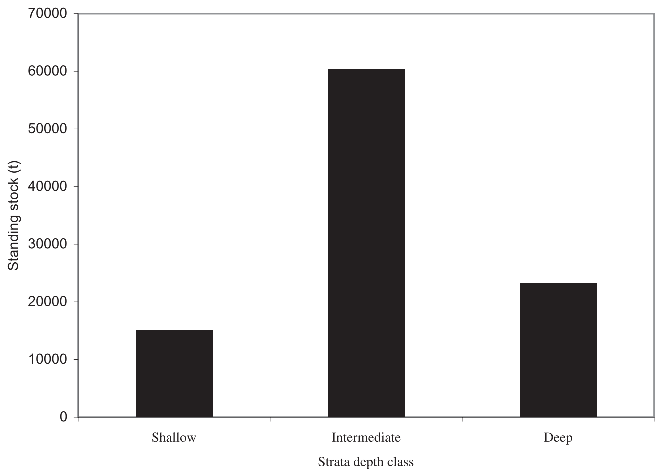


Figure 5.3. Standing stock (t) of all commercial sea cucumbers for strata grouped into depth categories. (Shallow = <20m; Intermediate = 20-50m; Deep = >50m)

There was wide variation in the spatial distribution and abundance of sea cucumbers in the study area. The shallow strata of the central Mahé Plateau, particularly surrounding Mahé and Praslin Islands, contained the highest density of sea cucumbers, with site densities of up to 875 indiv / ha. Sea cucumbers were also common on the perimeter of the Mahé Plateau and on the Amirantes. On the other hand, sea cucumbers were rare in the deeper sites of the south-eastern Mahé Plateau. The density of sea cucumbers in the remaining part of the Mahé Plateau was relatively low and there were a significant proportion of zero counts. The Mahé Plateau and Amirantes overall had similar densities of sea cucumbers (19.4, and 23.6 indiv / ha respectively) although the Mahé Plateau had by far the highest standing stock (89.5% of total biomass)

State of the fishery

The landed catch has been on an upward trend since catch data were first recorded in 1999 (Figure 5.4). Fishers have been targeting mainly 5 high-value species (*H. nobilis, H. fuscogilva, Holothuria sp. Pentard, Thelenota ananas and Actinopyga mauritiana*). *Holothuria scabra* has been caught in very low numbers due to its burrowing nature, but could also have been over-fished. Fishers claim that they do not really target *H. scabra* nowadays.

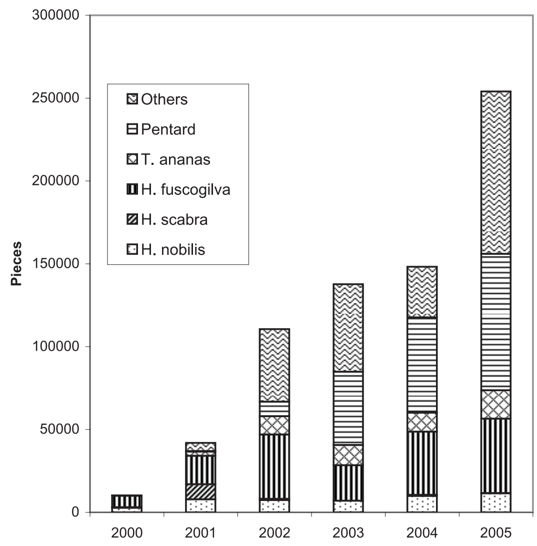


Figure 5.4. Catch data reported as the number of pieces of different sea cucumber species in fishery logbooks from 2000 to 2005.

The very high increase in catch between 2004 and 2005 is a cause for concern, considering that the number of fishing licenses (25) has remained the same. It is possible that the reporting of catch, which was an issue in the previous years, has improved in 2005. It is however more likely that the dramatic increase in the catch in 2004 is due to the change in approach taken by the fishers. Several fishers who have small fishing units are now transferring their catch at sea to a ‘mothership’ that then transports the sea cucumbers to the processors. Fishers can thus stay longer out at sea, and the fishing effort has probably increased considerably despite the number of fishing licenses remaining the same. The distribution of the fishing effort has also changed during the past 5 years spreading across the Mahé Plateau and in the Amirantes (Coeur de Lion 2005), as the fishers have to look for new fishing zones to keep increasing their catch. Some are already fishing some of the outlying islands, where the stocks have not yet been estimated.

At present there are three processors registered to process sea cucumbers in the Seychelles. Most of the product is exported dried, but one of the processors exports some semi-dried products. There is also an attempt to increase the value of the product; one of the processors removes the skin of the sea cucumbers during the boiling process (Figure 5.5) in order to fetch better prices on the market.

Figure 5.5. Skinless Holothuria sp. (Pentard) after boiling (left) and dried pentard and black teat (right). (Photo: R. Aumeeruddy)

Beche-de-mer has been exported from Seychelles for more than a hundred years. Traditional markets are countries from south-east Asia (Honk-Kong, Singapore, China and Malaysia). Historical export data dating back to 1894 (Marguerite 2005) shows that the amounts of beche-de-mer exported from Seychelles was fairly low till the late nineties (Figure 5.6). It is only during the last 6 years that the quantities of beche-de-mer exports have increased considerably, due to higher market demand from south-east Asian countries. The price obtained for the beche-de-mer (Figure 5.7), which was very low historically shows a fairly sharp increase in the late seventies.

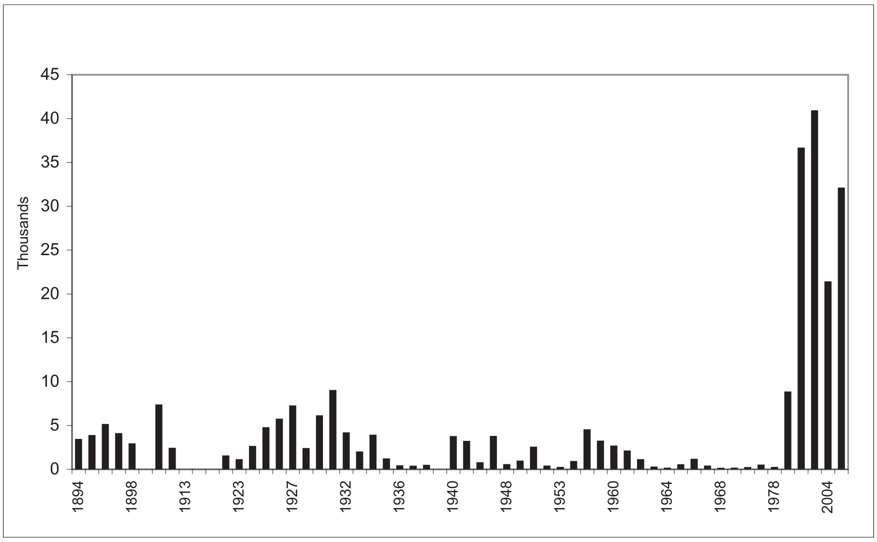
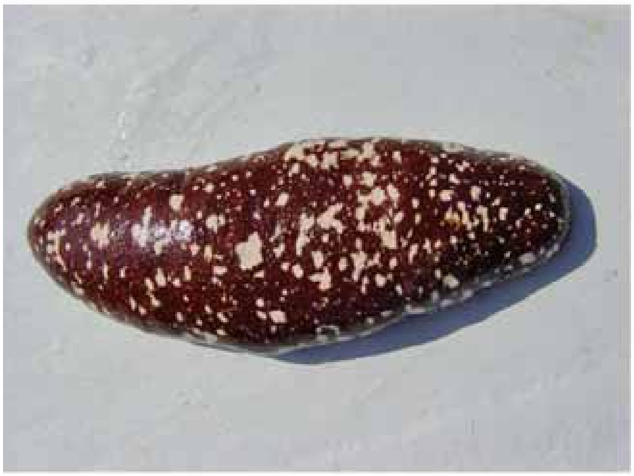


Figure 5.6. Amount of beche-de mer (‘000kg) exported from Seychelles (Adapted from Marguerite 2005)

Plates I, II and III illustrate respectively some of the species that are highly, moderately and not presently fished by the fishers.

Holothuria nobilis (black teatfish). Photo: R. Aumeeruddy

Holothuria fuscogilva (white teatfish). Photo: M. Taquet



Holothuria sp. (pentard). Photo: R. Aumeeruddy

White teatfish (top) and pentard (bottom). Photo: R. Aumeeruddy

Thelenota ananas (prickly redfish). Photo: M. Taquet

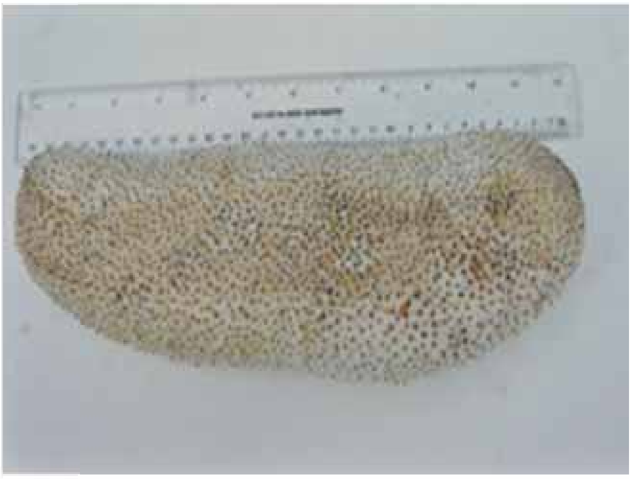
Actinopyga echinites (yellow surfish). Photo: R. Aumeeruddy

Plate 5.1. Sea cucumbers of high-value that are targeted by fishers in the Seychelles

Holothuria atra (lollyfish). Photo: M. Taquet

Holothuria fuscopunctata (elephant trunkfish). Photo : M. Taquet

Holothuria scabra (sandfish). Photo: T. Skewes



Holothuria scabra var. versicolor (golden sandfish). Photo: R. Aumeeruddy

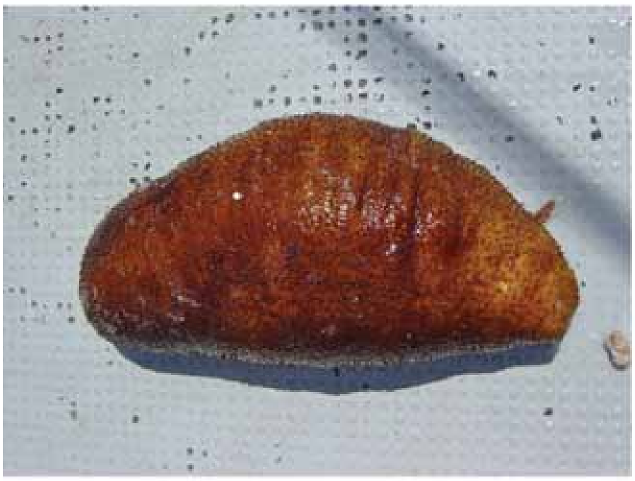
Holothuria edulis (pinkfish). Photo: M. Taquet

Thelenota anax (amberfish). Photo: R. Aumeeruddy

Plate 5.2. Sea cucumber species that are moderately fished in the Seychelles

Stichopus herrmanni (Curryfish). Photo: R. Aumeeruddy

Stichopus chloronotus (greenfish). Photo: R. Aumeeruddy



Actinopyga echinites (deep water redfish). Photo: T. Skewes

Bohadschia atra (Tigerfish). Photo: T. Skewes

Bohadschia marmorata (brown sandfish). Photo: T. Skewes

Bohadschia subrubra. Photo: T. Skewes

Plate 5.3. Sea cucumber species that are not fished in the Seychelles

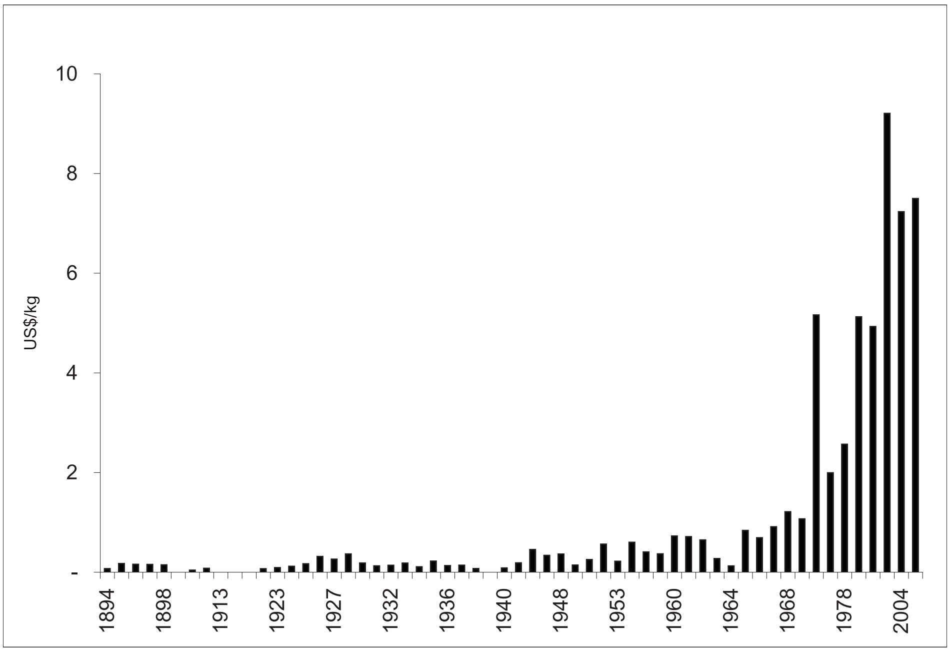


Figure 5.7. Price (US$/kg) of beche-de-mer exported from Seychelles (price converted from Seychelles rupee to US$ at 1US$ = 5.5 SR and does not take into consideration inflation). (Adapted from Marguerite 2005).

Management and Legal Framework

The sea cucumber fishery, as all fisheries in Seychelles is regulated under the Fisheries Act (1986). This core legislation does not address the sea cucumber fishery directly, but it makes provision for the Minister responsible for Fisheries to make specific regulations. Until 1999, the sea cucumber fishery was not regulated, and in effect it was an open-access fishery, without any control by the fishery authority. With the rapid development of the fishery in the late nineties, it was deemed necessary to regulate the fishery. This was done by the Fisheries (Amendment) Regulations (1999). These regulations provided control over the fishery through the following conditions; fishing and processing sea cucumbers required a specific license, fishing for sea cucumbers was prohibited in MPAs and the licensee was required to provide information related to fishing or processing to the SFA. A yearly fee of SR300 (US$ 55) was imposed for each license issued under the regulation. As a precautionary measure, SFA limited the number of fishing licenses to 25, with a maximum of 4 divers per license.

The sea cucumber fishing and trade business in Seychelles can be classified into three distinct operations and interrelated groups (Marguerite 2005) and include; a) harvesting, which relates principally to the collection of the sea cucumber; b) processing, which involves cleaning and drying of the product into the form and quality acceptable for trading, and c) trading, which involves sales to different markets, both local and overseas. The groups or operators associated with the harvesting operation can be further divided into two distinct sub-groups:

i) Single boat operators; these are operators normally doing their operations from small boats (mini-mahe, lekonomi and super sea-dog) ranging in size between five to eight meters. Fishing trips last for one day in the case of mini-mahe. Harvesting operations normally take place in areas not far from the coast.

ii) Licensed harvesters operating in bigger vessels, (whalers to schooners). Fishing trips last more than one day and trips usually involve some form of mothership/dory type operation, i.e. where the bigger vessels are accompanied with a smaller mini-mahe from which displacement and diving normally takes place. These harvesters normally operate in fishing grounds further from the main island of Mahe or in the outer islands. Some form of pre-processing is also done on board which include eviscerating the sea cucumber and preserving in salt.

Although only 25 licenses are allocated on a yearly basis, the fishery has generated a lot of interest, and there is a fairly long waiting list (around 25) to get a fishing license. There are 3 licensed operators who process and export sea cucumbers, and who are also usually involved in the drying and exporting of shark fins.

The fishery has the potential to create employment for a maximum of 170 people, if all licenses are taken and the bigger vessels have an average crew of 6 persons. This would amount to between 9% and 10% of the total employment in the artisanal fisheries sector or about 3% of total employment in the fisheries and related activities. Compared to the overall formal employment, the sea cucumber business could be classified as insignificant as it would account for only about 0.4% of total formal employment in the country. Fishing and fisheries related employment as estimated by the SFA in 2004 accounted for about 15% of total formal employment in the country.

Based on the results of a socio-economic survey done in 2004 (Marguerite 2005), it was estimated that between 120 to 125 households were to various degrees dependent on the sea cucumber harvesting and processing business, if boat owners that are not involved in the harvesting operations are included. The potential number of households that can directly or indirectly benefit from this fishery can be estimated at around 180 households. The earnings for the fishery vary widely depending on the boat category (small or big), but even within one category the earnings can vary considerably. However the results of the socio-economic survey have shown that in general, it is the smaller boats, doing day trips, which are more profitable. A recent development in the fishery is the fact that the processors who have access to foreign currency are supplying equipment to some of the fishers, in particular diving equipment. Fishers in turn are obligated to sell their catch to their suppliers at a lower price. There is thus a risk that the whole fishery may end up being controlled by the processors.

A number of threats to the sea cucumber fishery have been identified. The recently completed stock assessment of sea cucumbers shows that the shallow water high value species (sandfish, black teatfish and yellow surffish) are over-exploited or show signs of significant local depletion (Aumeeruddy *et al.* 2005). Some of the other targeted species (white teatfish, Pentard, and prickly redfish) are also heavily exploited, but as they are also found in deeper waters and not easily accessible to fishers, have some degree of protection. In addition, the shallow reef stratum adjacent to Mahé Island appears to be depleted of all the high value species; however this represents a relatively small localised depletion. These species need to be carefully monitored to avoid population depletion. The catch composition of the last few years shows that only 5-6 of the high-value commercial species are targeted by the fishers, and there is a risk of stock collapse if these species continue to be exploited as the current level.

Illegal fishing also threatens sea cucumber stocks; this concerns both unlicensed local and foreign fishers who come mainly to fish illegally around the islands of the southern group where control and enforcement are difficult due to the isolation of these islands and their distance from the main island. In April 2001, a Malagasy vessel fishing sea cucumbers illegally, was apprehended near Farquhar atoll with 110 seamen and several tons of sea cucumbers on board (Le Quotidien (La Reunion), 2001). The captain of the vessel was found guilty of illegal fishing by the court of justice, and the boat, equipment and catch was forfeited to the State. According to the license conditions, processors can only buy sea cucumbers from licensed sea cucumber fishers, but there have been reports of purchases made from unlicensed fishers. However to date, nobody has been caught in the act, thus it is difficult to take action against such suspects.

Given the amount of potential fishing effort in the fishery, including latent (under-utilised) effort, there is probably a case to constrain or reduce the current effort, particularly for the higher value species. Increased demand for beche-de-mer products will see a continued increase in the value of this commodity, extending to currently low value species (Conand 2004). Therefore there is a need to control the effort in the fishery, and to monitor it closely. A number of recommendations have been proposed by SFA in order for the fishery to remain sustainable:

1. Control fishing effort so that the catches do not exceed recommended TACs. This can be done using input (limits on licence numbers) or output (TACs) controls; however current effort (not including latent effort) in the fishery is probably too high for the high value species at least. Management measures should be designed to control effort on the higher value species and spread effort to the lower value species.
2. Control fishing effort for high value species in areas close to the main islands of the Mahé Plateau to alleviate local depletion of these species.
3. Continue to protect all sea cucumber populations in the designated Marine Parks.
4. Formulate, enforce and educate about minimum size limits for all species in the catch. Minimum size limits should be designed to protect individuals until they have spawned once. Research on size at sexual maturity may be required to apply this, but best "guesstimates" should be used in the meantime.
5. Monitor the catch and effort of the fishery through suitable logbooks and processor returns. Information should be gathered for all species in the catch.
6. Carry out periodic monitoring surveys to assess the performance of the current management strategies and modify if required.

Table 5.1. The recommended total allowable catch (TAC) for different species based on the model outputs and stock status. NB. TACs are all in fresh gutted weight and individual pieces (n) based on average survey weight and published conversion rates (these may need to be modified in future to reflect actual fishery based data). (Adapted from Aumeeruddy *et al.* 2005).

Species name	Market Name	Local name	TAC (t)	TAC (n)
H. nobilis	Black teatfish	Kokosier nwar	175	228,000
H. fuscogilva	White teatfish	Kokosier blan	80	94,000
Holothuria sp. 1 *	White teatfish	Pentard	60	71,000
H. fuscopunctata	Elephant trunkfish	Elephant trunkfish	160	200,000
H. atra	Lollyfish	Lollyfish	500	2,000,000
H. edulis	Pinkfish		25	88,000
H. scabra	Sandfish	Kokonm	0	0
H. scabra var. versicolor	Golden sandfish	Kokonm	0	0
A. mauritiana	Yellow surffish	Brizan	0	0
*Actinopyga sp.*1 *		White belly	0	0
A. miliaris	Blackfish		85	178,000
A. echinites	Deep water redfish	Spork	12	64,000
B. marmorata	Brown sandfish	Lakol	280	402,000
B. atra	Tigerfish	Lakol	180	214,000
B. subrubra		Lakol	16	39,000
P. graeffei			0	0
T. ananas	Prickly redfish	Sanpye	110	87,000
T. anax	Amberfish		0	0
S. herrmanni	Curryfish		24	34,000
S. chloronotus	Greenfish		0	0
H. pervicax			0	0

* These 2 species will require further taxonomic work for correct identification

A management plan has been proposed based on the results of the resource assessment. Following meetings with the stakeholders, the plan was finalised in August 2005, and is based on a mix of input controls (limited number of fishing licenses) and output controls (TAC for each commercial species) (Payet, 2005). It was agreed to continue with the limit of 25 fishing licences that had been implemented as a precautionary measure in 2001. The TAC was calculated based on maximum sustainable yield (MSY) for each species (Aumeeruddy *et al.* 2005). The total TAC for all species has been calculated at 1707 t landed weight (gutted), from which the high value species represent 425 t landed weight, which equated to approximately 50t dry beche-de-mer using a 14% recovery rate, medium value species (e.g. blackfish) made up 121 t (7.1%) and low value species (e.g. lollyfish) made up 1161 t (68.0%). Table 5.1 gives the TAC per species.

The implementation of the management plan will be supervised by an advisory management committee which is composed of representatives of government institutions, professionals involved in the sea cucumber industry (license holders, divers, processors and exporters) and NGO's. It is expected that the management plan will be implemented in 2006. An ammendment to increase the cost of the licence and requring a separate license for fishing and processing license was also proposed.

Literature cited

Aumeeruddy R, Payet R (2004) Management of the Seychelles sea cucumber fishery: status and prospects. *In*: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper 463 pp 239-246

Aumeeruddy R, Skewes T, Dorizo J, Carocci F, Coeur de Lion F, Harris A, Henriette C, Cedras M (2005) Resource assessment and management of the Seychelles sea cucumber fishery. FAO Project Number: TCP / Seychelles / 2902(A), November 2005. 49 pp

Clark AM (1984) Echinodermata of the Seychelles. In : Stodart DR (ed) Biogeography and ecology of the Seychelles islands. Monographiae biologicae 55 : 83-102

Clark AM, Rowe FWE (1971) Monograph of the shallow-water Indo-West Pacific Echinoderms. Bath, England, Pitman Press

Conand C (2004) Present status of world sea cucumber resources and utilisation: an international overview. In: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) (2004) FAO Fisheries Technical Paper 463 pp 13-23

Coeur de Lion F (2005) Capacity building in the resource assessment and management of the Seychelles holothurian fishery – Mapping the resources. FAO Project Number: TCP / Seychelles / 2902(A). August 2005. 20 pp

Le Quotidien (La Reunion) (2001) Illegal beche-de-mer fishing in the Seychelles – Indian Ocean. SPC Beche-de-mer Inf Bull 15:39

Marguerite M (2005) Capacity building in the resource assessment and management of the Seychelles holothurian fishery – Socio-economic analysis. FAO Project Number: TCP / Seychelles / 2902(A). August 2005. 55 pp

Payet R (2005) Management plan of the Seychelles sea cucumber fishery. Final Report of Project No. FAO / TCP / SEY / 2902(A), September 2005. 46 pp

Sloan NA (1982) Size and structure of Echinoderm populations associated with different coexisting coral species at Aldabra Atoll, Seychelles. Mar Biol 66: 67-75

CHAPTER 6

SEA CUCUMBERS IN TANZANIA

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Introduction

Sea cucumbers constitute one of the important marine resources of Tanzania (Semesi *et al.* 1998) and there has been a rapid expansion of sea cucumber exploitation at some sites in Tanzania (Mgaya *et al.* 1999). The sea cucumber fishery developed without baseline biological data and without any monitoring. Therefore to-date, Tanzania has unknown and unquantified sea cucumber resources though the fishery provides income to local collectors and generates export earnings (Mmbaga and Mgaya 2004). The fishery is largely artisanal with a small commercial operation monopolised by a few exporters. Exploitation occurs year-round on reefs close to shore with collection peaking during periods of light winds and trips can be made to the outer reefs. The level of exploitation differs from shore to shore depending on fisher folk experience, number and category of fishers, fishing techniques and season. Sea cucumbers are purchased by a number of traders based in Dar es Salaam, Tanga and Zanzibar from where they are exported to eastern Asia mainly Hong Kong SAR (China) and Singapore (Unpublished data). The increase in export of beche-de-mer was observed from 1980s (< 200 mt per annum) to 1992 (617 mt); exports have continued to decline thereafter (Marshall *et al.* 2001). These authors report further that the number of official beche-de-mer exporters on the Tanzania mainland has decreased from 23 in 1993 to 8 in 1997 and that the exporters have largely halted exports as a result of the declining profits.

State of the Resource

A study by Mgaya *et al.* (1999) on sea cucumbers in Bagamoyo reported that local exploitation occurred year-round on reef flats close to the shore or sheltered from the prevailing winds and that the main collection seasons were October to December and April to May, when the winds were usually light, and trips could be made to the off-shore reefs. Collection methods in Bagamoyo included: (i) hand-picking either from the intertidal reef flats or by snorkel diving over sand and seagrass areas, (ii) collection by free diving, using both manufactured and home-made goggles and (iii) collection using SCUBA. The latter technique is becoming increasingly popular as shallow water areas are depleted and fishers move to deeper waters. Free-diving and the use of SCUBA equipment by fishermen who are not taught to SCUBA dive correctly place the lives of collectors at risk, and drownings have been reported in Tanzania (Mgaya *et al.* 1999). The use of SCUBA diving to collect even the deepest animals makes the species vulnerable to over-harvesting and can deplete breeding stocks causing recruitment overfishing.

Mmbaga (2002) conducted a survey on the number of fisher folks involved in the fishery, the time taken per trip and interviewed fishers on distances traveled at three beaches in Dar es Salaam, namely, Kunduchi, Mjimwema and Buyuni is shown in Table 6.1.

Table 6.1. Observations made from a survey carried out at three locations in Dar es Salaam involving sea cucumber fisher folk. H: = Hand; M: = Male; F: = Female; C: = Children.

Sites	Kunduchi	Mjimwema	Buyuni	Observations
Collection method	H	H	H	Common to all shores
No. of collectors	4-5	1	4	Some are opportunists
Category of people	M 4-5	1	3	Go far into deeper waters
	F 0	0	0	Not involved in fishing
	C 0	0	1	Collect in shallow water
Fishing vessel	3 boats	0	0	Boats are used for distant trips
	1 canoe	1	1	
Time taken per trip (hr)	7-9	4-5	3-4	Depends on the abundance of sea cucumbers at the fishing grounds
Middlemen	3	0	1	Some didn't like to be interviewed
Owner of vessels and gear	Middlemen	Fisher	Fisher	Insist on availability of high-grade species

From the data in Table 6.1 and field observations (Mmbaga 2002) the presence of boats was an indicator of the availability of high grade species as middlemen were ready to offer facilities and equipment to collectors, while the presence of children in the fishery indicated relatively easy availability of the sea cucumbers (in shallow water) although this also encouraged collection of under-sized sea cucumbers. The length of the trip also indicated availability with the longer trips indicating depletion of stocks in the shallow waters. Males between the ages of 31 – 50 years dominated (99%) the fishery and and 60% of the fishers were married. Only male fishers were reported to venture into deeper water and dive for larger animals (Mmbaga 2002). Women and children periodically glean the intertidal flats on foot (Marshall *et al.* 2001; Figure 6.1.)

Figure 6.1. Sea cucumber fishery activities in Tanzania: from collection, to boiling to drying.

Awareness about the fishery was low amongst fishers with most of the knowledge being derived from delears (84%) and the rest from the media (TV, newspapers and radio). This lack of awareness had an impact on livelihoods since fishers had little negotiating power - high value species such as *H. scabra* were sold at the same price as low value species to dealers. This was partly due to the low level of education amongst fishers, but higher level amongst dealers and traders who were educated up to secondary level. There was little awareness about the management issues of the fishery including over-collection and processing, although there was some awareness not to collect juveniles. The general lack of knowledge about fishing was blamed on the weakening of the traditional system of fisheries management during pre and post-colonial times (Mmbaga and Mgaya 2004).

Biology and Ecology

Very few studies have been carried out on the general biology of sea cucumbers in Tanzania. Mmbaga (2002) and Kithakeni and Ndaro (2002) conducted a study on some aspects of the biology of *H. scabra* along the coast of Dar es Salaam at Kunduchi, the most exploited shore, and Buyuni, a shore with no history of exploitation. The total catch of *H. scabra* at Buyuni was significantly higher throughout the study period compared to that from Kunduchi. The stomach contents revealed sand, small gastropods, detritus, debris of red algae and fresh pieces of polychaetes and unidentified animal parts mixed with sediments (Mmbaga, 2002). Studies of the gonads indicated that although reproduction was continuous throughout the year, gonad indices showed two peak periods, June to August and December to January.

No studies on the growth, larval ecology, recruitment, or mortality of any sea cucumber species has been conducted in Tanzania. However, using the length distribution for 240 specimens of *H. scabra* measured between January and December 1999, Kithakeni and Ndaro (2002) showed that the frequency distribution was unimodal, with most individuals ranging in length between 8.5 and 26.5 cm. The most frequent length category was 17.5 cm. The total catch consisted of individuals measuring between 7 and 27 cm. Mmbaga (2002) conducted multiple comparisons of size frequency distributions of *H. scabra* among stations and revealed significant differences ($p<0.001$). Kithakeni and Ndaro (2002) reported size at first maturity of *H. scabra* at Dar es Salaam coast as 16.8 cm.

Management and Legal Framework

The new Fisheries Act of 2003 and the Fisheries (General amendment) regulations of 1997 (under the old Fisheries Act of 1970) recognise three types of license fees paid annually by dealers and exporters of fisheries products. These include, (i) Local individuals or companies with approved shore-based fish processing facilities, (ii) Local–individuals or companies without approved shore-based fish processing facilities, and (iii) Foreigner–individuals or companies with approved shore-based fish processing facilities. Foreigner–individuals or companies without approved shore-based fish processing facilities are prohibited from getting a license. There is no specific legislation that exists in Tanzania that refers to sea cucumbers; consequently indicators of overexploitation are seen in many landing sites (Mgaya *et al.* 1999; Marshall *et al.* 2001; Mmbaga 2002). In addition, fisheries regulations vary between the mainland and Zanzibar; for example, a ban prohibiting sea cucumber fishing was implemented in September 2006 on mainland Tanzania but not on Zanzibar. The impacts of such regulations on the fishery are difficult to assess due to the lack of adequate monitoring of the catch during the period the ban is in force.

Sea cucumbers do not constitute part of the diet in Tanzania but are fished for sale to exporters. In some places e.g., in Songo Songo, divers collect sea cucumbers at a depth of about 18 m (Darwall 1996). Sea cucumbers are also collected on an opportunistics basis by fishers looking for other marine resources – there have been reports that trawlers also collect sea cucumbers (Mmbaga and Mgaya 2004). In a discussion with 72 traders Marshall *et al.* (2001) reported that daily catches of sea cucumbers varied between 5 and 50 specimens per fisher. In the Songo Songo archipelago the average catch rate per person per trip was 8.1 sea cucumbers, and on Mafia Island it was 3.7 per person (Darwall, 1996). The difference between the two areas was attributed to the size of the fishing areas.

Sea cucumber prices have fluctuated over time ranging from US$ 0.10 to 0.50 per fresh animal; processors sell the dried product to middle men for US$ 0.9 to 6.00 / kg, who in turn sell to exporters at US$ 3.00 to 17.00 / kg dry weight (Marshall *et al.* 2001). The export prices range from US$ 1.80 to 23.70 / kg dry weight (Mmbaga and Mgaya, 2004). Along this value chain among 28 interviewed dealers only 5 had a license that is not specific for sea cucumbers but specified sea products (pers.

obs.). Despite this information on the value of sea cucumbers, the level and potential contribution of sea cucumbers to the national economy as well as to the livelihoods of coastal communities, is not yet known due in part to a lack of comprehensive data on the extent of the sea cucumber fishery in Tanzania.

Depletion of sea cucumber resources was first reported at Songo Songo by Darwall (1996) as indicated by the harvest of juveniles. Other reported cases of depletion included Jiddawi (1997) in Zanzibar, Guard (1998) in Mtwara, Horsfall (1998) and Mgaya *et al.* (1999) in Bagamoyo, and Kithakeni and Ndaro (2002) at Kunduchi, Dar es Salaam. Interviews conducted by Mgaya *et al.* (1999) with sea cucumber collectors in Bagamoyo indicated that the stocks were declining and the average size of individuals was decreasing. Removal of large individuals may affect reproduction and lead to recruitment overfishing. Although the collectors recognize that part of the problem is the harvest of juveniles, due to lack of effective policing, they continue to collect juveniles as “others will do if they don’t”—a typical tragedy of the commons scenario (Hardin 1968). Open access to unmanaged sea cucumber resources will definitely lead to depletion of the stock.

Importation statistics for sea cucumbers reported in Hong Kong during January–March 1996 showed that Tanzania ranked high in the Western Indian Ocean region (Table 6.2) – Tanzania produced up to 1644mt by the end of that year (Conand 2004). Although it is difficult to accurately estimate historical and current production of sea cucumbers in Tanzania the available data indicates a very serious decline in production in the last decade from >1500mt in 1994 to 10 mt in 2004 (Table 1.1). The number of exporters has also decreased over time from 23 to 8 on mainland Tanzania and 6 to 2 in Zanzibar between 1993 and 1997, an indication of the lowered profitability of the fishery (Marshall *et al.* 2001).

Table 6.2. Imports of sea cucumber in Hong Kong for the period January – March 1996 from selected Western Indian Ocean countries.

Country	Import Statistics (mt)	Value 1000 HK$
Tanzania	73.8	1,676
Madagascar	40.3	4,242
Kenya	7.4	250
South Africa	6.6	285
Mauritius	2.7	448
Mozambique	23	480

Source: Infofish Trade News 11/96, 17/6/96 (1996). Reported exports from Tanzania include those from the Mainland and Zanzibar.

Twenty species of sea cucumbers are harvested in Tanzania (Table 6.3); their distribution is described in Rowe and Richmond (2002). The importance and age of this fishery to the local coastal communities is indicated by the presence of at least 50 different Swahili names for different species (Marshall *et al.* 2001). A study conducted in Mafia Island from May to September 1998 revealed that *Actinopyga miliaris, Bohadschia argus, B. marmorata and Stichopus variegatus* occurred in the highest quantities in the trade while the most valuable species including *Holothuria scabra, H. nobilis, H. spinifera and Holothuria* sp. composed a very small percentage of the catch (Marshall *et al.* 2001). These results indicated that there has been a shift from the more highly valuable commercial species such as *H. scabra* and *H. nobilis* that previously dominated the catch (Marshall *et al.* 2001). The state of sea cucumber resources in Tanzania remains poorly documented and cross border transfers of beche-de-mer from Tanga to Vanga in Kenya and from Mozambique to Mtwara in Tanzania complicate the export statistics. The need for generating up-to-date information on the status of the resources cannot be overemphasized.

Table 6.3. Sea cucumber species traded in Tanzania. (Source Rowe and Richmond 2002; Marshall *et al.* 2001; Mmbaga and Mgaya 2004).

Scientific Name	Common Name	Local Name	Depth and Substrate Type
Actinopyga echinites	Deep water Redfish		Lower eulittoral, common on reef crests; rock, algae
A. mauritiana	Surf Redfish	Mbura-Khaki	Lower eulittoral and deeper; rock, coral
A. miliaris	Blackfish	Kijino	Shallow sublittoral
Bohadschia argus	Leopard Tigerfish	Barango	Shallow sublittoral; sand, seagrass, reef
B. marmorata			
Holothuria atra	Lollyfish/Blackfish	Pesa	Shallow sublittoral; sand
H. cinerascens			Shallow to deep water; sand, lagoons, rock
H. edulis	Pinkfish		Shallow; various substrate types
H. fuscogilva	White Teatfish	Pauni-nyeupe	
H. fuscopunctata	Elephant Trunkfish		
H. leucospilota		Sumu	
H. nobilis	Black Teatfish	Pauni-nyeusi/Chui	Shallow; Seagrass, coral
H. parva			Mid eulittoral; boulders, fine sand and mud
H. scabra	Sandfish	Jongoo mchanga	Lower eulittoral and deeper; sand
H. spinifera			
Pearsonothuria graeffei			Shallow; reefs, coral
Stichopus chloronotus			
S. herrmanni	Curryfish		Shallow; sand, coral
Thelenota ananas	Prickly Redfish	Spinyo mama	Shallow; reef, rubble
T. anax	Amberfish		Shallow; reef and on sand and rubble

The quality of beche-de-mer from Tanzania is also a cause for concern. Poor quality beche-de-mer from Tanzania has been reported in the international market (Ferdouse 2004) and this is reflected in the lower value of the product compared to other countries like Madagascar (Table 6.2). There are technological gaps in the various stages of processing including species-specific pre-treatments of fresh animals, processing environment, drying, packing, storage conditions and the generally poor hygienic and sanitary standards in all stages during the processing protocols. Poor processing leads to bacterial and fungal attack of the beche-de-mer, which gives the product a foul smell hence lowering its value. Marshall *et al.* (2001) reported that the worst quality beche-de-mer comes from southern Tanzania (Mtwara) and attributed this to poor preparation resulting from insufficient time spent on the process, or from efforts to increase weight with excess water, sand and gut content. The best quality beche-de-mer was reported from Mafia Island and Songo Songo.

With the increase in collection effort it is likely that the stocks of sea cucumbers will be even more seriously depleted over the next few years. Thus, the need for some form of management of the fisheries is obvious. The shape that this management will take, in a financially constrained country like Tanzania remains to be seen. Possible management approaches to ensure sustainable harvest include closed areas (reserves), closed seasons, quotas, gear restriction, and a legal size limit for collection. Since beche-de-mer from Tanzania is for export, monitoring of legal size limits can be done at the level of the middlemen, buyers and exporters. The biggest problem facing Tanzania, however, is not the development of appropriate legislation, but rather developing the capacity to enforce regulations initiated to protect the sea cucumber fishery. Legislation is useless without its three counterparts, political will, education and enforcement, but education and enforcement are expensive, hence casting a shadow of doubt on compliance by the fisher folk to existing regulations. It is hoped that the MASMA sea cucumber project will increase the knowledge required to improve the management of this fishery in Tanzania.

Literature cited

Conand C (2004) Present status of world sea cucumber resources and utilisation: an international overview. *In*: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) (2004) FAO Fisheries Technical Paper 463 pp 13-23

Darwall WRT (1996) Marine biological and marine resource use surveys in Songo Songo Archipelago, Tanzania. Report no. 7: Current status and management recommendations. Frontier-Tanzania marine research programme. The Society for Environmental Exploration, London and the University of Dar es Salaam

Ferdouse F (2004) World markets and trade flows of sea cucumber/beche-de-mer. In: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds). Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463:101-117

Guard M (1998) Marine biological and marine resource use surveys in the Mtwara district, Tanzania. Report no. 4: Local resource use within and adjacent to Mnazi Bay. Frontier-Tanzania marine research programme. The Society for Environmental Exploration, London and the University of Dar es Salaam. 30pp

Hardin G (1968) The tragedy of the commons. Science 162:1243-1248

Horsfall IM (1998) Sea cucumbers in Tanzania, the salad days are over. Miombo 18:4-5

Jiddawi N (1997) Reef dependent fisheries in Zanzibar. In: Johnston RW, Francis J, Muhando C (eds) Proceedings of the national conference on coral reefs. Coral reefs: values, threats and solutions. Zanzibar Tanzania, December 1997. SIDA/SAREC, UNEP and University of Dar es Salaam, pp 12-24

Kithakeni T, Ndaro SGM (2002) Some aspects of sea cucumber, *Holothuria scabra* (Jaeger, 1935) along the coast of Dar es Salaam. WIO J Mar Sci 1(2): 163-168

Marshall N, Milledge SAH, Afonso PS (eds) (2001) Stormy seas for marine invertebrates; trade in sea cucumbers, seashells and lobsters in Kenya, Tanzania and Mozambique. TRAFFIC East/ Southern Africa, Nairobi, Kenya. 70pp

Mmbaga TK (2002) Some aspects of fishery, ecology and reproductive biology of *Holothuria scabra* (Jaeger, 1935) along the coast of Dar es Salaam. M.Sc thesis, University of Dar es Salaam, Dar es Salaam, Tanzania. 118 pp

Mmbaga TK, Mgaya YD (2004) Sea cucumber fishery in Tanzania: Identifying the gaps in resource inventory and management. In: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) Advances in sea cucumber aquaculture and management. FAO, Rome. Fisheries Tech Paper 463 pp 193-203

Mgaya YD, Muruke MHS, Semesi AK (1999) The sea cucumber and molluscs fishery in Bagamoyo. In: Howell KM, Semesi AK (eds) Coastal resources of Bagamoyo District, Tanzania. University of Dar es Salaam, Tanzania, 65-72pp

Rowe FEW, Richmond MD (2002) Echinodermata. In: Richmond MD (ed) A guide to the seashores of Eastern Africa and the Western Indian Ocean Islands. Second edition, SIDA/SAREC. Sweden, 300-331pp

Semesi AK, Mgaya YD, Muruke MHS, Francis J, Mtolera M, Msumi G (1998) Coastal resources utilization and conservation issues in Bagamoyo. Ambio 27(8): 635-644

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

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Synthesis of national chapters

Sea cucumbers have been harvested in the Western Indian Ocean for centuries. However, in the last decade production of beche-de-mer from countries reporting to FAO has decreased from ~7000 tonnes in 1990s to 1000 tonnes by 2004 (Conand 2004). Several explanations are given for this decline including overexploitation of natural stocks in many producing nations combined with the high demand after the opening up of the largest market, China PR. The decline in production is expected to affect the livelihoods and local economies of producing nations not to mention the potential impacts on the environment that have yet to be investigated.

Although management authorities in the WIO have adapted to changes in the fisheries in various ways - as evidenced by bans of SCUBA use in some countries- management responses have often been on an Ad Hoc basis, responding to urgent needs often without sufficient scientific information to guide decisions. The vulnerability of this fishery is exacerbated by several factors that are not unique to the region including:

- The increased global demand for beche-de-mer;
- The ease of harvest and processing of sea cucumbers;
- The lack of adequate information for management of the fishery;
- Socio-economic and institutional barriers that result in poor management of the fishery.

To date, information on sea cucumbers in the WIO is limited in spatial scale and scope and no regional level assessment of ecological, social or fisheries management aspects has been attempted. There is a need to expand the knowledge base especially our understanding of the biological and ecological factors that affect sea cucumber resources and the linkages between socio-economic characteristics and effects on the management of the fishery.

To this end, this report provides the first step in the analysis of information that is derived from the key references on sea cucumbers in the WIO. A total of 145 references were analysed including articles from peer-reviewed journals, fisheries statistics, reports and archival material on the biology, ecology and fisheries management of sea cucumbers in five countries of the WIO: Kenya, La Réunion, Madagascar, Seychelles, Tanzania). Brief notes are also provided (see below) on Comoros, Mayotte, Mauritius and Mozambique where less information is available.

The selected countries present interesting case studies because they differ in their socio-economic, geo-political and management characteristics. In particular, La Reunion has no fishery allowing for assessments of pristine biomass of different species. Kenya on the other hand has MPAs that have been in existence for varying and long periods of time allowing for assessments of the impacts of MPAs on the biomass and reproductive biology of sea cucumbers. The countries that traditionally had the highest production, Madagascar and Tanzania, present interesting contrasts in the history and management of their fisheries. The Seychelles has the most sophisticated fishery and management program for sea cucumbers and Madagascar, which has the first sea cucumber hatchery in the region, will provide lessons on sea cucumber mariculture and the socio-economics of such ventures.

Sea cucumber biology and fisheries in other countries from the Western Indian Ocean

Information on sea cucumbers in other countries of the WIO is limited; however the information that is available is sufficient to derive some general patterns that are briefly described below.

Samyn *et al.* (2005) describes the fishery of Comoros, where harvesting and processing is controlled by Chinese immigrants. The key stakeholders in this fishery have expressed "their deepest concern in regard to the present, rather blind, overexploitation of the sea cucumbers in the Comoros" giving a few qualitative observations to support this view. Samyn *et al.* (2006) have also recently produced a detailed description of the different species of sea cucumbers and their habitat in the Comoros. In Mayotte, several brief studies have shown that the same problems are encountered (Pouget 2004, 2005; Conand *et al.* 2005). Mulochau *et al.* (2007) in a quantitative evaluation showed that sea cucumber abundance and diversity was low in different habitats from Geyser Bank (off Mayotte), and speculates that this is probably due to overfishing.

The holothurian fauna of Mauritius (including Rodrigues) attracted some attention recently, but a few species such as *Actinopyga mauritiana* had been described previuosly by Quoy and Gaimard in 1833. Additional taxonomic work includes Michel (1974) who listed 23 species of Aspidochirotida, and Arakaki and Fagonee (1996) who provided a species list from several countries including Mauritius. Luchmun *et al.* (2001) studied the distribution of a few species in Mauritius and unpublished student's reports present additional data on the distribution of the main species (Muller 1998). Exploitation of sea cucumbers only started recently in Mauritius, with a few licences to fishermen. Following the sampling of the echinoderms of Rodrigues by the Shoals of Capricorn, Rowe and Richmond (2004) give a list of 29 holothurians. Mrowicki (2006) reported on the distribution of sea cucumbers in Rodrigues but no information is available on exploitation of sea cucumbers in Rodrigues.

Very little information is available on the sea cucumber fisheries of Mozambique and the report by Marshall *et al.* (2001) remains the main review for this country. Many of the management issues that occur across the region probably also occur in Mozambique including inadequate data on the fishery and "illegal cross border exports to Tanzania" which exacerbates the difficulties of estimations of production in both countries.

The sea cucumber fisheries are developing in other countries of the Indian Ocean, such as Chagos (Spalding 2006) and Oman (Al-Rashdi *et al.* 2007). The present status of the traditional fisheries and aquaculture of India has been described in numerous publications including James and James (1994) and James (2004). The fishery in Sri Lanka is now experiencing a rapid decline, and illegal fisheries occur far from Sri Lankan waters (Kumara *et al.* 2005). Conand (per. com) is preparing a regional synthesis of the sea cucumber fisheries in east Africa and the Indian Ocean as part of an FAO project (Toral-Granda 2006; 2007).

The taxonomy and zoogeography of shallow water holothurians from the Indian Ocean have also recently received more attention. Around 250 species are distributed in the WIO (Richmond 1997; Samyn and Tallon 2005; Thandar 2007), with 30 species being of commercial interest. Genetic based programmes on holothurian biodiversity have also been undertaken in several countries (Uthicke and Benzie 2000; 2003; Uthicke and Conand 2005; Uthicke *et al.* 2001, 2004, 2005; Kerr et al 2005). Studies on the biology of sea cucumbers have not progressed as much, partly due to the time consuming nature of the studies.

Socio-economy of the fishery

Sea cucumber fisheries in the WIO are predominately artisanal making them an important contributor to livelihoods of coastal populations. Despite their potential for poverty alleviation, little is known about the socio-economic characteristics of the fisheries in the region. A few localized assessments have been undertaken in Tanzania (Mmbaga 2002), in Kenya (Muthiga and Ndirangu 2000; Beadle 2005) and Seychelles (Marguerite 2005). Marshall *et al.* (2001) also provided some socio-economic information on the fisheries in Kenya, Mozambique and Tanzania. Conand (2004) developed a general model of the different levels of the beche-de-mer fisheries, however, information on the details at each level are not available for each country. In order to address this large gap in information, the socio-economics component of the ongoing Regional Sea Cucumber Project - funded by WIOMSA through the MASMA program - has developed a conceptual model (Figure 7.1; de la Torre-Castro *et al.* 2007) that takes into consideration the local to global scale of the interactions within a sea cucumber fishery. It is hoped that this framework will allow a better understanding of the various socio-economic mechanisms at play in this fishery.

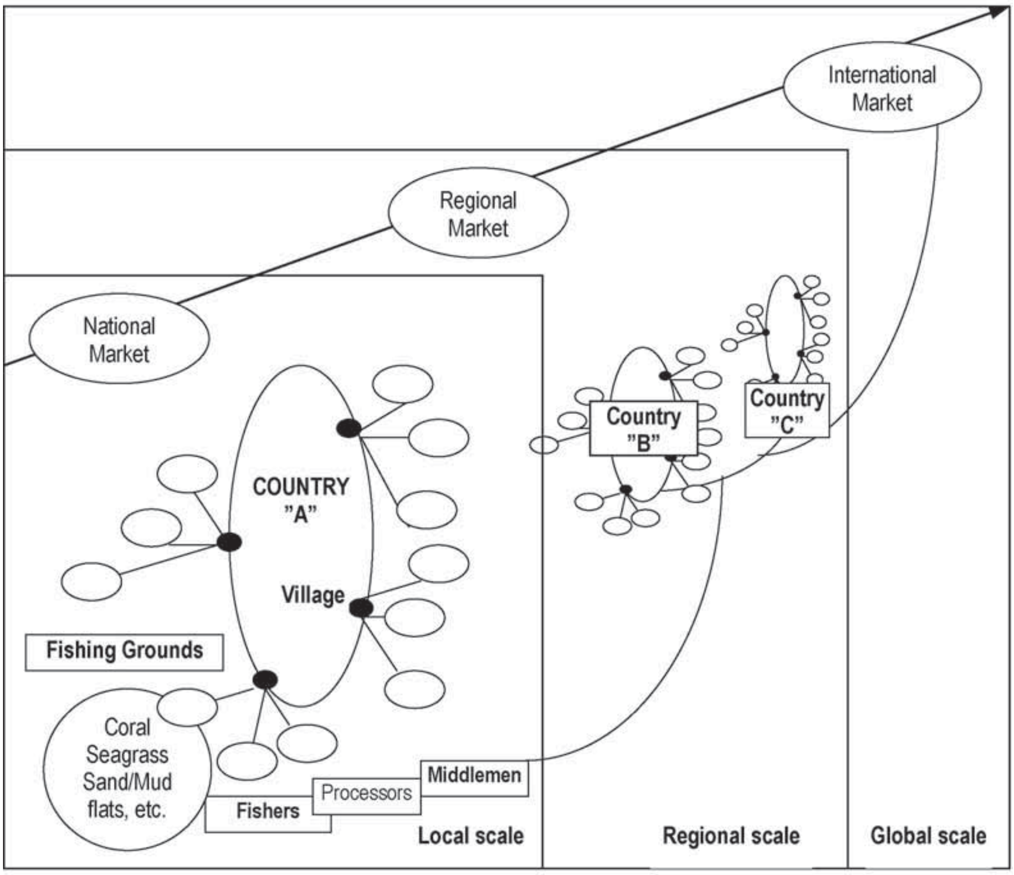

Figure 7.1. Conceptual model for the socio-economic analysis of the sea cucumber resource in the Western Indian Ocean (From de la Torre-Castro *et al.* 2007).

Conclusions and recommendations

Marine resources, including sea cucumbers, are vital to the coastal people of the WIO, however management of these resources has to balance sustainable use as well as conservation of the marine habitats within which these resources occur. This cannot be achieved without the key ecological and socio-economic information required for management. This report synthesizes what is currently known about sea cucumbers in five countries in the region. Results of the analysis indicate that the sea cucumber fisheries of the WIO have the following general characteristics:

- The fisheries are predominantly artisanal (Kenya, Tanzania, Madagascar) although semi-industrial operations are in existence in Madagascar and the Seychelles. Males dominate the fishery although women and children are involved in some countries (Madagascar and Tanzania). While gleaning during low tide was common, harvest using SCUBA in now the dominant form of fishing;
- The fisheries are based on ~20 species that are common throughout the region except *S. horrens* and *H. notabilis* that have emerged as important components of the catch in Madagascar;
- The processing of beche-de-mer is mainly carried out under poor conditions which affects the quality and hence the price of the product;
- Sea cucumbers are traded on the international market as a speciality product and are not consumed in any countries of the region. Although local fishers carry out harvesting, Chinese mainly from China PR and China Hong Kong SAR dominate the market;
- In all the countries there are various signs of overexploitation including; reduction in size and numbers of high value species, increase in collection times, collection of juveniles, increase in competition between harvesters, illegal use of gear and infringement of other nations EEZs.
- Fisheries management in most countries is weak partly due to lack of adequate information but also due to weak regulatory, operational and management measures.

Although the results of the national chapters can only be considered preliminary in light of certain limitations – unreliable production statistics and lack of knowledge on stocks- the sea cucumber fisheries have general characteristics and patterns that allow for some preliminary conclusions from which recommendations can be made. These recommendations will provide countries a suite of measures that can be implemented especially where the threat of over-exploitation is greatest. From the national synthesis, the following broad areas (not in order of priority) require attention to varying degrees in each country:

- In most cases, there is inadequate information on distribution and abundances especially of commercial species that would allow estimation of stocks. Only Seychelles has made some progress towards this objective. Stock assessments are recommended in the other countries;
- No studies on growth, mortality and recruitment that are considered crucial for fisheries management have been carried out in any of the countries. Although these types of studies present some challenges, local students and scientists can be encouraged to undertake such studies because ultimately this information is key for the sustainable management of stocks;
- The capacity of the management authorities in most countries is low and needs to be improved. This includes administrative, operational as well as policy capacity;
- Except for the Seychelles, none of the countries of the WIO have developed management plans for sea cucumbers. There is an urgent need to develop such plans that should include improved mechanisms for monitoring of catch statistics and involvement of local communities in the fishery sector;
- Although most of the WIO countries have MPAs, few assessments of their effectiveness in protecting sea cucumber resources have been carried out. A study in Kenya (Muthiga and Ndirangu 2000) indicated that MPAs have higher diversity and abundances of sea cucumbers, whether this is true across the region remains to be demonstrated;
- Few of the countries of the WIO have legislation that is specific for sea cucumbers. Specific legislation especially in view of the fact that some sea cucumber species are under review and may receive trade protection under CITES will greatly facilitate their management;
- Across the region, the quality of beche-de-mer is poor, markedly reducing its value. Initiatives to improve quality including training and infrastructure development for local communities need to be implemented;
- The general awareness about the economic and ecological value of sea cucumbers and their potential for poverty alleviation has not been recognised and needs to be enhanced in many countries;
- Mariculture is currently being undertaken in Madagascar and the lessons-learned from this project should provide useful information on the feasibility, ecological and social impacts of such trials in the region.

The ongoing Regional Sea Cucumber Project (Conand *et al.* 2006; Muthiga and Conand 2006; de la Torre-Castro *et al.* 2007) is expected to address some of the gaps in the information needs for the rapidly growing sea cucumber fishery in the region. Specifically the knowledge generated through this project will: (1) increase our understanding of the status of sea cucumbers and their management including potential for aquaculture; (2) provide key skills and information for management and improve our knowledge and identification of the gaps of the management systems; (3) increase our knowledge of the impact of the fishery on the socio-economic status of coastal communities. The project will also gather information on alternative management strategies, such as restocking, stock enhancement and aquaculture based on artificial reproduction and farming (Bell and Nash 2004; James 2004; Purcell 2004; Jangoux *et al.* 2001; Lovatelli *et al.* 2004; Rasolofonirina *et al.* 2004; Purcell *et al.* 2006; Bruckner 2006). Additional resource materials include the technical manual on the aquaculture of the highly valuable commercial species *H. scabra* (Agudo 2007).

Finally, despite difficulties of managing marine resources, national governments in the WIO are coming to the realization of the link between livelihoods, food security, biodiversity conservation and ecosystems services. This means that governments are now primed to take action to manage marine resources and it is hoped that the information gained from this report and subsequently from the Regional Sea Cucumber Project will set the stage for the improved management of sea cucumber resources in the region.

Literature cited

Agudo N (2007) Sandfish hatchery techniques. Australian Centre for International Agricultural Research, Secretariat of the Pacific Community, Worldfish Center: 44 pp www.worldfish.org

Al-Rashdi K, Al-Busaidi S, Al-Rassadi I (2007) Status of the sea cucumber fishery in the Sultanate of Oman SPC Bêche-de-mer Info Bull 25:17-21

Arakaki Y, Fagonee I (1996) Corals and echinoderms of the western Indian Ocean islands, Mauritius, Madagascar and Mahe (Seychelles). Bull Mei Univ 2 : 113-125

Beadle R (2005) Management, conflict and compliance: The case of the Kenyan sea cucumber (Echinodermata: Holothuroidea) fishery. M.Sc thesis in Tropical Coastal Management University of Newcastle upon Tyne

Bell J, Nash W (2004) When should restocking and stock enhancement be used to manage sea cucumber fisheries In: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463, pp 173-180

Bruckner AW (ed) (2006) The proceedings of the technical workshop on the conservation of sea cucumbers in the families Holothuridae and Stichopodidae. NOAA Technical Memorandum 44, 239 pp

Muller C (1998) The role and distribution of holothurians (Echinodermata: Holothuroidea) in shallow coastal lagoons, Mauritius. M.Sc Thesis, University of Bangor, North Wales, UK, 100pp

Conand C (2004) Present status of world sea cucumber resources and utilisation: an international overview In: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463, pp 13-23

Conand C, Muthiga N, Aumeeruddy R, de La Torre-Castro M, Frouin P, Mgaya Y, Mirault E, Ochiewo J, Rasolofonirina R (2006) A three years regional project on sea cucumbers in the south-western indian ocean: national and regional analyses to improve management. SPC Bêche-de-mer Info Bull 23: 11-15

Conand C, Dinhut V, Quod JP, Rolland R (2005) Sea cucumber inventory in Mayotte, south west Indian Ocean. SPC Bêche-de-mer Info Bull 22:19-22

de la Torre-Castro M, Ochiewo J, Mbaga T, Pinault M (2007) A framework addressing socio-economics and management of the sea cucumber resources in the Western Indian Ocean considering multiple scales. SPC Bêche-de-mer Info Bull 25: 22-28

James DB (2004) Captive breeding of the sea cucumber *Holothuria scabra*, from India. In: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463, pp 385-395

James DB, James PSBR (1994) Handbook on Indian sea cucumbers. Central Marine Fisheries Research Institute special publication 59: 1-46.

Jangoux M, Rasolofonirina R, Vaitilingon D, Ouin JM, Seghers G, Mara E, Conand C (2001) A sea cucumber hatchery and mariculture project in Tulear, Madagascar. SPC Bêche-de-mer Info Bull 14: 2-5

Kerr A, Janies D, Clouse R, Samyn Y, Kuszak J, Kim J (2005) Molecular phylogeny of coral-reef sea cucumbers based on 16S mitochondrial ribosomal DNA sequence. Mar Biotech 7: 53-60

Kumara PB, Cumaranathunga PR, Linden O (2005) Present status of the sea cucumber fishery in Southern Sri Lanka: a resource depleted industry. SPC Bêche-de-mer Info Bull 22: 24-29

Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) (2004) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463, 425 pp

Luchmun J, Mangar V, Mosaheb J, Terashima H, Yamamoto M (2001) Holothurian distribution in the lagoon at La Preneuse and Baie du Cap, Mauritius, Indian Ocean. Rep Mar Ecol Res Inst 3: 13-25

Marguerite M (2005) Capacity building in the resource assessment and management of the Seychelles holothurian fishery – Socio-economic analysis. FAO Project Number: TCP / Seychelles / 2902(A). August 2005. 55 pp

Marshall NT, Milledge AH, Afonso, PS (2001) Trade Review: Stormy seas for marine invertebrates: trade in sea cucumbers, seashells and lobsters in Kenya, Tanzania and Mozambique. WWF IUCN 70pp

Mmbaga TK (2002) Some aspects of fishery, ecology and reproductive biology of *Holothuria scabra* (Jaeger, 1935) along the coast of Dar es Salaam. M.Sc thesis, University of Dar es Salaam, Dar es Salaam, Tanzania. 118 pp

Michel C (1974) Notes on marine biology studies made in Mauritius. Mauritius Inst Bull 7 (2), 287 pp

Mrowicki R (2007) The abundance and distribution of holothurians (Echinodermata: Holothuroidea) in the shallow coastal lagoon of Rodrigues, Mauritius (abstract). SPC Bêche-de-mer Info Bull 25:

Mulochau T, Conand C, Quod JP (2007) Les holothuries et autres échinodermes du Banc de Geyser(Mayotte - Océan Indien). SPC Bêche-de-mer Info Bull 26: 7-13:

Muthiga N, Conand C (eds) (2006) Regional sea cucumber project: Proceedings of the start-up workshop, Mombasa Kenya, 26–29 January 2006. 20pp. (on line on WWW.wiomsa.org)

Purcell S (2004) Criteria for release strategies and evaluating the restocking of sea cucumbers In: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463, pp 181-191

Purcell S, Blockmans B, Agudo N (2006) Transportation methods for restocking of juvenile sea cucumber, *Holothuria scabra*. Aquaculture 251: 238-244

Pouget A (2004) Sea cucumber fisheries in the Mayotte reef system, Indian Ocean. SPC Bêche-de-mer Info Bull 19:35-38

Pouget A (2005) Abundance and distribution of holothurians on the fringing reef flats of Mayotte. SPC Bêche-de-mer Info Bull 21:22-25

Rasolofonirina R, Mara E, Jangoux M (2004) Sea cucumber fishery and mariculture in Madagascar: A case study of Toliara, south-west of Madagascar In: Lovatelli A, Conand C, Purcell S, Uthicke S, Hamel JF, Mercier A (eds) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463, pp 133-149.

Richmond M (1997) A guide to the seashores of eastern Africa and the Western Indian Ocean Islands. SIDA, 448 pp

Rowe FWE, Richmond M (2004) A preliminary account of the shallow water echinoderms of Rodrigues, Mauritius, western Indian Ocean. J Nat Hist 38, 3273-3314

Samyn Y, Tallon I (2005) Zoogeography of the shallow-water holothuroids of the western Indian ocean J. Biogeogr 32:1523-1538

Samyn Y, Vanden Spiegel D, Massin C (2005) Sea cucumbers from the Comoros archipelago. SPC Bêche-de-mer Info Bull 22: 14-18

Samyn Y, Vanden Spiegel D Massin C (2006) Taxonomie des holothuries des Comores. Abc Taxa

/ Vol 1, i-iii, 130 pp.
Spalding M (2006) Illegal fisheries in the Chagos Archipelago. SPC Bêche-de-mer Info Bull 23 : 32-34
Thandar AS (2007) Additions to the aspidochirotid, molpadid and apodid holothuroids (Echinodermata: Holothuroidea) from the east coast of southern Africa, with descriptions of new species *Zootaxa* In press: 1-64.
Toral-Granda V (2006) Fact sheets and identification guide for commercial sea cucumber species. SPC Bêche-de-mer Info Bull 24: 49-52
Toral-Granda V (2007) Facts on sea cucumber fisheries worldwide. SPC Bêche-de-mer Info Bull 25: 39-41
Uthicke S, Benzie JAH (2000) Allozyme electrophoresis indicates high gene flow between populations of *Holothuria nobilis* (Holothuroidea: Aspidochirotida) on the Great Barrier Reef. Mar Biol 137: 819-825
Uthicke S, Benzie JAH (2003) Gene flow and population history in high dispersal marine invertebrates: mitochondrial DNA analysis of *Holothuria nobilis* (Echinodermata: Holothuroidea) populations from the Indo-Pacific. Molec Ecol 12: 22635-22648.
Uthicke S, Conand C (2005) Amplified fragment length polymorphism (AFLP) analysis indicates importance of both asexual and sexual reproduction in the fissiparous holothurian *Stichopus chloronotus* (Aspidochirotida) in the Indian and Pacific Ocean. Coral reefs 24(1): 103–111
Uthicke S, Conand C, Benzie JAH (2001) Population genetics of the fissiparous holothurians *Stichopus chloronotus* and *Holothuria atra*: a comparison between Torres Strait and La Reunion. Mar Biol 139: 257-265.
Uthicke S, O'Hara T, Byrne M (2004) Species composition and molecular phylogeny of the Indo-Pacific teatfish (Echinodermata: Holothuroidea) bêche-de-mer fishery. Mar Freshw Res 55: 1-12
Uthicke S, Purcell S, Blockmans B (2005) Natural hybridization does not dissolve species boundaries in commercially important sea cucumbers. Biol Journ Linnean Soc 85: 261-270