Population status, fisheries and trade of sea cucumbers in Africa and the Indian Ocean

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Seychelles: a hotspot of sea cucumber fisheries in Africa and the Indian Ocean region

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SUMMARY

The region covered in this review is very diverse, including four FAO Fishing Areas and 30 countries. Sea cucumber fisheries presently exist in the Western Indian Ocean (WIO), where 16 countries have been documented, and in the Eastern Indian Ocean (EIO), with two countries covered in this review. The fisheries are for the dried product ("trepang" or "bêche-de-mer") which is consumed by Chinese populations and have a long history dating back to the ninteenth century.

Nearly thirty species are presently exploited (23 Holothuriidae; 6 Stichopodidae), with commercial value varying among species. Several differences in species composition between the Indian and tropical Pacific region have been shown recently, such as the teatfish *H. whithmei* found only in the Pacific, and *H. notabilis* and *H. spinifera* in the Indian Ocean.

The main information on the population status, reproductive biology and ecology of the commercially important species is synthesized in the present document. In 12 out of the 30 countries in the region the resource appears to be overexploited or fully exploited. Sea cucumbers are harvested and processed in different ways throughout the region, varying from small-scale, artisanal to semi-industrial activities. Globally, and according to FAO statistics, the region produces at least 1/3 of the world dried sea cucumber products.

There are several national management measures, including total bans; however, these seem to be insufficient for a sustainable use of the resources. The trade is characterised by exports from the producer countries, imports in "intermediate" (e.g. Yemen, Dubai) and final markets, where the key role of China Hong Kong SAR is most apparent. Illegal trade remains a problem in many countries.

The socio-economic aspects essential in small-scale fisheries are presented for several countries. Finally, several current projects in fisheries, or aquaculture as an alternative measure, are detailed.

In conclusion, the need for co-management, the improvement of the export statistics and the implementation of sustainable use are discussed.

1. REGION UNDER STUDY

The region covered for the present regional review (Figure 1) is very diverse and had to be separated into several sub-areas, following FAO Fishing Areas (FAO, 2005a). Table 1 lists the countries in each sub-area and points out the countries for which information on sea cucumber fisheries is available and countries that, although information is lacking, there may be commercial exploitation of sea cucumber species.

As in the tropical Pacific (Conand, 1986, 1990) the fishery for sea cucumbers in the Indian Ocean, for exports to the Asian markets, has a long history. For example, in India it is reported by Hornell (1917), in Madagascar by Petit (1930), in eastern Africa by Sella and Sella (1940) and in the Seychelles, Marguerite (2005) dates exports back to 1894. Following the FAO review in Lovatelli *et al.* (2004), an important recent source of information is the status report on sea cucumber fisheries from the Western Indian Ocean (WIO) prepared for the Western Indian Ocean Marine Science Association (WIOMSA) by Conand and Muthiga (2007a).

In the Africa and Indian Ocean region, the species commercially fished are benthic. Some species live on hard substrate (rocks and coral reefs), but most inhabit soft bottoms, either on the surface, or buried (temporarily or permanently) in the sediment. The common characteristics of the commercial species are: (i) abundance in rather shallow waters; (ii) large mean size of the specimens; (iii) diurnal habits; (iv) thickness and stiffness of the tegument that ensures a good processed trepang (bêche-de-mer). The first three characteristics make the commercial species very vulnerable to overexploitation.

An introduction is given on the four areas and the sub-areas of each main area, with general characteristics. Given the characteristics of the commercial species, they are found in the different shallow benthic environments, generally distant from estuaries as

FIGURE 1

Region under study and countries covered in this review (highlighted in yellow). The region encompasses the FAO Statistical Areas 51 (Western Indian Ocean), 57 (Eastern Indian Ocean), 34 (Eastern Central Atlantic) and 47 (Southeast Atlantic)

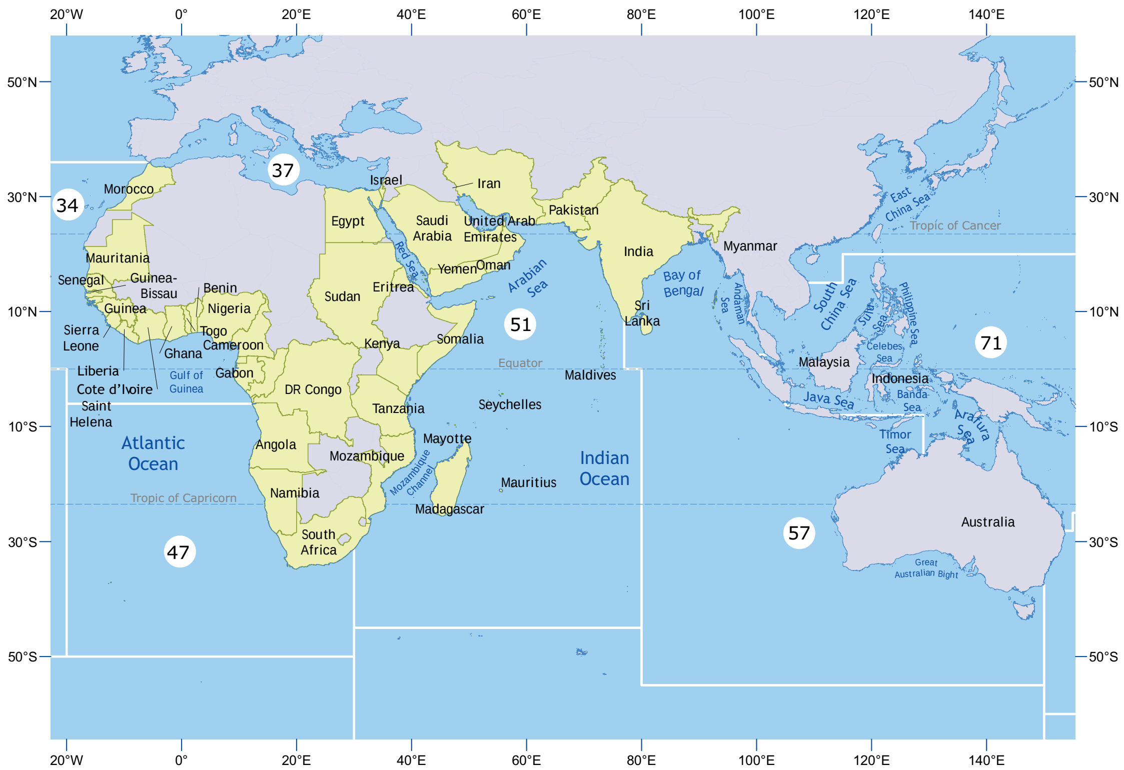


TABLE 1
Countries in the Africa and Indian Ocean region organized according to FAO fishing areas and sub-areas. Countries with documented sea cucumber fisheries are in italics and bold

FAO Area	FAO Sub-Area		Country	Main references
Western Indian Ocean (51)	51.1	Red sea	***Egypt***	Lawrence *et al.,* 2004; Ahmed and Lawrence, 2007
			Sudan	–
			Eritrea	Tewelde and Jeudy de Grissac, 2007; Kalaeb *et al.* 2008
			Saudi Arabia	–
			Israel	–
			United Arab Emirates	–
	51.2	Gulf	Djibouti	–
	51.3	Western Arabian Sea	***Oman***	Al-Rashdi, Al-Busaidi and Al-Ramadi, 2007
			Yemen	–
			Iran IR	Tehranifard *et al.,* 2006
	51.4	Eastern Arabian sea	Pakistan	–
			India	James, 1982, 1994b, 2001
			Chagos	Spalding, 2006
			Maldives	Reichenbach, 1999
	51.5	Somalia Kenya Tanzania	***Somalia***	Lovatelli, 1995
			Kenya	Marshall, Milledge and Afonso, 2001; Muthiga, Ochiewo and Kawaka, 2007; Samyn, 2003
			Tanzania	Marshall, Milledge and Afonso, 2001; Mmbaga and Mgaya, 2004; Mgaya and Mmbaga, 2007
	51.6	Madagascar, Mozambique Channel	***Madagascar***	Conand *et al.,* 1997, 1998; Mara *et al.,* 1997; Conand, 1999; Rasolofonirina, 2007
			Comoros	Samyn, Vanden-Spiegel and Massin, 2005, 2006
			Mayotte	Pouget, 2004, 2005; Conand *et al.,* 2005
	51.7	Islands	***Mauritius***	Arakaki and Fagonee, 1996; Conand and Muthiga, 2007b
			Réunion	Conand, 2003; Conand and Mangion, 2002; Conand and Frouin, 2007
			Seychelles	Aumeeruddy *et al.*, 2005; Aumeeruddy, 2007, 2008
	51.8	Mozambique	***Mozambique***	Marshall *et al.,* 2001; Hill, 2008
Eastern Indian Ocean (57)	57.1	Bay of Bengal	***India***	see 51.4
			Sri Lanka	Adithya, 1969; Terney Pradeep Kumara, Cumaramathunga and Linden, 2005
			Myanmar	see Choo, this volume
			Malaysia	see Choo, this volume
	57.2	Northern	Indonesia	see Choo, this volume
	57.3	Central		–
	57.4	Oceanic		None
	57.5	Western Australia	Australia	see Kinch *et al*., this volume
	57.6	Southern Australia	Australia	see Kinch *et al*., this volume
Eastern Central Atlantic (34)	34.1	Northern coastal	Morocco	No information available
			Mauritania	No information available
			Senegal	No information available
	34.2	Northern oceanic		No information available
	34.3	Southern coastal	Guinea Bissau	No information available
			Guinea	No information available
			Sierra Leone	No information available
			Liberia	No information available
			Ivory coast	No information available
			Ghana	No information available
			Togo	No information available
			Benin	No information available
			Nigeria	No information available
			Cameroon	No information available
			Equatorial Guinea	No information available
	34.4	Southern oceanic		No information available
				No information available
Southeast Atlantic (47)	47.1	Western coastal	Gabon	No information available
			Congo	No information available
			Rep Congo	No information available
			Zaire	No information available
			Angola	No information available
			Namibia	No information available
	47.2	Agulhas coastal	South Africa	No information available
	47.3	Southern oceanic		No information available
	47.4	Tristan da Cunha		No information available
	47.5	St Helena and Ascencion		No information available

most echinoderms are stenohaline organisms (intolerance to changes in salinity), with the possible exception of the sandfish *Holothuria scabra* (Conand, 1989; Hamel *et al.*, 2001); coral reefs, grass beds, or lagoons are favourable environments (Conand, 1989, 1990; Conand and Muthiga, 2007a).

Western Indian Ocean (FAO 51)

The Western Indian Ocean is divided in eight sub-areas and includes 24 countries. Only 16 countries had available documented information on sea cucumbers. Sea cucumber fisheries occur traditionally in most of them. However, it has changed during the last decade and show depletion of the stocks in many countries (Conand, 2004a, 2006b; Conand and Muthiga, 2007a). This has created awareness for management which have been raised at different stages and has had more or less success.

Eastern Indian Ocean (FAO 57)

The Eastern Indian Ocean is divided into six sub-areas and includes six countries. The sea cucumber fisheries are less important and less documented. Some will be presented in the Asia regional review (as Bay of Bengal) (Choo, this volume) and some are parts of Australia and the Pacific Island Countries and Territories (PICTs) (Kinch *et al.*, this volume).

Eastern Central Atlantic (FAO 34)

The Eastern Central Atlantic encompasses the areas of the tropical Atlantic on Africa's northwest coast. It is divided into four sub-areas and includes 14 countries. A few studies have been conducted on the inventories of Echinoderms, including sea cucumbers, but there is presently no sea cucumber fishery or information available in any of the countries.

Southeast Atlantic (FAO 47)

The Southeast Atlantic is divided into five sub-areas surrounding the southern part of the African continents, and includes seven countries. Many studies have been conducted on the inventories of sea cucumber species, mostly in the Republic of South Africa (Thandar, 2007), but currently no information is available on cucumber fishery and aquaculture.

This regional review will therefore concentrate on the Indian Ocean where information has been accessible for several countries. The information reported in this review is mostly based on articles from the 26 published Bêche-de-mer Information Bulletins (SPC 1970 to 2007) (www.spc.int/coastfish/), CITES meetings (Bruckner, 2006; Toral-Granda, 2007b), the FAO Workshop on Advances in Sea Cucumber Aquaculture and Management (ASCAM report; Lovatelli *et al.,* 2004), the ongoing Marine Science for Management (Masma) programme of the Western Indian Ocean Marine Science Association (WIOMSA) (Conand *et al.,* 2006; Conand and Muthiga, 2007a), and personal unpublished information and data.

2. BIOLOGICAL AND POPULATION STATUS

2.1 Key taxonomic groups

Within the region the key taxonomic group targeted for commercial purposes are the families Holothuriidae and Stichopodidae from the order Aspidochirota. These families comprise 100 percent of the catch. Table 2 presents the main 30 species fished, arranged taxonomically and with their commercial importance ranked from high (1) to low (4). These categories, sometimes different from previous documents (Conand, 1999, 2006a, b) and may well change in the future with the level of exploitation and the country concerned.

TABLE 2
Main commercial sea cucumber species in Africa and Indian Ocean. Value: 1 = high commercial value; 2 = medium commercial value; and 3 = low commercial value

Family	Genus	Species	Common name	Value
Holothuriidae	*Actinopyga*	*echinites*	Deep water redfish	2
		lecanora	Stonefish	3
		mauritiana	Surf redfish	2
		miliaris	Blackfish	2
	Bohadschia	*atra*	Tigerfish	3
		marmorata	Brownfish	3
		vitiensis	Brownfish	3
		subrubra	Leopardfish	3
	Pearsonothuria	*graeffei*	Flowerfish	3
	Holothuria	*atra*	Black lollyfish	3
		coluber	Snakefish	3
		cinerascens	–	3
		edulis	Pink lollyfish	3
		impatiens	–	4
		leucospilota	–	3
		notabilis	–	3
		nobilis	Black teatfish	1
		fuscogilva	White teatfish	1
		"pentard"	Flower teatfish	1
		fuscopunctata	Elephant trunkfish	2
		scabra	Sandfish	1
		scabra versicolor	Golden sandfish	1
		spinifera	–	3
Stichopodidae	*Stichopus*	*chloronotus*	Greenfish	2
		herrmanni	Curryfish	2
		horrens	–	3
		quadrimaculatus	–	4
	Thelenota	*ananas*	Prickly redfish	1
		anax	Amberfish	2

Source: Conand and Muthiga, 2007a.

This list was based on Bruckner (2006) and Toral-Granda (2006, 2007a, 2007b); however, some species have been added given the recent data from the Masma project in the WIO region (Conand and Muthiga, 2007a), which shows new species entering trade (i.e. *Holothuria* sp. "pentard" which is dominant, yet undescribed, in the Seychelles fishery [Aumeeruddy, 2007]; *H. notabilis* in Madagascar [Rasolofonirina, 2007] and *H. spinifera* fished in Sri Lanka and other islands [James, 1989]).

2.2 Biology and ecology of sea cucumbers

Due to the large number of species and countries covered in this review, a synthesis of the ecological and reproductive information available for each of the sea cucumber species in the region is presented in Table 3. More detailed information on a species basis is provided in the following sections.

Clark and Rowe (1971) and Richmond (1997) presented the general geographic distribution of the holothurians in the region. Recent papers on more specific localities have been published by Samyn (2003), Muthiga, Ochiewo and Kawaka (2007) for Kenya, Conand (2003), Conand and Mangion (2002), Conand and Frouin (2007) for Réunion, Rasolofonirina (2007) for Madagascar, Aumeeruddy (2007) for Seychelles, Marshall, Milledege and Afonso (2001) for Mozambique and Tanzania. Conand and Muthiga (2007b) have also summarised other recent data for the WIO (Conand and Muthiga, 2007a).

TABLE 3
Summary of ecological and reproductive information available for sea cucumber species in Africa and Indian Ocean. Geographical distribution – given the large number of countries and species, two categories are defined: W = wide distribution and R = restricted to a few countries within the region; NA: no information available

Genus	Species	Geographical distribution	Habitats	Substrate	Depth range (meters)	Ecological role	Other notes of interest on behaviour	Sexual reproduction	Size at Sexual Maturity	Larval development type	Fission (season and rate)
Actinopyga	*echinites*	W	Reef flats and seagrass	Coral and rubble	0–10	Deposit-feeder		Warm season	45 g		
	lecanora	W	NA	NA	NA						
	mauritiana	W	Outer reef flats	Coral	0–5	Deposit-feeder		Warm season	23 cm TL		
	miliaris	W	Reef flats and seagrass	Sand	NA	Deposit-feeder					
Bohadschia	*atra*	W	Seagrass	Sand	NA	Deposit-feeder					
	marmorata	W	Back reef, seagrass	Sand	0–20	Deposit-feeder	Burying				
	vitiensis	W	Back reef, seagrass	Sand	0–20	Deposit-feeder	Burying	Warm season			
	subrubra	W	Rubble	Sand	0–30	Deposit-feeder	Buried during day				
Pearsonothuria	*graeffei*	W	Living coral	Hard substratum		Deposit-feeder					
Holothuria	*atra*	W	Back reef, reef flats	Sand and Rubble	0–10	Deposit-feeder, bioturbation, productivity		Warm season			X cool season
	coluber	R	Back reef	Rubble	NA						
	cinerascens	W	Outer reef	Hard	0–3	Filter-feeding					
	edulis	W	Seagrass, lagoons	Sand	0–30						
	leucospilota	W	Back reef, reef flats	Sand and rubble	0–10	Deposit-feeder, bioturbation, productivity		2 seasons: February – May	180 g (total weight)		X, low rate
	notabilis	R (Madag.)	Lagoon, seagrass	Sand	0–10	Deposit-feeder					
	nobilis	W	Reef flats, slopes	Rubble	0–40	Deposit-feeder					
	fuscogilva	W	Slopes, lagoons	Sand	10–50	Deposit-feeder					
	"pentard"	R (Seych.)	Lagoons	Sand	10–50				1 500 g		
	fuscopunctata	W	Lagoons, seagrass	Sand	0–20	Deposit-feeder					
	scabra	W	Back reef,	Muddy sand	0–5	Deposit-feeder, bioturbation, productivity	Burying	November to April; mature individuals all year		Planctotrophic 2 weeks; epibiont juveniles 6 weeks	
	scabra versicolor	W	Lagoons	Sand	0–30	Deposit-feeder					
	spinifera	R India, Sri Lanka	Lagoons		NA			Warm season			
Stichopus	*chloronotus*	W	Reef flats	Rubble	0–5	Deposit-feeder					
	herrmanni	W	Lagoons, seagrass	sand	0–30	Deposit-feeder					
	horrens	W	Lagoons, seagrass	Sand, rubble	0–5	Deposit-feeder	Nocturnal	Warm season			X, cool season
	quadrimaculatus	R	Reef flats	rubble	0–5	Deposit-feeder	Nocturnal				
Thelenota	*ananas*	W	Coral slopes	hard	5–35	Deposit-feeder					
	anax	R	Lagoons	sand	10–40	Deposit-feeder					

Family Holothuriidae

Genus *Actinopyga*

Actinopyga echinites

Actinopyga echinites (the common name is deep water redfish, which does not correspond to its ecology) is a medium-sized species whose tegument varies in colour from light brown to orange. It has numerous papillae dorsally and the anus is ringed by five calcareous teeth as for the other species of this genus. The Cuvierian tubules are rarely expelled. It is a common species on the shallow reef flats of the region. On Réunion reefs, it is mostly found on outer reef flats with oxygenated waters, with a maximum density of 3 ind. m^{-2} (Conand and Mangion, 2002).

Some traits of its population biology (densities, reproduction, biometry) have been studied from Réunion as part of the Masma (WIOMSA) regional project. This first study in the region shows that the sexual reproduction is annual during the warm season and the weight at first maturity is at 45 g (Kohler, Conand and Gaudron, 2007). This species lives exposed on the hard substrate, without burying.

Actinopyga lecanora

Actinopyga lecanora (common name stonefish) is also a medium-sized species whose tegument makes it look as a stone. It is found in many countries in the region, but specimens are relatively rare and its biology has never been studied.

Actinopyga mauritiana

Actinopyga mauritiana (common name surf redfish) is relatively large, with a mean total length of 20 cm and up to 35 cm. Its medium weight is 380 g in Réunion (Conand and Mangion, 2002). It is common in most countries of the region. Its colour is variable according to locations, from uniform brown to dark brown; some specimens have a brown median band and are whitish laterally. The trivium is generally white. There are different morphs in the Indian Ocean and Pacific.

The habitat is restricted to the outer reef flats under the influence of the surf, where the individuals are exposed and hold strongly to the hard bottom (Conand, 1989). There is a narrow transition zone where *A. echinites* and *A. mauritiana* can be found together.

Several studies on the biology have been conducted in the Pacific (Conand, 1989, 1993; Ramofafia, Battaglene and Byrne, 2001) where the sexual reproduction occurs during the warm season. In Egypt (Red Sea) the reproduction has been studied and takes place between spring and summer; the spawning is partial and the gonads are reabsorbed at the end of the season; individuals are mature at 23 cm total length; after artificially induced fission the regeneration is generally slow (Gabr *et al.,* 2004).

Actinopyga miliaris

Actinopyga miliaris (common name blackfish) is a species with black tegument and characteristic five anal teeth. This species averages 20–25 cm total length. The individuals live in shallow waters up to 20 m on seagrass beds or rubble (Conand, 1989). Despite the high densities of some populations, there are no references on the biology of this species. They are found in Comoros, Mayotte, Madagascar, Seychelles and Kenya, but not in the Mascareigne Archipelago (Réunion, Mauritius, Rodrigues). They are actively fished in Kenya with *A. miliaris* contributing to 17 percent of the total catches in the two main landing beaches (Muthiga, Ochiewo and Kawaka, 2007). This species lives exposed on hard bottoms or in seagrass beds, without burying (Conand, 1989).

Genus *Bohadschia*

The species are of medium-low commercial value. Their Cuvierian tubules are very abundant and sticky which makes the processing difficult. They are usually collected when overexploitation has diminished the abundance of other commercial species.

Bohadschia atra

Bohadschia atra was recently taxonomically described (Massin *et al.*, 1999) and although no official records existed it was already commercially exploited. This shows that even large species, exploited in some places are probably still undescribed. It had probably been misidentified previously as *B. argus* and the fishermen call it tigerfish, the same name as *B. argus*. It is a black species with brown spots, numerous Cuvierian tubules. Since its description, it has been observed in several countries and it is a rather common species inhabiting shallow waters on sandy bottoms. Individuals do not bury themselves under the substratum.

Bohadschia subrubra

This species recently received interest as a commercial species (Conand 1999), and was re-described from Madagascar by Massin *et al.* (1999) (first described by Quoy and Gaimard in 1833 from Mauritius). It has an external appearance similar to *B. atra*, but its bivium is brown to orange with black areas that makes it easy to distinguish. Its Cuvierian tubules are expelled rapidly in large quantities. It is also a large species and may grow up to 35 cm. It is common in the region and populations are abundant; no studies have yet been conducted on its biology.

Several other *Bohadschia* species are not so easy to distinguish (Samyn, 2003) and there are probably yet some misidentifications between *B. marmorata, B. vitiensis, B. cousteaui* and *B. bivittata*.

Bohadschia vitiensis* and *Bohadschia marmorata

Bohadschia vitiensis has recently been identified by C. Massin (Département des invertébrés, Institut royal des sciences naturelles, Belgium, personal communication) from Réunion specimens and from Comoros (Samyn, Vanden-Spiegel and Massin, 2006) where *B. marmorata* has not been found.

The morphology of these species is rather similar; the body is cylindrical, up to 30 cm in length. The bivium is light brown dorsally spotted by brown dots in the tube feet, the trivium yellow-white; transverse banding could characterize some *B. marmorata*. The abundant large Cuvierian tubules are rapidly ejected when disturbed. *B. vitiensis* lives in rather dense populations in shallow back reef areas, where the individuals burrow into the anaerobic sand during the night and emerge at the surface of the oxygenated sand in the morning around 10 A.M. at Réunion (Conand, unpublished data). The characteristic behaviour during sexual reproduction (individuals in an upright position expelling sperm or oocytes out of swollen gonopores), has been described from Réunion during the warm season (Gaudron, 2006). Sexual reproduction also occurs during the warm season in Madagascar (Rasolofonirina, 1997).

Bohadschia vitiensis is cited for Kenya by Muthiga, Ochiewo and Kawaka (2007), while *B. marmorata* by Samyn (2003) and for the Seychelles by Aumeeruddy (2007). In Mauritius, *B. marmorata* is cited by Arakaki and Fagonee (1996). Its distribution and abundance in Mauritius in Trou d'Eau Douce has been described by Muller (1998) and in La Preneuse and Baie du cap sites by Luchmun *et al.* (2001). A taxonomic revision of the genus *Bohadschia* is still needed.

Genus *Pearsonothuria*

Pearsonothuria graeffei

Its previous name was *Bohadschia graeffei.* It is a species easy to distinguish given the elongated body, mottled grey and cream dorsally and with three bands of tube feet ventrally; the black oral tentacles bordered with a pale zone are conspicuous. The Cuvierian tubules are present but not expelled. The average length is 35 cm. It lives in shallow reefs, often feeding day and night on detritus found on corals. The species does not burrow. It is found in most countries of the region. Little is known on its biology. The juvenile of this species is different from the adult and very characteristic, looking like Phyllidiidae nudibranchs. The commercial value of this species is low as the tegument is thin; a fishery should therefore not be encouraged.

Genus *Holothuria*

Holothuria atra

It is the most abundant and frequent holothurian in all countries within the region (common name: black lollyfish), and therefore one of the most studied species despite its low commercial value (Conand, 1996; Jaquemet, Rousset and Conand, 1999; Uthicke, Conand and Benzie, 2001; Conand and Mangion, 2002; Conand, 2004a; Mangion *et al.*, 2004; Taddei, 2006). It is a black cylindrical species with the body often covered with sand, except in circular areas, with most specimens living in back-reef areas. Populations from the outer reef flat are composed of larger individuals uniformly covered in sand and presenting wart-like protrusions on the dorsal area. The populations have mostly been studied from the tropical Pacific (see references in Conand 1990; Conand and De Ridder, 1990). A few studies from the Indian Ocean show the characteristics (density, size) of the populations of this species; fission is an important mode of reproduction. In Réunion *H. atra*, showed higher densities in La Saline reef than *H. leucospilota* another common species in the site. The mean value in the reef was 0.68 ± 1.67 ind. m^{-2}. *H. atra* was dominant in back reefs (1.44 ± 2.46 ind. m^{-2}). However the distribution of this species over the reef complex is highly heterogeneous. Maximum values of 5.1 ± 0.1 to 6.6 ind. m^{-2} (Fabianeck and Turpin, 2005; Conand and Mangion, 2002) have been recorded in one back reef station, whereas no individuals were observed from other back reefs. In inner reef flats, densities were inferior to 0.1 ind. m^{-2}.

Conand (1996) had pointed the existence of populations with different biometric parameters, with larger individuals and low densities on the outer reef flats and smaller individuals in back reef and inner reef flat stations; these are also characterised by high fission rates. Conand (2004c) analysed data collected from 1993 to 2000 and found stable densities over the long term (average 4.7 ± 0.3 ind. m^{-2}), which could be partly explained by this particular mode of reproduction.

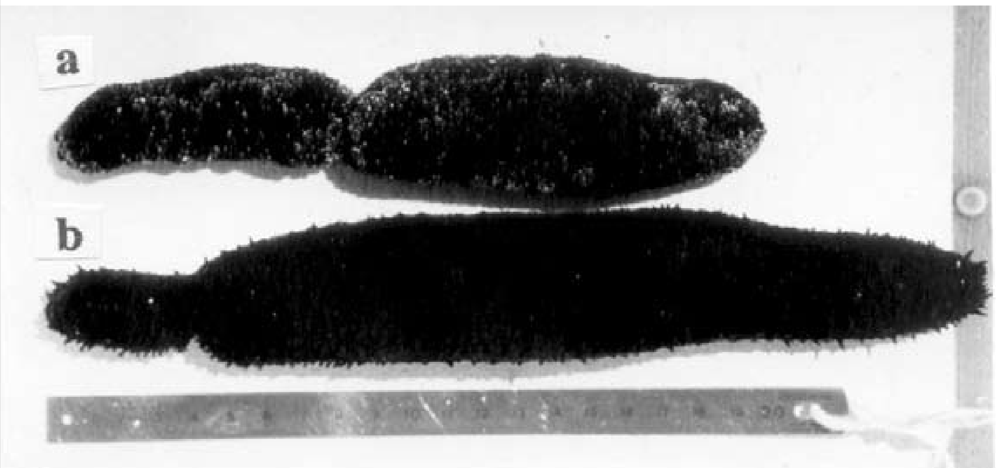
The nutrition of *H. atra* has recently been studied, as the species is a major component of the soft-bottom reef communities (Conand and Mangion, 2002; Taddei, 2006). The nutrition of the two dominant species, *Holothuria atra* and *H. leucospilota,* has first been studied at two sites, one eutrophicated and one oligotrophic (Mangion *et al.*, 2004). A relation has been 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 characterise oligotrophic areas. Gut content analysis showed that the organic matter ingested from the sediment was used with 10 percent efficiency for both species (Mangion *et al.,* 2004). The Carbon:Nitrogen 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). Holothurians from the oligotrophic reference station appeared to discriminate soft bottom patches with high nutritional value. In contrast, no selectivity was observed in the eutrophicated stations. *H. atra* also shows a significantly higher assimilation than *H. leucospilota*. Data suggest that efficiency of assimilation decrease with the eutrophication gradient. More recently, Taddei (2006) evaluated globally the role of the soft-bottom compartment during the transfer of matter and energy in the reefs. The holothurian biomass constituted a major element that could reach 7.92 g dry weight. m^{-2} in the most productive areas. The soft-bottoms played a key role in catching the organic matter provided by the back-reef. This was deeply influenced by the high hydro-dynamism which modulated the loss of mater and energy of the reef. These losses were however limited by the action of the holothurians, which stored organic matter such as biomass and probably enhanced local production.

The sexual reproduction of *H. atra* has attracted considerable research (Conand, 1981, 1982, 1989, 1993, 2006a). The reproductive biology (sexual and by fissiparity), population variations and genetics for this species have been described (Uthicke, Conand and Benzie, 2001; Conand, Uthicke and Hoareau, 2002; Uthicke and Conand, 2005b). The characteristics of the different stages in fission and regeneration have been described. Asexual reproduction (Figure 2) 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 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 Réunion Island reef (Conand, 2004b). These results are relevant to the assessment of species productivity which is affected by fission in addition to growth and recruitment.

The population genetics has been compared between the Torres Strait (Pacific) and Réunion to investigate connectivity between populations separated by large geographic distances (Uthicke, Conand and Benzie, 2001). This is the first study on genetics of a sea cucumber from the Indian Ocean. This comparison has shown that a high gene flow exists between the regions. Nevertheless, pooled populations within each region were significantly different from those of the other region. Despite the importance of asexual reproduction, the potential for widespread dispersal mediated by sexually produced larvae is large.

H. atra moves while ingesting the sediment at a rate of 30 cm h^{-1}; it is able to ingest the sediment under the surface, but it does not burrow (Taddei, 2006).

FIGURE 2
Fission in *H. atra* (a) at 1/3 of the length from the mouth and *H. leucospilota* (b) at 1/5 of the length



COURTESY OF C. CONAND

Holothuria coluber

Holothuria coluber (common name: snakefish) is a low commercial value species, sometimes fished in Madagascar. The body is an elongated dark cylinder up to 50 cm in length. The dorsal podia are large and stout yellow or white, arranged in irregular rows while the ventral ones are dispersed on the trivium. The oral tentacles are pale yellow. They live in calm shallow waters, on sandy bottoms with rubble. The species is often covered with sand but does not burrow. The posterior part of the body is generally hidden under blocks, making it look as *H. leucospilota.* However, its rigid tegument and the colour of the papillae make it different from the former species.

Holothuria cinerascens

Holothuria cinerascens is a low commercial value species, sometimes fished in Madagascar. The species live in crevices, in shallow water reefs or beach rocks, with a strong hydro-dynamism. The dorsal podia are large and stout but few while the ventral ones are very numerous. The oral tentacles are pelto-digitated and the species filters water which is an exception among the aspidochirotids. The body is a short cylinder, brown, measuring from 12–18 cm in length; it is burrowed or hidden, only the mouth and tentacles surfacing with an appearance of a cauliflower (local name given in Madagascar). Very little is known on this species.

Holothuria edulis

Despite its species name (*edulis* means "edible") the pink lollyfish is of low commercial value and little is known apart its distribution. It looks like *H. atra*, but the colour is different, from pink to grey on the bivium, mostly pink on the trivium. The species attains up to 40 cm of length. It is reported to occur in several countries. The species is often covered with sand but does not burrow.

Holothuria leucospilota

Holothuria leucospilota is a conspicuous long black species very frequent and abundant in many countries of the region. In Réunion, the individuals were present in all back reefs and inner flat stations, with total mean density 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}. It is fished in several countries despite its low value.

Fission in *H. leucospilota* (see Figure 2) has been described for the first time in Réunion (Conand, Morel and Mussard, 1997). The morphology and anatomy of the different stages of the regeneration have been detailed and allow their observation in the field. The fission rates are much lower than for other species such as *S. chloronotus* or *H. atra*. Fission has now been observed on other reefs (Purwati and Luong Van, 2003; Drumm and Loneragan, 2005).

The modalities of the sexual reproduction have been followed in Réunion by monthly sampling. (Kohler, 2006; Gaudron, Kohler and Conand, 2007) and will allow comparisons with other WIO countries. Two peaks of spawning were found in Réunion, the first in February marked by a sharp decrease in the gonadal index and numerous individuals in post-spawning stage, the second peak in May. It reaches SOM at a weight of above 180 g. It is also studied in Kenya to allow a regional synthesis on this species (Kawaka and Muthiga, 2007).

As it is so common and abundant in the region, the effects of its nutrition have been evaluated on the reefs of Réunion as an average of 88.8 g dry weight.ind^{-1}.d^{-1} of sediment in the two sites studied (Mangion *et al.,* 2004). Holothurians from the oligotrophic reference station appeared to discriminate soft bottom patches with high nutritional value. In contrast, no selectivity was observed in the eutrophicated stations. Assimilation by *H. leucospilota* shows a lower rate than *H. atra* (Taddei, 2006). It moves while ingesting the sediment at a rate of 30 cm h^{-1}, without daily pattern and with periods without movement; *H. leucospilota* ingests the surface sediment with its large tentacles, but it does not burrow (Taddei, 2006).

Holothuria notabilis
This species, first described by Ludwig (1875), has been added to the list of commercial species, as it is presently one of the main species exploited in the south of Madagascar (Rasolofonirina, 2007), where it has been determined recently (Massin, C., Département des invertébrés, Institut royal des sciences naturelles, Belgium, personal communication). It lives in seagrass beds where the population biomass had already been estimated at 6 000 tonnes/ha (Mara *et al.*, 1997). This species has not been observed in other countries in the region. The holothurian fauna of Madagascar, based on Cherbonnier's (1988) studies, is the richest in the region. Its reproductive biology is presently under study (Rasolofonirina, R., Université de Toliara, Madagascar, personal communication).

Teatfish *Holothuria (Microthele).* There are two common teatfish species *H. nobilis* and *H. fuscogilva*; a third one, the "pentard", as it is called by the Seychelles fishers may need to be added to this group. These large species typically present lateral processes on the body wall known as "teats".

Holothuria nobilis
The common name of *Holothuria nobilis* is black teatfish despite more or less developed white to golden patches on the body wall. It has recently been separated from the Pacific black teatfish (*H. whitmaei*) by Uthicke, O'Hara and Byrne (2004) and in a near future other species may probably differ for the two regions, as (i) more attention is being paid to holothurians and, (ii) an increased use of genetic tools will allow better identifications.

H. nobilis is one of the species with the highest commercial value and therefore overexploited. It is a large species, up to 50 cm in length, loaf-shaped. The body is usually covered by sand but it does not bury. The Cuvierian tubules are present, but not expelled. The species occurs in a variety of coral reef habitats, in dispersed populations, at low densities. For example, only a few dispersed specimens have been seen on Réunion reefs, raising the question of successful egg fertilization if spawning and recruitment occurs (so far never detected).

Holothuria fuscogilva
Holothuria fuscogilva (common name: white teatfish) has been described by Cherbonnier (1980) from New Caledonia, but the fishers from the tropical Pacific had traditionally used different names for this white teatfish as well as the black teatfish (*H. nobilis* now *H. whitmaei)*. It is a large species (mean length 40 cm, maximum up to 60 cm) with a variable coloration from yellow to grey and often presents brown patches. It inhabits deep habitats, found up to 40 m depth, but its densities are generally low (Conand, 1989). Despite the taxonomic uncertainties (Samyn, 2003), it appears that it is now accepted as different from the black teatfish. However, it remains to be demonstrated if it is the same species in the Pacific and the Indian Ocean. Uthicke, O'Hara and Byrne (2004) using mtDNA sequences have shown that a large intraspecific sequence divergence exists indicating potential for presence of several cryptic species in a white teatfish complex.

It is fished in Comoros, Kenya, Madagascar and Seychelles, but now found much deeper than before, as it is highly overfished in coastal waters.

In the Maldives, Reichenbach (1999) assessed its ecology from three habitats. It is the dominant species in the lagoon floor and is also abundant in passes. The species recruits in shallow seagrass beds, as observed in Fiji (Conand, 1989) and then moves to deeper waters. The species is often covered with sand but does not burrow. Size at maturity was found to be the same as in New Caledonia (Conand, 1981, 1993) around 1.5 kilograms, which is a very late maturity. The growth is also probably very slow; they are long-lived and therefore sensitive to overexploitation.

***Holothuria* "pentard"**

This third teatfish (common local name: "pentard") is the main species collected and exported by Seychelles (Aumeeruddy, 2007; Aumeeruddy *et al*., 2005; Aumeeruddy and Conand, 2007) (Figure 3). It is also found in the Comoros (Samyn, Vanden-Spiegel and Massin, 2006). Future studies will help decide if it is another species or simply a variety of the black teatfish. Very little is known apart from its presence in the catches.

Holothuria fuscopunctata

Unlike the other *Holothuria (Microthele*), *Holothuria fuscopunctata* (common name: elephant trunkfish) has a low commercial value. It is yet a large species up to 60 cm length. The colour is characteristic, with a dorsal body wall yellow to light brown scattered with the darker spots of the tube feet. The body wall is thick. No Cuvierian tubules. It has been observed in Madagascar, Kenya, Seychelles, Comoros and Mayotte, but not in the Mascareigne Archipelago (Réunion, Mauritius, Rodrigues). It lives on coral sand in shallow waters, up to 30 m. The populations are not as abundant in the Indian Ocean as in the Pacific and individuals are rare and scattered. The species is often covered with sand but does not burrow.

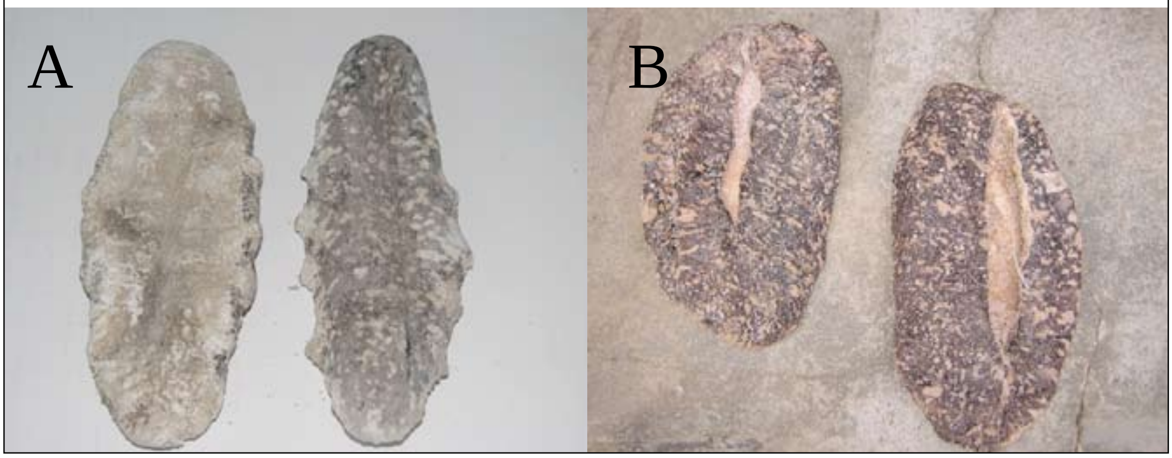
Sandfish *Holothuria scabra* and *H. scabra* var. *versicolor*

The two sandfish *Holothuria scabra* and *Holothuria scabra versicolor* (Conand, 1986, 1989, 1998b, 1999; Hamel *et al.,* 2001*)* have also raised considerable interest in recent years. These species have a high commercial value and rank probably number one on the world bêche-de-mer market. Genetic studies have recently allowed proper identification of the species. The results of the DNA and allozyme analyses show that they are distinct species (Uthicke, Purcell and Blockmans, 2005). In this review we still use the names *H. scabra* and *H. scabra* var. *versicolor*.

Holothuria scabra

Holothuria scabra (common name: sandfish) is largely distributed and probably supports most of the tropical captures of sea cucumbers for bêche-de-mer. It shows

FIGURE 3
Dried (a) and salted (b) specimens of "Pentard" teatfish from the Seychelles



COURTESY OF R. AUMEERUDDY AND C. CONAND some variability in colour between the Pacific and Indian Oceans. In the Indian Ocean it is most often grey to dark with small yellow patches or horizontal bands. Its lateral wrinkles are characteristic. It shows a preference for muddy sands and is often found in the vicinity of mangroves. Many studies (Kithakeni and Ndaro, 2002; Rasolofonirina *et al.,* 2005) and a recent synthesis (Hamel *et al.,* 2001) have been conducted on this species, which is also used for stock enhancement or aquaculture in different places (India, the Solomon, Madagascar, Indonesia). In India aquaculture experiences started well before other countries (James, 1994a, 1994b, 1996, 2004a, 2004b; James *et al.,* 1988). Such development then started in the Pacific with the support from The Worldfish Center in the Solomon Islands (Ramofafia, 2002; Mercier, Battaglene and Hamel, 1999) and New Caledonia (Purcell, 2004). More recently, the interest emerged in Madagascar where the aquaculture of this species has progressed with assistance from the Belgian cooperation (Jangoux *et al.,* 2001; Rasolofonirina, Mara and Jangoux, 2004; Rasolofonirina and Jangoux, 2005).

The reproduction of this species has been studied in Tanzania by Kithakeni and Ndaro (2002) and in Kenya by Muthiga, Kawaka and Ndirangu (2007). Rasolofonirina *et al.* (2005) detailed the gonad anatomy and the tubule's development from monthly samplings carried out at Toliara (Madagascar) from 1998 to 2001; these are synchronous within an individual but gametogenesis was not synchronous in the population; most individuals were mature or spawning between November and April. The burying behaviour of the adults has been described by Yamanouchi (1956) and of the juveniles by Mercier, Battaglene and Hamel (1999, 2000).

Holothuria scabra var. *versicolor*

Holothuria scabra var. *versicolor* (common name: golden sandfish) differs from *H. scabra* by a number of characters, including a larger mean size and a deeper habitat in New Caledonia (Conand, 1986, 1989, 1998a, b). The dorsal tegument is highly variable from beige to black, with many specimens having black patches. The papillae and tube feet are also more developed. Its seasonal reproductive cycle differs from *H. scabra.* The genetics has been studied by Uthicke, Purcell and Blockmans (2005). In the WIO, the reproduction has been studied from Madagascar; spawning is annual during the warm season and gametogenesis is synchronous in the population (Rasolofonirina, 1997). The burying behaviour, observed in New Caledonia (Conand, 1989), is not described from the Indian Ocean.

Holothuria spinifera

In India, the species *Holothuria spinifera* (common name: brown sandfish) is abundant (James, 2001). The species reaches 30 cm in length. In the Gulf of Mannar and Palk Bay it is found on clean sands where it burrows. In Sri Lanka it has the local name "Gal-atta" or "Weli-atta".

Family Stichopodidae

The main commercial Stichopodidae are less numerous than the Holothuriidae and belong to two genera *Stichopus* and *Thelenota*. Their characteristics are: a body square-shaped or trapezoidal in cross section, Cuvierian tubules always absent, gonad in two tufts appended on each side of the dorsal mesentery and dominant spicules in branched rods and C- and S-shaped rods.

Genus *Stichopus*

The genus *Stichopus* has a bivium covered by tubercules and papillae at least on its sides; the spicules develop as tables, branched rods and C and S rods.

Stichopus chloronotus

Stichopus chloronotus (common name: greenfish) is a rather small species with a firm body of quadrangular shape. Its green tegument gives origin to its common name. The ventral mouth is surrounded by a row of 20 stout tentacles. It lives in very shallow areas of the coral environment, with some populations attaining high densities. Some populations show a high rate of asexual reproduction by fission. In Réunion, *S. chloronotus*, exhibits two spawning seasons, similar to other populations previously studied on the Great Barrier Reef (GBR, Australia) (Franklin, 1980; Uthicke, 1997). However, this population is quite unusual in terms of the high densities recorded (3.7 ind. m^{-2}), low average specimen weights (between 35 and 80 g in the two populations sampled between 1998 and 2001) (Conand, Uthicke and Hoareau, 2002) and high rate of asexual reproduction (Conand *et al.*, 1998). Spawning has recently been observed at Étang Salé site by Barrère and Bottin (2007); fission occurs during the cool season (Conand, Uthicke and Hoareau, 2002). The population genetic has been compared between Pacific and Indian Ocean sites, showing that asexual reproduction is an important feature in most populations, over a wide geographic range, but also that the potential for widespread dispersal mediated by sexually produced larvae is large (Uthicke, Conand and Benzie, 2001). More recently, amplified fragment length polymorphism (AFLP) analysis have indicated 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, 2005b). It is a very common species throughout the region. It does not burrow.

Stichopus herrmanni

*Stichopus herrmanni (*formerly called *variegatus*) (common name: curryfish) is a medium-sized species (mean length about 35 cm), but larger specimens have been observed. The firm body wall disintegrates easily when collected, as in other *Stichopus.* Its colour, yellow to greenish gives it its name of curryfish. The bivium is covered by irregular conical warts arranged in eight longitudinal rows, with smaller papillae in between. It occurs in reefs and lagoons, in seagrass beds, rubbles and muddy-sand bottoms. It is not rare in Kenya and Madagascar. The sexual reproduction takes place during the warm season in the Pacific. The only study in the Indian Ocean by Tehranifard *et al.* (2006) in Kish Island (Islamic Republic of Iran) also shows a summer spawning. The authors have calculated that the average body length at first maturity is 310 mm and the diameter of mature oocytes is 200 µm. This species does not burrow and is able to move rapidly when disturbed.

Other Stichopus species are quite difficult to distinguish and need a taxonomic revision: *S. horrens, S. monotuberculatus, S. quadrifasciatus, S. quadrimaculatus* and *S. naso*.

Stichopus horrens

It is presently heavily exploited in Madagascar (under the name "smurf"), but yielding a rather low quality product (Rasolofonirina, 2007). The body is square in cross section and the length is up to 40 cm. Dorsal papillae are conspicuous. The reproductive biology is presently studied as part of the Masma (WIOMSA) project (Rasolofonirina, R., Université de Toliara, Madagascar, personal communication); it will be the first study for this species in the Indian Ocean. Fission has recently been described in Japan (Kohtsuka, Arai and Uchimura, 2005). The species is mentioned from several countries of the region and seems to have a wide distribution, as it currently illegally fished in the Galapagos Islands (Hearn and Pinillos, 2006). It does not burrow, but hides under rocks during the day.

Stichopus monotuberculatus
In Réunion, the species previously called *S. horrens* has been identified as *S. monotuberculatus* (Massin, C., Département des invertébrés, Institut royal des sciences naturelles, Belgium, personal communication). It is probably also found in Comoros, Madagascar and other places. In length it averages 35 cm. The species is nocturnal and hides contracted under rocks or rubbles during the day, which explains why it has not been observed all that frequently.

Genus *Thelenota*

Thelenota ananas
Thelenota ananas (common name: prickly redfish) is a large species (maximum length 85 cm; mean 45 cm) found in the reef environment. It is fished in several countries as it has a high commercial value. Although it is still found in storage rooms of collectors and middlemen from Madagascar and the Seychelles (Aumeeruddy and Conand, 2007), this species is now becoming increasingly rare. Its bright orange-red to brown in colour and the large papillae give it a pineapple appearance and make it very vulnerable to fishing. Its densities are generally low. It lives in coral reef environment, mostly on outer slopes. It is observed in Comoros, Mayotte (including Geyser Banks, see Mulochau, Conand and Quod, 2007), Madagascar, Kenya and Seychelles. It is very rare in Réunion. The potential fecundity is low and sexual maturity late in New Caledonia (Conand, 1989, 1993), compared with other species from the Holothuriidae (from studies in New Caledonia by Conand, 1981, 1993) which makes it vulnerable to overexploitation. Few studies have been made on its biology. It does not burrow.

Thelenota anax
Thelenota anax (common name: amberfish) is even larger (mean length 60 cm; up to 90 cm) than *T. ananas*. The body is squarish. Despite its medium commercial value, it is exploited in several countries. It lives exposed on white coral sand at the base of the relatively deep reef slopes. Nothing is known about its biology. It is cited from Comoros, Madagascar, Seychelles and Kenya, and more recently from South Africa, but not from the Mascareigne Archipelago or the Red Sea. Nothing is known about its biology in the region. It does not burrow.

A conclusion from the above summary is that the biology of most species has received less attention in the Indian Ocean than in the Pacific where many studies started in the 1980s. The regional Masma project from WIOMSA (Conand *et al.,* 2006; Conand and Muthiga, 2007a) will shortly contribute new data on the reproductive and fishery biology of several commercial species.

Globally the main ecological role of these detritus-feeders is bioturbation of the sediments and building organic matter from bacteria and micro-phytobenthos. More attention is currently given to their specific role in tropical ecosystems (Taddei, 2006; Wolkenhauer, S., Australian Commonwealth Scientific and Research Organization [CSIRO], Australia, personal communication).

Genetic analysis is only starting in the region (Uthicke and Benzie 2003; Uthicke, Conand and Benzie, 2001; Uthicke and Conand, 2005b; Kerr *et al*., 2005); some studies have been concentrating on comparisons with Australian populations of *H. atra, S. chloronotus* and *H. nobilis* (Uthicke, Conand and Benzie, 2001; Uthicke and Conand, 2005b) as little is known on the connectivity among populations.

Several species can reproduce by fission, but they also reproduce sexually with a seasonal periodicity (Conand, Uthicke and Hoareau, 2002). Recruitment from sexual reproduction is still poorly understood, as the juveniles are not found for most species, apart for a few anecdotal observations (Shiell, 2004a, b, 2005). Burying is known from several species, but needs scientific investigations to understand its rhythms and its effects. Aestivation is not observed for any of the tropical Indo-Pacific species.

2.3 Background of sea cucumber fishery

Following the data presented during two recent and important workshops (Lovatelli *et al.,* 2004; Bruckner, 2006), the review will first concentrate on the WIO where a recent synthesis for the regional Masma (WIOMSA) project has been prepared (Conand and Muthiga, 2007a).

Kenya

In Kenya the sea cucumber fishery is (Muthiga, Ochiewo and Kawaka *in* Conand and Muthiaga, 2007a) primarily artisanal as many other coastal fisheries along the Kenyan coast, however it does contribute to the livelihoods of fisher households (Muthiga and Ndirangu, 2000; Marshall, Milledge and Afonso, 2001; Beadle, 2005; Conand and Muthiga, 2007a). The fishery has been in existence since the early 1900s as shown by Kenya National Archives (KNA) and Government reports (1985, 1991). Many species have local names, indicating the cultural identification of this fishery by the local communities. Sea cucumbers are currently collected either as bycatch 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 the collectors carry out the processing and drying at the landing beaches. The local level dealers in turn sell their products to a few exporters based in the coastal capital of Mombasa that export to China Hong Kong SAR. 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, Milledge and Afonso (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 licence ended but his family members and other interested parties could take up the concession. The fishery was then considered very lucrative. 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.

Réunion

Holothurians have never been exploited in Réunion, because the reefs are so small that the resource would be depleted within a few days or weeks and the valuable species are not abundant (Conand and Frouin *in* Conand and Muthiga, 2007a). Some projects presented to local administrations have always been discouraged, as the scientists rejected them as a precautionary approach.

Madagascar

In Madagascar sea cucumber harvesting is a traditional and permanent activity in coastal regions, especially near coral reefs (Conand *et al.*, 1997; Rasolofonirina, Mara and Jangoux, 2004; Rasolofonirina *in* Conand and Muthiga, 2007a). This activity steadily expanded from the early 1990s and it is currently rather intense on the west coast of Madagascar (Petit, 1930; Rasolofonirina and Conand, 1998). Fishers collect various resources on the reef flat, during the low tide, such as shellfish, urchins, octopus and sea cucumbers (Rosa, 1997; Rakotonirina, 2000). Presently, 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* and *Thelenota ananas* are the main collected species. *Holothuria notabilis* which has recently been described for Madagascar (Massin, C., Département des invertébrés, Institut royal des sciences naturelles, Belgium, personal communication) is also intensively fished.

Seychelles

In Seychelles, the fishery has developed recently and has been closely followed by the Seychelles Fishing Authority (SFA) through an FAO project (Aumeerudy *in* Conand and Muthiga, 2007a). The Seychelles has been chosen as the hotspot presentation (see Aumeeruddy and Conand, this volume, for more details). Sea cucumbers in Seychelles have been fished for more than a hundred years, with reports of bêche-de-mer exports dating back to the late 1800s (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 bêche-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 most of the harvesting is done by divers using SCUBA gear. A lot of fishers have entered the fishery during the last eight years, and the fishery which was uncontrolled and unregulated, had to be put under management. The national fisheries authority first placed a number of management measures in 1999 in view of the local depletion of some species. The measures adopted included a licensing system for fishing and processing sea cucumbers, a quota on the number of fishing licenses allocated annually, and limits of four 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) listed 115 Echinoderm species, detailed 151 species, including 35 sea cucumbers and gave some brief information on the ecology of the most common ones.

Tanzania

Sea cucumbers constitute an important marine resource for Tanzania (Semesi *et al.*, 1998; Marshall, Milledge and Afonso, 2001; Mgaya and Mmbaga *in* Conand and Muthiga, 2007a). There has been a rapid expansion of sea cucumber exploitation at some sites of Tanzania (Mgaya, Muruke and Semesi, 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 few exporters. Local exploitation occurs year-round on reefs close to the shore sheltered from prevailing winds. The peak in the collection of sea cucumbers falls in the period October to December and April to May when winds are usually light, and trips can be made to the outer reefs. The level of exploitation differs from shore to shore depending on fisher experience, number and category of fishers, fishing techniques used 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 to China mainland, China Hong Kong SAR and Singapore (Marshall, Milledge and Afonso, 2001). The increase in export of bêche-de-mer was observed from 1980s (< 200 tonnes per annum) to 1992 (617 tonnes) while they have continued to decline thereafter (Marshall, Milledge and Afonso, 2001). These authors report further that the number of official bêche-de-mer exporters on the Tanzania mainland has decreased from 23 tonnes in 1993 to 8 tonnes in 1997 and that the exporters have largely halted exports as a result of the declining profits. A list of 15 species currently harvested dates back to the synthesis by Marshall, Milledge and Afonso (2001) and includes *Actinopyga miliaris*, *Bohadschia* sp., *Stichopus variegatus* (now *herrmanni*) and *Bohaschia argus* (probably *B. atra*).

Comoros
The fishery of Comoros is briefly addressed in Samyn, Van den Spiegel and Massin (2005). They express their deepest "concern with regards to the present, rather blind, overexploitation of sea cucumbers in the Comoros" giving a few qualitative observations to support this. They have recently produced a detailed description (in French) of the different species and their habitat (Samyn, VandenSpiegel and Massin, 2006). The harvesting and processing is controlled by Chinese immigrants.

Mayotte
In Mayotte, several brief studies have shown that the same problems are encountered (Pouget, 2004, 2005; Conand *et al.,* 2005). Mulochau, Conand and Quod (2007) in a quantitative evaluation have shown that in the different habitats from Geyser Bank (off Mayotte), the sea cucumbers are presently very few and only from a few species; it is highly probable that they have now been fished.

Mauritius
The Mauritius (including the islands of Rodrigues and Saint Brandon) holothurian fauna has attracted attention recently, but a few species as *Actinopyga mauritiana* had been described long ago by Quoy and Gaimard (1833). Michel (1974) listed 23 species of Aspidochirotida and Arakaki and Fagonee (1996) gave a list of species from several countries including Mauritius. The distribution of a few species has been studied (Luchmun *et al.,* 2001) and unpublished reports present further data on the distribution of the main species *A. echinites, H. atra* and *H. leucospilota* (Muller, 1998). The echinoderms from Rodrigues have been sampled by the Shoals of Capricorn and studied by Rowe and Richmond (2004) who identified 29 holothurians. Other studies on the distribution have been recently conducted (Mrowicki, 2007). In Saint Brandon the main holothurian abundances have recently been reported (Laxaminaraya, A., Indian Council of Agricultural Research [ICAR], India, personal communication). The exploitation in Mauritius started on a trial basis in late 2005 and was continued by six licensed operators with exports of around 80 tonnes (Kadun, S., Mauritius Government, Mauritius; Laxaminaraya, A., ICAR, India, personal communication).

Mozambique
It has not been possible to get recent information from Mozambique, except on the present fishery from Querimbas Archipelago (Hill, 2008). The detailed report by Marshall, Milledge and Afonso (2001) remains the main review for this country where only "minimal data on the fishery" and "illegal exports to Tanzania" exist. The dozen species exploited are the same as in the other countries of the region. The mean annual quantities exported for the decade 1980–90 were around 65 tonnes, but they have dropped in the 1990s. Exports are to Taiwan Province of China, China Hong Kong SAR and Singapore. The report by Marshall, Milledge and Afonso (2001) presents several management initiatives and recommendations for different localities, as for example in Inhaca, in 1990, a closed season from December through to March, a minimum size of 20 cm, rotational exploitation arrangements, while in 1995 for Inhambane the closure of the fishery (which fishers continued to exploit due to lack of control). From recent information, most of the sea cucumber resources in the central and the southern regions of the country are depleted, with the exception of

those in the Bazaruto Archipelago National Park (Motta, H., Mozambique, personal communication). The species most captured in these two regions is *H. scabra*. In the north the mammy holothurians (teatfish) may still be available but only at some depth, for which fishers need to dive in deeper waters. A recent study by Hill (2008) shows that the fishery is still active in the Querimbas Archipelago. Mozambique is certainly one of the countries in the region where the sea cucumber fishery should be carefully followed, aquaculture developed and management of wild resources encouraged.

Egypt

The bêche-de-mer fishery in Egypt has been described by Lawrence *et al.* (2004). It began in 1998, in the southern part of the country. It was initially performed by trawling boats. It expanded dramatically and the Red Sea Governorate initiated a ban in 2001. Illegal fisheries therefore developed along the coast. Under the pressure from the fisheries authorities the ban was lifted in 2002. As the preliminary observations on the stocks showed a rapid decline of the resources, a new ban was decreed in 2003 and new decisions were expected based on the results of the stock assessment. Ahmed and Lawrence (2007) have recently updated the situation. Following the initial study, they have re-visited some of the sites to determine whether there was any evidence of stock recovery following the 2003 fishery ban. Four sites were assessed using the belt transect method applied in the original study. The sites were selected based on their accessibility, initial levels of stocks and levels of exploitation. A further six sites were assessed visually to determine the presence or absence of commercial species. It appeared that four years after the ban on the fishery, there is some evidence of the return of selected commercial species to some of the sites, but no evidence of stock recovery.

Eritrea

Recent information on sea cucumber fisheries has been reported by Tewelde and Jeudy de Grissac (2007) and Kalaeb *et al.* (2008). Sea cucumbers have been harvested for more than forty years by local artisanal fishers, but only in small quantities. The artisanal fishers collected sandfish (*Holothuria scabra*) by skin diving using a "nadur" or home-made mask. The catches are gutted, dried and marketed to Aden (Yemen). Exploitation of sea cucumber on a larger scale started in 2000 with the products exported to Asia. Ten species are presently collected and the largest quantity is from *Holothuria atra* (lolly fish) locally known as "Lega" which is found in abundance in shallow waters. Deeper species are now harvested by divers using an air compressor or SCUBA or by artisanal trawling.

India

In India this old artisanal activity is reported to have been introduced by Chinese long time ago (Hornhell, 1917). During the last two decades considerable scientific

TABLE 4
Commercial sea cucumber species exploited in Eritrea

Species	Common name	Local name	Commercial value
Holothuria scabra	Sandfish	Hedra beyda	1
H. fuscogilva	White teatfish	Abu habhab abyed	1
H. nobilis	Black teatfish	Abu habhab aswed	1
H. atra	Lolly fish	Lega	3
H. edulis	Pink fish	Abu sanduk tina	2
Thelonota ananas	Prickly redfish	Abu mud	2
Actinopyga miliaris	Black fish	Abu shelalik	2
A. mauritiana	Surf redfish	Abu sanduk hager	3
Stichopus herrmanni	Curry fish	Hamra	3

Source: Tewelde and Jeudy de Grissac, 2007.

studies have been conducted on the taxonomy, the ecology and the exploitation of sea cucumbers; a comprehensive list of references is given in James (2004b). Subsequent studies focused on hatchery techniques (James, 1994a). Starting in 1994, the need for management of the resources was recognized as overexploitation was noted as the fishery typically focused on successive species, first *H. scabra*, then *A. echinites*, followed by *A. miliaris* (James and James, 1994). The Government of India has banned collection, processing and export of all sea cucumbers from several regions since 2002 (James, 2004a). Illegal fisheries, however, still continue with "huge quantities of *Stichopus herrmanni* processed every year near Tuticorin during the months of May to July. Two lakhs (Indian numbering system equal to one hundred thousand) of sea cucumbers are collected every day during this period. No seed is produced since 2000 since the scientists are unable to collect broodstock due to the fishing ban. There are some indications that the ban may be lifted in the near future if certain conditions are met" (James, D.B., India, personal communication). Recently "the National Fishers Forum (NFF) has sought the Prime Minister's intervention in lifting the ban as this had adversely affected the livelihood of thousands of fishers in Tamil Nadu. The Forum said there was no fear of depletion of this fish as it was caught by diving and its longevity was estimated to be 10 years. The ban on shark and some items was lifted following protests by the fishing community, but no exemption was made in the case of sea cucumber, the Ministry had constituted a committee to review the ban, but there has been no response since then. The Forum has also sought lifting the ban on *Holothuria atra* and *H. spinifera* species. The NFF activists arrived in the capital and would sit on an indefinite dharna near Parliament until the ban would be lifted"[1].

Maldives

Maldives has experienced a short term fishery with a boom-and-bust cycle after only a few years (Reichenbach, 1999). Some projects for mariculture had been set up. No recent information has been found.

Sri Lanka

In Sri Lanka sea cucumber collection "is rooted in antiquity, when Arab and Chinese merchants employed local inhabitants of western, northern and eastern maritime regions, to gather and cure the animals for them" (Adithiya, 1969). Terney Pradeep Kumara, Cumaranathunga and Linden (2005) have recently described the present fishery. In the western, northern and eastern waters the activity flourished with increased demands from East Asian countries. As shallow areas were fished out, the availability of SCUBA gear in the 1990s enabled deeper habitats to be exploited. Published Sri Lanka Customs Department statistics (Terney Pradeep Kumara, Cumaranathunga and Linden, 2005) for the whole Island shows steep rises and declines in quantities exported (see Figure 7). These fluctuations appear to correspond with discoveries of new sea cucumber grounds and their depletion as a result of unrestricted and intensive collection. In the southern parts, along the coastline from Negombo to Dondra the fishery commenced only about ten years ago. Regrettably, overexploitation with no effective management measures has led to its complete collapse. Sea cucumbers are locally known as "muhudu kekiri" or "atta" and are exported to other Asian countries. There are nearly 200 known species in the ocean around Sri Lanka. About 75 species have been shown to be present in shallow waters while nearly 50 species can be collected from the intertidal region (Clark and Rowe, 1971). Although sea cucumbers were abundant, they were not harvested in the south until buyers from Singapore created a demand. They bought mainly two species, *Holothuria edulis* and *Holothuria atra* for very low prices. Although they paid only one rupee (USD 0.01) per animal, fishers earned a considerable amount of money because

[1] Source: The Hindu (http://www.hinduonnet.com/2007/08/29/stories/htm).

of the abundance of the organism in the shallow coastal waters. The price increased up to five rupees each as supplies dwindled. Harvesting at first was done by hand while wading or using snorkel gear in shallow water. As the shallow areas were fished out, SCUBA gear was used to exploit increasingly deeper sea cucumber beds. Over the past three to four years the sea cucumber fishery in the shallow areas off southern Sri Lanka declined rapidly and collapsed. The fishers and divers of these areas then turned to distant sea cucumber beds. Although fishers from Negombo on the western coast started the fishery in the southern part of the Island, fishers/divers from the southern fishing towns of Mirissa and Dondra now dominate. The sea cucumber fishery in the south of the Island is by opportunistic tuna fishers. Whenever exploitable sea cucumber beds are located they switch to that; and when the beds are fished out, revert to tuna fishing. The duration of each spell of activity depends on the sea cucumber population and the number of boats and divers that participate in the fishery. The catch is washed and stored on ice. SCUBA divers complain that they now need to dive to increasing depths to harvest holothurians, leading to accidents, and also that they are forced to look for new fishing grounds.

Oman

Oman has re-started its sea cucumber fishery very recently (Al-Rashdi, Al-Busaidi and Al-Rassadi, 2007). Mahout Bay in the Gulf of Masira (Arabian Sea) is the main area of sea cucumber fishery in Oman and the fishing dates back to 1960s, when Mahout Island was considered a travelling port to East Africa and India. The islanders used to collect sea cucumber and exchange it for food provisions from abroad. The fishery was then discontinued in 1970s as the port was no longer in operation. However, the fishery re-commenced in 2003 due to the demand of bêche-de-mer from traders from the United Arab Emirates. Intensive fishing was practiced throughout 2004 and 2005 when the fishery was totally unregulated. The sea cucumber in Oman forms a minor fishery of the traditional sector with almost 50 percent women involvement. The fishery is located in Mahout Bay and supported by the sandfish, *Holothuria scabra* which is still abundant in seagrass beds. The local name of the species is "Feik Albahar" meaning "sea jaw". The sandfish are hand picked by walking in the shallow areas during low tide between late November and May. Sandfish is traditionally processed to a dried form after gutting, boiling and cleaning.

Chagos Archipelago

The Chagos Archipelago, in the central Indian Ocean, were first inhabited in the late eighteenth century, and by the mid-twentieth century there was a small economy based around copra (dry coconut flesh), but the resident population was removed by the British in the early 1970s. With the exception of Diego Garcia, where there is now a large US military base, the islands have remained uninhabited for over 30 years. Surveys of the coral reefs during the 1970s revealed a remarkably pristine reef fauna. Fisheries patrols, largely to monitor the licensed tuna fishery, began in the 1990s. At the same time the first observations of illegal sea cucumber fishing were made. An expedition in 1996 revealed that reef shark populations had declined by some 85 percent linked to the illegal fisheries (Spalding, 2006).

South Africa

According to the author no information exists or is readily available on sea cucumbers exploitation in South Africa where the rich holothurian fauna was recently reviewed by Thandar (2007).

Most reports on sea cucumber fisheries are still qualitative and the situation in the region is not very clear particularly for a number of countries. Probably uncontrolled overexploitation is widespread and occurs in many areas.

2.4 Species in trade

Currently, the only use of sea cucumbers in the region is for the export of bêche-de-mer (Conand, 2001, 2004a; Bruckner, 2006; Conand and Muthiga, 2007). Table 2 lists 30 species with their commercial importance ranked as follows: 1 = high commercial value; 2 = medium commercial value; and 3 = low commercial value.

The processing is generally done artisanally in this region, following the methods already described for sandfish and the other species (Anonymous, 1994; Conand, 1999); in the Seychelles some processors operate large plants with considerably large drying rooms (Pinault and Conand, 2007). Currently the fishers have to fish further away from the traditional grounds than they used to. Sea cucumbers tend to eviscerate after collection they need to preserve their catches in salt as described for Indonesia by Tuwo and Conand (1992). This practice occupies less room in the boat and enables fishers to go out on longer fishing trips. In India some processing techniques have been refined as for example the removal of the skin of the sandfish which suppresses the need of the burying them in sand (James, 1994b).

2.5 Population status

The population status is a important parameter which can be estimated through several methods: (i) scientific evaluations of densities, or biomasses; (ii) fishery data on catches, efforts and CPUE; (iii) trends in these indicators; and (iv) retro-calculations from export statistics (Conand, 1989). Concerning the scientific evaluations, the method used and the spatial scale of the study are important factors to take into consideration. Some density data have been transformed to numbers of individuals per 100 m^2 to allow comparisons. Some examples will be presented, despite few data available and no synthesis has been carried out. The lack of historical data in many countries reflects the lack of interest on this resource until recently. Table 10 summarizes the population exploitation status in each country in the region. Recent information on abundance has been collected from WIO countries through the Masma project (Conand and Muthiga, 2007) and is presented below.

In **Kenya** the relative abundance of sea cucumbers, calculated from transects, was highly variable ranging between 0.3 to 7 ind. 100 m^{-2} and averaging ~3.5 ind. m^{-2} (Muthiga and Ndirangu, 2000; Muthiga, Ochiewo and Kawaka, 2007). The density of individual species was generally low (0.01 to 1.5 ind. m^{-2}). In general, the highest densities of sea cucumbers were found in shallow water habitats, primarily reef lagoons and channels (around 6 ind. 100 m^{-2}), as well as in Marine Parks; however, the factors that control variability have not been yet sufficiently explored.

In **Réunion** quantitative data on holothurian densities can be found in Conand and Mangion (2002), Conand (2003) and Fabianek and Turpin (2005) (Conand and Frouin, 2007; Frouin *et al.,* 2007), however, more data is needed for a good understanding of the structure and function of holothurian guilds in Réunion reefs. *H. leucospilota* and *H. atra* are the dominant species. Most studies were done in the Saint-Gilles/La Saline reef which is the most important in Réunion (almost 40 percent of reef surface in Réunion). Back reef areas (characterized by dominant sandy bottoms) and inner reef flats (dominated by hard substrata) were extensively sampled. *H. atra* showed higher densities in this reef than *H. leucospilota*. The mean value in the reef was 0.68 ± 1.67 ind. m^{-2}. *H. atra* was dominant in back reefs (1.44 ± 2.46 ind. m^{-2}). 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} (from Fabianeck and Turpin, 2005; and Conand and Mangion, 2002, respectively) or a mean around 580 ind. 100 m^{-2}, has been recorded in one reef station (Planch'Alizes). Jaquemet, Rousset and Conand (1999) found 4.8 ± 0.53 ind. m^{-2}. Conand (2004c) analysed data collected from 1993 to 2000 and determined a density over this long term (4.7 ± 0.3 ind. m^{-2} or 470 ind. 100 m^{-2}). In inner reef flats the densities were <10 ind. m^{-2}. In contrast, *H. leucospilota* was present in all back reef and inner flat stations, with total mean density 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 one station (Planch'Alizés). Other holothurian species have been observed in the field, but few quantitative data are available. *Stichopus chloronotus* showed a total mean density of 0.34 ± 0.69 ind. m^{-2} with no individuals found in inner flats. Mean density in back reefs was 0.78 ± 0.91 ind. m^{-2} (Fabianeck and Turpin, 2005). Conand *et al.* (1998) found 3.7 ind. m^{-2} in Trou d'Eau, a station where the sexual reproduction and fission were studied. Large size *Actinopyga echinites* and *A. mauritiana* on the outer reef flats and reef front respectively, are also frequent species (Conand and Mangion, 2002).

In **Madagascar** an investigation of the abundance and distribution of the different exploited species was carried in 1996 on the Toliara Great Barrier Reef (southwest of Madagascar) (Mara *et al*., 1997; Rasolofonirina *in* Conand and Muthiga, 2007a). The results indicate the biomass of edible species on different habitats of the reef (Table 5). The maximum biomass and density observed at the time was for *Holothuria notabilis* with 0.06 ind. 100 m^{-2} (or 60 kilograms) on the spatially-limited zone of the dune in the seagrass habitat. This species was not exploited at that time, but currently it is the most exploited one, which has resulted in a considerable decrease of its biomass.

For **Seychelles,** Aumeeruddy and Conand (this volume) and other reports (Aumeeruddy *et al*., 2005; Aumeeruddy, 2007) present density and biomass estimates for large areas in the Seychelles (using a stratified sampling according to depth and substrates). Due to the extended size of Seychelles' EEZ (1.4 millions km^2), a recent stock survey focused on two main fishing grounds, i.e. the Mahé Plateau and the Amirantes which together cover an area of approximately 48 305 km^2. During the surveys, around 20 species of large sea cucumbers were recorded. The overall average density in the study area was 19.78 ind. ha^{-1} which equates to a standing stock of approximately 95 millions individuals corresponding to an estimated live weight of about 98 600 tonnes. The highest density of commercial sea cucumbers was found in the shallow strata (<20 m) while the deep strata (>50 m) had the lowest density. In the intermediate depth strata (20–50 m), the sea cucumber density was of an intermediate level, but due to the large size of the specimens, it had the bulk of the overall standing stock. Figure 3 presents the mean densities for the main species.

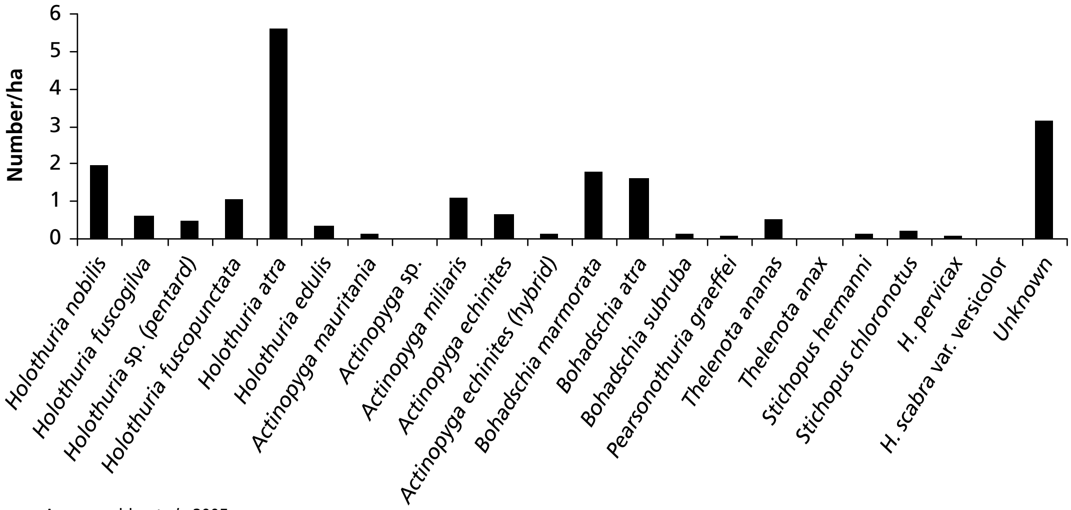
TABLE 5

Biomass of the main holothurians per biotope in the Toliara Great Barrier Reef, southwest Madagascar. The unit in kg/ha is chosen given the low biomass of most species

Species	Common name	Biomass (kg/ha)				
		Inner slope	Seagrass	Microatoll	Detrital fringe	Outer flat
Actinopyga echinites	Trokena		0.018		1.125	
A. mauritiana	Fotsitreka				1.159	0.117
A. lecanora	Zangabato	0.09		0.299		
Bohadchia vitiensis	Falalijaka	33.38	2.151			
Holothuria atra	Stylo noir	2.617	0.618	3.7	0.884	1.316
H. cinerascens	Zanga fleur				1 520	
H. edulis	Stylo rouge	0.602	0.095	0.515		
H. excellens	Delave	1.380	0.274	0.124		
H. leucospilota	Zanga kida	13.302	1.004	4.243	1.515	
H. notabilis	Dôrilisy		6 000			
H. nobilis	Benono	0.1	0.046			
H. scabra	Zanga fotsy	0.298	3.774			
H. scabra var. *versicolor*	Zanga mena	0.802	1.207			
Stichopus horrens	Smurf	0.228	0.137	0.218	0.113	0.033
S. herrmanni	Trakitera	0.636	1.022	0.048		
Total		**53.44**	**6 010.3**	**9.15**	**1 524.80**	**1.47**
Percentage		**0.70**	**79.09**	**0.12**	**20.07**	**0.02**

Source: Mara *et al*., 1997 in Rasolofonirina 2007; Common names are from Conand (1999).

FIGURE 4
Abundance of the main commercial species in the Seychelles



Source: Aumeeruddy *et al.*, 2005.

As in other tropical countries, *H. atra* is the most frequent and abundant species with a mean density of nearly 0.06 ind. 100 m^{-2}; the three teatfish species are quite abundant with a mean density of 0.02 ind. 100 m^{-2}. It is worth noting that there is a need to harmonize stock monitoring methodologies in order to produce results and data which are comparable, as different methods will produce dissimilar findings in terms of densities and biomass.

Concerning other countries, data are mostly lacking or are too old, but they give at least an idea on the state of the populations, as in **Maldives** where *H. fuscogilva* has been heavily exploited (Reichenbach, 1999). Lawrence *et al.* (2004) provided detailed density estimates for different areas in **Egypt**. *Holothuria atra* was by far the most abundant followed by *A. mauritiana*. A second survey conducted four years following the official fishing ban, has shown that there was some evidence of the return of some commercial species, but no evidence of stock recovery (Ahmed and Lawrence, 2007).

Catch and effort data are necessary to calculate catch-per-unit-effort (CPUE) values in a given fishery. Nevertheless, a value of CPUE is sometimes used by scientists as an indicator of abundance, when the densities are not directly accessible, as in the case of very large zones. The counts of the different holothurian species are therefore done during a temporal interval rather than over a unit surface area, as it was done for the crown of thorns (*Acanthaster* sp.) in New Caledonia (Conand, 1985). Overall, CPUE values are not yet available on a regular basis for the countries in the region, except for the **Seychelles** where the fishery is regularly monitored (Aumeeruddy and Conand, this volume). The data presented on the main species by Aumeeruddy (2005) shows that the CPUE, given in number of specimens per diver per day, has decreased from 2001 to 2006 (Table 6); the exception of the “pentard” is explained by an increase of effort on this species.

TABLE 6
Number of the main commercial sea cucumber species in the Seychelles collected daily by one diver from 2001 to 2006

Year	Black teatfish	Sandfish	White teatfish	Prickly red	Pentard	Other spp.
2001	7,15	0,20	29,09	4,86	4,83	5,95
2002	4,75	0,52	30,06	4,67	7,32	29,78
2003	3,22	0,01	9,97	6,09	18,68	27,15
2004	1,82	0,12	7,98	2,38	11,51	10,12
2005	1,52	0,01	6,04	2,26	11,01	12,88
2006	1,05	0,19	3,94	1,43	16,22	10,08

Source: Aumeeruddy *et al.*, 2005.

Based on a socio-economic survey in **Eritrea** the mean CPUE by day by diver is 1.68 kilograms dried sea cucumber (Tewelde and Jeudy de Grissac, 2007); given the mean crew per boat of 4.68, the mean number of days of the trip of 23 the average boat catch in dry weight is 175 kilograms.

In conclusion, the unit used for catches, effort and CPUE should be standardized in the future to get a more accurate regional view. The relations between fresh and dried weights, as shown in Aumeeruddy and Conand (2007) are useful to compare different sets of data.

2.6 Catches

In the region the only use of the wild sea cucumbers resources is for bêche-de-mer for the export markets (Conand, 2004a; Conand, 2006b *in* Bruckner, 2006b). Aquaculture has been at an exploratory level in Madagascar from 2000 (Jangoux *et al*., 2001), but the encouraging results obtained from the Belaza hatchery (Rasolofonirina, Mara and Jangoux, 2004; Lavitra *et al.,* 2007) may well encourage the commercial production of sea cucumber (Rasolofonirina, R., Université de Toliara, Madagascar, personal communication).

The fishery is artisanal in most countries, but at a larger scale in the Seychelles. As a result there are generally no reliable data on the catches as the sea cucumbers are collected by untrained fishers from scattered villages. It is however possible to obtain a general picture of the catches by analyzing the statistics of the processed products, which being for export market require official export permits. In most countries the sea cucumbers (and other marine species) are generally collected at low tide wadding on the reefs and snorkelling. Since the reef flats have been mostly depleted, fishers now dive with SCUBA.

Table 7 presents FAO production data from different countries for the last 12 years. The data shows that (i) seven countries in the FAO Area 51, compared to only 3 countries in Area 57 report sea cucumber catches; and (ii) the WIO accounts for over a third of the world's total sea cucumber landings. The regional data presented are mere indications as probably several countries in the region are exploiting sea cucumbers without declaring exports or simply lumping sea cucumber with other dried export items such as shark fins.

More detailed information on present and historical catches in selected WIO countries is presented below (Conand and Muthiga, 2007a).

TABLE 7

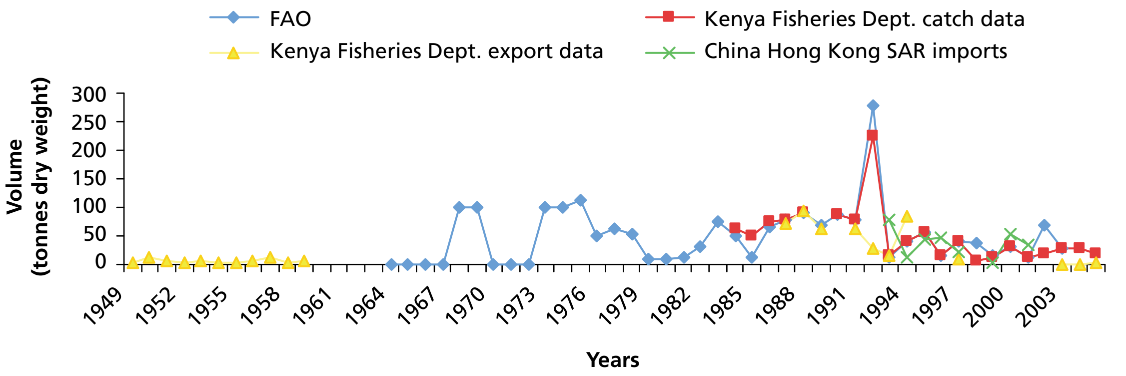
Sea cucumber production by countries and fishing areas and percentage of total world production (in tonnes)

Country	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Average 1994–2005	Percentage world total
Egypt	-	-	-	-	-	-	20	139	2 310	527	15	5	**502.7**	*3.4*
Madagascar	5 400	5 400	5 400	5 400	1 446	1 500	1 500	1 500	500	500	500	500	**2 462.2**	*1.8*
Maldives	66	94	145	318	85	54	205	226	191	239	182	117	**160.2**	*1.1*
Tanzania	1 591	1 460	1 644	1 527	1 800	189	372	340	65	75	10	10	**756.9**	*0.2*
Kenya	41	55	15	41	38	15	30	13	68	27	28	18	**32.4**	*0.2*
Yemen	102	-	-	-	-	1	-	-	14	10	380	400	**151.2**	*1.0*
Mozambique	0	6	54	7	2	8	12	11	10	4	1	1	**9.7**	*0.1*
FAO Area 51	7 200	7 015	7 258	7 293	3 371	1 767	2 139	2 229	3 158	1 382	1 116	1 051	**4 075**	*27.8*
Indonesia	548	227	269	338	630	689	903	697	649	870	360	624	**567.0**	*3.9*
Sri Lanka	92	100	150	272	203	170	145	90	150	170	280	260	**173.5**	*1.2*
Malaysia	-	-	-	-	-	-	-	-	-	-	-		**-**	*-*
FAO Area 57	640	327	419	610	833	859	1 048	787	799	1 040	640	884	**741**	*5.1*
World total [1]	16 246	15 556	17590	15 295	13 613	12 596	16 020	11 964	15 243	18 578	13 017	9 878	**14 633**	*100*

[1] Excluding data from Japan and the Republic of Korea as data is reported in fresh weight.

Source: FAO, 2005b.

FIGURE 5
Kenyan annual bêche-de-mer production



Source: Kenya Fisheries Department; FAO; Kenyan imports into China Hong Kong SAR (Infofish Trade News) (from Muthiga, Ochiewo and Kawaka, 2007).

Kenya (from Muthiga, Ochiewo and Kawaka, *in* Conand and Muthiga, 2007a). Historical and current production statistics on sea cucumbers are difficult to obtain as they are inadequately collected and recorded often resulting in landing and export statistics that often fail to tally. Comparison between data from FAO (FAO, 2005b), the Kenyan Fisheries Department and Kenyan imports into China Hong Kong SAR show a variable trend of production (Figure 5). In general, the catches were fairly low in the early 1950s averaging between 3 and 12 tonnes; they increased to about 80 tonnes between the late-1960s and mid-1990s. The production has averaged about 20 tonnes in the last decade. In Kenya, although more than seventeen species of sea cucumbers are harvested, *H. fuscogilva* dominates the catch (Muthiga, Ochiewo and Kawaka, 2007).

Madagascar (from Rasolofonirina *in* Conand and Muthiga, 2007a). Concerning the historical records, the first exports recorded from Madagascar were in 1920 with about 40 tonnes of trepang from three species (Petit, 1930). Then exports varied annually from 50 to 140 tonnes. Since 1990, the harvesting of sea cucumbers greatly increased. Exports of trepang reached nearly 600 tonnes in 1991 and 1994 (or about 6 000 tonnes in fresh weight) and about 980 tonnes in 2002. After 2002 official data showed a significant decline in exports. Since 1990 signs of overexploitation have been observed and included: (i) the declining quality of the product; (ii) the decrease in product size; (iii) the use of illegal fishing equipment; (iv) strong competition between collectors (Conand *et al.*, 1998); (v) fishing outside territorial waters; and (vi) the collection of juveniles (Conand, 1999).

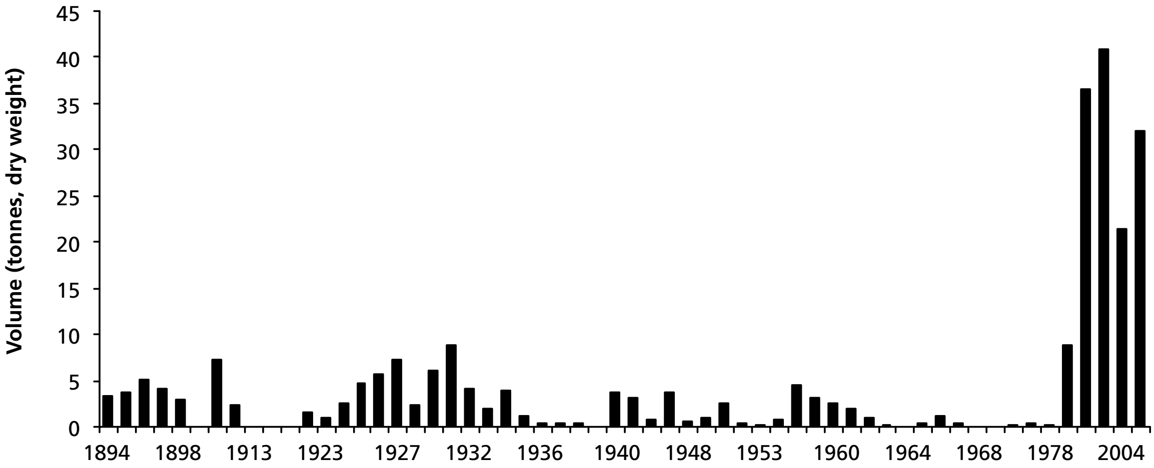
TABLE 8
Evolution of trepang exports from Madagascar

Year	Exports from Madagascar (tonnes)
1987	60.6
1988	119.4
1989	113.8
1990	202.6
1991	545.3
1992	423.2
1993	356.6
1994	539
1995	317.2
1996	307.4 ; (340.5)[3]
1997	(150.9)[1,2]; (331)[2]; (161.5)[3]
1998	322.5, (6.5)[2]
1999	326.6
2000	389.8
2001	355.2
2002	986.9
2003	204.5
2004	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.

In **Seychelles** (from Aumeeruddy *in* Conand and Muthiga, 2007a) bêche-de-mer has been exported for more than a century. For a long period and until 1999, the fishery was unregulated and thus no catch and effort data were collected. Figure 6 shows the limited yearly exports from 1894 to 1999 (<10 tonnes) and the sudden increase in 1999.

FIGURE 6
Bêche-de-mer exports from the Seychelles

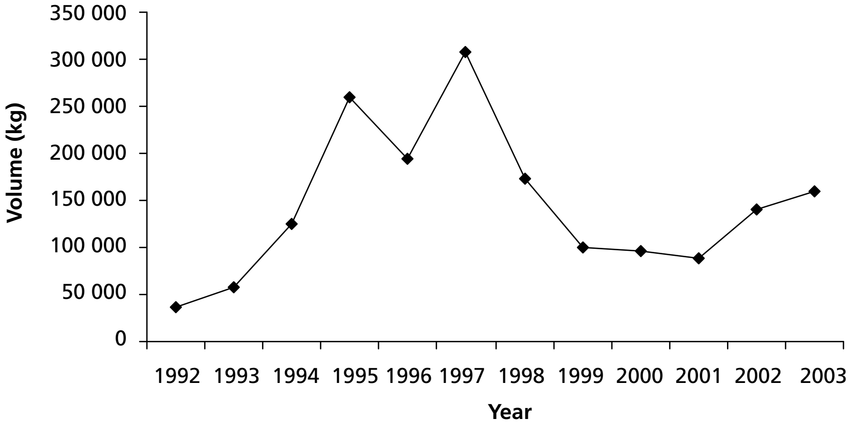


Source: Aumeeruddy, 2007.

Traditional markets are countries from Southeast Asia (China, China Hong Kong SAR, Malaysia and Singapore). Aumeeruddy and Conand (this volume) report an upward trend in the catch of the main targeted species since 1999. Fishers have been targeting mainly six high-value species (*Holothuria nobilis*, *H. fuscogilva*, *H. scabra,* "pentard", *Thelenota ananas* and *Actinopyga mauritiana*)*.* The very high increase in catch between 2004 and 2005 is worrying, 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 improved in 2005. However one of the main reasons for the high increase in catches in 2005 is the change in fishing practice adopted by fishers. Several fishers who have small fishing units are now transferring their catch at sea to a mothership which then brings back the sea cucumbers to the processors. They can thus stay longer at sea, and the fishing effort has increased considerably with the same number of fishing licenses.

From these examples, it appears that catches in the region have increased strongly during the 1990s and then have dropped in some countries due to overexploitation. Countries have been aware of the situation and some of them are trying to take measures for a better management, as is the case in Seychelles.

FIGURE 7
Export of bêche-de-mer from Sri Lanka



Sources: External trade statistics of the customs; Terney Pradeep Kumara, Cumaranathunga and Linden, 2005.

TABLE 9
Official sea cucumber harvest in Eritrea from 1998 to 2006, gutted and dried weight (tonnes)

Year	1998	2000	2001	2002	2003	2004	2005	2006
Harvest	0.258	11.66	80.584	451.89	283.58	379.90	278.00	241.77

Source: Ministry of Fisheries and National Fisheries Corporation (Tewelde and Jeudy de Grissac, 2007).

Data on exports from some countries as **Sri Lanka** (Terney Pradeep Kumara, Cumaranathunga and Linden, 2005) (Figure 7) can be used to infer catches. They also appear to have peaked in the 1990s with around 300 tonnes and decreased to 150 in 2003. These data slightly differ from the FAO statistics (cf Table 7).

The recent report by Tewelde and Jeudy de Grissac (2007) gives the annual data on the products prepared from the catches in **Eritrea**, from 1998 to 2006. In 2007 the fishery was closed to prepare a new management plan. Two government bodies follow the planning regulation, management, exploitation and marketing of fisheries resources: Ministry of Fisheries (MOF) and National Fisheries Corporation (NFC); they will be presented in section 2.7. The highest production occurred in 2002, after three years of increase. In the last three years the harvest dwindled. However, the decrease could be interpreted as a result of increase of illegal trade to Yemen. The fishermen are attracted by the high price of sea cucumber in Yemen and the secure supplies of fuel, food items and spare parts. The survey showed the mean catch per unit effort (CPUE) per day for collector is 1.68 kilograms.

Taking into account the available information from the different countries on densities, CPUE, catches and other more or less anecdotal information, the status of sea cucumber resources in the region can be summarized in the Table 10.

It appears that in 12 out of the 30 countries covered in the region, the resources are presently over-exploited (at least for the main commercial species) or fully-exploited. Even in the countries where the fishery has recently started (or re-started), resources are been depleted rapidly, given the use of scuba the favourable fishing grounds. This “bust and boom” cycles are sometimes difficult to identify in the catch statistics. In conclusion, with an increased market demand in the 1990s, the sea cucumber fishery increased in the different countries of the region, then dropped slightly in the 2000s. Because bêche-de-mer is mainly an export product, the volume of catches can only be inferred from the export statistics in countries that have no capacity to set up the collection of catch statistics. Careful consideration to the units of export used (pieces numbers or weights, fresh, in salt or dried) is rather important when estimating catches from exports.

2.7 Management measures in place

Unlike for marine finfish, there are no large-scale assessment of the stocks of sea cucumbers, except for the Seychelles (Aumeeruddy *et al.*, 2005). Management measures have therefore not been based on scientific data and have sometimes caused conflicts of interest. Several examples of national management have been presented in Lovatelli *et al.* (2004) and Bruckner (2006). Recent information concerning the WIO is presented in Conand and Muthiga (2007).

Despite the long history of the sea cucumber exploitation in **Kenya** (Muthiga, Ochiewo and Kawaka *in* Conand and Muthiga, 2007a), this fishery has evolved without much intervention from the management authority. Early records of management interventions include the removal of royalties in 1959, originally imposed to control collection and to revitalize sea cucumber trade. Along the Kenyan coast only a few studies have been conducted on some aspects of the fishery (Muthiga and Ndirangu, 2000; Samyn and Vanden Berghe, 2000; Marshall *et al.*, 2001; Samyn, 2003; Beadle, 2005). Most 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. However, the lack of historical information makes it difficult to discern whether production peaks

TABLE 10
Exploitation status of sea cucumber resources, by area and country. Countries with documented sea cucumber fisheries are in italics and bold

Western Indian Ocean		Overexploited	Fully exploited	Moderate	Underutilized	NA or other regional review
Red Sea	***Egypt***	X				
	Sudan					NA
	Eritrea		X	X		
	Saudi Arabia					NA
	Israel					NA
	UAE					NA
Aden Gulf	Djibouti					NA
Western Arabian Sea	***Oman***					
	Yemen					
	Iran IR					
Eastern Arabian Sea	Pakistan					NA
	India	X				
	Chagos	X				
	Maldives	X				
Somalia, Kenya, Tanzania	Somalia					NA
	Kenya	X				
	Tanzania	X				
Madagascar, Mozambique channel	***Madagascar***	X				
	Comoros	X	X			
	Mayotte	X				
Islands	***Mauritius***		X	X		
	Réunion				X	
	Seychelles		X	X		
Mozambique	***Mozambique***	X				
Eastern Indian Ocean						
Bay of Bengal	***India***	X				
	Sri Lanka	X				
	Myanmar					Poh Sze, this volume
	Malaysia					Poh Sze, this volume
Northern	Indonesia					Poh Sze, this volume
Western Australia	Australia					Kinch *et al.*, this volvume
Southern Australia	Australia					Kinch *et al.*, this volume

NA = no information available

and troughs are due to stock depletions, gear improvements, global markets or other socio-economic factors impacting the coastal communities.

The resource management problems in **Madagascar** (Rasolofonirina *in* Conand and Muthiga, 2007a) are related to overfishing, legislation and administration. Various actions have been taken since 1990 by the scientists, professional organisations and the government to monitor the fishery. While legislation on sea cucumber exploitation exists in Madagascar, they are not effectively applied or even not applicable to all species exploited. Although the use of diving tanks is forbidden, this gear type is commonly used. A major problem is the lack of reliable statistics. The different administrations ignore the exact quantity of product that the country exports, and exporters wishing to avoid paying corresponding taxes and consequently do not declare the exact quantity of trepang. Implementation of sustainable management methods will only take place through actions involving the various participants in the fishing sector, from the fisherman to exporters (Conand, 2001, 2004a).

The national PRE/COI/UE programme, funded by the European Union (EU) and coordinated in Madagascar by the National Committee (CN-MAD), has helped the efforts of the Fishery Department and the professionals to manage the resource. The National Association of Sea Cucumber Producers (ONETH, in French) was created in 1996 through a pilot operation to implement the sustainable management of sea cucumber resources and exploitation (Conand, 1998a; Conand *et al*., 1998). In order to reduce over-exploitation of sea cucumbers, they planned to study the current status of the resource, the production and export statistics, to create a quality management manual for this product (Conand, 1999) and to experiment with sea cucumber farming. ONETH encountered several problems in the years following its creation. It is now active again but still faces difficulties in the implementation of sustainable fisheries for the resource (Rasolofonirina, R., IH-SM, Université de Toliara, Madagascar, personal communication).

The information presented for **Tanzania** is based on Magaya and Mbaga *in* Conand and Muthiga (2007a). In this country, 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 licence fees paid annually by dealers and exporters. They include, (i) a local individual or company with approved shore-based fish processing facilities, (ii) a local individual or company without approved shore-based fish processing facilities, and (iii) foreigner individual or company with approved shore-based fish processing facilities. Foreigner–individual or company without approved shore-based fish processing facilities cannot have licenses to operate. There is no specific legislation in Tanzania that refers to sea cucumbers. The biggest problem facing Tanzania, however, is not the development of appropriate legislation, but rather hoe to develop capacity to enforce regulations, including those that may be developed to protect bêche-de-mer fisheries. Legislation is useless without its three counterparts: political will, education and enforcement. However, education and enforcement are expensive, hence casting a shadow of doubt on compliance by the fisher folk to existing regulations.

Seychelles (Aumeeruddy and Conand, this volume; Aumeeruddy, 2007) offers an important example of management since the beginning of the recent fishery development. In 1999, the need for fisheries management was felt and measures to control the fishery were done through the Fisheries Regulations (1999). A management plan was also prepared, and is based on the results of the resource assessment done on a large spatial scale (Aumeeruddy *et al.,* 2005). Stakeholders were consulted several times, and the management plan was completed in August 2005 during a final stakeholders' workshop. This plan is based on a mix of input controls (limited number of fishing licenses) and output controls (Total Allowable Catch [TAC]) for each commercial species) (Payet, 2005). The TAC was calculated based on the maximum sustainable yield (MSY) for each species (Aumeeruddy *et al*., 2005). The total TAC for all species has been calculated at 1 707 tonnes landed weight (gutted), from which the high value species represent 425 tonnes landed weight. An Advisory Management Committee, composed of representatives of government departments, professionals involved in the sea cucumber industry (boat-owners, divers, processors and exporters) and environmental NGOs was set up to oversee the implementation of the management plan. Discussions have not been finalised yet, and several other issues are being taken into consideration (number of fishing licenses, closed season). The timely provision of catch and effort data by fishers and processing data by processors remains a problem which makes it difficult to assess the level of catch and will be even more difficult when TACs are introduced. Currently, the accuracy of the data provided is not checked. Recent interviews carried out with the different actors of the "fishery system" (Pinault and Conand, 2007), showed that the holothurian fishery is very difficult to assess and to effectively monitor catches at fishermen level. It seems more efficient and easier to intervene at the processor level, by monitoring the export stocks and the undersized sea cucumbers.

In **Eritrea** (Tewelde and Jeudy de Grissac, 2007), the Ministry of Fisheries (MOF) and the National Fisheries Corporation (NFC) are the two government bodies that follow the planning, regulation, management and exploitation of fisheries resources. The main responsibilities of the MOF are (i) planning and implementing national fisheries policies and regulations; (ii) fisheries research and statistics collection; (iii) fisheries management design and implementation; (iv) monitoring, control and surveillance; (v) fish quality control; and, (vi) infrastructure and community development. The NFC was established in 2004 as an autonomous agency of the Government with the objective to develop and promote a profitable and long term export fishing industry. There is a Memorandum of Understanding between the MOF and NFC concerning the sea cucumber fishing activities where the NFC is given the authority to establish sea cucumber fishing enterprises. In addition to its own industrial development programs, the NFC undertakes trade of fishing products including dry products such as sea cucumber produced by local artisanal and commercial fishermen. Finally, the Corporation allocates quotas, given by MOF, to locals as well as chartered industrial fishing foreign vessels or companies. Presently no law directly regulates the harvesting and management of sea cucumber. However the MOF, in an effot to ensure that marine resources are not endangered by exploitation, has instroduced a closed season (from November to March), fishing quotas, and a minimal size limit of 5 cm. The fishing quotas of sea cucumber are 500 tonnes per year of dried sea cucumber (this quota has not been reached until now). In addition MOF established areas protected from fishing of sea cucumber and prohibited the operation of fisheries within four miles away from fishing villages. The fishery was closed in 2007 in order provide opportunity to spawning and will make some reorganization in the sea cucumber fisheries that will benefit the country's economy.

Commercial fishermen do not have business licenses but enter in contract agreements with the NFC. Licenses are issued for the boats owned by the commercial fishermen and working permits for sea cucumber non-Eritrean divers and assistants. MOF does not ask diving certificate when issuing working permits for the divers, and no regular checking is made for the diving equipment.

The MOF acts as regulatory as well as an economic stakeholder through collecting licensing and registration fee, royalty and resources utilization fee. The NFC exploits the marine resources through government-owned firms, private commercial fishermen and artisanal fishermen. The commercial fishermen enter into contract agreements with the NFC to exploit fisheries resources (37 presently, but less than 25 working). The contract contains the following terms and conditions: (i) licenses for all vessels working in the collection of the products; (ii) specific fishing quotas for the fishermen; (iii) calculation and payment of registration, royalty, and utilization fees; fishing, marketing and collection, and selling of the products to NFC; (iv) sea cucumber prices; (v) closed season and areas; (vi) transshipment and illegal trade; (vii) grade of the products; (viii) employment; (ix) reporting, inspection; (x) size limit; (xi) quality of the products; and (xii) revocation, suspension and termination. The NFC does not buy products from the fishermen who do not have a contract. NFC collects sea cucumber from the commercial fishermen and exports it. It set the prices that are paid to the commercial fishermen based on the export prices. NFC also procures the fishing gears to fishermen who regularly supply sea cucumbers and provides supporting letters to commercial fishermen to allow them get food supplies and to assist them in getting permits to employ foreign divers given the shortage of local fishermen.

Bans on the whole fishery, or on the use of some gears, have been chosen in different countries where signs of over-exploitation had been observed, but they have often been abandoned under the fishers and exporters pressure. There was a ban on the use of SCUBA in the **Republic of Maldives** to protect the stocks of *H. fuscogilva* and *T. ananas* (Reichenbach, 1999). No recent information has been provided. **Egypt** is an example of a country introducing and lifting bans (Lawrence *et al.*, 2004; Ahmed and Lawrence, 2007).

In **Oman,** the situation of the *H. scabra* fishery's management is now changing (Al-Rashdi, K., Marine Science and Fisheries Center, Sultanate of Oman, personal communication). For the first time in the country, a set of regulations have been set up and are in place now, including the identification of the amount produced, the determination of the quantity exported, the total amount fished and the price from the fisheries statistics year book. Before this, no systematic data collection existed as this fishery was not of official concern, and data were included among unidentified fish. Currently only *H. scabra* is commercially exploited; most of the product is sent to the United Arab Emirated (UAE) where they are dried for (bêche-de-mer) or frozen (a smaller quantity than dried one).

Sea cucumber fishing in Oman was not subjected to any management and control regulation. This is related to lack of research on biological and ecological information of Oman sandfish resources. A few general fishery management restrictions are practiced, such as the restriction of SCUBA diving for any fishery in Oman; sea cucumber collection is mainly restricted to hand-picking while walking at low tide or via free diving at depth less than 2 m. The presence of unexploited populations below the present depth limits has been considered a possible buffer against overfishing, however the presence or extent of such stocks have not been demonstrated. Although there is no specific closed season for sea cucumber, fishers usually collect them for six months, with peak fishing from January to March. Moreover, all fishers involved in sandfish fishing are originally from local community of Mahout Area, and restricted to traditional fisheries only. From the above description of the fishery coupled with the walk survey using transect (Al Rashdi, Al-Busaidi and Al-Rassadi, 2007), several issues have been raised in the management point of view: (i) because of lack of information, collection of data on landing, effort, CPUE, density and processed production of *H. scabra* should be initiated; (ii) the Directorate of Fisheries at Al-Wusta (Central) Region should collect the above data by providing the local traders with export permission certificate, showing the name of the trader, age, area of the trader, form of product (dried, frozen, live or salted), quantity of the product, origin of the product, country/area to which the product to be exported, name of border, date of permission; (iii) the fish inspectors at borders should be trained on sea cucumber species and bêche-de-mer to facilitate the Directorate of Fisheries Statistics to group sea cucumber data separately in the annual statistical book; (iv) research in various aspects of biology, ecology and stock assessment and enhancement and marketing should be initiated; (v) exploration of new fishing grounds and application of marine protected areas (MPA) in some remote sea cucumber sites are also needed to minimize the fishing pressures in limited grounds and to protect brooders respectively; (vi) marketing structure should be studied to develop the socioeconomic part of this fishery; (vii) initiation of feasibility studies on sandfish aquaculture in Oman is important; (viii) capacity building programmes (e.g. training, study tours, participation in national and international meetings and workshops on sea cucumbers) should be conducted and supported by governmental organizations.

3. TRADE

Data for several countries have already been presented in section 2.6, as catches are often evaluated from exports. The principal sea cucumber export destinations are China, China Hong Kong SAR, Singapore, Malaysia and Taiwan Province of China with some reciprocal exchanges between them, which complicate the synthesis (Conand and Byrne, 1993; Conand, 2004a; 2006b). The destination of the exports is known for some countries. In the **Seychelles** the recent exports appears to be mostly to China Hong Kong SAR (Table 11) (from Aumeeruddy and Conand, this volume).

TABLE 11
Exports of dried sea cucumbers (kg) from the Seychelles and percentage of total export volume to the main market destinations

	China Hong Kong SAR	Malaysia	Singapore	Others
2001	4 662	2 387	1 729	0
2002	22 805	8 995	2 170	2 625
2003	30 467	13 085	1 075	0
2004	12 555	0	2 605	0
2005	22 858	2 415	6 030	1 725
2006	46 794	8 742	5 762	240
Total	**140 141**	**35 624**	**19 371**	**4 590**
%	70	18	10	2

TABLE 12
Annual dry sea cucumber exports (kg) from Sri Lanka to the main market destinations

	Singapore	Taiwan Province of China	China Hong Kong SAR	Total
1996	73 266	27 457	69 803	170 526
1997	–	–	–	307 578
1998	88 959	68 330	46 424	203 713
1999	30 905	45 112	22 001	98 018
2000	16 479	39 626	29 530	85 635
2001	19 739	48 649	14 205	82 593
2002	25 519	50 593	40 057	116 169
2003	47 223	44 866	40 746	132 835

Source: External trade statistics of the customs (From Terney Pradeep Kumara, Cumaranathunga and Linden, 2005).

Another example is taken from **Sri Lanka** where the major export destinations of sea cucumbers are Singapore, Taiwan Province of China and China Hong Kong SAR, with Singapore being the dominant buyer from Sri Lanka since 1999. Taiwan is the second biggest market and China Hong Kong SAR is the third (Table 12) (Terney Pradeep Kumara, Cumaranathunga and Linden, 2005). The mean annual export to these three major countries since 1997 is around 50 tonnes dry weight.

As suitable shallow habitats for sea cucumbers are restricted in the southern part of Sri Lanka and following the collapse of this fishery in the south, fishermen from these areas have been compelled to seek other sites for their fishery, in distant locations (e.g. the Chagos Archipelago, the Laccadive Islands and the Andaman Islands). Customs statistics for the whole country suggests that import of sea cucumbers in Sri Lanka commenced in 1996, with small quantities from the Maldives (collected by Sri Lankans) for processing and re-export. The imported quantity gradually increased to 23 609 kilograms in 2000. The source of imports has not been established, but probably reflects clandestine operations. This makes the interpretation of the available data difficult.

The trade routes in **Oman** are particular as generally almost all its bêche-de-mer production is exported to the United Arab Emirates (UAE) for re-export to the international markets. However, lately (2000/2001) import of Oman bêche-de-mer products was made by China Hong Kong SAR (Bruckner, Field and Johnson, 2003) with lower quantities comparing with UAE import at the same market and same time. The production from Oman rarely appears in the international bêche-de-mer statistics because small quantities are exported directly into international markets or to the UAE. Local price paid to collectors varies from 10 Omani Rials (OR) (approximately USD 26) per kilogram of dried sandfish to 50 OR, depending on the size of sea cucumber and season of occurrence.

Table 13 presents the 2004 imports by China Hong Kong SAR from the countries of the region and the total for the period 1999–2005. It appears that (i) the main supplier is Madagascar; (ii) countries from the Red Sea and western Arabian Sea, as Yemen and the UAE which are not well documented, are major suppliers; (iii) the percentage of the region is important and increasing with 23 percent in 2004, more than the mean

TABLE 13
China Hong Kong SAR imports of sea cucumber from Africa and the Indian Ocean region between 1996–2005

Country of origin	Quantity (tonnes)		Total
	2004	2005	1996–2005
Madagascar	176	246	1 982
Yemen	479	301	1 031
Tanzania	95	59	1 019
Sri Lanka	107	78	619
Maldives	21	8	348
Mozambique	42	33	330
South Africa	15	5	309
Kenya	22	23	205
United Arab Emirates	140	15	194
Djibouti	9	0	148
Seychelles	18	40	100
Mauritius	4	0	76
Egypt	18	22	58
India	21	2	54
Ethiopia	12	12	24
Saudi Arabia	9	–	13
Oman	4	4	10
Saudi Arabia	9	3	13
Comoros	0.7	0.3	1.6
Sudan	–	0.6	0.6
Total region	**1 201**	**851**	**6 533**
Total (all imports)	**5 070**	**4 479**	**44 000**
Region/total	*0.24*	*0.20*	*0.15*
Value HKD (million)	778	869	–
Value USD (million)	100	112	–

Source: Census Statistic Department, China Hong Kong SAR, 2005.

TABLE 14
Imports of sea cucumber into China Hong Kong SAR from Oman and United Arab Emirates

Year	Oman		United Arab Emirates	
	Quantity (tonnes)	Value (USD 1 000)*	Quantity (tonnes)	Value (USD 1 000)
1996			3	19
1997			22	70
2000	0.96	14.25	10.85	161
2001	0.49	7.26	40.62	602

* Estimated values based on UAE values during the same period

Source: After Bruckner, Johnson and Field, 2003; Ferdouse, 2004 *in* Al Rahsdi, Al-Busaidi and Al-Rassadi, 2007).

value of 15 percent for the period 1999–2005. Table 14 presents the reported imports of bêche-de-mer into China Hong Kong SAR, from UAE and Oman.

The illegal, unregulated and unreported (IUU) fisheries for sea cucumbers are a problem mostly encountered where countries have no regulations or little control. A first example will be taken from the **Chagos** presented by Spalding (2006). The United Kingdom government efforts to police these waters have increased since 1996 and the waters are now patrolled year-round by a Fisheries Protection Vessel while regular sorties to the islands are made by British military personnel. This has led to increases in prosecution of illegal fishing vessels and crew; however, rates of arrival of new illegal vessels remain high. It seems likely that, as fish stocks become increasingly impacted elsewhere around the Indian Ocean margin then the risks associated with illegal fishing in Chagos waters become increasingly worth taking. Reports point to an illegal sea cucumber fishery in Chagos that has been in operation from Sri Lanka for several years. This is supported by direct observations and discussions with fishers.

Large quantities of sea cucumber from Chagos waters were found in Sri Lanka ports (Spalding, 2006). The start of the fishery in the years leading up to 2000 would tie in well with the recorded decline in national stocks in Sri Lanka that began around this time. In April 2005 a camp of illegal Sri Lankan fishers was observed in Chagos, on the northern end of Eagle Island, a Strict Nature Reserve. About ten fishermen were present. They had arranged a series of drying platforms on wide sandy beach area at this end of the island, with strong black plastic sheeting to cover the sea cucumbers during rainy days. Around 6 000 sea cucumbers were observed drying. These were not identified, although it would appear that they included several species. These fishers were reported to the British officials on Diego Garcia. The fishers were arrested, duly tried and fined, and on payment of the fine were allowed to return (without their catch) to Sri Lanka. Since this date, over a period of five months, a further three vessels and crew have been caught and each fined amounts ranging from £6 000–10 000 (USD 10 000–17 000). Some, but not all were found with diving equipment, which would greatly extend their harvesting capability and would allow them to access some of the higher value species. To be added to the cost of these fines must be considered the costs of mounting an expedition to fish in Chagos waters. The journey is made in relatively small vessels, using considerable quantities of fuel. An expedition may take 1–2 months. Such an expedition is clearly worth undertaking when the chances of success are high. This is heightened by the growing market value of these animals. The total value of the haul observed drying in April 2005 could have been as high as USD 60 000–80 000, and this by no means represents the complete intended catch. Perhaps the capture of four such ventures in the last five months will begin to have a deterrent effect (Spalding, 2006).

Another example is given by Tewelde and Jeudy de Grissac (2007) for **Eritrea**. The decline in catches is partially explained by the illegal trade practiced by the local fishermen with Yemen. Apart from official trade records, traders and fishermen claimed that there is a significant amount of illegal (not recorded) trade to Yemen. Fishermen are attracted by the higher prices of sea cucumber and low price of food and fuel in Yemen. For instance, according to fishermen, the price of *H. scabra* (dry) per kilogram is about three times higher in Yemen than in Eritrea for the same products (ERN 296 to 536). In order to avoid illegal trade across the Red Sea the Eritrean Ministry of Fisheries has a plan to reduce royalty for shore-based fishermen, but this has still to be implemented.

A prices analysis is also necessary, but never easy, as there are several buying levels from the fishers to the exporters (Conand, 2004a, 2006b).

In **Seychelles** some sea cucumber prices are given in the hotspot report (Aumeeruddy and Conand, this volume) extracted from the export documents or collected from interviews made in May 2007 (Pinault and Conand, 2007). The price depends on the species, the size and the grade of the product; it is not easy to obtain the pricing structure from the fishers or the processors. The high valued species such as white teatfish, pentard and black teatfish fetch respectively a maximum of USD 17.3, USD 13.8 and USD 8.6 per piece for the best grade and large size dried individuals.

Although **Oman** produces sea cucumber since 1995, the Directorate of Statistics groups sea cucumber production along with unidentified fishes (Al Rahsdi, Al-Busaidi and Al-Rassadi, 2007). The prices paid by local traders to the collectors vary by sizes and season. However, the average price paid from 2000 to 2004 was roughly OR 10 per 100 pieces of live sea cucumber (1 Omani Rial = USD 2.61). During January–March 2005, the price jumped to OR 45–50 for 100 live sea cucumber with an average price of OR 30. All fishing and processing expenditures, are made by the traders, these include transportations, fuel, mask, gas, salt and generator. This is also the case in other countries as for example Eritrea (Tewelde and Jeudy de Grissac, 2007). In Oman, when the bêche-de-mer is ready, it is stored in warehouse in bulk unsorted. Just two or three days before loading, they are sorted into different sizes and packed in polypropylene bags. Presently, four major local traders are actively involved in marketing of bêche-de-mer. They have agents in UAE purchasing the products. Prior to the fishing season, the agents visit the area and give instructions to the traders on the required processing techniques and negotiate the price.

In conclusion, the trade in bêche-de-mer differs considerabely among the countries in the region. A more careful analysis, based on the main markets (China, China Hong Kong SAR, Malaysia, Singapore and Taiwan Province of China,) is necessary. Data on imports, exports and re-exports will have to be collected and processed. Trade between countries, as shown on the example of Oman and the UAE, complicates the analysis, as is the reciprocal trade between the markets of Singapore, China Hong Kong SAR and Taiwan Province of China (Conand, 2004a, 2006b).

4. SOCIO-ECONOMIC IMPORTANCE TO LOCAL FISHING COMMUNITIES

Understanding the socio-economic aspects of sea cucumber fisheries are essential in the case of small-scale fisheries (McClanahan and Pet-Soede, 2000; McClanahan and Sheppard, 2000; Cesar *et al.*, 2002; De La Torre-Castro, 2006). It also constitutes an important objective of the regional WIO Masma project (Conand *et al.,* 2006; Muthiga and Conand, 2006). The project foresees the application of the same methods, using specific questionnaires and interviews, in selected sites of the different countries (De La Torre-Castro *et al*., 2007). A conceptual model of sea cucumber resource dynamics in the WIO countries has been developed (De La Torre-Castro *et al*., 2007) based on the previous knowledge on these fisheries (Conand, 2001, 2006b). This model encompasses multiple levels and considers the main structures of the sea cucumber fishery such as fishing and collection grounds, resource users and other stakeholders involved in the fishery (e.g. fishers, middlemen and importers), the links between stakeholders, villages and countries, and the associated management initiatives at different levels. This framework is promising when analyzing the sea cucumber national fisheries from a holistic perspective, considering both social and ecological interactions. The results are still preliminary for a few countries.

In **Kenya** (Ochiewo and De La Torre-Castro, 2007), the study has been conducted in villages located along its southern coast. The results indicate that sea cucumber collectors are mainly men who fish in the sub-tidal areas, between three and ten metres deep. These fishers do not use SCUBA and fishing is heavily done during the north-east monsoon season when the sea is calm and water is clear. About 50 percent of the sea cucumber fishers also collect other marine products such as octopus. Sea cucumbers are sold fresh to local dealers (middlemen) who process them and sell to more prominent middlemen in the neighbourhood of Mombasa. The fishers occasionally borrow money from dealers especially when they fail to catch sea cucumbers. This in turn makes them in debt to the dealers who lend them money. Sea cucumber fishing is regulated by the Fisheries Department that issues fishing licences. According to the law, fishers pay Kenya Shillings (KES) 100 (1 KES = USD 0.015) for the fishing licence annually. However, apart from the main fisheries legislation, there is no special law or policy that is devoted specifically to govern the sea cucumber fishery.

In **Madagascar**, the fishery is very active; when a site is overexploited, then fishers move temporarily to another place along the coast, set up a new village, and dive either with artisanal mask and fins or with SCUBA. These settlements sometimes raise conflicts with traditional villages.

The photos in Figure 8, taken in June 2007, illustrate this activity. It is worth observing that catches are composed of large specimens, many of the high commercial value species (*H. fuscogilva, T. ananas* and *Bohadschia* spp.); these fishers were diving for the first time in this site and will move again when the catches decline.

FIGURE 8
Sea cucumber fishery in northwestern Madagascar, 2007. A: the skin divers and their canoe; B: fishing sea cucumbers; C: processing in a temporary village; D: multispecies catch

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The situation in the **Seychelles** is presented in Marguerite (2005) and Aumeeruddy (2007). Interviews of the different stakeholders from boat owners to international traders of sea cucumbers were conducted during a recent survey of the Masma project (Pinault and Conand, 2007). Through this socio-economic study, it was estimated that the holothurian fishery is employing about 100 people in the Seychelles, and from the Marguerite's survey (2005) which focussed on the economical dimension, it was estimated that 120 to 125 households were, to various degrees, dependent on the sea cucumber harvesting and processing business. This fishery amounts to between 9–10 percent of the total employment in the artisanal sector. Boat owner data tend to indicate that the harvesting activity is not profitable with the prices declared during the interviews, especially for the bigger vessels. Increasing prices for "pentard" gives more realistic results but it appears that the boat owner fishing strategy is more commanded by the high prices proposed by the processors for one or two species than by a real profitability evaluation. The Amirantes sector seems to present the more profitable fishing grounds with an interesting relation between the distance to cover and the money to earn. Processors interviews tend to indicate that the trade in dried sea cucumber is unprofitable. A comparison between the export incomes based on the InfoFish (http://www.infofish.org) prices and the expenditures of processors to buy the products to fishermen, indicates that the processors and exporters would be making important losses. On the other hand, the continuous interest in both harvesting and processing would suggest that the sea cucumber business is still profitable

At present, **Sri Lankan** fishermen from the south are exploiting sea cucumber beds in distant parts of the Indian Ocean (Terney Pradeep Kumara, Cumaranathunga and Linden, 2005). Although fishermen from Negombo on the western coast started the fishery in the southern part of the Island, fishermen/divers from the southern fishing towns of Mirissa and Dondra now dominate. There are around thirty-five boats engaged in the sea cucumber fishery along the southern coast. Fishermen use multi-day operating craft (MDOC) and Global Positioning Systems (GPS) to navigate far from shore. The lengths of the boats range from 35 to 50 feet and they use inboard 45 Hp engines. These boats are usually four to six years old and modified to accommodate 10 to 12 people. The crew consists of the skipper of the boat, divers, a cook, a compressor operator and an electricity generator operator. At times these boats operate in three or four units: by this strategy they are able to maximise their profits by carrying fewer support personnel (such as cooks and compressor operators) and a larger number of divers. The sea cucumber fishery in the south is by opportunistic tuna fishermen. Whenever exploitable sea cucumber beds are located they switch to that; and when the beds are fished out, revert to tuna fishing. The duration of each spell of activity depends on the sea cucumber population and the number of boats and divers that participate in the fishery.

A few data have also been presented by Al Rashdi, Al-Busaidi and Al-Rassadi (2007) for **Oman**. Sea cucumbers are harvested by hand picking during low tides, mainly spring low tides. There are five main *H. scabra* fishing grounds well-known to the collectors. To reach barrier flats, collectors use motorized boats, which usually belong to the traders. The latter often contracts a group of collectors, mostly women, to buy their sea cucumber catches, providing them with free services such as transportation (boats or vehicles), drivers, mask and food. About three boats each by four main traders are usually used in fishing operation with 7–10 collectors in each boat, while the vehicle may take two round trips with 10 collectors in each trip. The time required to get to the fishing grounds ranges from 15 to 60 minutes. Fishers work individually; they collect and store sea cucumbers separately in a large flour bags or a plastic bucket. Free diving (mask only) is infrequently used and is restricted to men only. The number of monthly fishing days was estimated to vary from 10 to 20. The estimated number of fishers increased from 100 in 2004 to 200 in 2005, which could indicate an increase in demand for bêche-de-mer and high income for the fishers and traders. The average fishing hours per working day (unit of effort) is 3–4 hours with a collection of 100 live sandfish approximately. Among the collectors, women represented the largest share of about 50 percent, while men and children accounted for 30 and 20 percent, respectively. The fishery for sea cucumber is usually linked with the shrimp fishing season in the area. Once the shrimp fishing activity decreases, the fishing season of sandfish commences. The sea cucumber fishing activity begins in late November and reaches its peak between January and March and then gradually decreases to May. The fishing season is also influenced by traditions of Mahout Community and sea conditions. As most of the Mahout communities are Bedouins, they seasonally move out of Mahout to adjacent areas particularly in the summer (June-August) when the sea condition is rough.

In **Eritrea** (Tewelde and Jeudy de Grissac, 2007) the situation is complex, with four big traders companies who employ fishermen (Eritrean and foreigners) and sell the products to NFC through auctions. Table 15 shows the main traders organization and the dried sea cucumber supplied to NFC in 2005 and 2006. The number of diving tanks and air compressors shows the importance of SCUBA diving. This fishing practice results in frequent decompression accidents (i.e. paralysis or death) because fishers are not well trained on Scuba diving.

TABLE 15
Main traders, fishermen and dried sea cucumber harvesting in Eritrea

Trader	Divers (fishermen) origin					No. boats	No. dive tanks	No. air compressor	Tonnage 2005	Tonnage 2006
	Eritrea	Somalia	Yemen	Egypt	Tanzania					
1	230	–	–	–	–	30	80	40	166.02	85.61
2	350	30	161	–	–	–	–	24	54.42	43.05
3	40	–	–	70	85	6	100	–	7.27	4.1
4	8	30	3	–	–	12	120	3	1.49	7.07
Other	–	–	–	–	–	–	–	–	32.34	94.62
Total									**278.37**	**241.84**

Source: Tewelde and Jeudy de Grissac, 2007.

This presentation clearly shows that although most sea cucumber fisheries are generally small in size, they are important for many communities in the Africa and Indian Ocean region.

5. CURRENT PROJECTS/DEVELOPMENTS ON FISHERIES, BIOLOGICAL STUDIES, AQUACULTURE VENTURES UNDERWAY

In the region there are several projects underway investigating commercial holothurians. The Masma (WIOMSA) Regional Project for WIO, which started in 2005, (Conand *et al.,* 2006; Conand and Muthiga, 2007a) has as main goals to: (i) increase the understanding of the status of sea cucumbers and their management including their potential for aquaculture; (ii) provide key skills and information for management including identification skills and information on reproduction and recruitment of key commercial species that is crucial for fisheries management; (iii) improve the knowledge of the management systems and the gaps in knowledge that will form the basis for any management plans; (iv) increase the knowledge of the impact of the fishery on the socio-economic status of coastal communities. It is intended to be multidisciplinary, with a close collaboration between biologists, ecologists and social scientists. Training in sea cucumber taxonomy, biology and fisheries will provide the capacity for monitoring and evaluating the effectiveness of the management systems currently in place. The project will focus on Kenya, Madagascar, Réunion, Seychelles and Tanzania. The main intended outputs are: species inventories and distribution, assessment of the impacts of MPAs, understanding of the biology of the main species, socio-economy and management of sea cucumber fisheries, and the training of practitioners and students, as well as guidelines for the collection of catch statistics. Several national contributions are underway (see abstracts for the WIOMSA's symposium, Durban, October 2007), but the regional synthesis will be prepared at a later stage.

Several countries, including Egypt (Ahmed and Lawrence, 2007), Eritrea (Tewelde and Jeudy de Grissac, 2007; Kalaeb *et al.*, 2008), Oman (Al-Rasdi, Al-Bussaidi and Al-Rassadi, 2007), are giving a special attention to sea cucumbers resources and fishery through different projects. It is important that their results and reports are disseminated. The socio-economy of sea cucumber fisheries also deserves a special attention in the Middle East region.

Aquaculture is considered as a solution for sustainable management of this resource, to reduce the anthropic pressure on the natural population and to restock wild stocks. Since 1998, some successful aquaculture experiences have been conducted in Tuticorin, south-eastern coast of India, on the sandfish *H. scabra* (James, 1994a, b, 1996, 2004a; James *et al*., 1988; James *et al*., 1995).

In Madagascar (Rasolofonirina, 2007), a programme was set up with the help of the Belgian Cooperation resulted in the construction of a sea cucumber hatchery and farm in Toliara region (Conand, 1997; Conand *et al.*, 1998; Jangoux *et al.,* 2001; Rasolofonirina, Mara and Jangoux, 2004; Rasolofonirina and Jangoux, 2005; Lavitra *et al.,* 2007; Rasolofonirina *in* Conand and Muthiga, 2007). Recent information has been communicated by I. Eeckhaut, R. Rasolofonirina and M. Jangoux (Université libre de Bruxelles, Bruxelles, personal communication) on "Madagascar Holothurie" (MH S.A.) the first trade company based on sea cucumber aquaculture in Madagascar. They also provide a brief history of the project. In 1999, a sea cucumber mariculture project undertaken in Madagascar arose from alarming reports of widespread overexploitation of the natural sea cucumber populations. The work was funded by the Belgian University Corporation for Development (CUD) and involved the Universities of Brussels and Mons (both from Belgium) and the Malgachian University of Toliara. It first consisted in building a sea cucumber hatchery on the setting of the Toliara Marine Sciences Institution (IH.SM). The hatchery was functional in 2003 and currently produces tens of thousand of juveniles of the valuable *H. scabra*. Its main section consists of a 120 m^2 air-conditioned building with six rooms for growing seaweed, rearing larvae, caring for the broodstock and undertaking microscopic and computer analyses. The aquaria of the hatchery are connected to a saltwater pumping station, whose reservoir fills up at high tide and whose water pours into a 30 m^3 settling pond. Decanted water is then sterilised by repeated applications of UV before being used in the larvae rearing tanks.

The second phase of the project, launched in 2004, consisted in setting up a sea cucumber farm to grow-out juveniles until they reach a marketable length. The farm was erected at Belaza, 20 km south from Toliara. This setting, which borders a mangrove, fulfils the ecological requirements of *H. scabra*. The farm allows bringing sea cucumber juveniles produced by the hatchery to a marketable size and weight (more than 20 cm and 300 g) in 10 to 12 months. The method for growing sea cucumber includes three successive phases, each requiring specialized infrastructures (internal aquaria, external tanks and sea fences) related to the animal sizes. Aquaria are set up in a 120 m^2 air-conditioned building. They each contains 200 l of filtered sea water where juveniles grow up to a length of 2 cm. Sea cucumbers are then transferred in 25 000 l external tanks where they are maintained until they reach a length of 5 cm. This size is adequate for allowing individuals to survive in sea fences. Thousands of sea cucumbers are currently produced by the farm.

In March 2008 when the funds from the Belgian CUD ended, private firms have formed a partnership involving a spin-off from Belgian universities, the IH.SM and private firms to form the first trade company based on sea cucumber aquaculture in Madagascar. The expected production of the trade company in the next five years is of 250 000 sea cucumbers per year. Development of cooperatives in villages will be essential for the development of the sea cucumber mariculture. The farm productivity is indeed not limited by the number of juveniles bred in the hatchery (a single pair of genitors, one male and one female, produce tens of thousands of fecundated eggs), but rather by the surface of the available farming structures (surface of enclosed spaces). The trade company would have to supply various local organizations (groups of fishermen, coastal villages) so that they could be trained to operate the farming. If the experience is positive, it could rapidly extend to the entire west coast of Madagascar when a reliable mean of transportation of juveniles is set up (enhancement of various coastal sites for the growing of specimens).

In the other countries, there are probably ongoing projects, but the author has not been able to get further information. The Manual on Sandfish Hatchery Techniques by Agudo (2007) and other publications from the Pacific (Purcell, Blokmans and Agudo, 2006) will certainly be useful for the countries who want to find alternative ways to protect their natural sea cucumber resources.

6. ADDITIONAL THREATS TO SEA CUCUMBER POPULATIONS

A general indirect threat to sea cucumber populations worldwide is the degradation of the habitats. This is more important in the tropics and the overall decrease of the coral reefs worldwide is widely recognized. Bryant *et al.* (1998) in a publication entitles "Reefs at Risk" gave a general picture of the threat of the reefs worldwide. The indicator (low, medium and high threat) is a composite of four coastal risk factors. Table 16 indicates that in the Middle East and Indian Ocean more than half of the reefs are with medium and high threats. From these regions, Tanzania and the Comoros have both high biodiversity and high threat from human activities.

The coral reef holothurians are particularly vulnerable. For India (Gulf of Mannar) James (1982) mentioned that several species such as *S. chloronotus,* which were abundant in 1927, had disappeared as a result of habitat destruction. Aumeeruddy and Conand (this volume) have analysed the situation for the Seychelles which is also applicable to other countries in the region with decreasing CPUE.

TABLE 16
Total area of reefs at risk

Region	Total reef area (km²)	Threat category (%) Low	Medium	High	Coastal population density/km²
Middle East	20 000	39	46	15	24
Indian Ocean	36 100	46	29	25	135
Global	255 300	42	31	27	101

Source: Bryant *et al.*, 1998.

The main direct threat for sea cucumbers is overexploitation for the production of of bêche-de-mer. Species with high economic value (see Table 2) are more threatened, but as their numbers decrease other species with lower commercial value are now declining. The major consequence is the depletion of sustainable breeding populations to allow natural replenishment of populations. In Malaysia other uses are made from sea cucumber, for medicines, ("gamat oil" or "gamat water") and a variety of balms. Pharmaceutical research for new products is also ongoing (Baine and Choo, 1999), but this is not reported in other countries of the region.

Illegal fisheries are probably quite important in several countries of the region. The example of the Chagos is characteristic (Spalding, 2006). These islands represent one of the few remaining wilderness areas of the Indian Ocean, and provide an invaluable reserve of natural reef communities, and may well play a wider regional role in the movements of species and genetic material to other reefs across the ocean. The government of the United Kingdom has expressed its concern and will be further seeking to halt this illegal fishery through improved detection and arrest as well as through diplomatic approaches with other Indian Ocean states.

Improving sea cucumber fishery management and conservation is presently very urgent. The efforts of international and national agencies should lead to international, regional and national recommendations and application of new management measures (see Bruckner, 2006; Aumeruddy and Conand, this volume).

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