Conservation strategies for sea cucumbers: Can a CITES Appendix II listing promote sustainable international trade?

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Introduction

Sea cucumbers, especially of the families Holothuridae and Stichopodidae, form an important part of a multi-species invertebrate fishery that has been in existence in the Indo-Pacific for traditional and subsistence uses for over 1000 years. Since the late 1980s, sea cucumber fisheries have expanded to supply growing international markets with beche-de-mer, and also to provide organisms for aquaria and biomedical research. Trends during the 1990s indicate that the number of producing countries and species in trade have increased worldwide, both in tropical and temperate regions, and holothurian fisheries have spread to many non-traditional fishing areas such as Mexico, the Galapagos and North America. In Hong Kong Special Administrative Region (Hong Kong SAR) import statistics show an increase from 25 source countries in 1987–1989 to 49 countries that exported beche-de-mer in 2000–2001. While worldwide landings of sea cucumbers were estimated to amount to 25,000 metric tonnes (t) live (approx. 2500 t dried weight) in 1983, the total trade in holothurians reached a global annual volume of about 13,000 t of dried sea cucumber (130,000 t live) by 1995, valued at about USD 60 million (Jaquemet and Conand 1999; Conand 2001).

The high value of some species, the ease with which such shallow water forms can be harvested, and their vulnerable nature due to their biology, population dynamics and habitat preferences all contribute to the overexploitation and collapse of fisheries that have been reported in some regions. Holothurians are susceptible to overexploitation due to their late maturity, density-dependent reproduction, and low rates of recruitment. Although sea cucumbers have a wide distribution, with some species occurring throughout entire ocean basins, most species have very specific habitat preferences such as a specific zone within reef habitats, algae, or grass beds. A marked increase in landings and export of holothurians, combined with a limited amount of fishery data, a paucity of biological information and population parameters for commercially important species, and the existence of few management measures are all factors involved in the decline of holothurian populations (Conand and Byrne 1993).

Biological and trade information strongly suggest that sea cucumbers may qualify for listing in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Given the past and continuing levels of exploitation to meet international demand, these species meet CITES criteria for inclusion of species in Appendix II, as adopted in Resolution Conf. 9.24 (Annex 2a Bi): "harvesting of specimens from the wild for international trade has or may have a detrimental impact on the species by exceeding, over an extended period, the level that can be continued in perpetuity". Available trade data are thought to represent an underestimate of the total global commerce, as trade routes for holothurians are complicated, export data are incompletely reported, commodities in trade can include several forms of dried product as well as chilled, frozen and salted beche-de-mer, and individual species are rarely differentiated in trade reports. Beche-de-mer is primarily exported from producer countries to a central market in Hong Kong SAR, Singapore or Chinese Taipei, and then re-exported to Chinese consumers worldwide (Conand and Byrne 1993). Also, a large number of species and possibly several hundred thousand sea cucumbers are available for home aquaria, but data on species, quantities and source countries are largely undocumented due to a lack of international trade controls.

The United States of America submitted a discussion document (CoP 12 Doc. 45) to the CITES Secretariat requesting that this issue be discussed by the Conference of Parties in Chile, November 2002, to address the fundamental questions of whether a CITES listing is appropriate for and can contribute to the conservation of sea cucumbers. Of critical importance is whether a CITES listing can contribute to the sustainable management of sea cucumbers. A number of issues have to be addressed before this question can be answered, including taxonomic uncertainties within the families, ability to distinguish taxa in the form they are traded, adequacy of biological information for making non-detriment findings, and ability to

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Table 1. **Primary species involved in the international trade in sea cucumbers and location of collection. High value (*), medium value (**) and low value (***) species are indicated. Most species shrink to approximately 50% of their length and 8% of their weight when dried (adapted from Conand 1990)**

Species	Common name	Distribution
*Actinopyga echinites****	brownfish (deepwater red fish)	S. Pacific
*A. lecanora ***	stone fish	S. Pacific
*A. mauritiana***	surf red fish	S. Pacific
*A. miliaris***	black fish	S. Pacific
Athyonidium chilensis		Peru, Chile
*Bohadschia argus****	leopard (tiger) fish	S. Pacific, SE Asia
*B. graeffei**** (= *Pearsonothuria graeffei*)	orange fish	S. Pacific, SE Asia
*B. marmorata marmorata***	chalky fish	SE Asia, S. Pacific, Red Sea
*B. marmorata vitiensis***	brown sandfish	SE Asia, S. Pacific, Red Sea
*B. vitiensis****	brown sandfish	S. Pacific, Indian Ocean
Cucumaria frondosa	pumpkins; orange footed cucumber	West Atlantic (Maine/Canada)
*Halodeima atra****	lolly fish	S. Pacific
*H. edulis****	pink fish	S. Pacific
*H. fuscogilva**	white teatfish	S. Pacific, SE Asia, Indian
H fuscopunctata	elephant trunkfish	S. Pacific, SE Asia
H. impatiens	slender sea cucumber	Caribbean (Mexico)
H. mexicana	donkey dung	Caribbean (Venezuela)
*H. nobilis***	black teatfish	S. Pacific, SE Asia
*H. scabra**	sandfish	S. Pacific, SE Asia, Indian Ocean
*H. scabra versicolor**	golden sandfish	S. Pacific, SE Asia
Isostichopus badionotus	three-rowed sea cucumber	Caribbean (Venezuela)
I. fuscus (= Stichopus fuscus)		East Pacific from Baja to Peru (Galapagos)
Parastichopus californicus (= *Stichopus californicus*)	giant red sea cucumber	East Pacific (US/Canada)
P. parvimensis (= *Stichopus parvimensis*)	warty sea cucumber	East Pacific (California/Mexico) [to Cedros Island, Baja]
*Stichopus chloronotus**	green fish	S. Pacific, Indian
*S. hermanni**	curry fish	SE Asia, S. Pacific
S. japonicus		Japan
S. mollis	New Zealand sea cucumber	New Zealand, W. Australia, Tasmania
*Thelenota ananas**	prickly redfish	S. Pacific
*T. anax****	amberfish	S. Pacific

make legal acquisition findings. The main purpose for highlighting this issue at CoP 12 is to: (1) establish dialogue between Parties, scientists, industry and communities dependent on these resources; (2) encourage continued research to clarify taxonomy and identification of live and dried specimens in trade, and compile life-history characteristics, species distribution and demographic data; (3) improve the collection of data quantifying the extent of harvest and international trade, documenting location and catch data by species; (4) compile the best information about the current status of these species and the impact trade has on sea cucumber populations and their environments; and (5) evaluate possible management approaches to promote sustainable harvest. This paper summarises the discussion document, the full text of which is available at: http://www.CITES.org/eng/cop/12/doc/E12-45.pdf.

Harvest and trade

Holothurians that are targeted for beche-de-mer range in size from about 5 cm to over 1 m in length, and include over 30 deposit-feeding species and one filter feeder belonging to two families and seven genera of the Aspidochirotids: *Actinopyga, Bohadschia, Holothuria* (Holothuridae) and *Isostichopus, Parastichopus, Stichopus* and *Thelenota* (Stichopodidae) and one family and genus of the Dendrochirotids: *Cucumaria* (Cucumariidae) (Table 1). Tropical and subtropical fisheries are multi-species with fishers primarily targeting shallow water (up to 50 m depth) environments, while most temperate fisheries are based on single species. The species of highest commercial value in tropical waters of the western Pacific and Indian Oceans are *Holothuria fuscogilva* (white teatfish), *H. nobilis* (black teatfish) and *H. scabra* (sandfish). Species of medium value include *Actinopyga echinites* (brownfish), *A. miliaris* (blackfish) and *Thelenota ananas* (prickly redfish). Species of low value include *H. atra, H. fuscopunctata, Stichopus chloronotus* and *S. variegatus*. A small, but growing fishery exists in the eastern Pacific, including Ecuador and Galapagos, for *Isostichopus fuscus*. Temperate fisheries are divided into western Pacific regions for *Stichopus japonicus*, eastern Pacific coasts of North America for *Parastichopus californicus* and *P. parvimensis* (Alaska, Oregon, California and Washington, USA, and British Columbia, Canada), and a small fishery in the Atlantic for *Cucumaria frondosa* (Maine, USA, and Quebec, Canada). Fishing gear and methods include small bottom trawl nets (roller pulling nets and beam trawl nets) for sandy bottoms, scallop-drag gear in nearshore rocky-bottom habitats, spears, hooks and scoop nets for reefs, and scuba and hookah for deeper reef and lagoonal environments.

World landings of sea cucumbers were estimated to amount to 25,000 t (live) in 1983. *Stichopus japonicus* was the most important species by weight during the early 1980s, with over 13,371 t harvested in Japan and Korea each year prior to 1985. Most of the remaining harvest consisted of tropical species from the Indo-Pacific. Worldwide harvest increased threefold from 1985–1986, and it again doubled during 1987–1989 in response to increased demand in Asian markets. In 1989, a total catch of 90,000 t was recorded, consisting of about 78,000 t from the South Pacific and Southeast Asia, and 12,000 t from temperate fisheries. Holothurian fisheries have continued to expand, with a total worldwide harvest of 120,000 t by the early 1990s (Conand 1997).

There is a substantial amount of information on the trade routes and main sea cucumber markets, but the volume and location of harvest and export are still incompletely recorded. The Chinese have sought sea cucumbers for over 1000 years in India, Indonesia and the Philippines, but traders began gathering them from a wider area in the 18th and 19th century (Conand and Byrne 1993). Over the last two decades, much of the beche-de-mer in international trade was exported from the producer countries to a central location, and then re-exported to Chinese consumers (Conand and Byrne 1993). Hong Kong SAR, China, Singapore, Malaysia, Chinese Taipei, Korea and Japan currently account for almost 90 per cent of the total imports of beche-de-mer, with approximately 80 per cent of the overall international trade destined initially for Hong Kong. Based on import data from Hong Kong, the number of exporting countries for dried, fresh and frozen beche-de-mer has continued to increase from about 25 countries in 1989 to 49 in 2000/2001, with exports dominated by about 30 species (Table 2). In 2000 and 2001, Chinese Taipei imported sea cucumbers from 28 countries. Singapore currently receives about 50 per cent of its imports from Hong Kong SAR, with Papua New Guinea, Tanzania and Madagascar the other main suppliers. An examination of trade statistics for the three main markets also reveals the existence of two-way trade, particularly for the Singapore and Chinese Taipei markets. For instance, between 1995 and 1996 Singapore shipped 72 per cent of its re-exports to Hong Kong SAR and 6 per cent to Chinese Taipei; Chinese Taipei also imported 42 per cent of its beche-de-mer from Hong Kong SAR, with imports destined for local consumption or later re-export, depending on the market (Jaquemet and Conand 1999).

Export data are available for only a small number of countries, and only limited information is available on total harvest of individual species. In the late 1980s and early 1990s, Indonesia was the major world producer and exporter, with a production of around 4700 t of dried sea cucumbers per year since 1987. The Philippines emerged in the mid 1990s as the second major producer and exporter of dried sea cucumbers, with catches of around 20,000 t (live) per year (Conand and Byrne 1993). Other major exporters include Fiji Islands, Japan, Madagascar, Papua New Guinea, Solomon Islands, Thailand and USA (Table 3).

Population status and trends

There are a growing number of reports indicating that sea cucumber populations are declining worldwide in tropical and subtropical countries with sea cucumber fisheries, including information from collection areas in Australia, India, Thailand, Papua New Guinea and the Galapagos (Conand 1997; Jaquemet and Conand 1999; TRAFFIC South America 2000). For instance, in the Great Barrier Reef in Australia, densities of *H. nobilis* were found to be four to five times higher on reefs protected from fishing when compared to 16 reefs open to fishing, and the average weight of individuals was substantially smaller (1763 g) on fished reefs than on unfished reefs (2200 g) (Uthicke and Benzie 2001). In many locations fisheries have gone through boom and bust cycles, and high value species are typically rapidly depleted shortly after a fishery became established. As certain high value species become overexploited the focus first shifts

Table 2. **Amount of dried sea cucumbers (metric tonnes) imported into Hong Kong SAR. Source: Hong Kong SAR import statistics. * Data from Singapore, Hong Kong SAR and Chinese Taipei. ** The Western Indian Ocean countries that export sea cucumbers include South Africa, Mozambique, Tanzania, Kenya, Yemen, United Arab Emirates and Madagascar, some of which are listed separately in subsequent years.**

Country	1983	1988	1989	1993	1994	1995	2000	2001
Africa	145.43	0	0					
Australia	0	7.60	1.10				14.19	21.83
Brazil							0	0.45
Canada	0	33.60	15.00				2.69	58.54
Chile							22.32	7.60
China	0	98.50	117.10				13.16	11.78
Colombia							0	0.55
Costa Rica							0.66	0
Cuba							19.02	13.94
Djibouti							0	0.01
Ecuador	0	0	0				15.28	0.09
Fiji Islands	0	*1295.00	*251.00	119	176	402	364.37	275.54
France							0	0.16
India	0	*33.00	*94.00				0.40	3.81
Indonesia	836.65	*3633.00	*1987.00	2620	2599	1694	1007.06	1060.39
Japan	483.98	34.20	39.40				74.94	102.76
Kiribati				99	130		9.07	13.96
Korea	368.26	42.90	22.40				2.54	0
Madagascar	0	86.60	57.70	379	318	170	178.39	179.08
Malaysia	0	19.50	125.16	17.50			59.31	66.04
Maldives	0	*347.00	*367.00				39.42	28.76
Mauritius							3.19	0
Mexico							0.15	0.59
Morocco							0	2.24
Mozambique	0	39.10	22.90				0.11	0.95
Netherlands							0	0.01
New Caledonia	0	*34.00	*28.00				0	0
New Zealand							11.04	31.19
Oceania	59.28	0	0				14.19	21.83
Oman							0.96	0.49
Papau New Guinea	0	327.00	226.00	179	150	236	531.90	493.41
Philippines	918.07	1718.50	621.70	1,872	1726	1270	1069.95	736.93
Seychelles							7.12	15.68
Singapore	51.93	797.70	1067.90				345.39	334.81
Solomon Islands	0	139.60	91.50	319	247	161	144.37	259.73
South Africa	0	34.30	22.30	28	93		27.88	28.78
Spain							1.00	0
Sri Lanka	1.30	*72.00	*52.00				64.85	32.90
Swaziland							0.35	0
Chinese Taipei	0	0	0				40.36	56.72
Tanzania	0	61.20	18.30	478	303	257	114.58	56.38
Thailand	0	0	15.50				133.86	101.02
Tonga	0	0.20	0				0	0
Tuvalu	0	0	0		0.871		0	0
United Arab Emirates							10.85	40.62
USA	0	12.10	24.20				181.57	89.74
Vanuatu	0	2.20	0	6	40		28.48	16.35
Vietnam							0.70	3.27
Western Indian Ocean countries**	0	*620.00	*470.00					
Yemen							0	3.20
Other	0	151.80	161.70					
TOTAL	**2125.4**	**9640.6**	**5898.9**	**6099**	**5782**	**4190**	**4758.7**	**4382.3**

Table 3. **Countries involved in the export of sea cucumbers, species collected, type of use, status of fishery and existing regulations. Information was compiled from a variety of sources, including range state consultations, reports identified in the *SPC Beche-de-Mer Information Bulletin*, and other published documents.**

Country/Region	Species	Comments and trade volume	Status and management
Australia	*H. scabra; H. nobilis; T. ananas;* 3 other species	Decreasing catch rates and declines in abundance and biomass of *H. nobilis*	Fishery for *H. nobilis* closed in October 1999 on the Great Barrier Reef
Canada	*S. californicus; S. parvimensis; C. frondosa*	East coast: *Cucumaria*; west coast: *Stichopus*	Fishery began in 1971 in BC, and a rapid increase in the 1980s; management actions including a limited entry, reduced fishing times, area closures, and an area quotas were introduced in 1991. 1999: new fishery in Quebec
CNMI	*A. mauritiana; H. nobilis*	Harvest in 1995–1996 in Rota; fishery moved to Saipan in 1996–1997	Fishery managed using CPUE data only; fishery halted due to declining CPUE
Cook Islands	*A. mauritiana*	Low population abundance; small export market	Export from 2 areas in the 1980s, Rarotonga and Palmerston; most today for subsistence only
Ecuador	*I. fuscus*	Fishery started in 1989	Stocks depleted; fishery moved to Galapagos
Fiji	*H. scabra; A. miliaris*	*H. scabra* catches rose to 700 t in 1988; stocks depleted. Export of *H. scabra* prohibited (1995). *A. miliaris* 95% of exports (1993)	Harvest restricted to Fijian natives; use of scuba gear forbidden; minimum legal dry length of 7.62 cm for all species
Galapagos (Ecuador)	*I. fuscus*	Fishery started in 1990	New management plan in place in 1999; two-month season
India	*H. scabra; H. spinifera; B. marmorata; A. echinites; A. miliaris; H. nobilis; T. ananas; H. atra; A. mauritiana; S. chloronotus*	*H. scabra; H. spinifera; B. marmorata* collected over last 1000 years; began collecting other species in 1990, in response to high export value and population declines; *A. echinites* and *A. miliaris* populations overexploited in some areas after 2 years	Sea cucumber collection banned in Andaman and Nicobar Islands; fishery exists in Gulf of Manner, Pal Bay, but CPUE and size of specimens has dramatically declined
Indonesia	16 species	16 species harvested in Sulawesi. Estimated exports from Indonesia increased from 878 t in 1981 to over 4600 t per year from 1987 to 1990	The world's largest source of sea cucumbers. No known management measures specific for sea cucumbers
Japan	*S. japonicus*	The catch of *S. japonicus* in Japan has decreased annually by 5–10%, dropping from over 10,000 t (wet weight) in 1978 to 7133 t in 1987	
Madagascar	*B. vitiensis; H. scabra;* other species	Export fishery began in 1921, with exports of 50–140 t annually. Exports increased from 56 t in 1986 to over 500 t in 1991 and 1994	Declining exports, quality and size of sea cucumbers indicate resources are overexploited (1998)
Malaysia	*S. hermanni; S. horrens; H nobilis; H. scabra, H. fuscogilva; T. ananas; T. anax; B. argus*	Imports may exceed exports. Annual catch 1989–1991 about 800 t	There are no countrywide regulations for the holothurian fishery
Maldives	*T. ananas; H. nobilis; B. marmorata*	Export increased from 3 t in 1986 (start of the fishery) to 740 t in 1990	
Mexico	*I. fuscus*	Fishery in Baja started with *I. fuscus* in 1988, *P. parvimensis* in 1989 and *H. impatiens* in 1994. Catch for each species from 57–1038 t (live)	*I. fuscus* declared endangered in 1994. Dive surveys in Baja indicate drops in CPUE from 2000 kg/diver/boat to 150 kg, along with increases in number of permits, diver hours and diver depths
Micronesia		Minimal subsistence use.	No international trade (1993)
Mozambique	*H. scabra; H. nobilis; H. fuscogilva; H. atra; A. echinites; A. mauritiana*	High fluctuation in exports may be due to irregular reporting or to overexploitation. Catch reported at 500 t in 1990; 700 t in 1993; 6 t in 1995; and 54 t in 1996	In Inhambane Province, holothurian fishery is closed until stocks rebuild

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Table 3 (continued)

Country/Region	Species	Comments and trade volume	Status and management
New Caledonia	*A. miliaris; H. scabra; H. scabra versicolor*	Exports of over 125 t in 1990 and 1991 with declines to less than 81 t yr^{-1} from 1992 to 1994. Exports continued to decline from 79.8 t in 1994 to 39.1 t in 1998	*A. miliaris* harvest ~75% of exports; *H. scabra* harvest ~25% of exports
New Zealand	*S. mollis*	Experimental fishery started in 1990	15 t quota
Palau	*B. argus; H. scabra*	Small export fishery (2.13 t 1990)	
Philippines	25 species including: *H. scabra; H. nobilis; B. marmorata; H. fuscogilva; H. atra; A. Lecanora*	Exports increased from 250 t in 1977 and 1189 t in 1984 to 2123 t in 1996	
Papau New Guinea (PNG)	*H. scabra; A. mauritiana; H. nobilis; H. fuscogilva;* 13 other species	Dramatic increase in exports from 1982 to 1989	In Torres Strait, 1000 t of *H. scabra* in 1995; populations collapsed and fishery for this species stopped. In Milne Bay total allowable catch of 140 t implemented in 2001, with new fishery management provisions planned for 2002
Solomon Islands	22 species	Increase from 15 species in 1988 to 22 species in 1993. Dramatic increase in exports from 17 t in 1982 to 622 t in 1991	50% of exports from western province but populations in severe decline (1992); ban on collection and sale of *H.scabra* in 1997, but locals continue to collect them
Tanzania	7 primary, 13 additional species	*H. atra* is the most prized species	Fishery is unregulated
Thailand	*H. scabra; H. atra; H. leucospilota; B. marmorata; B. argus; S. hermanni; S. chloronotus*	Decrease in abundance in fished areas	No management or regulations
Tonga	*A. mauritiana; H.atra; S. chloronotus; A. lecanora; H.fuscogilva; S.variegatus;* 8 other species	Traditional use: commercial fishery began in mid1980s; increased in 1990 due to unregulated use of scuba and hookah. Recorded exports are 9767 kg (1991); 35,367 kg (1993); 61,449 kg (1994) and 60,160 kg (1995, 5 months). Top species are listed for 1994–1995 exports	Legal minimum sizes for some species; ban on use of scuba and hookah. A ten-year ban on take implemented in 1999
Torres Strait (Australia, PNG)	*H. nobilis; H. fuscogilva; H. scabra; Actinopyga* spp.	*H. nobilis, H. fuscogilva* at turn of century; annual catch averaged around 500 t; *H. scabra* dominated catch in 1990–1991, but other species including *Actinopyga* spp. are targeted because *H. scabra* stocks are depleted	Fishery primarily on Warrior Reef complex. Australia and PNG cooperate in management, conservation. Australia imposed a minimum size of 18 cm and total catch of 260 t in 1996. The fishery has been closed on the PNG side since 1992
Tuvalu	*H. fuscogilva; T. ananas; H. nobilis; H. fuscopunctata;* 4 other species	Small fishery between 1979 and 1982 with exports of 1800 kg in 1979, 805 kg in 1980, 90 kg in 1981, and 198.5 kg in 1982; fishery active between 1993 and 1995 with exports of over 3000 kg each year. *H. fuscogilva* (50–70% of export); *T. ananas* (14–20% of export); *H. nobilis* (0–10% of export); *H. fuscopunctata* (5–13.4%); 4 other species (2.8–12.8%)	The fishery is not regulated, but there are recommendations to ban use of scuba and hookah gear to harvest sessile organisms including sea cucumbers
USA	*S. californicus; S. parvimensis; C. frondosa* (Maine)	Fishery started in 1970s on the west coast; 1994 in Maine	Management plan, research, monitoring in place; west coast fishery appears to be sustainable
Vanuatu	At least 15 species	No traditional fishery, but important export product. Low population abundance	Annual export limit of 40 t established in 1991, but fishers never reach the quota
Venezuela	*I. badionotus; H. mexicana*	Fishery began in 1991–1992, but catches were made in a national park and were illegal. In 1993, 4 boats received one-year license each to harvest 200 kg	Sporadic legal commercial fishing and frequent closures; illegal fishing in parks involving Asian entrepreneurs

to other, lower-value species, and once collectors have removed all animals from one location they search for new populations in other areas. Until recently, deepwater populations may have provided a refuge for some heavily fished species, because most collection was done by wading or snorkelling. However, populations have been depleted in shallow water in many locations, and the use of scuba and hookah is rapidly increasing throughout the Pacific and Southeast Asia.

Populations may fail to recover even after fishery closures, and some studies indicate that populations of sea cucumbers in overexploited fishing grounds may require as much as 50 years in the absence of fishing pressure to rebuild. For instance, the Torres Strait fishery for *H. scabra* was closed in the mid 1990s, and the current biomass today is still estimated at less than 8 per cent of the virgin biomass (Skewes et al. 2000). Average densities of *H. nobilis* populations for the Torres Straits, Papua New Guinea (PNG), New Caledonia and Tonga ranged from 9.4–18.4 individuals per hectare in the late 1980s, with maximum reported densities of 100 (Conand 1990) to 275 ind. ha^{-1} (Lokani 1990). In PNG waters, peak catches occurred in 1991–1992 and subsequently declined, with the fishery switching to other less valuable species. As sites were serially depleted, fishing effort shifted to more distant locations, until the fishery was closed. Surveys conducted in 1995–1998 on Warrior Reef identified progressively smaller breeding populations each year, leading to smaller and smaller recruitments. Breeding year classes (larger than 18 cm) were heavily depleted in both Australian and PNG waters, while recruiting year classes were more abundant in Australian waters. Surveys conducted in PNG several years after closure indicate little recovery; both adults and the recruiting year class were notably absent (D'Silva 2001).

Importance in the ecosystem

Sea cucumbers are important components of the food chain in temperate and coral reef ecosystems, and they play an important role as deposit feeders and suspension feeders. Rapid declines in populations may have serious consequences for the survival of other species that are part of the same complex food web, as the eggs, larvae and juveniles constitute an important food source for other marine species including crustaceans, fish and molluscs. In addition, several species have unique symbionts, including molluscs and fish, that may disappear once a species is overexploited.

Sea cucumbers have often been called the earthworms of the sea, because they are responsible for the extensive shifting and mixing of the substrate, and recycling of detrital matter. Sea cucumbers consume and grind sediment and organic material into finer particles, turning over the top layers of sediment in lagoons, reefs and other habitats and allowing the penetration of oxygen. Sea cucumbers are important in determining habitat structure for other species, and can represent a substantial portion of the ecosystem biomass. In absence of fishing pressure, sea cucumbers may occur on Indo-Pacific reef flats at densities in excess of 35 per square metre, where individuals process an immense amount of sediment each day. For example, the common western Atlantic *I. badionotus*, which is about 20 cm in length, can process 160 g of ocean debris in 24 hours (Fechter 1972). In Bermuda, in an area of 4.4 km^2, *I. badionotus* populations have been estimated to ingest 500–1000 t of sand annually. This process prevents the build-up of decaying organic matter and may help control populations of pest and pathogenic organisms including certain bacteria and cyanobacterial mats. In some areas, extirpation of sea cucumbers has resulted in a hardening of the sea floor, eliminating habitat for other benthic and infaunal organisms.

Issues that need to be addressed in relation to CITES

To address the fundamental questions of whether CITES listing is appropriate for and can contribute to the conservation of sea cucumbers, a number of issues have to be considered, including taxonomic uncertainties within the families, ability to distinguish taxa in the form they are traded, adequacy of biological information for making non-detriment findings, and ability to make legal acquisition findings, among others. Below we elaborate on what we perceive to be some of the key issues.

A. Taxonomic uncertainties within the families

While the taxonomy of the holothurian families is generally well known, the distinction of similar species is difficult, as they may exhibit similar morphology. In recent years several new species have been described from the Indo-Pacific, which is the centre of holothurian biodiversity. Nevertheless, there are many undescribed large species that are common in shallow water and there are relatively few holothurian taxonomists. The large number of extant sea cucumber species (1250) and the growing number of species in commercial trade complicate this issue even further.

B. Ability to distinguish taxa in the form they are traded

It is possible to identify most of the common species that are traded as live animals for home aquaria and other uses, based on the gross morphology. In contrast, it is very difficult to determine the species from the dried processed product, which is the dominant component of the international trade in sea cucumbers. Customs officials and wildlife inspectors may have difficulty identifying dried specimens even to genus. Photos of dried specimens of the main commercial species of the western tropical Pacific are available in a booklet from the Secretariat of the Pacific Community (1994), but there are no detailed identification guides. Most sea cucumber species can be identified by holothurian taxonomists by using the calcareous skeletal ossicles found in the body wall, and the ossicles are preserved during the drying process, but this may be unfeasible for law enforcement.

C. Adequacy of biological information for making non-detriment findings

There are very limited data currently available on the biological status of populations from areas with holothurian fisheries, with exception of selected countries such as Australia, Canada, New Zealand and the United States that have established, regulated fisheries. In these countries, population surveys are undertaken and this information is used in combination with fishery-dependent data to determine sustainable levels of harvest. Unfortunately, various parameters such as recruitment, growth and mortality are available for only selected high value species, and catch data may be incompletely reported, complicating the ability of scientific authorities to make a non-detriment finding. In addition, in response to the rapid expansion of holothurian fisheries and the high value of beche-de-mer, several countries have established experimental fisheries without having sufficient information to determine sustainable harvest. There are virtually no data available on the biological status of sea cucumbers and few management measures in the two largest exporting countries, the Philippines and Indonesia, and thus it is unlikely that these countries could make a non-detriment finding without capacity building for improved monitoring and data collection.

D. Ability to make legal acquisition findings

Because of the complex trade routes for sea cucumbers, often involving import and subsequent re-export, or transshipment ports that export mixed shipments of different origins, it is very difficult to determine the country of origin. For instance, Malaysia has a well established holothurian fishery, and they also import and export holothurians. It is also difficult to determine whether the harvest was legal, as shipments often include multiple species that are difficult to differentiate when dried, and those countries that have established regulations for holothurian fisheries generally prohibit the harvest of selected species or in specific locations, while harvest of other species is legal. Furthermore, the processed product generally passes from the producing country to the main world distribution centres (Hong Kong SAR, Singapore and Chinese Taipei) before being imported to the consumer country, making it difficult to determine its origin. Trade statistics are further complicated by the variety of products available in international markets, including several types of dried holothurians (spiked and not spiked), as well as frozen, live, fresh or chilled, and salted or in brine.

E. Research needs

There is currently insufficient knowledge to develop models for sustainable management of beche-de-mer fisheries due to very limited biological information of the local fisheries and stocks (Conand 1990 and 2001). Further studies are needed on: recruitment, growth, and mortality of most commercial species; stock assessments; and improved statistics on catch and international trade. Sea cucumbers are sedentary animals that are especially susceptible to overexploitation because they are large, easily collected, and do not require sophisticated fishing techniques. Heavy fishing pressure can cause a decline in the density and biomass of the target species, and populations may be unable to rebound once they fall below a critical biomass. Most tropical and subtropical holothurians are broadcast spawners, and fertilisation success is highly dependent on population density. Reduction of population densities by fishing may render remaining individuals incapable of successful reproduction, due to the greater distance between males and females. Possible approaches to enhance and increase yield of sea cucumber stocks may include relocation of recruits, induced asexual reproduction through fission, hatchery rearing of larvae, and grow-out of juveniles in cages placed on the sea floor.

More research is needed to quantify population parameters, and stock assessments are needed in fished and unfished areas to develop sustainable management approaches. Because of the paucity of data for the spatial distribution of fishing effort, the depletion of stocks may not be detected using surplus yield models without detailed field monitoring. Additionally, fishery monitoring that only involves catch and effort statistics is likely to be erroneous as fishers may report catch as being made in areas other than those actually fished. For instance, the overall catch for the *P. californicus* fishery in Washington State, USA, appeared to be stable, but in reality half of the fished areas were overfished.

As stocks were serially depleted CPUE did not appear to decrease, due to a shift in fishing effort to deeper waters (Bradbury 1994).

There is substantial risk associated with managing fisheries of species assemblages (e.g. "sea cucumbers") versus managing and collecting catch data for individual species. As one species is depleted, fishing effort may shift to less valuable species, and the CPUE for the "sea cucumber" fishery may actually increase. There is also the danger that fisheries targeting more abundant species can support continued fishing pressure on rare, but extremely valuable, species. Thus, the management presumption that a fishery will become economically extinct before it is biologically extinct is not necessarily true.

Population genetic analyses are necessary to determine the appropriate scale of management strategies. The protection of whole reefs from fishing appears to be an effective management tool for the conservation of holothurian stocks. However, the division of a reef into fished and unfished zones may be effective only when the protected areas are large (Uthicke and Benzie 2001). In Australia, *H. nobilis* populations were found to have high gene flow, suggesting that recruits can be received from a wide geographical area and stocks could be managed on a regional scale. In contrast, separate genetic stocks of *H. scabra* were detected, which implies limited recruitment within regions that may reduce the potential for recovery of overfished areas. *H. scabra*, in particular, needs to be managed as separate stocks and local refugia are needed (Uthicke and Benzie 2001).

F. *Capacity building*

Capacity building is necessary in most developing countries with sea cucumber fisheries to promote development and implementation of sustainable management approaches and conservation of sea cucumber populations through mariculture, restocking programs, and other strategies.

Conclusion

While sea cucumber fisheries remain unregulated in a number of developing countries, other countries have established management measures to various degrees, in attempt to prevent overfishing (Table 3). In many countries, certain sites have been closed to harvest a short time after the fishery commenced, due to rapid overexploitation and biological or commercial extirpations, while the take of certain species is now prohibited in other locations due to their rarity. Traditional fishery management approaches were formerly successful in many countries because holothurians were primarily harvested at much lower levels, only for traditional and subsistence uses. In many countries, these approaches are no longer effective because 1) some of the traditional cultures are being lost; 2) population growth has put increasing pressure on the resource; 3) populations of sea cucumbers are being targeted that were not traditionally exploited, due to availability of motorised boats and scuba and hookah gear which allows fishers to reach distant and deepwater reefs and lagoons; and 4) non-local collectors are fishing in many areas and poaching and illegal trade has increased.

Possible approaches to sustainable management include adoption of specific collection and no-collection areas, permitting systems, quotas, seasonal harvest, rotational harvest, and other fishery management strategies. A CITES listing may provide an additional tool to ensure that harvest to supply international markets is conducted in a sustainable manner, without detriment to the target species or its ecosystem. CITES establishes an international legal framework for the prevention of trade in endangered species and for effective regulation in trade in other species. It gives producer and consumer countries their share of the joint responsibility, creates the necessary means for the international cooperation which is essential for fulfilling this responsibility, and it provides for monitoring of international trade. Through an Appendix II listing sea cucumber trade can be managed so as to yield the greatest sustainable benefit to fishers, exporters and importers, while maintaining these species such that they can continue to serve their important ecological role and also meet the needs and aspirations of future generations.

Literature cited

Bradbury, A. 1994. Sea cucumber dive fishery in Washington State. SPC Beche-de-Mer Information Bulletin 6:15–16.

Conand, C. 1990. The fishery resources of Pacific Island countries. Part 2: Holothurians. FAO Fisheries Technical Paper 272.2. Rome: FAO. 143 p.

Conand, C. 1997. Are holothurian fisheries for export sustainable? Proceedings of the Eighth International Coral Reef Symposium, Panama 2:2021–2026.

Conand, C. 2001. Overview of sea cucumbers fisheries over the last decade - what possibilities for a durable management? In: Barker (ed). Echinoderm 2000. Swets & Zeitlinger: 339–344.

Conand, C and Byrne, M. 1993. A review of recent developments in the world of sea cucumber fisheries. Mar. Fisheries Rev. 55:1–13.

D'Silva, D. 2001. The Torres Strait beche-de-mer (sea cucumber) fishery. SPC Beche-de-Mer Information Bulletin 15:2–4.

Jaquemet, S. and Conand, C. 1999. The Beche-de-Mer trade in 1995/1996 and an assessment of exchanges between main world markets. SPC Beche-de-Mer Information Bulletin 12:11–14.

Lokani, P. 1990. Beche-de-mer research and development in Papua New Guinea. SPC Beche-de-Mer Information Bulletin 2:1–18.

Secretariat of the Pacific Community. 1994. Sea cucumbers and beche-de-mer of the tropical Pacific. A handbook for fishers. Handbook no. 18. SPC, Noumea New Caledonia. 51 p.

Skewes, T.D. Dennis, D.M. and Burridge, C. 2000. Survey of *Holothuria scabra* (sandfish) on Warrior Reef, Torres Strait, January 2000. CSIRO Division of Marine Research.

TRAFFIC South America. 2000. Evaluation of the trade of sea cucumber *Isostichopus fuscus* (Echinodermata: Holothuroidea) in the Galapagos during 1999. Quito. 19 p.

Uthicke, S. and Benzie, J.A.H. 2001. Effect of beche-de-mer fishing on densities and size structure of *Holothuria nobilis* (Echinodermata: Holothuridae) populations on the Great Barrier Reef. Coral Reefs 19:271–276.

Sexual reproduction in a fissiparous holothurian species, *Holothuria leucospilota* Clark 1920 (Echinodermata: Holothuroidea)

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Abstract

Holothuria leucospilota Clark 1920 inhabiting tropical Darwin waters primarily undergo asexual reproduction by fission throughout the year (Purwati 2001). However, there is also evidence of sexual reproduction. Monthly sampling from August 1998 to January 2000 revealed that the gonadal tubules within each individual of *H. leucospilota* grew simultaneously. Complete spawning, where the oocytes throughout the gonad have equal opportunity to be released in one spawning event, could therefore be expected. Post-spawning tubules were absorbed, resulting in the disappearance of gonads between reproductive cycles. The development of gonadal tubules in this holothurian does not conform to the "tubules recruitment model" proposed by Smiley (1988), as reassessed by Sewell et al. (1997).

A seasonal reproductive cycle with a restricted spawning period was recognised in the population studied. The resting stage that occurred simultaneously amongst individuals in the population made it possible to estimate gametogenesis, which may take less than a year. It is likely that gamete release occured in the period between new moon and full moon of April, at the end of the wet season in Darwin. The continuous flooding of the reefs during this period is thought to be effective for fertilisation.

Introduction

Variations occur in holothurian gonad structures and development (Conand 1981; Harriott 1985; Tuwo and Conand 1992; Hamel et al. 1993; Conand et al. 1997). In a holothurian population where the gonads develop simultaneously and spent tubules are absorbed after the reproductive season, the gonads may not be visible for a certain period. However, intraspecific variation can occur, such as in *Stichopus mollis* of New Zealand, where the population from the east coast of the North Island absorbs the after-spawned tubules and the gonadal basis, whereas the population in the South Island maintains its spent tubules (Sewell 1992). Intraspecific variation in number of gonad tufts is also possible. One example is dendrochirote *Cucumaria frondosa*, in which geographical and latitudinal factors are the suggested influencing factors (Sewell 1992; Hamel and Mercier 1996).

In view of these variations occurring amongst holothurian populations, it was of interest to study the sexual reproduction of *Holothuria leucospilota* from Darwin harbours, northern Australia. The investigation aimed to elucidate the types of gonadal

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