CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES
OF WILD FAUNA AND FLORA

Technical workshop on the conservation of sea cucumbers
in the families Holothuridae and Stichopodidae
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MANAGEMENT AND CONSERVATION STRATEGIES AND PRACTICES FOR SEA CUCUMBERS

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EXECUTIVE SUMMARY

This document presents a summary of current sea cucumber fishery practices and management options, with discussion on opportunities for sustainable wild harvest, aquaculture, efforts to enhance wild populations and trade controls. Sea cucumbers are both economically and ecologically valuable marine invertebrates, with a growing international trade for food, medicinals, nutritional supplements, biomedical research, aquarium displays and other uses. The greatest threat to sea cucumber resources is overfishing, primarily as a result of the present fishery system, which usually involves foreign buyers offering a low price to indigenous fishermen for valuable species. While indigenous fishermen may be concerned with sustainable resource utilization, buyers focus on the largest profit in the shortest time period. As a result, fishermen initially target the largest individuals of the high value species; once these are fished out, larger numbers of individuals of a smaller size are taken, along with harvest of medium and low value species. Once an area is depleted, fishermen and buyers must look for new sources.

Developing management strategies for an exploited fishery resource requires consideration of specific details of the biology of the target species and their population dynamics, details on the fishery, processing and marketing methods, and the social and economic context of the fishery. Alternative and complementary conservation measures such as aquaculture and stock enhancement programs can help conserve and rebuild wild populations. However, these measures also require considerable investment in research on life history and ecological data, as well as information on optimal conditions for reproduction, settlement, growth and release into the wild. Proposed or existing fishery management strategies have included minimum sizes, spatial and temporal closures, rotational harvest, harvest or export quotas, gear restrictions and limited entry. While each of these approaches can assist in sustainable management of the resources, they are likely to be most effective when multiple strategies are combined under one plan, such as a minimum size and quota for each target species along with establishment of protected areas. In developing countries, regional management plans combining multiple fishery approaches and emphasizing adaptive management are likely to be most successful at ensuring conservation and sustainable harvest, provided that the measures are adopted through consensus with multiple stakeholders and local communities take on some of the responsibilities for management.

INTRODUCTION

Trends in Sea Cucumber Fisheries and Trade

The harvest of sea cucumbers for bêche-de-mer provides a valuable source of income for many coastal communities in developing countries throughout the tropical and subtropical IndoPacific. Until recently, sea cucumbers were harvested primarily at low subsistence levels through small scale artisanal fisheries, as access was restricted due to smaller and fewer boats and certain gear types such as SCUBA and hookah were not used. Many of these fisheries had been operating for up to 1000 years, with the particular species, product type and use varying between islands (Conand, 2001). Since the 1980s, sea cucumber fisheries have been characterized by boom and bust cycles, with a growing number of reports of over-harvesting as fishermen attempt to supply an increasing demand for bêche-de-mer in Asian markets (Adams, 1992; Trinidad-Roa, 1987; Conand 2000; 2001; Ibarra and Soberon, 2002). Production from tropical holothurian fisheries increased almost fivefold between 1985 and 1989, reaching an estimated worldwide trade of 9,000 metric tons (mt) dried (Conand and Byrne, 1993). By 1995, exports of sea cucumbers to Chinese markets were approximately 13,000 mt, valued at over USD $60 million (Conand 1997; 1999). Recent trends in the export fishery include increases in the number of producing countries and species in trade, and an expansion of fisheries in both tropical and temperate regions into non-traditional fishing areas such as the Caribbean, eastern Pacific and North America (Conand and Byrne, 1993; Ibarra and Soberon, 2002; Fiendel, 2002; Buitrago and Boada, 1996; Rodríguez and Marques-Pauls, 1998; Fuente-Betancourt et al. 2001). Statistics from one of the largest importers show an increase from 25 source countries in 1987-1989 to 49 countries in 2000-2001 (Hong Kong Special Administrative Region data). In addition to a growing international trade of bêche-de-mer, additional species are being harvested for aquarium organisms, biomedical research, pharmaceuticals, traditional medicines, nutritional supplements and plant fertilizer (Beumer, 1992; Baine and Sze, 1999; Chen, 2003).

Recent Status of Sea Cucumber Fisheries and Target Stocks

The rapid decline of sea cucumber populations worldwide has triggered fluctuations in market prices, rapid expansion and spread of fisheries, severe overfishing, and poaching by nationals and foreign fishermen (Conand, 1999; Kinch, 2002; Jun, 2002; Conand, 2001). During the 1980s and 1990s, increased commercial harvesting and export of sea cucumbers stimulated financial gains for fishermen and local communities that process the meat, but the benefits to any one fishing community are typically short-lasting (Kinch, 2002). In at least 10 countries, catch per unit effort for high value species declined shortly after fisheries became established, forcing a shift in fishing effort to smaller individuals and lower value species [e.g., Australia (Uthicke and Benzie, 2000); Fiji (Adams, 1992); India (Nithyanandan, 2003); Indonesia (Moore, 1998); Madagascar (Jangoux et al., 2001); Malaysia (Baine and Choo, 1999); New Caledonia (Conand and Byrne, 1993); Papua New Guinea (Kinch, 2002); Philippines (Trinidad-Roa, 1987); and Solomon Islands (Holland, 1994)]. Sea cucumber fisheries were historically managed by local communities or through tenurial systems. In more modern times, commercial fisheries have often been poorly managed, with management measures applied in response to dwindling stocks. For example, commercial harvest in most developing countries initially begins as an open access fisheries, with a subsequent closure or relocation of the fishery within a few years due to overexploitation (Castro, 1995; Lokani, 1996; Trianni, 2002).

The marked increase in landings and export of holothurians in combination with few existing management measures, as well as limited fisheries, trade, biological and population data for commercially important species, are key factors contributing to the decline and extirpation of holothurian populations (Conand and Byrne, 1993). Certain aspects of sea cucumber life history and ecology such as a late maturity and ease of collection renders them highly susceptible to over-exploitation, and may result in recruitment failure with prolonged recovery times (Richmond, 1996). It is now apparent that certain populations of high value sea cucumbers like the sandfish (*Holothuria scabra)* have been exploited so heavily in some Pacific Islands that it will take decades for stocks to recover in absence of adaptive management measures (Preston, 1993; Kinch, 2002).

Purpose of this Document

This document has been prepared by NOAA Fisheries for a technical workshop that will be convened by the CITES Secretariat in Kula Lumpar, Malaysia from 1-5 March, 2004. The purpose of the workshop is to develop conservation priorities and actions to secure the conservation status of sea cucumbers, addressing trade monitoring and controls, national legislation, fisheries management provisions, other conservation approaches, enforcement, and capacity building. This document summarizes current sea cucumber fisheries practices, management options and conservation practices applied both domestically and regionally, including opportunities for sustainable wild harvest, aquaculture, and efforts to enhance wild populations. The benefits and drawbacks of these measures and their contribution to the recovery of overfished stocks are evaluated. Brief descriptions of sea cucumber fisheries are provided for each of the major exporting countries, as well as possible adaptive management approaches that have been recommended and/or implemented to reduce pressure on depleted stocks or promote sustainable harvest.

CURRENT SEA CUCUMBER FISHERIES PRACTICES

Holothurian fisheries are based on about 30 of the over 1000 existing species, with most utilized as a raw, frozen, salted or dried product for human consumption (e.g., bêche-de-mer; trepang); numerous additional species are harvested at a much lower volume for aquarium displays, biomedical research, dietary supplements and other uses (Conand, 1993; Baine and Sze, 1999; Chen, 2003; Conand, 2001). Tropical and subtropical fisheries in the western Pacific are multi-species as compared to tropical fisheries in the Indian Ocean *(H. scabra),* eastern Pacific (*Isostichopus fuscus*) and Caribbean (*Isostichopus badionotus, Holothuria mexicana* and *Astichopus multifidus)*. In the western Pacific, fisheries primarily target shallow water (up to 50 m depth) deposit-feeding holothurians belonging to two families and eight genera: *Actinopyga*, *Bohadschia*, *Microthele* and *Holothuria* (Holothuridae) and *Isostichopus, Parastichopus*, *Stichopus* and *Thelenota* (Stichopodidae). The more recent temperate water fisheries are each based on one or two species that are found in the western Pacific around Japan, Korea and Russia (*S. japonicus*), southern hemisphere off New Zealand (*S. mollis*), eastern Pacific coast of North America (*P. californicus* and *P. parvimensis*) and western Atlantic coast of North America (*Cucumaria frondosa).*

Holothurians that are targeted by bêche-de-mer fisheries range in size from about 5 cm to over 1 m in length, while aquarium specimens are typically smaller (2-20 cm). Bêche-de-mer species may be classified into three categories of commercial importance based on their abundance, appearance, odor and color, thickness and quality of body wall, and main market demand and value (Conand, 1993). Worldwide, the single most important species by volume is the temperate holothurian, *S. japonicus*, with over 12,000 mt consumed in Japan and Korea in 1983 (McElroy, 1990). However, the total landings of *S. japonicus* in Japan declined from 25,000 mt in 1983 to 7000 mt in 1995, while the volume of tropical sea cucumbers in trade has grown considerably (Conand, 1986; McElroy, 1990; Ito and Kitamura, 1998). Currently, the species of highest commercial value are *H. fuscogilva* (white teatfish), *H. nobilis* (black teatfish) and *H. scabra* (sandfish), worth US$15-40/kg on the Asian market in 2002, with bigger specimens fetching a higher price per kilogram than smaller specimens (Infofish trade news, 2002). Species of medium value include *A. echinites* (brownfish), *A. miliaris* (blackfish) and *T. ananas* (prickly redfish) (USD $10-12/kg). Species of low value include *B. marmorat*a, *H. atra*, *H. fuscopunctata*, *S. chloronotus* and *S. variegates* (USD $2-10/kg). Most other tropical and temperate species are medium to low value.

Fishermen may operate from shore, or out of small boats (dugout canoes, sailing boats, motor boats) fitted with SCUBA, a hookah system or trawl gear. For instance, in Papua New Guinea, small, motorized banana boats and outrigger canoes with sails and outboards are used to access sites, but most collection is done by walking on the reef flat at low tide and snorkeling while hand collecting (Lokani et al., 1996). In British Columbia, geoduck and urchin dive fishermen target sea cucumbers to supplement their operations; boats are 22 foot skiffs to 40 foot salmon boats converted for diving, with 2-3 divers and one tender per boat (Muse, 1998). In tropical countries, the sea cucumber fishery is often one part of a multi-species fishery for reef fishes, corals, and other invertebrates. In remote tropical areas, vessels may remain at sea for several weeks.

Fishing gear and methods for sea cucumber fisheries include:

- Small bottom trawls (roller pulling nets, beam trawl nets, scallop-drag gear etc.) used primarily in soft bottom habitats away from reef structures;
- Direct collection by hand (reef flat gleaning at low tide or wading) or collection with spears, hooks and scoop nets in shallow-water mangrove lagoons, reef flats and grass beds;
- Collection by hand using snorkel and diving gear (SCUBA and hookah) and lift bags for deeper reef and lagoonal environments; and
- Collection at night with SCUBA, snorkeling or wading using underwater lights or torches.

MEASURES TO ENSURE SUSTAINABLE OR ENHANCED SEA CUCUMBER FISHERIES

Possible approaches to ensure sustainable sea cucumber fisheries include:
1) Aquaculture and mariculture to provide an alternative source of bêche-de-mer;
2) Reseeding and relocation of juveniles/adults to rehabilitate degraded areas and enhance wild stocks;
3) National controls on harvest or export, including a CITES Appendix III listing (Ecuador) or placement of overharvested species on National endangered or threatened species lists, with prohibitions on take or export (India, Mexico);
4) Specific domestic fishery management strategies to conserve wild populations while allowing sustainable harvest.
5) Regional management approaches and cooperation in resource harvesting and marketing by multiple stakeholders and resource management agencies; and
6) International controls on exports such as a possible CITES Appendix II listings for one or more species.

Aquaculture and Mariculture

Sea cucumber farming practices have greatly expanded over the last five years, with programs underway in China, Indonesia, Vietnam, Marshall Islands, Japan, Maldives, New Zealand, India and other countries. Aspects of the development of sea cucumber larvae are described for a number of commercially important species, and researchers are successful at inducing spawning, gamete fertilization and early larval rearing for several of these (Conand, 1993; Ito, 1995; Ramofafia et al., 1995; Morgan, 2000; Pitt, 2001). Broodstock can be collected from the wild and induced to spawn in captivity. In addition, several high-value species have been reported to reproduce asexually by fission and induced fission is being examined as a potential technique to propagate commercially important species (Reichenbach et al., 1998). For many species reliable feeding regimes for sea cucumber larvae through the planktonic part of their life cycle to settlement have been developed (Purcell et al., 2002). One temperate species (*A. japonicus*) can be produced successfully in large commercial quantities. However, the rapid expansion and intensification of sea cucumber farming has led to the occurrence of various diseases, causing economic losses and becoming one of the limiting factors in the sustainable development of the industry (Yin-Geng et al., 2003). Aquaculture of tropical sea cucumbers has been more challenging due to difficulties in holding adults in captivity, and reduced feeding, weight loss and poor gonadal development has been reported (Battaglene, 1999). Currently, most effort in the tropics is geared towards *H. scabra.*

Some of the recent successful sea cucumber farming ventures include:

- The Sea Farming Center in southern Japan that can produce up to 1 million juveniles per year (Ito and Kitamura, 1998).
- China is one of the first locations to successfully raise *A. japonicus* sea cucumbers on a large commercial scale in ponds and enclosures at sea. For instance, Chen (2003) reports of production of about 1000 mt of A. *japonicus* each year, and 1025 mt of several other species in another location during 2001. Total landings of A. *japonicus* from farms in Liaoning and Shandong Provinces is reported to have exceeded 5,800 mt in 2000 (Jiaxin, 2003). In addition, in the Dalian area more than 2000 hectares of ponds are being used for polyculture of shrimp and sea cucumbers (Yaqing et al., 2003)
- A sea cucumber ranching operation was established on an atoll in the Maldives involving *H. scabra* from India, a species that is not native to this area. In less than one year, juveniles have grown to 15 cm and are being harvested for export.
- Collection of small (juvenile) sandfish *(H. scabra*) from the wild for grow out in ponds and pens has been reported from India, Indonesia and Vietnam (Pitt, 2001).
- India is able to produce larvae and juveniles of *H. scabra* from wild brood stock, which are produced in a hatchery, and are grown out in cages and pens on the sea floor in several Bays and harbours, and also in shrimp ponds in polyculture (James, 2003)
- Madagascar established a sea cucumber hatchery in 2000 that can now produce juveniles (1-2 cm) of *H. scabra*, and a sea cucumber grow-out farm has been established (Jangoux et al., 2001).
- Indonesia has developed sea cucumber farms in four areas with substantial production, including Papua (378 mt), Central Sulawesi (200 mt), southeast Sulawesi (3 mt) and East Kalimantan (1 mt); some of the production is actually wild harvested juveniles that are grown to market size in cages or ponds (Tuwo, 2003).
- In several countries commercial shrimp farming ponds are being used for grow out of sea cucumbers, as holothurians ingest large amounts of sediment and may improve water conditions by removing organic debris. Preliminary experiments show high survivorship and rapid rates of growth until the wet season, when salinities fluctuate and mass mortalities may occur (Pitt, 2001; Chen, 2003).
- Rearing of *Isostichopus* on land and in abandoned shrimp ponds is underway in Ecaudor, with 30-50% survival of larvae and rapid growth (8 cm in 3.5 months) (Mercier et al., 2003).

Restocking

The release of juvenile sea cucumbers produced in hatcheries is thought to be one way of rebuilding wild stocks (e.g., "restocking" or "reseeding") to the point where they can sustain regular harvest. There is also the potential to increase harvests beyond historical levels by releasing sufficient cultured juveniles into the wild to reach the carrying capacity of the habitat and overcoming recruitment limitations (e.g., "stock enhancement") (Munro and Bell, 1997; Battaglene and Bell, 1999). Relocation of recruits and juveniles from areas of high abundance to depleted areas as a form of sea ranching has also been recommended, but not attempted on a large experimental scale. In addition, artificially aggregating adults is also another option to enhance stocks.

These approaches may be beneficial in areas where populations of certain species have been reduced to such low levels by fishing that remaining individuals are incapable of successful reproduction due to Allee effects, or when recruitment is be limited due to a) certain physio-chemical properties of the site (e.g., water circulation patterns); or b) the larvae of target species have limited dispersal capabilities. However, there are numerous concerns associated with reintroduction of hatchery produced species, including possible genetic considerations and disease introductions.

Holothuria scabra appears to be the tropical holothurian most suited to restocking in the western Pacific and Southeast Asia; however, it has not been demonstrated that farm-raised juveniles will survive in the wild and information is lacking on optimal release strategies (Pitt, 2001). Research in restocking and stock enhancement of tropical sea cucumbers is being undertaken or has been proposed in Ecuador, Philippines, India, Kiribati, Maldives, Marshall Islands and the Solomon Islands (Battaglene and Bell, 1999).

- Some of the earliest restocking experiments were attempted in Japan. In one area, 1,700 juveniles were released and fishing was closed for two years to allow these to mature. At the end of the prohibition, the 90 fishing boats that targeted this area had an estimated total catch that was 30 X higher than previous catches in this area (Arakawa, 1990). More recently, 11 farming centers released 2,557,000 juvenile sea cucumbers (9 mm) in 1995 (Ito, 1995); it is unclear whether follow-up studies were conducted to determine what proportion of these survived.
- International Center for Living Aquatic Resources Management (ICLARM) has been examining the potential for releasing cultured juveniles of *H. scabra* and *A. mauritiana* in the Solomon Islands as a means of restoring and enhancing tropical sea cucumber stocks (Battaglene, 1999). ICLARM produced over 200,000 juveniles from six spawning events in the mid-1990s. In 2000, they released 2600 juveniles in the Western Province in areas where spawning adults were found; survival rates are unknown (Battaglene, 2000).
- In preliminary trials from the Solomon Islands, 15-90% of the hatchery bred animals released in sea grass sites were missing after 24 hours (Dance et al., 2000). In a second trial, juveniles were released in sand or silt reef flat, mangrove and seagrass sites, with the highest short-term survival at mangrove sea grass sites and high rates of predation occurring in reef environments (Dance et al., 2000).
- A sea cucumber project in New Caledonia aims to determine the best strategies for releasing into the wild the sandfish (*Holothuria scabra*), for purposes of restocking and stock enhancement of inshore fisheries. The sandfish have been cultured from local broodstock and have shown high survival and growth in certain habitat types. Transportation methods and the sizes, densities, habitats, times of the day and year for release will be optimized by tracking the fates of juveniles at inshore sites in the Provinces of New Caledonia (Purcell, Gardner and Bell, 2003).

- In Suez Canal University, the release of cultured juveniles of *A. mauritiana* on the red Sea coast is being explored to restore depleted populations and possible enhancement of fisheries (Gabr et al., 2003).

CONSERVATION PRACTICES AND STRATEGIES

While sea cucumber fisheries remain unregulated in most developing countries, other developing and developed countries have established measures to manage and conserve holothurian resources, in an attempt to prevent over-harvesting (Table 4, 5; Appendix I). In most countries with open-access sea cucumber fisheries, fisheries have passed through four phases, inevitably leading to overfishing (Ibarra and Soberon, 2002). Fishermen first target dense populations with easy access, especially nearshore, shallow environments; stocks are initially underexploited, but the catch keeps on growing as effort increases and the industry flourishes. As the industry matures, the level of capture becomes constant, but more fishing effort is needed to achieve these levels. As all of the suitable species and size classes are removed from one area, the distribution of fishing effort expands to more remote areas and deeper environments. This practice may result in extensive areas that are essentially free of harvesting pressure, but it also leads to the localized depletion of stocks where fishing has occurred.

Development of sustainable management approaches for sea cucumber fisheries are not easy, and current management tools like size limits, gear restrictions, spatial and temporal closures, quotas and marine reserves have not been very effective in managing large commercial export fisheries in tropical regions (Preston, 1993; Dalzell et al., 1996). Part of the problem is that developing countries do not have the human resources to collect data on the biology, ecology and population dynamics of sea cucumbers necessary to develop adaptive management plans, or the capacity to enforce regulations. The multi-species nature of most tropical sea cucumber fisheries, as well as the remote and artisanal nature of these fisheries, makes it difficult to obtain data needed to manage sea cucumber fisheries.

Traditional Management and Tenurial Arrangements

Traditional, tenure or community-based management approaches were highly successful in Pacific islands and other areas when holothurians were harvested at much lower levels only for traditional and subsistence uses. These approaches are less effective now, since:
1) some of the traditional cultures are being lost;
2) population growth and increasing international demand places greater pressure on the resources;
3) sea cucumbers populations are being targeted that were not traditionally exploited, due to availability of motorized boats, SCUBA and hookah gear which allows fishers to reach distant and deepwater habitats; and
4) non-local collectors are fishing in many areas, and poaching and illegal trade has increased (Samyn, 2000).

Regional Management Approaches

When developing management plans for sea cucumber fisheries, the target species in some locations should be considered as transboundary stocks. Management of these stocks plans requires bilateral and international agreements targeted at protection of reef habitats, spawning aggregation areas and parental stocks. Although adult sea cucumbers are relatively sedentary, fertilized eggs and developing larvae may disperse away from the natal reef. If larvae are widely dispersed, managing an adult population of sea cucumbers may not guarantee a healthy stock if that managed population depends on an upstream source of larvae for replenishment. This is particularly relevant in the Indo-Pacific where larval dispersion may occur across international borders, separating healthy and overexploited reef systems. Conversely, if larvae are locally retained, local management will have local consequences. In these situations, poor ecosystem and fisheries management may cause declining stocks, but good management will lead to local recovery of fished populations and sustainable fisheries.

To date, only Papua New Guinea and Australia have initiated a regional management approach for the Torres Strait Fishery. They have ratified the Torres Strait Treaty, which includes provisions for joint management and cooperation in surveillance activities (Lokani et al., 1996).

There has also been a recent resurgence of interest in community involvement and participation in all aspects of marine resource management and monitoring. One approach involves collaborative efforts between industry, resource management agencies, local communities and non-governmental conservation and sustainable management organizations. As an alternative approach, communities have taken on the responsibility for managing their resources, with the government providing limited support and infrastructure. Examples include:

- Development of an association of licensed exporters in Fiji (Bêche-de-mer Exporter's Association) to maintain quality standards and provide the Fiji government data on the fishery (Preston, 1990).
- While the Fisheries Division in Fiji has no authority to set up no-take reserves, the Fisheries Act allows resource custodians to endorse fishing permits and to ban fishing for a particular species in an area under their control (Adams, 1992).
- Sea cucumber fishermen from a village in Sulawesi near the Wakatobi Marine National Park have agreed to avoid harvesting juveniles (Moore, 1998).
- Shared management was introduced in Madagascar in 1998, with partnership between the Madagascar National Trepang traders group and the government resource managers.

National Conservation Measures

Several countries have adopted conservation measures to prevent illegal fishing and export, and to recover depleted sea cucumber stocks. These include:

- The Ecuadorian government requested international assistance in preventing illegal exports and adopted a CITES Appendix III listing in 2003.
- India added all sea cucumbers to Schedule I list of the Wildlife Protection Act in 2001, with a prohibition on exports.
- Mexico declared *I. fuscus* in danger of extinction in May of 1994; the species was placed on a "species under special protection" list in March 2000.

MEASURES IN FISHERIES COUNTRIES TO CONTROL OR MONITOR HARVEST AND TRADE AND TO PROTECT OR ENHANCE STOCKS

The management goal for sea cucumber fisheries is to preserve, protect, and perpetuate sea cucumber resources; provide for their sustainable harvest; protect the habitat necessary to sustain these harvests; and minimize by-catch mortalities of other species. For effective conservation, a sea cucumber fishery must conserve target stocks, sustain marine ecosystems and non-target species, and also provide economic and social benefits consistent with the goals and desires of coastal communities. Domestic management options include a number of tools that have been applied to manage tropical and temperate fisheries, summarized under input controls (restrictions on fishing effort) and output controls (restrictions on sea cucumbers that can be retained by the fishery) (Table 2, 4 and 5; Appendix I).

Input Controls

Fisheries closures: Sea cucumber fishery closures include prohibitions on the take of certain species, or entire closures of the fishery. Entire fisheries (e.g., Venezuela, Ecuador) or certain sites (e.g., Mexico, Panama) have been closed to harvest a short time after the fishery commenced, due to rapid overexploitation and biological or commercial extirpations of target species (Castro, 1995; Rodríguez and Marques-Pauls, 1997; Guzman and Guevara, 2002). In other locations, the take of certain species is now prohibited due to their rarity. This includes bans on the harvest or export of three of the most widespread and highest value species, including *H. scabra* (Fiji, PNG), *H. atra* and *H. nobilis* (parts of Australia). In India, all sea cucumbers were placed on Schedule I list of the Wildlife Protection Act (1992) in 2001, and their collection was strictly banned. This was a conservation step taken by the government of India to revive depleted stocks, but illegal fishing pressure has persisted and field monitoring studies indicate low biomass of target species with little or no recovery (Nithyanandan, 2003).

While a closure may be necessary to prevent extirpations or to rebuild depleted stocks, there are few social or economic benefits of this approach, as it is likely to lead to illegal fishing and export and substantial loss of revenue for fishermen.

Gear Restrictions: The most common gear restrictions for sea cucumber fisheries include prohibitions on the use of SCUBA, hookah and other types of underwater breathing apparatus; restrictions on locations that can be trawled; and limitations on the size and shape of trawl gear. Restricting collection to free-diving, wading, and reef flat gleaning (ban on SCUBA or hookah) would limit the amount of time available to search for animals hidden away in the coral reef and it would prevent most fishing below 30 m. This is a conservative method that should reduce recruitment overfishing because up to half the stock of some species live at depths greater than 30 m (Preston and Lokani, 1990). In New Caledonia, black and grey color morphs of sandfish occur in different habitats, with black primarily found in deeper water. Genetic studies indicated that both populations were closely linked, suggesting that deep populations can constitute a buffer and a source of new recruits to the fished shallow zones, as long as trawl or dive fisheries are prohibited in these areas (Uthicke and Benzie, 1999). While a ban on the use of underwater breathing gear may protect a critical portion of the population of species such as white teatfish and prickly redfish that have a wide depth distribution, other high value species have a relatively shallow distribution and are unlikely to benefit from this measure (Lokani et al., 1996).

Spatial closures: Spatial closures that have been used to protect sea cucumber populations include limits on the depth of collection, closure of specific locations, and closure of a certain percentage of the coastline. The establishment of no-take protected areas or other types of marine reserves and sanctuaries can benefit sea cucumber fisheries by protecting a portion of the spawning stock that may provide recruits to replenish fishing grounds, and by enhancing catches in adjacent, fished areas through emigration of juveniles or adults. Marine reserves offer benefits to both fishery and non-fishery interests, but these are likely to be successful only when developed in consensus with local communities and user groups, and when properly enforced. Other factors fundamental to the design of effective sanctuaries include size, shape, and number of protected areas; habitat types included; the life histories of the target species; the location of protected areas relative to currents that may disperse larvae; and, the type of activities that are allowed.

A recent study from Australia found that the protection of whole reefs from fishing is an effective management tool for the conservation of sea cucumbers, while the division of a reef into a fished and unfished zone is only effective when protected areas are large or there is considerable genetic exchange among sites (Uthicke and Benzie, 2000). 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. Thus, *H. scabra* needs to be managed as separate stocks and local refugia adjacent to collection sites must be established that have breeding populations of this species (Uthicke and Benzie, 2001).

Seasonal closures or rotational harvest areas: Temporal closures are generally timed to protect certain life history stages of a population or certain critical periods in their life, such as the time of spawning, and may also be applied to maximize the quality of the product. Often referred to as "pulse fishing", rotational harvest typically involves harvesting a stock heavily, letting it lie fallow for a few years, and then harvesting it heavily again. Seasonal closures and rotational harvest areas are effective strategies to control effort and limit yield in one particular area to sustainable levels.

The main benefit of rotational harvest is that there would be an accumulation of individuals during the closed period, with many growing to larger sizes, increasing their value in the marketplace. One concern is that each time the closure is lifted, the removal of all or most of the spawning stock occurs. Thus, all new recruits must come from elsewhere, unless the closure is left in place for a sufficient period to allow self-seeding. Another disadvantage is that fishermen cannot fish in those areas during the closed years, and other sites must be available to provide continuing employment. One way to address this involves designing a system where different island states rotate harvest closures among species and countries, so that when the harvest is closed in one area, it would be open in others.

Limited entry: Limited entry typically involves some form of licensing or permitting to restrict the number of fishermen or the number of vessels. Restricted access to a fishery resource can reduce competition among fishermen, help ensure long term economic and social viability and promote conservation among fishery participants by giving those in the fishery a greater stake in the resource. It may also assist in obtaining data on the fishery necessary for management, as most licensing schemes typically involve a requirement of logbook submissions detailing location and amount of catch and other fishery-dependent statistics. This approach appears to work well in developed countries, including the U.S. and Australia, where other alternative sources of income are available for displaced sea cucumber fishers. In the U.S., licenses are given only to those fishermen that landed a certain volume of sea cucumber in previous years. However, limited entry may not be favored in developing countries, as it may have negative social effects. By reducing take or by limiting the number of fishermen or vessels, certain fishermen or communities dependent on these resources for their livelihood may become unemployed, with few alternative sources of income.

Output Controls

Quotas: A quota is a set limit on the amount of resource that can be harvested or exported during any year or fishing season. Quotas are usually established to achieve a desired level of harvest, such that maximum sustainable yield will not be exceeded. Quotas for sea cucumber fisheries have included total allowable catch for the fishery overall, specific quotas for individual species, or quotas for specific areas. To be effective, a desired maximum catch must be established and continuous monitoring of the catch must occur to determine when the quota is reached. When the quota limit is reached, harvesting must cease until the next fishing year.

Management by total harvest quotas (e.g., "sea cucumbers ") versus managing for individual species may be problematic because of the patchy spatial component of the fishery and holothurian populations, and the possibility that the high value species will continue to be fished until stocks are extirpated. Another disadvantage of using a quota is that a substantial amount of data on the fishery and the resource is necessary to determine maximum sustainable yield. There are several approaches to determining maximum sustainable yield including:

- Application of data on total catch and fishing effort over a number of years, with the maximum catch per unit effort providing an estimate of the maximum sustainable yield (Richmond, 1996). In a typical scenario, when a bêche-de-mer fishery is first established, the total catch increases as harvesting effort increases. Some maximum level of harvest is rapidly reached at which time additional fishing effort becomes less and less effective, and ultimately catch declines. The point at which catch per unit effort is maximized would be equivalent to MSY. This scenario may not work for multi-species fisheries, however. As one species is depleted, fishing effort shifts to less valuable species, but the total CPUE for the "sea cucumber" fishery may actually increase, giving a false sense of security. 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. The most effective quota system would involve dividing a location into harvest areas, each with its own quota developed for each target species.
- MSY can be estimated from biological parameters of the harvested stock, such as growth rates, natural and fishing mortality rates, stock size, and recruitment rates. However, this requires data on the size and age structure of populations and patterns of growth, which may not be available in most areas.
- MSY can also be estimated more simplistically by 1) estimating the size of the harvested stock; 2) determining the average age of individuals in the exploitable size classes; and 3) set an annual harvest quota at a value equal to the stock size divided by its age. For example, if the harvestable portion of the stock is 10 years old and you take 10% of the population each year, 10 years later the stock would have rebuilt itself to the original condition (Richmond, 1996).

When a quota is used to manage sea cucumber fisheries, it is important that this quota is reevaluated frequently, as new information becomes available, so any necessary adjustments can be made to prevent overexploitation.

Minimum sizes: Minimum sizes are typically based on the size at first sexual maturity, to ensure that the stock does not crash because of recruitment failure. There are numerous benefits to delaying harvest until a species has reached some minimum size, including the contribution of an individual to the population before its removal and a higher market value typically associated with larger individuals. Large female sea cucumbers typically produce more eggs than small females, there by contributing more to the abundance of future generations (Richmond, 1996).

Blanket size limits on all bêche-de-mer species has been suggested as one of the mechanisms to prevent growth overfishing, but this is impractical because the size at sexual maturity varies between species. However, determining size at reproductive maturity requires a significant amount of data and the primary burden is placed on the fishermen, who must determine the species being harvested and whether that species meets the minimum established size requirement. Nevertheless, a number of countries such as Australia, Papua New Guinea, Fiji, and Tonga have recommended or adopted separate size limits for each species (Table 7; Appendix I).

The advantage of using minimum size for managing an export fishery is that enforcement can be done at the marketplace, avoiding the need to intercept harvesters while fishing. Since the price of sea cucumbers is based on size, cucumbers have to be weighed at the market already, providing an opportunity to detect undersized animals. The disadvantage of this approach is that rejected undersized animals are already dead, and they represent a loss to the reproductive capacity of the stock as well as economic loss to the fishermen (Richmond, 1996). Another disadvantage of using minimum sizes is that this method does not guarantee that the maximum sustainable yield will be harvested, and it does not predict how many sea cucumbers will be harvested. In fisheries managed solely by minimum size, the harvest will be large in initial years, as all the individuals larger than the minimum size will be subject to harvest. Over time, the largest individuals will become scarce, and annual fishery will depend on how many animals grow to legal size in a year.

CONCLUSIONS

Commercially valuable sea cucumber populations are in decline or overexploited in many locations due to a high demand for bêche-de-mer and other holothurian products, and the high value to fishermen, particularly in developing countries where this provides a substantial component of their livelihood. One of the primary reasons for the decline is that management measures have not been applied until after the stocks crashed. In most countries, sea cucumbers have been harvested through open-access fisheries which initially target dense populations with easy access, especially nearshore, shallow environments; stocks are initially underexploited, but the catch keeps on growing and the industry flourishes. As the industry matures, the level of capture becomes constant, but more fishing effort is needed to achieve these levels. As all of the suitable species and size classes are removed from one area, the distribution of fishing effort expands to more remote areas and deeper environments. While this practice may result in extensive areas that are essentially free of harvesting pressure, it also leads to the localized depletion of stocks where fishing has occurred (Ibarra and Soberon, 2002).

Management strategies for holothurian fishery resources have many problems, and in most instances have been reactive in response to dwindling stocks. Some of the issues hindering effective management include 1) a lack of information on the population dynamics of exploited species and on holothurian biology and ecology; 2) few reliable fishery and trade statistics; 3) illegal fishing and export; 4) unregulated or ineffective regulations combined with insufficient enforcement; and 5) difficulties in measuring the effectiveness of management measures. However, it is difficult to identify overarching problems with sea cucumber fisheries, as each fishery is unique. Available information on the resource and the fishery varies by country or area, trade routes are complex and existing fishery, and trade statistics are often insufficient to determine location of fisheries and catch on species by species basis. In addition, monitoring is problematic, particularly in developing countries due to the widespread and often remote nature of the fishery and lacking financial and human resources.

The management of sea cucumbers resources has to be approached on a site by site basis with appropriate controls for each region. The most effective management plans are those that combine multiple controls, such as a minimum size in combination with rotational fishing. In addition to effective fishery management plans and regulations, additional capacity is necessary through training programs and better monitoring efforts for the resource, the fisheries and exports, and enforcement programs must be in place. One way to achieve this is by involving local communities, fishermen and other stakeholders in managing the resource and monitoring fishery impacts. Several countries and regions are already exploring the possibility of developing bêche-de-mer associations to control prices and maximize product quality. These associations are likely to be most effective when they involve partnerships among the fishermen, processors, exporters and other resource users as well as the resource management agencies, with increased involvement in all aspects of resource management and monitoring. In addition, marine park rangers can be trained in dive survey methodology and holothurian taxonomy, and can be encouraged to expand existing monitoring programs to include sea cucumbers. This will provide a constant supply of field data on species presence, temporal and spatial distribution, and growth. Marine parks and no-take reserves could also be sites for sea cucumber research.

Table 1. Information needed to develop sustainable management plans for sea cucumber fisheries.

Information Requirement	Description	Methods
Taxonomy	Unambiguous identification of species	Morphological, microscopical (spicule analyses) & molecular analyses; photographic keys for live and dried specimens.
Distribution	Extent of species occurrence within- and between-countries Spatial structure of populations (clumped or uniform)	Museum specimens, fisheries-dependent & fisheries-independent surveys
Habitat	Habitat requirements and preferences; effects of habitat type (e.g., soft sediment, grassbed, cobble) on growth, reproduction and survival	Remote sensing and *in situ* mapping and habitat characterization; fisheries-dependent & fisheries-independent surveys; broad-based underwater censuses, physio-chemical measurements
Stock structure	Single or multiple stocks Standing stock (size, biomass) Exchange of individuals among stocks	Genetics, tagging, habitat surveys, fisheries-independent surveys
Reproduction	Number, timing and season of broadcast spawning events Age- & size-specific fecundity Age & size at first reproduction	Fisheries-dependent & fisheries-independent surveys, laboratory studies, tagging and underwater studies
Recruitment	Duration of larval existence; Dispersal of larvae and juveniles; Settlement cues (physical, chemical or biological)	Tagging, genetic analyses, ecological surveys
Growth	Age-specific growth rates Seasonal growth rates Relationship between environmental attributes and growth	Tagging, cohort analysis
Natural mortality	Age-specific mortality rates Size-specific mortality rates	Fisheries-independent surveys, life-table analysis
Fishing mortality	Size of fishing fleet Spatial and temporal distribution of fishing effort Size-specific fishing mortality Sex-specific fishing mortality	Logbooks, fisheries-dependent surveys, fisheries observers, catch sampling
Density dependence	Compensatory or dispensatory (?) reproductive output (including Allee effects); Density-dependent growth (resource limitation)	Fisheries-independent surveys, meta-analyses from multiple populations and years

Table 2. Management approaches to enhance sustainability of sea cucumber fisheries.

Approach	Description	Benefits
Seasonal closure	Fishery closure during breeding season	Enhance recruitment of stocks; one problem is that some species reproduce from Nov-Jan while others peak between June-July.
Spatial closure	Fishery closure in sensitive areas or in areas that are depleted	Can include establishment of no-take areas which may help in the recruitment of stocks to fished areas and zoning for multiple uses which may reduce conflicts among different user groups.
Rotational closure	Rotate between participating islands; divide collection areas into sections, each open to harvest during a certain time period on a rotational basis.	This will reduce pressure in one area and allow a fished site to recover. Allows countries to pool resources and obtain minimum needed for export without destroying resources in one area.
Temporal closure	Fishery closed at night.	Certain species such as *H. scabra* emerge at night and would be easily overexploited at night.
Quotas	Species-specific total allowable catch for each location; total closures for certain species with low abundance.	Avoid declines in CPUE masked by shifts in fishing effort to other less valuable species; ensure that the total depletion of high value species does not occur.
Minimum size	No take until species have reached reproductive maturity.	**Biological justification**: maximize yield per recruit; allows individuals to reach reproductive maturity and spawn at least once before harvest. **Economic justification**: bigger specimens commend a higher price than smaller specimens **Drawback:** animals can change size and shape dramatically once caught; at least one species (curryfish) fetches a higher price at a smaller size.
Maximum size	Take of juvenile species for mariculture grow-out, aquarium organisms, and other uses.	Harvest of juveniles at a vulnerable stage in their development may provide a source for individuals for commercial grow-out with minimal implications to wild populations.
Gear restrictions	Limitations on use of trawls	Reduce bycatch and habitat destruction.
Gear restrictions	Prohibitions on use of SCUBA or hookah.	Provides a refuge for part of the population (depth).
Limited entry	Limitations on amount of effort based on a licensing or permitting system; restrict entry to locals or nationals.	Improves compliance with management measures. Ensures that profits from fishery benefit local community. Assigning territorial rights to fishing coops may reduce problems associated with uncontrolled open-access fishing.
Logbooks	Information on catch location, species composition, method of collection, quantity and destination.	Facilitate acquisition of more reliable fishery dependent data for use in management; increase compliance with management measures.

Table 3. Other tools, approaches, and information needs that contribute to the development of sustainable management plans for sea cucumbers.

Approach	Description	Benefits
Baseline surveys and monitoring	Baseline surveys and monitoring of Population abundance estimates including abundance and diversity in areas under exploitation and control areas.	Field data necessary to determine sustainable harvest guidelines including which sites are feasible for harvest and to set their quotas; establish permanent surveys sites to monitor harvest pressure, recovery from harvest and seasonal variation in recruitment.
Fishery-dependent data	Monitoring of catch data (numbers of individuals harvested, sizes, dates and location of collection) and trade.	Fishery dependent data necessary to feed into development of management plan and subsequent adaptive management measures.
Industry/ community associations	Development of associations of licensed fishers and exporters in partnership with local communities and national resource management agencies.	Multi-stakeholder decision making process increases likelihood of success: Improve understanding of conservation and management needs; facilitate enforcement of community-adopted management measures; provide training and reporting of catch and export data; contribute to resource assessments.
Training in processing	Improve skills of sea cucumber processors to minimize wastage.	A proportion of the catch is rejected due to decomposition caused by incomplete drying and improper storage.
Sea cucumber research	Research programs on taxonomy, biology and ecology, including growth, length and weight analyses; reproductive biology; and genetics.	Provide information needed on life history, population connectivity, habitat requirements etc. than can feed into management actions.
Aquaculture/ mariculture	Spawning, growth and settlement of larvae; raise juveniles to commercial size.	Reduce demand on wild populations; grow-out may be preferable for curryfish, which fetches a higher price at a smaller size and can be grown to market size faster.
Sea ranching operations	Grow-out of farm raised juveniles or juveniles removed from wild.	May reduce demand on wild populations. Effect of harvest on juveniles unknown.
Restocking programs	Release of farm-raised juveniles.	Recover extirpated stocks; Increase yield of fishery.

Table 4. Examples of existing regulations for sea cucumber fisheries in temperate waters. THQ= Total harvest quota; HAQ=Harvest area quota; mt= metric tons.

Location and species	Open Season	Harvest Area	Gear type	Quota
Alaska, USA	Oct-March	13 Fishery Management units (FMU).	SCUBA, Surface supplied air; snorkel. No mixed gas or saturation diving.	Max harvest for each fisher and each FMU.
Washington, USA	All year	5 management areas; Rotation of harvest with 3.5 yr closure after 6 month fishing period.	SCUBA or surface supplied air. Experimental trawl fishery.	Quota for each area; quota for recreational harvest.
Oregon, USA	All year	Permits issued geographically until 2003, with half for the southern coast and half for the northern coast.	Dive gear and trawl gear.	No quota.
British Columbia, Canada	October; 1-20 days long	25% coast open under a quota; 25% under experimental fishery to evaluate effects of varying harvest levels; 50% of coast is no-take.	Dive fishery; hookah and SCUBA.	THQ=385.6 mt; individual license quotas of 4.5 mt; HAQ for each area .
California	All year	Recreational dive harvest allowed below 6 m; Sea cucumber trawl gear prohibited in trawl rockfish conservation areas; small closed sites around Channel Islands.	Trawl and dive fishery.	No quota.
Maine	Oct-June; no night harvest	No area restrictions.	Trawl gear (modified “urchin drag”gear or scallop drag gear).	No quota.
Newfoundland Canada	Year round fishery	No area restrictions.	Harvested as scallop bycatch, also small dive fishery (12 divers).	Max catch by divers, 24,000 lbs daily.

1. Alaska fishery is based on *Parastichopus californicus* **Closed Season:** selected to protect spawning aggregations; can be closed early if harvest level is reached; **Fishery management units**: each has biomass estimate completed within last two years; **Quota:** harvest level for each site based on surplus production

model that includes 1) an estimate of virgin population size and allowance of harvest rate of 5%; and 2) additional conservative measures: quota is reduced to 50% of the harvest rate derived from the model plus another 30% to account for field sampling variability (Ruccio and Jackson, 2000).

2. Washington fishery is based on *Parastichopus californicus*and *P. parvimensis* **Season:** Year round dive fishery; Experimental trawl fishery closed during soft-shell Dungeness crab periods and in shrimp areas Experimental trawl fishery in specific locations; beam trawl gear with max beam width or otter trawl with minimum mesh size. **Quota**: for each area determined using surplus production models and estimates of biomass from catch-effort data, video surveys, and dive surveys. There is also a daily limit of 25 animals for two species (*P. californicus* and *P. parvimensis*) for the recreational fishery (Bradbury, 1994)

3. Oregon's fishery is primarily a dive fishery based on *Parastichopus californicus*; harvest by trawl required an experimental gear permit until 2003. The target species has been placed under category B of the Developmental Fisheries List, which include species with less potential for viable fisheries; a permit is no longer required (McCrae, 1994; pers. comm).

4. British Columbia fishery is based on *Parastichopus californicus* **Season**: occurs during October after reproduction (when internal organs are atrophied) to maximize product quality. **Total quota** is determined from a precautionary fixed exploitation rate which is divided into harvest area quotas based on an estimate of a coastwide density of 2.5 sea cucumbers per meter of shoreline, an allowable harvest of 4.2% of biomass, shoreline length and average weight (Muse, 1998; Fisheries and Oceans Canada, 2002).

5. California fishery started in 1978 and is based on *Parastichopus californicus* and *P. parvimensis.* A special permit was required for sea cucumber harvest beginning in 1992-1993, with separate permits for each gear type and a limit on the total number of permits implemented in 1997. There are no restrictions on catch. Until 1996 an average of 75% of the annual catch was from the southern California trawl fishery. Between 1997-199, the dive fishery accounted for 80% of the take. Recent surveys show a 50-60% decline in abundance between 1994-1998, but no correlation was noted between decline in abundance and data on landings. The only increase in abundance was noted at two no-take reserves (39% increase) (Rogers-Bennett and One, 2001; Schroeter et al., 2001).

6. Maine fishery is a low value/high volume fishery that started in 1994 and is based on *Cucumaria frondosa*. The "urchin drag"gear used in the fishery is limited to 5"6" width and 22' length; head bail constructed of less than 1.5" round steel stock. Logbook data indicates fishing effort is clumped with most cucumbers coming from three locations in eastern Maine (Feindel, 2002).

Table 5. Examples of fishery management measures in the tropical western Pacific.

Location and species	Permits	Harvest area, species and season	Gear type	Quota
Australia: Great Barrier Reef	Licensing system and logbooks. Quota on number of licenses; 18 active fishermen .	Great Barrier Reef Marine Park Act 1975 closed several reefs to fishing. *H. nobilis* fishery closed in October 1999.		Minimum size: 15 cm; TAC = 500 mt (90% of the estimated yield .
Australia: Torres Strait	Permit system through Island Community Councils.	None?	Hand or hand-held non-mechanical implements only; a ban on SCUBA and hookah gear; 7 m maximum length of Islander dinghies.	Total allowable catch of 260 mt and minimum size limits of 18 cm.
Australia: Northern Territory	6 commercial licenses, 3 per management zone, 4 divers per license	2 management zones; collection restricted to areas covered by water at low tide; no take in marine parks, reserves or sanctuaries and around particular islands and shoals.	Hand collection only by diving.	TAC is 380 mt (127 mt white teatfish and 253 mt of other spp.; minimum sizes.
Fiji	Harvesting and processing restricted to Fiji nationals .	A 5.6 square mile area around Namena Atoll closed to harvest in 2001. No export of *H scabra.*	Use of SCUBA gear prohibited, but hookah was not prohibited.	7.6 cm 3 inch minimum export size.
Papua New Guinea (PNG)	PNG citizens only; license for storing or export.	Open season from 16 Jan-Sep 30. Quota divided into two value groups (high and low). Torres Strait fishery closed in 1992.	Hookah, SCUBA and lights prohibited.	TAC for each province; Minimum sizes for 17 species (live and dried) .
Tonga	Exporters limited to 10 licenses.	Scheduled closed season and closed areas; 10 year moratorium in 1999.	Ban on SCUBA and hookah.	Min size for some species (live and dried).
Solomon Islands		Moratorium in certain areas of Makira in 1994. 1998 ban on collection and sale of sandfish.	Ban on SCUBA and hookah in the Western Province.	

Table 6. Examples of controls and enforcement measures for sea cucumber fisheries in temperate waters.

Location	Licensing	Reporting	Validation
British Columbia Canada	Limited entry; 85 licensed fishers; maximum 5 licenses per vessel.	Fishers use standard logbooks .	All landings are monitored by an independent industry funded firm; dockside landings only at designated ports; license holders pay a fee.
Alaska, USA	Divers registered and permitted.	Dive/harvest logbook with date, location (GPS), depth, bottom time, quantity.	Divers can only obtain permits for urchins or sea cucumbers but not both.
Washington, USA	Limited entry; 190 divers in 2000.	Logbooks with daily reporting of catch to avoid exceeding quota.	Must submit logbooks every month with data on date, depth location and amount (number and weight) collected.
Oregon, USA	Commercial shellfish license was required for dive fishery until 2003, when only 2 permits were issued.	Fish receiving tickets (dock ticket) required from sea cucumber dealers with fishermen's name, location, date and amount.	Cucumbers are listed under Developmental Fisheries species list category B. As of 2004 a permit is no longer required.
California, USA	Separate annual permits for each gear type: 113 dive permits and 36 sea cucumber trawl permits.	Dive and trawl fisheries target different species; all data lumped as sea cucumber landings.	Limit permits by requiring a minimum landing of 50 lbs during the previous year. Trawl fishery declined in 1998-1999 due to prosecution of 16 trawl fishermen that fraudulently obtained sea cucumber permits.
Maine, USA	16 endorsements (only 3 active).	Harvester Logbooks.	Limit licenses to fishermen that landed >250,000 lbs in a previous year. No incidental take allowed, only take through targeted, licensed fishery.

Table 7. Minimum size restrictions for tropical sea cucumbers. Other tropical nations with minimum sizes for sea cucumbers include: 1) Queensland, Australia- 15 cm live minimum size for all species; 2) Fiji- 7.6 cm size dried for all species; 3) Maldives- 15 cm size for *H. atra* only.

		Papua New Guinea		W Australia
Scientific name	Trade name	Live	Dry	Live
Actinopyga lecanora	stone fish	15 cm	10 cm	
H. scabra *H. scabra versicolor*	sandfish	22 cm	10 cm	16 cm
A. miliaris	black fish	15 cm	10 cm	
A. mauritiana	surf red fish	20 cm	8 cm	
H. fuscogilva	white teatfish	35 cm	10 cm	32 cm
S. chloronotus	green fish	20 cm	10 cm	
S. variegates (S. hermanni)	curry fish	25 cm	10 cm	
H. nobilis	black teatfish	22 cm	10 cm	26 cm
Thelenota ananas	prickly redfish	25 cm	15 cm	30 cm
Actinopyga lecanora	stone fish	15 cm	10 cm	
T. anax	amberfish	20 cm	10 cm	
B. argus	leopard (tiger) fish	20 cm	10 cm	
Bohadschia vitiensis	brown sandfish	20 cm	10 cm	
H. edulis	pink fish	25 cm	10 cm	
Holothuria fuscopunctata	elephant trunk fish	45 cm	15 cm	
Halodeima (Holothuria) atra	lolly fish	30 cm	15 cm	15 cm
A. echinites	brownfish (deepwater red fish)	25 cm	15 cm	12 cm
B. marmorata mamorata (B. similes)		25 cm	7 cm	

Appendix I: Current Status of Existing Sea Cucumber Fisheries

Australia. Sea cucumber fisheries date back to the 1700s, with Indonesians most active participants of the fishery until the late 1880s. Increasing interests in the 1980s led to an expansion of fisheries off Queensland, Torres Strait and around the Great Barrier Reef (GBRMP), along with the development of management measures and regulations. In the GBRMP intensive fishing in the mid 1980s-1990s led to depletion of the main target species (H. nobilis) and the fishery on this species was closed in 1998 (Uthicke, 2003). Surveys in GBRMP within fished areas and no-take areas showed that fishing reduced densities of sea cucumbers by about 75%.

British Columbia, Canada: Sea cucumbers have been commercially harvested in British Columbia Canada since 1971, with substantial changes in the management regime over time to address resource declines and to avoid overfishing. The fishery was an open access fishery through 1990. Management measures include: 1) a regional quotas and area closures first introduced in 1986; 2) a reduction in the regional quota in 1989 and 1991; 3) rotational harvest with six months of fishing followed by a two year closure in each defined site between 1993-1996; 4) a license-type limited entry system was introduced in 1991 with individual quotas in 1995; and 5) adaptive management practices were introduced in 1997, with closed areas and areas open to dive fishery, as well as an experimental fishery to assess affects of different harvest levels and determine what is sustainable. In experimental areas resource managers conduct annual pre-harvest surveys, allow take at 0, 2, 4, 8 and 16% of the biomass, and then conduct follow-up surveys to evaluate effects of variable fishing pressure on stocks. Three experimental fisheries are underway in three different habitat types, with annual surveys and experimental fisheries continuing for at least 10 years. At the end of the study management measures will be further refined.

Cook Islands: The only commercially exploitable sea cucumber species in Cook Islands is *A. mauritiana*, with exports from 2 areas reported in the 1980s and some subsistence use in the southern islands. Recommendations were presented in 1988 that included: 1) establishment of conservative management guidelines; 2) conducting baseline surveys prior to start of fishery; 3) implementation of seasonal closure during breeding seasons; rotational fishing; quotas; minimum sizes; and reserve areas; 4) limited entry and required reporting guidelines; and 5) a ban on the use of SCUBA (Adams, 1993b).

Cuba: A fishery was established in 1999, with over 3 million animals landed during the first two years by one company operating out of 12 boats in the southeast region. The CPUE averaged around 1,153 +/- 630 animals per boat per day, with a decline throughout the year to about 350 animals/boat/day. In the southeastern region, a quota of 611 tons has been established.

Ecuador: In 1989, sea cucumber fishermen from mainland Ecuador began setting up operations in the Galapagos, as the fisheries off the coast of Ecuador were depleted. There was no management plan enacted at this time. Populations of *Stichopus fuscus* became dramatically reduced almost immediately, prompting a ban on all harvesting of sea cucumbers. Illegal fishing continued, however, and in early 1994, under protest by fisherman and pressure from environmental groups the ban was lifted. In 1996 a consensus based participatory management process was adopted for the sea cucumber fishery, with representatives of various stakeholders. In 1999 Ecuador passed the Galapagos Marine Management Plan and harvesting of sea cucumbers became regulated under a concrete legal and conservation framework. . Current management initiatives include a season of 60 consecutive days between March and May; open areas must have minimum observed density; zoning plan with closed areas that correspond with spawning zones; minimum size (20 cm); and a fixed quota (Traffic South America, 2000). In 2002 the Participatory Management Board (PMB) prepared a proposal for the five year period fishing calendar. This proposal had the agreement from the local sectors (fishing, conservation, tourism and Galapagos National Park) for the management of sea cucumber fisheries. This proposal was approved by the Interinstitutional Management Authority (IMA) on February 25th and established that the fishery would open when the results of a study on the sea cucumber population density was completed. The study was carried out by the fishing sector, the Galapagos National Park and the Charles Darwin Foundation from March 4th to April 10th, 2002 on 6 islands of the archipelago. The results from this joint study indicated that none of the island in the study met the criteria of having a density of 40 sea cucumbers per 100 square meters that were larger than 22 cm.

Egypt: A fishery began in 1998 with catch primarily associated with trawling. Expansion of fishery effort in 2000 led to a ban on sea cucumber fishing in 2001 until baseline stock assessments were completed. The fishery was reopened in 2002, but population surveys indicated resource depletion and a new ban was declared in 2003.

Fiji. Sea cucumbers are harvested for subsistence (sandfish) and export, with the export fishery dating back to the early 1800s, when collection and processing facilities for sea cucumber were established in Fiji primarily to supply Chinese markets (Adams, 1992). Numerous reports of overexploitation of sandfish are associated with the bêche-de-mer boom of the mid 1980s, with exports increasing from less than 15 mt prior to 1982 to 717 mt in 1988. Severe depletion of stocks led to declining exports and a subsequent total ban on export of sandfish; *A. miliaris* now accounts for up to 95% of the exports. Bêche-de mer Exploitation Guidelines were first published by the Fisheries Division in 1985 with amended regulations in 1988 in response to a 10-20 fold increase in exports (Adams, 1992).

India: Sea cucumbers are taken in a trawl fishery, as bycatch of "thallumadi", a local fishing gear, and by skin diving primarily in the Gulf of Mannar and Palk Bay. *H. scabra, H. spinifera and B. marmorata* were the most important species over last 1000 years, but fishermen began collecting other species in 1990, in response to high export value and population declines of the preferred species. In 1982, a ban on export of bêche-de-mer below 3 inches was implemented and collection of all sea cucumbers was also banned in Andaman and Nicobar Islands. A fishery exists in Gulf of Manner, Palk Bay, but CPUE and size of specimens has dramatically declined in these areas. Problems with the fishery include an overlap between the peak fishing season and the peak spawning season for *H. scabra* during July and October; other problems include habitat damage associated with fishing gear. Drag-nets used for sea cucumbers in shallow sea grass beds cause severe destruction of sea grasses. In 2001, all sea cucumbers added to Schedule I list of the Wildlife Protection Act, which bans their collection. However, illegal fishing continues and most stocks are depleted (Nithyanandan, 2003).

Indonesia: Indonesia has the worlds largest sea cucumber fishery with estimated exports increasing from 878 mt in 1981 to over 4600 mt per year from 1987-1990 (Tuwo and Conand, 1992). There are few management measures, although regulations exist in various regions on trawling for sea cucumbers and maximum densities for cage culture of juveniles collected from the wild. Some locations are implementing various voluntary community based conservation measures.

Japan: Sea cucumbers have been consumed locally for centuries, with one species (*S. japonicus*) harvested in local waters and now also under intense aquaculture. The catch of *S. japonicus* in Japan declined from 25,000 mt in 1983 to 7000 mt in 1995. Hatchery production increased substantially during this period (Ito and Kitamura, 1998). Japan prohibits fishing between March and November to take into account spawning and seasonal high water temperatures. In addition, area closures are in place in some locations and gear restrictions have been implemented (Arakawa, 1990).

Kenya: Sea cucumbers are collected for export with little or no local consumption. Exports increased from 78-86 mt per year between 1989-1991, to 277 mt in 1992, followed by a sharp decline in the next 3 years (14, 41, 55 mt respectively). Fourteen species are exported (Marshall et al., 2001). The only regulations in place are licenses, which are required to collect or trade in sea cucumbers, although most fishermen do not hold licenses.

Madagascar: Export fishery began in 1921, with exports of 50-140 mt annually. Exports increased from 56 mt in 1986 to over 500t in 1991 and 1994. Although it is now illegal to fish with SCUBA, this has been difficult to enforce. Shared management was introduced in 1998, which included a partnership between the Madagascar National Trepang traders group and the government resource managers to administer management and exploitation of trepang (Conand et al., 1998). Madagascar fishers and exporters also formed the National Association of Sea Cucumber Producers (ONET). Some of the proposed initiatives of these associations include: studies of current status of resource; formulation of a monitoring and joint management system using simple assessment methods to evaluate resource and its fluctuation; creation a management manual; and sea farming experiments.

Malaysia. There are three different fisheries for sea cucumbers, including one near Pulua Langkawi with well established trade routes through Thailand; a small artisanal fishery in western Malaysia with a single fisherman, and an expanding fishery along the coast of Sabah in northeast Borneo. In Pulua Langkawi, one target species, S. hermanni, has been depleted and may possibly be extirpated around Langkawi Islands. In Sabah, annual catch was about 400-500 mt, while annual catch in the 1990s has fallen to around 100 mt.

Currently there are no countrywide regulations of the sea cucumber fishery (Baine and Sze, 1999).

Maldives. Bêche-de-mer production began around 1986, with three species targeted: *T. ananas, H. nobilis and B.marmorata.* Exports increased from 3 mt in 1986 to 740 mt in 1990 (Reichenbach et al., 1998). The only formal regulations are a ban on SCUBA implemented in 1996. The Bay of Bengal programme made recommendations that include a 4-5 yr ban on take of *Thelenota ananas,* a min size of 6 inches for *H. atra,* and they discourage night fishing.

Mexico: In Baja California, harvesting of the sea cucumber *Isostichopus fuscus* for export to Asian markets rose very sharply between 1985 and the mid nineties. A permitted commercial dive fishery was established in 1992. In 1994 a closed season was imposed in Baja and size limits for *Isostichopus fuscus* and *P. parvimensis* were established; in May of 1994 *I. fuscus* was declared in danger of extinction by the National Institute of Ecology of Mexico (NOM-059-ECOL-94) with a ban on fishing (Castro, 1995). Illegal fishing continued into 1997, when *I. fuscus* stocks reached 2% of their original estimated size. In March 200, *I. fuscus* was placed on a "species under special protection" list, which authorizes scientific research by fishermen and government scientists. Illegal fishing continues (Ibarra and Soberon, 2002).

Micronesia: A small fishery for *A. mauritiana* and *H. whitmaei* occurred in Saipan, CNMI during 1996 and 1997, but was halted in early 1997 due to declining CPUE (Trianni, 2003). The Saltonstall Kennedy grant program funded a five year project in Micronesia (American Samoa, Guam, and FSM) on resource surveys, aquaculture and management with emphasis on three species. The project resulted in a general moratorium on export harvests in Palau and portions of the FSM and the development of a generic sea cucumber Management Plan for Micronesian states (Richmond, 1996).

Mozambique. The sea cucumber fishery targets 11 species, with apreference for *H. scabra, H. nobilis, H. fuscogilva*, *H. atra, A. echinites and A. mauritiana.* Collection occurs in intertidal areas while wading (by women and children) and in deeper areas with snorkel and SCUBA gear (men); some bycatch in trawl and gill-net fisheries is reported. Between 1979-1990 exports fluctuated from about 20-110 mt; during the 1990s exports fluctauated between 17.7-52.4 mt with a drop to 2.9 mt inm 1997 (Marshall et al., 2001). The primary management measure has involved closed seasons, although fishermen continue to exploit the resource during closed periods.

New Caledonia. The bêche-de-mer fishery dates to the 19^{th} century, with a recent revival in 1983 and harvest of 55-180 mt per year until 1990, when the fishery declined. About 100 fishermen were involved in the fishery in 1993 at the tribal level or in cooperatives on the northeast Coast of Caledonia (Conand and Byrne, 1993). There is no formal management by the government, but local communities have implemented certain conservation measures. In 1992 the people of Arama undertook a voluntary suspension of fishing by during the crab season (April and January). Fishers of Nepoui Poum and Pouebo also established independent minimum size limits.

Panama. Exploitation of sea cucumbers began in an unplanned way, with a permit granted by the government in 1997 for harvesting and processing bêche-de-mar in Bo-cas del Toro. The negative effect of this unmanaged extraction occurred immediately and the permit was revoked 30 days later. An estimated 750 000 sea cucumbers of the three species had been caught during the period, and illegal fishing continues. A recent study comparing population survey data with fishing effort reported severe overfishing and suggested these species will collapse within a year if fishing pressure is maintained or permitted (Guzman and Guevera, 2002). The authors recommend no fishing of *A. multifidus* and *I. badionotus* in the entire archipelago for 3-5 years followed by a tightly controlled harvest for Bo-cas del Toro that includes the creation of no-take areas that are stocked with adult holothurians. They also recommended a fishery for *H. mexicana* with limited access, quotas, season, minimum size and site-based closures in depleted areas that are currently affected by illegal fishing (Guzman and Guevera, 2002).

Palau, Ponphei and Samoa: A number of species are harvested in the Pacific Islands for subsistence use, with some species harvested for their body wall while others are harvested for their gonads and intestines (Lambeth, 2000). Traditional knowledge and resource management practices are commonplace, including collection only during morning hours over four mornings twice per month (Palau), use of a finger to induce evisceration instead of cutting the animal thereby leading to faster regeneration times (Pohnpei), and a requirement that removal of the intestine must be processed on the spot, with animals returned to the water (Samoa).

Philippines. The sea cucumber fishery is a year round activity with a peak season from March to June. Holothurians are collected primarily by women during low tide at night by walking along the intertidal zone, while men snorkel or use hookah gear to collect from deeper areas. Exports of sea cucumbers from the Philippines have occurred for over 300 years, with little or no local consumption (Jun, 2002). Export statistics available since 1970 indicate that the Philippines has emerged as the second largest producer in the world, with catches of around 20,000 mt per year since the mid 1980s (Conand and Byrne, 1993). Exports have been maintained at about 1000 mt, although there has been a decline in high value species compensated for with low value species. There is very little information on the fishery, and there are no management measures specific for sea cucumber fisheries. Many areas stripped of high commercial value species and others of all species (Trinidad-Roa, 1987).

Papua New Guinea (PNG). The fishery dates back to the 18th century, with some local consumption of H. scabra. After a period of low activity from 1977-1985, the fishery has been an important source of income for coastal communities (Conand and Byrne, 1993). The primary target in 1989 was *H. scabra*, leading to establishment of a minimum size in 1996 as a measure to protect stocks. In Torres Strait, problems of illegal fishing in Australian waters led to a closure of the fishery in 1993, which was extended through 1995 (Lokani, 1996). In 2001, a National Bêche-de-mer Fishery Management Plan was adopted. The Plan outlines access, size and catch limits, and storage and export requirements and includes a closed season (Oct 1- Jan 15), total allowable catch by

Province and species, and a licensing and logbook system (Polon, 2003). The Plan also encourages provinces in forming Provincial Management and Advisory Committees. The Provincial Fisheries Management Committee made thorough stock assessment in Oct/Nov 2001 throughout Milne Bay and found that most commercial sea cucumber species occur at very low densities. Fisheries data indicate that catch of high value species declined from 36% in early 1990s to 15% in 2002. Although regulations are in place for sea cucumber fisheries, illegal fishing occurs during closed seasons; quotas are often exceeded; and prohibited gear (hookah and lights) is still used (D'Silva, 2001).

Seychelles. A small open access fishery has occurred since the 1950s, with recent increases in harvest of six species mainly for export markets. In 1999 management measures were introduced by the Seychelles Fishing Authority, including licenses for fishing and processing, with 25 fishing licenses granted per year (Seychelles Nation Online, 2003).

Solomon Islands. The fishery increased from 8 mt in 1985 to 622 mt in 1992, which represented 62% of the countries exports worth $3.4 million USD (Richards et al., 1994). Since 1992, landings have decreased to 240 mt in 2001, with over 75% of the landings derived from species with medium and low commercial value. The South Pacific Commission Inshore Fisheries Research Project 1992 recommended community management, alternate closed seasons of 6-12 months, possible application of size, effort, gear or seasonal limitations that apply to subsistence and commercial fishing, establishment of marine reserves, and monitoring of catch data. None of these recommendations were adopted except for a ban on the use of SCUBA (Adams, 1993). Due to failure of centralized management of the fishery, there is a push to return to customary marine tenure with active participation by fishers and resource owners in implementing management measures (Ramofafia et al., 2003) .

Tanzania. Sea cucumbers are collected by hand-picking, free diving and SCUBA, with a small amount of bycatch associated with commercial trawlers. Collection is year round, with peak periods between March and May and September to November. The fishery targets 7 species, with a lower take of 13 other species. The fishery is currently unregulated (Mmbaga and Mgaya, 2003). Landings increased from 324 mt in 1989 to 1460 mt in 1995, although official exports during the 1990s ranged from 189-565 mt with a peak in 1994 and subsequent declines to about 277-324 mt in subsequent years (Marshall et al., 2001). Separate licenses are required for traders and exporters and exports are taxed.

Thailand. Sea cucumbers are harvested for local consumption and export with *H. scabra* and *H. atra* being most popular. An export fishery emerged in the late 1970s, with collection primarily by hand during low tide. As resources declined, snorkelling to depths of 5-10 m became popular; use of SCUBA or hookah is not reported. Overexploitation and a shift to less valuable species have been reported. There is currently an absence of management, with recommendations for the establishment of minimum sizes and stock management in marine national parks and sanctuaries (Bussarawit and Thongtham, 1999).

Tonga. The fishery began in the early 1980s with rapid expansion in the late 1980s and early 1990s with the introduction of assisted underwater breathing apparatus. By 1994, exports exceeded 60 mt. In 1996 a widespread public awareness campaign targeted towards fishermen was initiated to develop the fishery in a more sustainable manner. The government encouraged community management, recommending bêche-de-mer liason officers, closed seasons at the end of each year, and closed areas (Ministry of Fisheries 1996). In 1999, a ban with a ten year moratorium on all species was implemented.

Tuvalu. A small fishery existed between 1979 and 1982. The fishery was revived in 1993, with 871 kg of exports; exports increased four-fold in 1994-1995 (Belhajali, 1997). The fishery is not regulated, but there are recommendations to ban use of SCUBA and hookah gear to harvest sessile organisms including sea cucumbers.

United States. Sea cucumber fisheries in the U.S. are primarily temperate water fisheries with commercial harvest by trawl or dive gear occurring off the east coast (Maine) and west coast (California, Oregon, Washington and Alaska). There is currently little to no harvest in tropical regions. On a state-wide basis, these appear to be sustainably managed, although localized depletions have been reported.

Vanuatu. No fishery in Vanuatu has operated under a formal management plan. The Fisheries (Amendment) Act No. 2 (1989) provides the Minister and the Director with broad discretionary power to manage the country's fish stocks. An annual quota of 40 mt was established by Ministerial order in 1991 and put in place in 1996. Cooperative management was introduced between 1990-1993, in which the government fisheries department provides scientific information and advice, while coastal villages assume the bulk of the responsibility for local management. While bêche-de-mer fishing per se was not being managed, many villages employ total fishing ground closures which constitute de facto bans on bêche-de-mer harvesting.

Venezuela. One year licenses for 200kg/wk were first issued in 1993 and later suspended; four licenses were issued in 1994 for the original site plus a new area (Rodríguez and Marques-Pauls, 1998).

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