Conservation and sustainable use of sea cucumber resources in India

suggestions and way forward

ISSN 2394-8019
CMFRI Marine Fisheries Policy Series No. 7

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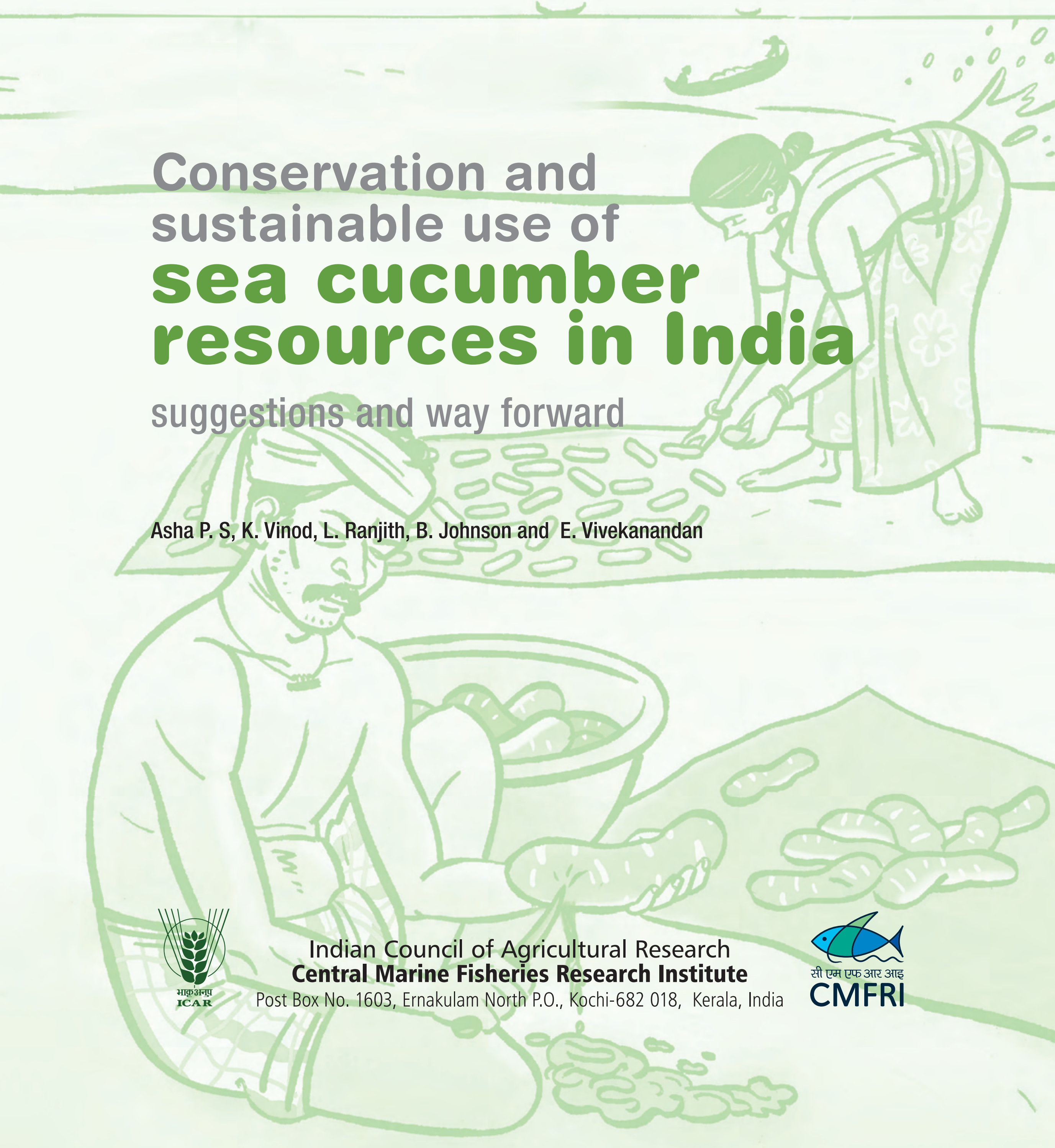
CMFRI Marine Fisheries Policy Series No. 7 ISSN 2394-8019



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CMFRI Marine Fisheries Policy Series No. 7
March 2017.

Published by
Dr. A. Gopalakrishnan
Director, ICAR-CMFRI

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Design
Graficreations, Kochi

Printed at
Print Express, Ernakulam

Production & Co-ordination
Library and Documentation Centre

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ISSN 2394-8019

Citation: Asha P.S., Vinod K., Ranjith L.,Johnson B., and Vivekanandan E. 2017.
Conservation and sustainable use of sea cucumber resources in India: suggestions and way forward.
CMFRI Marine Fisheries Policy Series No. 7, Central Marine Fisheries Research Institute, Kochi, India pp. 80.

Foreword

Sea cucumbers are prime seafood resources, harvested throughout the world for the preparation of a dried product '*beche-de-mer*', besides other health products. However, in recent years, the wild population of sea cucumbers is on the decline due to the increasing market demand and the consequent over-harvest of resources. The global scenario of stock decline was witnessed in Indian waters too in the early 1980s, and as a regulatory measure, the Ministry of Environment, Forests & Climate Change (MoEF & CC), Government of India implemented a size regulation on the export of '*beche-de-mer*' in 1982. As this regulation was not very effective, the Government imposed a blanket ban in the year 2001, and listed all species of holothurians under the Schedule I of the Indian Wildlife (Protection) Act, 1972, thereby putting an end to the sea cucumber fishery and trade from the country. In India, the fishery of sea cucumbers was restricted mainly to the Gulf of Mannar and Palk Bay, along the south-east coast and the moratorium imposed by the Government affected scores of coastal communities whose livelihood was dependent on the collection, processing and trade of sea cucumbers.

This special publication is an outcome of several studies conducted on sea cucumbers by the ICAR-Central Marine Fisheries Research Institute (CMFRI), during the last five decades. The publication presents an overview of the species diversity, habitat, biological characteristics, fishery and trade of sea cucumbers in the Indian context. The resource status of sea cucumbers, based on the recent studies conducted by the ICAR-CMFRI under the FAO-BOBLME Project is also highlighted in the present document.

The publication is focused on bringing out various management measures, based on scientific principles, for conservation and sustainable management of sea cucumber resources. The recommendations outlined in the document were the outcome of various workshops and consultation meets held with all the concerned stakeholders, to ensure the long-term sustainability of sea cucumber resources in Indian waters. I sincerely hope that this special publication will be useful to scientists as well as natural resource managers, and serve as a road map in their on-going efforts to manage and conserve the Indian sea cucumber resources.

A. GOPALAKRISHNAN
Director, ICAR-CMFRI

Contents

Executive summary

The ever-growing demand for sea cucumber in the export trade, consequent over-exploitation and inadequate management measures have resulted in depletion of stock in many parts of the world. An overarching goal in the management of sea cucumber fisheries should be to safeguard the reproductive capacity of breeding stocks so that the resources are available to future generations. This document is an outcome of the extensive research work carried out by the ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI) in the last five decades and the project on sea cucumbers implemented by the ICAR-CMFRI with financial support from the Bay of Bengal Large Marine Ecosystem (BOBLME) project in 2015.

In India, sea cucumbers are distributed mainly in the Gulf of Mannar, Palk Bay, Lakshadweep Islands, Andaman and Nicobar Islands and the Gulf of Kachchh, besides some places along the mainland coasts. However, the fishery and trade existed mainly in the Gulf of Mannar and the Palk Bay, providing livelihoods to scores of poor fishermen inhabiting the region. Of the 39 species reported from the Gulf of Mannar and Palk Bay, the fishing was mainly centred around two commercially valuable species *viz.*, *Holothuria scabra* and *H. spinifera*, and occasionally on four to five additional species based on their availability and market demand. The indiscriminate exploitation led to decline in wild population and as a regulatory measure, the Ministry of Environment, Forests and Climate Change, Government of India implemented a size regulation on the export of '*beche-de-mer*' in 1982, restricting the export of size below 75 mm length. As the regulation was not effective, the Government imposed a blanket ban in 2001 by listing all species of holothurians under Schedule I of the Indian Wildlife (Protection) Act, 1972, which is under implementation since 2003.

The ICAR-CMFRI has conducted extensive studies on sea cucumbers since 1962 and was also successful in captive breeding and seed production of two commercially important species *viz.*, *H. scabra* and *H. spinifera*. During the twelve years of fishing ban, sea cucumber stock status survey conducted by the Zoological Survey of India (ZSI) and by ICAR-CMFRI indicated wide fluctuation in population status of nine holothurian species in the Gulf of Mannar and Palk Bay, which warrants the need for conducting periodic stock assessment studies.

Despite the national moratorium, illegal fishery and trade continues, making the moratorium ineffective. Fishermen complain loss of livelihood and are vehement in their voices to lift the ban. A controlled regulatory mechanism of collection and trade of sea cucumbers involving all concerned stakeholders might be a preferred policy solution, as this would help in conservation as well as sustainable use of these resources. The potential management measures would encompass catch quota and licensing, minimum legal size, seasonal closures, rotational fishing, no take zones, gear limitation, species protection, habitat protection, trade management and restocking through hatchery seed production and aquaculture. Implementation of various regulatory measures is a challenge, but holds the key for sustaining the sea cucumber fisheries as well as livelihood of the communities.

Participation of all stakeholders holds the key for success in any management plan. Effective management of sea cucumber fishery could be achieved by following an ecosystem approach, in which multiple regulatory measures and management actions could be agreed upon and applied in a participatory manner in consideration of the sea cucumber stocks, the ecosystems in which they live and the socio-economic systems that drive exploitation. The role of communities is an important factor for conservation and the communities should have access to the resources and at the same time should take the responsibility to conserve and sustainably use it.

Chapter-1

Fishery of sea cucumbers

Background

Sea cucumbers are commercially important echinoderms, forming significant sources of global seafood catches and integral parts of coastal livelihoods and employment for more than three million fishers globally (Purcell *et al.*, 2013). They are harvested throughout the world predominantly for the raw body wall, viscera, or to produce a dried product known as '*beche-de-mer*' or '*trepang*', and other health products which are exported to eastern Asian markets (Conand, 1990; Akamine, 2004; Ferdouse, 2004). The Indo-Pacific region is engaged in sea cucumber trade for over one thousand years, primarily for Chinese consumers (Conand and Byrne, 1993).

Throughout the world, 66 species of sea cucumbers are commonly exploited (Purcell, 2010) with the highest number (47) from Philippines (Labe, 2009). At least 70 countries are engaged in sea cucumber fishing and trade (Toral-Granda *et al.*, 2008). Majority (66%) of sea cucumber fisheries involves small-scale fishing operations which are common in shallow habitats of tropical waters (Berkes *et al.*, 2001). The participation of export fisheries, in terms of number of fishers/km^2 of reef, was highest in Philippines (37.4) followed by Papua New Guinea (18.1; presently under moratorium) and Indonesia (15.9). In the Indian Ocean and African fisheries, it averaged 1.7 fishers/km^2 (Purcell *et al.*, 2013).

Soaring market demand, lack of alternative income streams for fishers, ineffective management measures and inherent ecological and biological vulnerability of sea cucumbers has led to over-exploitation of the resource. Studies indicated an alarmingly high incidence of over-exploitation and depletion of sea cucumber stocks, particularly in the Indo-Pacific areas. Overall, 20 per cent of fisheries has been depleted, 38 per cent over-exploited, 14 per cent fully exploited and 27 per cent underexploited or moderately exploited. About 27% are operating illegally, despite national moratoria. These illegal fisheries (official moratorium but clandestine fishing) occur in Central and South America and the Western Indian Ocean (Purcell *et al.*, 2013). *Isostichopus fuscus* (brown sea cucumber), is the only sea cucumber species from Ecuador, currently listed in CITES (Appendix III) (Toral-Granda *et al.*, 2008). Of the 377 sea cucumber species examined, the International Union for Conservation of Nature (IUCN) Red List has classified seven species as Endangered or at high risk of extinction and nine species as Vulnerable or at risk of extinction (www.iucnredlist.org).

Globally, sea cucumber fisheries have often lacked comprehensive management plans and enforcement capacity to deal with intense exploitation rates (Evans *et al.*, 2011; Purcell *et al.*, 2013) which is more evident across the Indo-Pacific region. In the Indian Ocean, national sea cucumber fisheries have been in existence in different countries for many decades (Conand, 1990) but the institutional capacity for management is weak (FAO, 2012; Eriksson *et al.*, 2015). An overarching goal in the management of sea cucumber fisheries should be to safeguard the reproductive capacity of breeding stocks so that the resources are available to future generations (FAO, 1995; Friedman *et al.*, 2008; Purcell, 2010). Enforcement (and compliance) capacity varied greatly among fisheries and tended to be weak in tropical fisheries in low-income countries. It is found that the depleted and over-exploited fisheries tended to have far fewer regulatory measures (mean: 2.6) than better-performing fisheries (mean: 4.7) (Purcell *et al.*, 2013) and it is emphasised to have multiple management measures which are easily understood and enforced (FAO, 2010; Purcell, 2010). However, the global sea cucumber production has not fallen because there are still available supplies, aquaculture production, limited public conservation awareness and insufficient regulatory environment (Eriksson and Clark, 2015). It is postulated that resilience in sea cucumber fisheries will be possible if fishers are part of the management system and can adapt quickly to changes in the resource (Lebel *et al.*, 2006; Andrew *et al.*, 2007).

In India, sea cucumbers are distributed mainly in the Gulf of Mannar, Palk Bay, Lakshadweep Islands, Andaman and Nicobar Islands, and the Gulf of Katchchh and as well as along some other parts of the mainland coast of India in small numbers. However, the fishery and the '*beche-de-mer*' production existed in the Gulf of Mannar and Palk Bay. The fishery was around a millennium years old and was introduced by the Chinese, which provided livelihood to thousands of poor fisher folks in this region (Hornell, 1917). The sea cucumber fishery was artisanal in nature and consisted of fishermen, who were divers, the processors who act as middlemen and the exporters.

Of the 39 sea cucumber species reported from the Gulf of Mannar and Palk Bay (Sastry, 1998), the '*beche-de-mer*' production was mainly centred around two species *viz.*, *Holothuria scabra* and *H. spinifera* and occasionally on 4 to 5 additional species based on their availability. The fishery showed a boom and bust in the 1970s and 1980s. Among the commercial sea cucumbers, certain species *viz.*, *Actinopyga echinites*, *A. miliaris* and *Stichopus chloronotus* totally disappeared from the fishery


A catch of *Holothuria scabra*

over the years. Like in many other Indo-Pacific countries, indiscriminate exploitation and insufficient management measures have caused over exploitation of sea cucumber resources in the Indian waters, as evidenced from the decrease in export, decreased size of the specimen fished and absence of certain species from the fishery.

As a regulatory measure, the Ministry of Environment, Forests and Climate Change, Government of India implemented a size regulation on export of '*beche-de-mer*' in 1982 (ban on '*beche-de-mer*' below 75 mm length). The legislation was not successful as the fishery was scattered and not organized and hence there was difficulty in monitoring and enforcement. The fishery continued until the Ministry imposed a blanket ban in 2001 on the fishery and trade from Indian waters by listing all holothurians under schedule I of the Indian Wildlife (Protection) Act, 1972 which was implemented strictly since 2003. Despite the national moratorium, illegal fishery and clandestine trade were going on, making the moratorium ineffective. The affected fishermen and traders made repeated representations to the government to lift the ban, citing negative impact of the ban on their livelihood. The ministry entrusted the Zoological Survey of India, to evaluate the impact of the ban and recovery status of sea cucumber stock in the Gulf of Mannar and Palk Bay during 2006 and 2011. The study indicated poor recovery and less improvement of the sea cucumber stock, after implementation of the ban (Venkitaraman, 2006; Venkataraman *et al.*, 2012).

The Indian Council of Agricultural Research (ICAR)-Central Marine Fisheries Research Institute (CMFRI) has made immense contribution on various aspects of conservation of Indian sea cucumbers through different projects since 1962. The institute has carried out research on systematics, zoogeography, parasites, animal association, bio-toxicity, biology, ecology and captive breeding and farming of sea cucumbers (James,1967, 1968, 1978, 1982, 1988b, 1995a, 1995b, 1996; James *et al.*, 1988, 1994, 1996, 1999 and Rao *et al.*, 1991). The institute pioneered the production of seedling of *Holothuria scabra*, one of the high valued species in 1988 as a primary effort towards conservation of the fragile resource (James *et al.*,1988; 1994) and convened the first national workshop on '*beche-de-mer*' in 1989 and a training programme in 1992 for the fishermen on the improved method of handling and processing of sea cucumber for export. The institute trained a scientist from Marine Science and Resource Research Centre, Aden on resources, processing, hatchery and culture of sea cucumbers in 1992. CMFRI also supported four doctoral research projects on various aspects of sea cucumbers (Baskar, 1993; Kandan, 1994; Ram Mohan, 2001; Asha,2005). In 2001, the institute gained success in the seed production of another, commercially important and over-exploited sea cucumber species, *H. spinifera* for the first time (Asha and Muthiah, 2002, 2005). The institute has published more than 250 research papers, 4 special publications and several brochures on sea cucumbers.

During the ban period, the institute has taken several steps for solving the issues raised due to the ban on the livelihood of fishermen, and has suggested formulation of effective and renewed management measures for conservation of sea cucumbers.


Stakeholders workshops held at Mandapam and Tuticorin CMFRI (Source: BOBLME, 2015)

The workshop convened by the ICAR-CMFRI on conservation of sea cucumbers at ICAR-Central Institute of Brackishwater Aquaculture (CIBA), Chennai in August 2008 stressed the supportive measures to be taken for the revival of sea cucumber populations to their pre-depleted level. In view of the issues related to over-exploitation of resources, livelihood and ineffective management measures, a series of stakeholder meetings were conducted with the active participation of fishermen, traders, village leaders, officials of fisheries and forest departments, scientists and academicians. A significant consultation meet was held at Mandapam Regional Centre of ICAR-CMFRI in 2014 to debate on the issues associated with conservation and sustainable management of sea cucumbers in the Gulf of Mannar.

Through the BOBLME/FAO supported project, "An evaluation of the current conservation measures on sea cucumber stocks in Palk Bay and Gulf of Mannar of India" the institute conducted studies on the status of sea cucumber population and also interviewed fishermen and stake holders to obtain their insights into conservation and to understand the impact of moratorium on their socioeconomic and livelihood status. The resource surveys and interview surveys indicated that the status of sea cucumber population in the Gulf of Mannar and Palk Bay could be improved by obtaining the consent of the fishermen to follow regulatory measures with participatory co-management (BOBLME, 2015). The present document is an outcome of all the initiatives taken by the ICAR-CMFRI and is aimed to propose guidelines and principles for effective conservation measures ensuring long-term sustainability of sea cucumber resources in this region.


Interviewing the fishermen (Source: BOBLME, 2015)

Objectives

- Evaluate the status of sea cucumber fishery, trade and the socioeconomic condition of fisher folk in the Gulf of Mannar and Palk Bay.
- Appraise the effectiveness of current management measures.
- Recognize the knowledge gaps in generating effective management measures.
- Propose guidelines for conservation and sustainable use of holothurians.

Challenges for recommending regulatory measures

- Absence of pre-ban stock assessment data for comparisons to assess the current stock status.
- Inadequate biological data to evaluate vulnerability and resilience of major sea-cucumber species.
- Knowledge gaps on sea cucumber habitat status and associated fauna.
- Recommending conservation measures exclusively for sea cucumber species in the multi species fishery.
- Recommending regulatory measures for species in different status of exploitation.
- Lack of information on clandestine and trans-boundary trade.

Significance of sea cucumbers

Nutritional Importance

Holothurians are economically important for their nutritional and medicinal properties. Many species are also harvested in small quantities for aquarium display. They are exploited for their dried end product or raw body wall or viscera, but mostly for the processed product called '*beche-de-mer*,' in French, *'iriko'* in Japanese, *'haisom'* in Chinese and '*trepang*' in Indonesian. The Chinese are the traditional consumers and the Japanese, Koreans, Melanesians, Micronesians, Polynesians and Africans also consume '*beche-de-mer*' in significant ways and quantities (Morgan and Archer, 1999). The Chinese consume sea cucumbers more as a tonic than as sea food. Commercially, the product '*beche-de-mer*' can be graded into low, medium or high economic value depending upon the species, appearance, abundance, colour,

'*Beche-de-mer*' of *Holothuria scabra*

odour, thickness of body wall, and market trends and demands. Different species also have different tastes and textures, and certain species are used for preparation of specific dishes. The sea cucumber is consumed in a variety of ways. In Japan and Korea, the gutted body wall of sea cucumber is consumed raw or pickled, and specialized range of products are consumed from the gonad, respiratory trees and viscera (Mottet, 1976; Conand and Sloan, 1989). '*Konowata*', the fermented or pickled guts or intestine and '*Kuchiko*', the prepared and dried sea cucumber gonad are considered delicacies. In the USA, the body wall is consumed in tablet form (Mottet, 1976).

From nutritional point of view, the sea cucumber is an ideal tonic, higher in protein and lower in fat content and has impressive profile of high-value nutrients such as Vitamin A, Vitamin B1 (thiamine), Vitamin B2 (riboflavin), Vitamin B3 (niacin), essential amino acids, trace metals and minerals, especially calcium, magnesium, iron and zinc (Bordbar *et al*., 2011). The protein content in sea cucumber is comparable to that of a hen's egg and the very low fat content makes it ideal for people with high blood pressure.

Medicinal importance

In addition to nutritional values, the sea cucumbers have long been recognized in the folk medicine system of Asian countries. In traditional Chinese medicines, the sea cucumber is used for treating body weakness, impotency, debility of the aged, constipation due to intestinal dryness and frequent urination. Recent research has indicated the presence of several bioactive compounds with anti-angiogenic, anticancer, anticoagulant, anti-hypertension, anti-inflammatory, antimicrobial, antioxidant, antithrombotic, antitumor, and wound healing properties. Sea cucumbers also contain copious amounts of mucopolysaccharides, like chondroitin sulfate, which is known for reducing the arthritis pain and inhibit viruses such as herpes and is well known for HIV therapy. Thus sea cucumbers are gaining recognition in biomedical research (Roginsky *et al*., 2004; Nagase *et al*., 1995). In view of the medicinal potential, modern food and pharmaceutical industries are keen to develop functional foods and nutraceutical products from different body parts of sea cucumbers. Recently an increasing number of commercial products like juice, balm, liniment oil, cream, toothpaste, gel face wash, body lotion, and soap made from sea cucumber or its extracts are available in the market (Chen, 2007; Bordbar *et al*., 2011) which include branded products such as ArthiSea, SeaCuMax (arthritis medicine), and Sea Jerky.

Ecological importance

Being suspension feeders and detritivores, the sea cucumbers play an important role in ecosystem functioning by recycling nutrients and carbonates as well as in the bio-turbation of the environment. As suspension feeders, they regulate water quality by affecting the carbonate content and pH of water (Massin, 1982). Sea cucumbers contribute calcium carbonate to the coral reef's "chemical budget" and act like a natural antacid to neutralize other acidic environmental sources and also help in the recycling of suspended matter (Haemel and Mercier, 1998a). Sea cucumbers help to break down organic materials and redistribute the nutrients to the water column thus preventing hypoxia and other toxic substances going down in the sediment. When they ingest sand, the natural digestive processes in sea cucumber's gut increase the pH of water on the reef where they defecate, countering the negative effects of ocean acidification. The ammonia waste produced when sea cucumbers digest sand also serves to fertilise the surrounding area, providing nutrients for coral growth and enhance productivity and turnover of benthic diatom communities (Wolkenhauer *et al.*, 2010). Hence its over-exploitation could lead to indirect deleterious effects on the reef and soft bottom ecosystems (Uthicke, 2001; Purcell, 2004b).

Deposit feeding sea cucumbers change the size of ingested particles and turn around the sediment via bioturbation, thereby altering the stratification and stability of muddy and sandy bottoms (Massin, 1982). They are often called the earthworms of the sea, and are responsible for extensive shifting and mixing of substrate and recycling of detrital matter into animal tissue and nitrogenous waste, which can be taken up by algae and sea grass (Uthicke, 2001; Wolkenhauer *et al.*, 2010). In laboratory experiments, the removal of holothurians resulted in development of algal mats, which indicates the negative effect on sediment in fauna as a result of potential anoxia (Uthicke, 1999). Removal of sea cucumbers in some system may therefore reduce primary production for the whole food chain. Holothurians also form an important prey in coral reef and temperate food webs (Birkeland *et al.*, 1982; Birkeland, 1989; Francour, 1997) both in shallow and deep water (Jones and Endean, 1973; Massin, 1982), where they are consumed particularly by fishes, sea stars and crustaceans (Francour, 1997) and their larvae are part of the plankton-based food chains.

Distribution, species diversity, habitat and biological characteristics

Zoogeography and Distribution

Holothurians are found in all the oceans, at all latitudes and from the shore down to abyssal plains. Among the coastal commercial holothurians, the Aspidochirotid holothurians are predominant in the tropics while the Dendrochirotid are more common in temperate regions. Most of the commercially important holothurians are

Holothuria fuscogliva

Thelenota ananas

found in the intertidal region to a depth of 20 meters. In India, the holothurians are mostly distributed in Andaman and Nicobar Islands, Lakshadweep Islands, Gulf of Mannar, Palk Bay and Gulf of Katchchh and in Malvan (Maharashtra), Ennore (Tamil Nadu), Kakinada Bay (Andhra Pradesh) and also along several parts of the mainland coast of India.

Most of the holothurian species have a wide range of distribution in the Indo-Pacific region. While about 650 species of sea-cucumbers are known from various parts of the world, about 200 species have been recorded in the Indian seas. Andaman and Nicobar Islands have the richest diversity of sea cucumbers in India, followed by Lakshwadweep Islands, Gulf of Mannar, Palk Bay and Gulf of Kutchchh. Of the 200 species, 75 are restricted to shallow waters within 20 metre depth. The distribution pattern of shallow water echinoderms of the Indian seas indicates that owing to their relatively sedentary life, the larval life has a narrow bathymetrical range (James, 1986c). Of the shallow water species, only 12 species are of commercial value and are harvested for preparing '*beche-de-*

mer'. The southeast coast of India, particularly the Palk Bay and Gulf of Mannar, are known for '*beche-de-mer*' resources.

Holothuria nobilis the most valuable species for '*beche-de-mer*' preparation, is found in large numbers in some of the islands of the Lakshadweep and in Andaman and Nicobar Islands (James, 1986b). *H. scabra*, another commercially important species, is well distributed in the Andamans, Gulf of Mannar and Palk Bay. It is also recorded along the Malvan coast in the west coast by Parulekar (1981) but totally absent in the Lakshadweep Islands. Another commercially important species *H. spinifera* has a restricted and localized distribution and is known only from the Gulf of Mannar and Palk Bay. Other commercially important genera like *Actinopyga*, *Bohadschia* and *Stichopus* have wider distribution range and are found in Andaman and Nicobar Islands, Lakshadweep Islands, Gulf of Mannar and Palk Bay. *H. atra* is the most common sea cucumber with a wider distribution range, whereas the massive commercially important genus *Thelenota* is restricted to the lagoons of the Lakshadweep.

Systematic and species diversity

There are six taxonomic orders of holothurians but most of the commercially important species belong to the Order Aspidochirotida and a few to the Order Dendrochirotida (Conand, 2006a). The species diversity of holothurians of the Gulf of Mannar and Palk Bay has been listed as 23 by James (1986b) and later as 39 species by Sastry (1998). Daniel and Haldar (1974) reported 32 species of holothurians from Andaman and Nicobar Islands based on earlier reports and Sastry (1998) reported 88 species from the Andaman and Nicobar Islands. Daniel and Haldar (1974) recorded 23 species from Lakshadweep, whereas James (1989a) reported 25 species. Asha (2015) reported 18 species from different habitats and depths of Tuticorin waters.

Habitat

The habitats of the holothurians are diverse and vary from coral reefs, sea grass meadows, rocky, sandy, muddy shores, salt marshes and mangrove beds. Most of the adult stages are benthic, and a few larval stages are pelagic. In general, their distribution is patchy and several species are known to display specific habitat preferences. Generally they live on hard substrates, rocks, coral reefs, soft bottoms, on the sediment surface or buried in the sediment, or as epizoites on plants or invertebrates.

Sea cucumber in seagrass beds

Seagrass meadows

High abundance of sea cucumbers in seagrass has been recorded by several authors highlighting the importance of these habitats in the early life stages for settlement (Conand, 2008; Friedman *et al.*, 2011). Seagrass beds are also important habitats for *H. scabra* and several other species since the larvae and juveniles of sea cucumbers rely heavily on seagrasses for settling cues and early life stages (Mercier *et al.*, 2000). In addition, seagrasses contribute to secondary production mainly by the detrital food web comprising sea cucumbers (Vizzini, 2009). The nutrients produced by decomposition of sea grass are utilized by the primary producers, which then become an important part of the detrital food chain and facilitate the cycling of nutrients (Nelson, 1981).

Coral reefs

Species of the genus *Actinopyga* are essentially coral dwelling forms. They live in the intertidal region on the coral reef. Clark (1976) mentioned some of the coral dwelling echinoderms. *A. mauritiana* is a surf loving species being found very near the low-water mark. *H. pyxis* occurs on the reef flats in Andaman Islands and is found always to live under the stones. The dorsal body wall of *A. echinites* is wrinkled with sand settling in the depressions and it is often found attached at the base of big rocks by curving its

Sea cucumbers in coral rubbles

body. *Bohadschia* spp. also live on the coral flats. *B. vitiensis* lives on the reef flats and lies exposed during low tide with a thin coating of fine mud on the body.

Mudflats

Mudflats are by far the best habitats suitable for sea cucumbers as they are detritus feeders and feed on the organic matter present in the mud. *H. scabra* is characteristic of muddy flats. During low tide, a number of them can be seen in half-buried condition with their posterior end of the body always kept outside. Small forms (50 to 90 mm in length) are also seen to be lying freely on the muddy grounds during low tides. At some places 2 to10 specimens are distributed in an area of 5 sq.m. The species living in muddy flats are also found on sandy habitat.

Lagoon

The lagoons in the Lakshadweep waters are calm with very little disturbance and offer excellent habitats for the holothurians. *H. nobilis*, the most priced holothurian for '*beche-de-mer*' is characteristic of the lagoons. There are two colour forms of this species; the white variety is usually found in deeper waters between 3 to 20 m. It is most abundant on clean sand in reef passages and near turtle-grass. The black variety is typically found in shallow waters at about 3m depth on clean sand bottoms where there is living coral and free movement of water. *Bohadschia argus* and *Stichopus chloronotus* are other common species found in the lagoons of Lakshadweep.

Biological characteristics

Reproductive biology

Commercial sea cucumbers are predominantly gonochoric; that is, they exist as males or females separately. However, a few species are known to be hermaphroditic (combining both sexes in the same individual). In most gonochoric species, it is not possible to distinguish males from females by their outer appearance, but sea cucumber populations are generally present in 1:1 sex ratio. The majority of sea cucumbers are broadcast spawners, releasing sperms and oocytes (unfertilized eggs) directly into the water column. Females can release thousands to millions of oocytes in a single spawning event. The motile sperm cells (spermatozoa) have to swim to find and fertilise the oocytes. Fertilisation success is, therefore, maximized where males and females are relatively close to each other. The release of gametes, *i.e.* oocytes and sperm by adults is generally triggered by environmental (for example, certain tidal conditions, lunar phases, temperature fluctuations etc.) and chemical cues from other individuals of the same species. The oocytes of most commercial species of sea cucumbers are generally under 200μm in diameter, and more or less neutrally buoyant when released in the water column. However, commercial species from temperate regions may possess large yolk buoyant oocytes that can measure up to 1mm in diameter. Reproductive cycles are variable among species, but most tropical species have biannual spawning activity and fewer species have annual spawning activity. In addition to sexual reproduction, about 10 species reproduce asexually by transverse fission by dividing at the middle of the body; both halves re-grow necessary organs and form clones of the original individual (Conand,1981; Hyman,1955).

ICAR-Central Marine Fisheries Research Institute (CMFRI) has documented the biology of *H. scabra*, (Baskar, 1993); *H. nobilis* and *Actinopyga mauritiana* (Kandan, 1994); *H. atra* (Ram Mohan, 2001) and *H. spinifera* (Asha, 2005).

Growth and longevity

Growth in sea cucumbers is difficult to assess (Conand, 1990) because they are not amenable to conventional tagging methods (Purcell *et al.*, 2006). However, studies on growth rates in the wild are available using modal progression analysis, genetic fingerprinting, and release and monitoring of juveniles. Some species, like *H. scabra* are relatively fast growing when young, reaching the size at first maturity (<180 g) in a year or so but take another couple of years to reach an acceptable market size (Purcell and Simutoga, 2008). Shelley (1985) estimated growth to be 14g per month for *H. scabra* and 19 to 27g per month for *Actinopyga echinites*. Uthicke (1994) found modest weight gain of 70-80g per year by *Stichopus chloronotus* of 70-80 g per year. Longevity has been estimated as 10 to 15 years for *A. mauritiana*, *A. echinites* and *Thelenota ananas* but only as about 5 years for *S. chloronotus* (Conand and Sloan, 1989).

Food and feeding

Most of the commercial sea cucumbers are deposit feeders that consume detritus, bacteria and diatoms mixed with sediments on the seabed (Conand, 2006a). Those species on hard reef surfaces "mop up" the particulate organic matter that coats rocks and benthic vegetation. A few commercial species are suspension feeders, which sweep minute organisms and detritus adhering to the tentacles through mucous secretion (Hamel and Mercier, 1998). Holothurians are therefore a low-food chain group.

Predators

Sea cucumbers are prey to a vast array of invertebrate predators like sea stars, crabs and some gastropods (Francour, 1997). A short-term study on released sandfish *H. scabra* shows that juveniles are prone to being eaten readily by a range of fishes (Dance *et al.*, 2003). Some birds, turtles and marine mammals are also believed to eat sea cucumbers occasionally. However, some species of sea cucumbers develop passive or active mechanisms of defence (e.g. *H. atra*, *H. leucospilota* etc.) that have proved to be efficient predator deterrents.

Fishery and resource status

Fishery

Sea cucumbers that are targeted for '*beche-de-mer*' production range in size from about 5 cm to over 1 m in length (Conand, 1993). Harvesting in the tropics is typically done by small bottom trawls (roller pulling nets, beam trawl nets, scallop-drag gear etc.) used mainly 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 lagoon environments; and collection at night with SCUBA, snorkeling or wading using underwater lights or torches (Conand, 2006b).

Tropical and subtropical sea cucumber fisheries in the western Pacific are generally multi-species as compared to tropical fisheries in the Indian Ocean (*H. scabra*), eastern Pacific (*Isostichopus fuscus*) and Caribbean (*I. badionotus, H. mexicana* and *Astichopus multifidus*). In the western Pacific, the sea cucumber fisheries primarily target shallow water (up to 50 m depth) deposit-feeding holothurians belonging

Sea cucumber collection by *'Attai madi'* to two families and eight genera: *Actinopyga*, *Bohadschia*, *Microthele* and *Holothuria* (Holothuridae) and *Isostichopus*, *Parastichopus*, *Stichopus* and *Thelenota* (Stichopodidae). In temperate waters, the sea cucumber fisheries are based on one or two species that are found in the western Pacific around China, Japan, Korea and Russia (*Stichopus japonicus*), southern hemisphere off New Zealand (*S. mollis*), eastern Pacific coast of North America (*Parastichopus californicus* and *P. parvimensis*) and western Atlantic coast of North America (*Cucumaria frondosa*) (Conand, 2006a).

In India, the '*beche-de-mer*' production was mainly dependent on *H. scabra* along with *H. spinifera*, *Bohadschia marmorata* and *H. atra* in small quantities initially. However, the processing of *B. marmorata* and *H. atra* were stopped because of their poor market value (James,1996). The sudden boom and burst of *Actinopyga* spp. into the export happened during 1991-1995. In 1986, the processing of deep water red fish, *A. echinites* was started along the Gulf of Mannar and Palk Bay coasts (James and Badrudeen, 1995). Processing of another massive form *A. miliaris* was started in 1992 (James, 1992) but the catch declined in subsequent years. Asha and Diwakar (2006) reported huge landings and processing of *Stichopus hermanni* collected from a depth of 20m from Tuticorin waters.

Skin divers collecting sea cucumbers

In India, no special gear or net has been devised exclusively to catch sea-cucumbers. They were usually collected by skin diving, either picked up by hand or by small scoop nets, or caught in '*Attai madi*', a type of prawn trawl net, modified with added sinkers or bobbins in the foot ropes. They are also caught in '*Thallu madi/Thallu valai*', bottom trawl nets and bottom-set gillnets as accidental by catch (James, 1989a; BOBLME, 2015).

Holothurians are collected by skin diving to a depth of 1.5 to 6.0 m in Palk Bay and Gulf of Mannar. Non-mechanised country crafts are used for collection by skin diving. Four to six divers go in country boats with sails at sun rise and return in the afternoon. Even small boys are engaged in diving operations. The divers take net bags in which live sea cucumbers are brought to the shore. The introduction of face masks and use of aluminium plates for the feet as improvised flippers helped efficient locating and collecting of sea cucumbers (James, 1973; 1994a).

Sea cucumbers are caught by trawl nets accidentally as by catch. Since the introduction of trawling in the 1960s in the Gulf of Mannar and Palk Bay, more sea cucumbers are exploited. In certain centres of Gulf of Mannar where large number of trawlers are operated, the entire source for processing comes from the trawlers. The overall length of trawlers used for sea cucumber fishing was 11 to 20m, with 70 to 120 horse power engines. The length of trawl net was 13 m with cod end mesh size of 25 mm. Sea cucumbers are also caught by '*Thallu madi*' during its operations. The overall length of country craft used for sea cucumber fishing with *'Thallu madi'* was 4 to10 m. The length of '*Thallu madi'* was 8m, with cod end mesh size of 15 to 25 mm. During low tide, vast areas of mud-flats get exposed and women and children were engaged in the collection of half buried sea cucumbers (James, 1994a).

In a mixed catch of sea cucumbers, the common size ranges between 60 and 150 mm; of this 100 to 150 mm size constitutes 15 to 20%, 70 to 100 mm about 30% and 50 to 70 mm about 50%. Specimens measuring 150 to 210 mm live size are reduced to 60 to 75 mm after processing (James, 1994a & b). In short, after processing the whole catch will fall under the commercial category below 3".

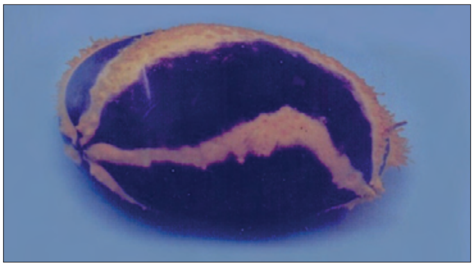
Sea cucumbers are collected in all the seasons. In the Palk Bay, fishing is conducted from March to October, the peak season being April and May. In the Gulf of Mannar fishing is conducted from October to March with peak season being December and January. March and October are transition months to switch over fishing from Palk Bay to Gulf of Mannar and vice versa. The Palk Bay and Gulf of Mannar become rough during October to March and from March to October respectively (James,1989a). When the sea becomes rough due to high velocity winds, the water gets mixed up and becomes turbid and fishing is suspended during the rough season (James, 1986b; James, 1994a).

Resource status

Reliable long-term estimates are not available on the exploited as well as potential stocks of holothurians in the Indian waters and hence it is difficult to evaluate the stock status. The only publication providing some information on the fishery and landings of holothurians from different centres of Gulf of Mannar and Palk Bay is by James and Baskar (1994a). During the last 12 years of moratorium, the survey conducted twice by Zoological Survey of India during 2006 (Venkitaraman, 2006) and 2011-12 (Venkataraman, *et al.*, 2012) and by the ICAR-CMFRI in 2015 (BOBLME, 2015) indicated wide fluctuation in the population of nine holothurian species in the Guf of Mannar and Palk Bay (Table 1). A definite conclusion on the stock trend could not be arrived at from these surveys and therefore there is a need for continuous monitoring of sea cucumber from this region. While a few specimen of *A. miliaris* were reported during 2006 from Gulf of Mannar (Venkitaraman, 2006), it was not reported in 2011 and 2012 (Venkataraman *et al.*, 2012). Similarly none of the surveys indicated the occurrence of historically processed species namely *A. echinites* and *Stichopus chloronotus* from Gulf of Mannar and Palk Bay, indicating the high vulnerability of these species to fishing and the inability of the depleted stock to repopulate to its original level because of their low reproduction or recruitment rate.

Sri Lanka, the country sharing part of Palk Bay and Gulf of Mannar with India, is also having the century old practice of sea cucumber processing introduced by China (Hornell, 1977). It is interesting that survey on sea cucumbers in the Sri Lankan waters indicated more number of sea cucumber species than the Indian side of Gulf

Holothuria sp. (type 'Pentard')



Pseudocolochirus violaceus

of Mannar. A total of 25 species belonging to 7 genera, out of which, 20 are of commercial importance have been reported from the Sri Lankan waters (Dissanayake and Stefansson, 2010). Except issuing license for diving and transportation, no other regulatory measures are practiced for sea cucumber fishery in Sri Lanka. In spite of this, the main reason for the higher diversity of sea cucumber species in Sri Lanka is probably due to the absence of destructive fishing practice like trawling and may be due to the practice of selective fishing like hand picking through skin or SCUBA diving which ensures the maintenance of conducive pristine habitat for sea cucumber growth (Dissanayake and Wijayarathne, 2007).

Table 1. Reported density (nos.ha^{-1}; mean ±SE) of sea cucumbers

Species	Gulf of Mannar				Palk Bay		
	2006[a]	2011[b]	2012[b]	2015[c]	2011[b]	2012[b]	2015[c]
Holothuria scabra[1]	174±117	1.2±1.7	70.6±23.6	178.9±16.2	39.98±59.03	18.09±28	2352.6± 546.7
H. spinifera [2]	-	-	1.9±6.7	69.14±33.02	-	0.26±0.82	75.5±57.7
H. atra [3]	1268±419	3220±512	560.4± 1255.9	767.7±177.6	-	0.14±0.74	190.3±101.9
H. leucospilota [3]	-	1.6±1.5	5.6±35.5	987.4±362.5	0.06±0.03	0.02±0.11	5.21±2.31
Bohadschia marmorata [3]	302±184	-	3.3±14.3	192.9±89.6	-	0.02±0.12	10.9±1.2
Stichopus spp.[2]	162±112	1.2±1.3	-	1599.8±619.2	0.52±1.95	-	6.8±3.4

a: Venkitaraman, 2006; b: Venkataraman *et al.*, 2012; c: BOBLME, 2015

1: high-valued, exploited; 2: medium-valued, exploited; 3: low-valued, not-exploited

Chapter-2

Vulnerability, trade and socio-economic relevance

Vulnerability and over exploitation of sea cucumbers in the global context

Increase in demand in the international market coupled with the ease of harvesting and low cost of processing has augmented holothurian fishing and trading in the Indo-Pacific areas (Conand, 2004; Choo, 2008). Inadequate fishery management measures and anthropogenic disturbances are also factors in creating drastic population-size fluctuations and over-fishing of commercial sea cucumbers (Uthicke *et al.*, 2009).

Sea cucumber populations are particularly vulnerable to over-fishing for many reasons. Primarily, harvesters can easily and effectively capture the shallow water holothurians (Uthicke and Benzie, 2000). Most tropical sea cucumber species tend to occur in shallow waters within the limit of breath hold diving (Kinch *et al.*, 2008). Because of their sluggish nature (Conand 1991; Shiell and Knott, 2008), they are incapable to get away quickly from patches of high density once detected and hence are easily caught by fishers.

Second, late age at maturity, slow growth, high longevity, low rates of recruitment make some species vulnerable to over fishing and slow population replenishment (Bruckner, 2005; Conand, 2001; Uthicke and Purcell,2004). In addition, high value species on tropical reefs co-inhabit with those of low–value, allowing opportunistic depletion of high value species by fishers after shifting to low value species. Perhaps a few species are short-lived with regular recruitment.

As sedentary and gonochoric broadcast spawners, the sea cucumbers need to be in close proximity to mates for successful fertilization of gametes (Badcock *et al.*, 1992; Mercier and Haemel, 2009). In low density population, if the animals are too far apart, they may not find mates in spawning periods or the sperm released from males is too far from females to successfully fertilize the oocytes (unfertilized eggs) that they expel resulting in asynchronous spawning. When this occurs, the reproduction from those populations fails to compensate for annual mortality of animals, and the population declines to a point where the animals become locally extinct or reproductively extinct-*i.e*. some individuals may still exist but there is no effective reproduction. This effect is called the Allee effect (Allee 1938; Courchamp *et al*., 1999; Uthicke *et al*., 2009) or 'depensation', and is believed to be a primary cause of collapse of many invertebrate fisheries inhibiting recovery, particularly of the sedentary groups (Bruckner, 2005; Uthicke and Benzie, 2000). However, such density thresholds for successful reproduction are poorly known for sea cucumbers. Bell *et al.* (2008) speculated that the "threshold densities to avoid dispensation for most tropical sea cucumbers will be in the range of 10 to 50 individuals per hectare over substantial areas, depending on species and location". As the life history traits and ecology of the populations of many of the commercial species are poorly documented and very little is known on the larval stages, recruitments, growth and mortality of most species, it is difficult to come to a conclusion on the status of the resources.

Over fishing has severely decreased the biomass of many sea cucumber populations (Conand 2004; Lawrence *et al*., 2004; Skewes *et al*., 2000). Thus far, even with harvesting closures, sea cucumber stocks seem slow to recover (Ahmed and Lawrence, 2007;D'Silva, 2001; Uthicke, 2004); and recovery can potentially be on the order of decades (Uthicke, 2004). Over-fishing depleted a few populations to levels at which they could not recover, even 50 years after fishing ban (Battaglene and Bell, 2004).

Because of current concerns that over-fishing is causing an unacceptable decline in sea cucumber populations, many countries are being urged to reduce their fishing efforts in the hope that stocks will recover (Friedman and Chapman, 2008). However, lack of documented information on stock recovery, or knowledge of the point where natural productivity will support sustainable extraction, remains a critical shortcoming to management (Conand and Sloan, 1989; Uthicke and Conand, 2005). Appropriate fishery regulations are needed to limit the current rate of depletion of stocks in many countries.

Trade

The historical world *beche-de-mer* market data from 1917 to 1986 was reviewed by Conand (1990). Initially the trade was largely controlled by the Chinese. According to Hornell (1917), the Chinese traded with South India and Sri Lanka for one thousand years for *'beche-de-mer'* and pearls. Records on the export of *'beche-de-mer'* are available from 1898 onwards from the Madras Presidency. Later the trade has shifted to two main markets namely, Hong Kong and Singapore. These markets are also the major re-exporting centers. The leading exporters were Indonesia, the Philippines, Fiji Islands, Japan, Madagascar, Papua New Guinea, Solomon Islands, Thailand and the USA (Conand, 2004).

The *'beche-de-mer'* production in India is exclusively export-oriented and the bulk of the export from India goes to Singapore. The export trend of *'beche-de-mer'* from India from 1963 to 1987 and from 1995-96 to 2002-03 is given in figures 1, 2 and 3. The annual export ranged from 3.0 t to 53.8 t (Fig.1). The *'beche-de-mer'* exported to Singapore and Hong Kong prior to 1980 was confined to sizes 4" to 6" and 3" to 4". Since the market demand overshot the production, the buyers started placing orders with exporters for sizes 2" and below in spite of the fact that such smaller sizes contained a higher percentage of sand content. Since the smaller sizes were exported in large quantity, the Marine Products Export Development Authority (MPEDA) represented to the Government of India to ban the export of '*beche-de-mer*' below 3" in size, which was enforced from 1982.

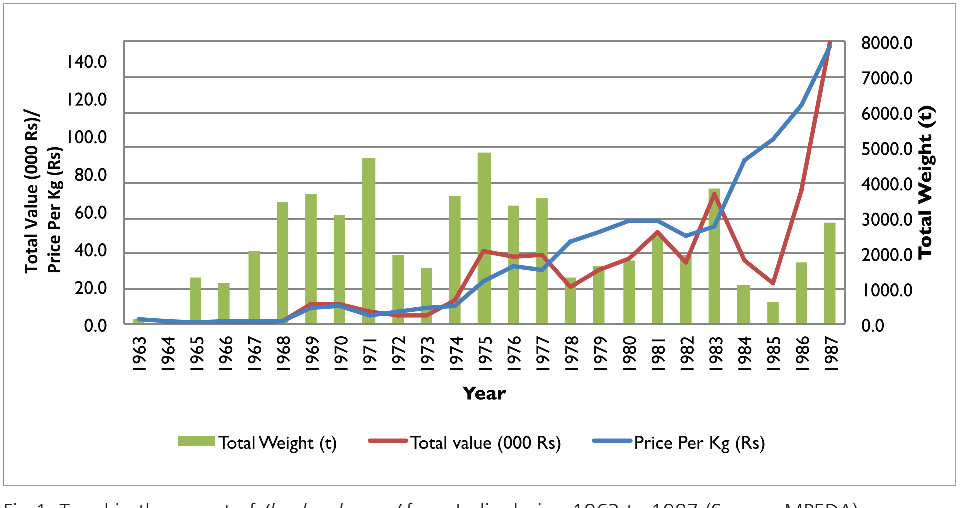


Fig.1. Trend in the export of *'beche-de-mer'* from India during 1963 to 1987 (Source: MPEDA)

Because of the ban, export of *'beche-de-mer'* suffered a severe setback in 1982 and declined to 37.14 t from 47.84 t in 1981 (Fig.1). Since the major portion of exports of *'beche-de-mer'* was constituted by the size grades 2" to 3" the exporters of '*beche-de-mer*' were affected considerably and hence they demanded removal of the ban. At that time, no country had restricted the body size for export and hence, other countries

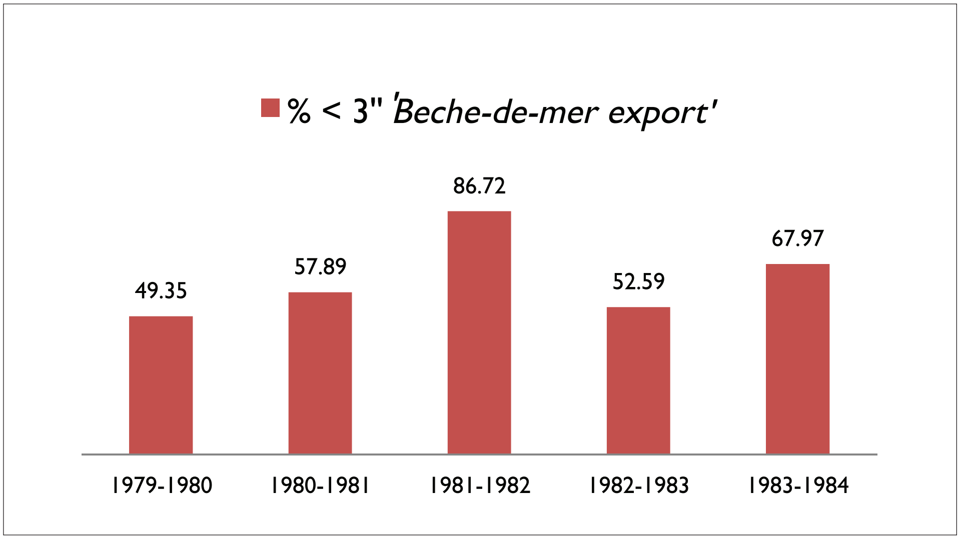


Fig. 2. Percent export of *'beche-de-mer'* < 3'' size from India (Source: MPEDA)

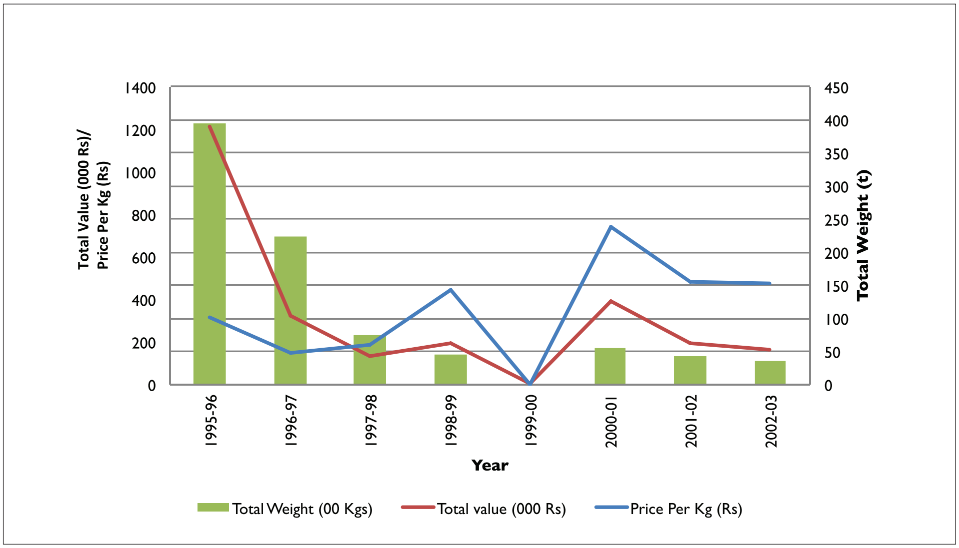


Fig. 3. Trend in the export of *'beche-de-mer'* from India during 1995-96 to 2002-03 (Source: MPEDA)

were exporting size below 3". From the analyses of commercial invoices of exports for the period from 1979-80 to 1983-84 it has been found that the size grades below 3" accounted for 49 to 87% (Fig. 2). During 1983 to 1987, the exports picked up due to extra effort put by the traders to procure material from various places due to the higher price offered (Rs. 86 to 148 per kg) of *'beche-de-mer'* .

The export figures from 1995-96 to 2002-03 shows a gradual decline to 11 t during 2002-03 from 123 t in 1995-96 (Fig. 3). The export value increased from 1995-96 to 1998-99 with an average price of Rs 275.5 per kg but during 2002-03 the average price was higher (Rs 567 per kg Source: MPEDA).

The body size is the most important criteria during '*beche-de-mer*' preparation as sea cucumbers shrink to one-third of their original size during processing. In India, the species covered in the standard of the Bureau of Indian Standards were *H. scabra*, *H. spinifera*, *H. atra*, *H. nobilis*, *B. marmorata*, *B. argus*, *A. mauritiana*, *A. lacanora*, *A. miliaris*, *A. echinites* and *Thelenota ananas* (James, 1986a). The dried *'beche-de-mer'* also came under the purview of Export (Quality Control and Inspection) Act of 1963 where only two grades of '*beche-de-mer* ' were allowed for export, *i.e.*, 3" to 4" and 4" to 6".

Fisherwomen engaged in sea cucumber processing

Effect of fishing ban on the livelihood of fishers

About 20,000 fishers were involved in sea cucumber fishery and more than 50,000 (including fishers, middlemen and traders) were benefited from this fishery in the Gulf of Mannar and Palk Bay (Chellaram *et al.*, 2003). The 1982 ban on the export of the processed holothurians of less than 3'' size partially affected the livelihood of fishers. However, the 2001 blanket ban totally affected the livelihood of thousands of fishermen families involved in sea cucumber fishing. There was a loss in their regular income as they were not able to do other fishing activities due to lack of capacity for investment. As a consequence, their debts increased and they were unable to give quality education to their children. They also found difficulty in arranging marriages of their daughters. A few fishers migrated to other districts and states in search of occupation after implementation of the ban (BOBLME, 2015). Deprived fishermen and traders of this region made several representations to the Ministry of Environment, Forests and Climate Change, Government of India, requesting to lift the ban and to allow fishing of sea cucumber. As there was no positive response from the Ministry, the fishermen and traders have recently approached the judiciary. As the ban has affected thousands of fishermen families, they want the ban to be lifted at least for a few commercially important species. They are agreeable to follow regulatory measures like size restriction on fishing of undersized sea cucumbers, exclusion of breeding stock from fishing, restraining from use of destructive gears, exclusive fishing ban period for stock replenishment, sea ranching and stock enhancement programmes.

Economic aspects

During the ban, the sea cucumbers were mostly taken by skin diving and as by-catch in trawling, *'thallumadi'* and *'chankuvalai'*. Fishing by skin diving was economically most efficient than other modes of fishing as the cost of operation and investment were very low. However, the revenue was five times the operating cost during the pre-ban period, which has reduced to 3.3 times in the ban period, since fishers are receiving lesser price during ban as it is a clandestine activity. Moreover most of the fishers were selling fresh sea cucumbers during ban for which they receive lower prices (BOBLME, 2015).

'All those in the supply chain received a better price for processed sea cucumbers in comparison to unprocessed ones, since fresh sea cucumbers cannot be stored for long duration and the processed sea cucumbers can be readily used for consumption and medicine preparation. The processed sea cucumbers are sold based on count (20 or 45 counts per kg), whereas fresh ones are sold based on size (25 to 30cm or 10 to 15 cm per piece). Before the ban, the trade was mostly on 20 counts per kg of processed sea cucumbers. During ban, the fishers mostly sell fresh sea cucumbers (*H. scabra*) of length 25 to 30 cm (approximately 500 gm) to the first level middlemen for Rs. 150/- per piece. Sea cucumbers of length 25 to 30 cm are mostly preferred, since it will give a desirable size after processing. However, some fishermen are also selling fresh sea cucumbers of length 10 to 15 cm (approximately 250 gm) to the first level middlemen for Rs. 50/- per piece. The first level middlemen process the sea cucumbers. To get one kilogram of processed sea cucumbers, 10 kg of fresh sea cucumbers (20 pieces of length 25 to 30 cm or 40 pieces of length 10 to 15 cm) are required (BOBLME, 2015).

Table 2. Average market price for processed sea cucumbers across the supply chain in 2015 (1US$= approximately Rs.68/-)

Actors in supply chain	Before ban (Rs. per kg)		After ban (Rs. per kg)	
	20 counts	45 counts	20 counts	45 counts
Fishermen	5,000	2,000	9,000	3,000
1st level Middlemen	5,100	2,100	9,600	3,500
2nd level Middlemen	5,300	2,250	10,400	4,100
3rd level Middlemen	5,600	2,500	11,800	5,000
Traders	6,200	3,400	15,000	7,000
Exporters	10,500	5,000	18,000	11,400

Source: BOBLME, 2015

In the last 15 years of ban, the price of sea cucumbers has doubled at every level in the market chain. The increase in price is due to the high demand in international markets. At every level in the market chain, the price of larger sea cucumbers (20 counts) was 2 to 2.5 times higher than the smaller ones (45 counts) (Table 3). The fishermen get approximately 50% of the value of sea cucumbers before and during the ban. The maximum profit before the ban was for the exporters, who sold the products for Rs.10,500 (for 20 counts) by investing only Rs 6,200, i.e. a profit of about 70% over investment. However, during ban, the profit margin (% over investment) is almost equally distributed along the market chain. This may be because of fear that all are involved in illegal activities and do not want to be exposed. Both before and after the ban, the traders were not revealing the export price to the fishers/middlemen.

Chapter-3

Guidelines for conservation and sustainable use

The listing of all species of holothurians in Schedule I of the Indian Wildlife (Protection) Act, 1972 and imposing a total ban on the collection and trade is a more stringent, but legitimate policy option within the CITES agreement. Although the listing was aimed as a management measure by the Government of India for the protection and conservation of the natural stock of sea cucumber, the collection and trade continues illegally and may increase in future. This is mainly because of the continuing demand for *'beche-de-mer'* in the international markets and livelihood dependency which has led to clandestine exploitation and trade of both raw and processed sea cucumbers from the Gulf of Mannar and Palk Bay. The enforcement of ban by the Government might have perhaps helped in reviving the population of sea cucumbers in the Gulf of Mannar and Palk Bay, but at the same time, the ban has social and economic impacts on scores of people, particularly the fishers who were dependent on sea cucumber for their livelihood. Almost everyone involved in the collection and trade of sea cucumber opposes the ban. A controlled or a regulatory mechanism of collection and trade of sea cucumbers involving all concerned stakeholders might be a preferred policy solution, as this would help in conservation and sustainable use of these resources, as well as put an end to the thriving illegal trade.

The twin objectives of sea cucumber fishery management are conservation of resources and sustainable utilization of stock. The role of communities is an important factor for biodiversity conservation. The communities should have access to the resources and at the same time should take the responsibility to conserve and sustainably use it. For any conservation action, adequate scientific information on the habitat, biology and fishery is imperative. Although sea cucumber fishery has been in vogue since many decades in the Gulf of Mannar and Palk Bay, there is lack of sufficient information on many aspects including growth, mortality and recovery rates, spawning season, longevity, habitat preference etc. which are vital to arrive at robust management decisions for effective conservation. If scientific information is inadequate, it is essential to collect the required information through concerted scientific efforts on a continuous basis. In this situation, the managers must go ahead and implement the best management practices as a precautionary approach while gathering more information to assess the stock.

Measures for management

In the Gulf of Mannar and Palk Bay, the sea cucumber fishery was on a small-scale, and spatially structured, targeting the sedentary stocks. The management of sea cucumber fishery is different from that of other fishery resources which are highly mobile. The potential management measures for sea cucumber fishery may be grouped under three major categories *viz.*, (i) regulatory, (ii) restocking and (iii) implementation. The regulatory measures are those imposed on the fishers and traders, while restocking is a stock recovery measure. Institutionalizing and implementing the first two measures forms the implementation part. The management of fishery is location-specific and the management tools to be used vary with the specific situations. Although wide range of management options is available, it is not essential to use all tools in the kit for all situations. The selection depends on the management objectives, type of fishery, species to be managed, technical capacity of the managers and acceptance by all stakeholders.

Suggested regulatory measures

a) Catch quota and licensing

The fishermen involved in the collection of sea cucumber should be registered and license need to be issued to each one of them. Also, catch quotas should be fixed for individual fishers or a fishing group (usually diving group comprises of 5 individuals operating from a boat), so that resources are not over-exploited and there is also equity in sharing of resource. Deciding upon 'Quota of Harvest' for each fishing unit should be based on the outcome of periodic stock assessment studies conducted by research institutions. However, it is a challenge to fix a quota for trawl by-catch. The authorities/managers should ensure that the fishermen involved in collection of sea cucumbers maintain log books and receipt books for verification of sales, and carry out random inspections at the processing facilities. The concerned authorities should also deny license to fishermen for non-compliance.

b) Minimum Legal Size (MLS)

For any sustainable fishery, the 'Minimum Legal Size' (MLS) is one of the important measures which would ensure restriction on removal of juveniles. The MLS is fixed based on the length at first maturity and this would vary from one species to the other. The purpose of prescribing MLS is to protect juveniles and allow mature individuals to spawn for one or two seasons. Since sea cucumbers are traded in the form of dried and processed '*beche-de-mer*', correspondingly MLS has to be fixed for *'beche-de-mer'* also. The Government of India had set the MLS as 75 mm for the export of *'beche-de-mer'* in 1982. The MLS therefore need to be fixed for each of the traded species so that each individual animal gets an opportunity to spawn at least once during its life time, before they are caught. This would ensure a steady recruitment in the wild. Though MLS is followed in many countries, it is not easy to determine, as the sea cucumbers contract the body immediately when handled. The length and weight can be measured after allowing the animal to relax for a while and to release the engulfed water. Generally the size at first maturity varies with species. The size at first maturity in the case of *Holothuria scabra* is estimated as 230 mm (Baskar, 1993). Therefore the MLS can be fixed marginally above 230mm as suggested by James and James (1994). This regulation can be implemented effectively through skin divers, who can visibly note the length of the animal in relaxed condition under water and can perform selective harvesting to avoid juvenile fishing. As sea cucumbers can remain alive out of water for some time, the juveniles caught by other modes of fishing practice can be returned to the sea.

c) Seasonal closures

Seasonal closures could protect reproductive stocks of sea cucumbers. For seasonal closure, it is necessary to consider the spawning period of important species of sea cucumbers. However, this measure would be difficult to implement because reproductive seasons may extend for many months and species exhibit asynchronous spawning periods. It is suggested that seasonal closure may be considered for the peak spawning periods and frequency of spawning months of commercially important species of sea cucumber, which would help in recruitment and replenishment of wild stock. In locations close to the equator, *H. scabra* is known to display a biannual pattern with two spawning periods (Muthiga *et al.*, 2010). Asha and Muthiah (2008) reported that effective spawning of *H. spinifera* is caused due to changes in salinity, temperature and productivity of the marine environment during the post-monsoon season (north-east monsoon) along the south-east coast of India which has been proved in the laboratory experiments. Effective spawning of *H. scabra* occurred during the same period in the laboratory induction studies (Asha *et al.*, 2007). Effective spawning in *H. scabra* has also been reported during the same period along the Sri-Lankan coast also (Ajith and Dissenayake, 2015). Hence, November to January is the ideal period for seasonal closure for ensuring the spawners to breed and propagate their progeny.

Along the coast of Tamil Nadu, there is a forty five days' fishing ban for mechanized boats during summer from April 15 to May 30, every year, based on the peak spawning season of commercially important species of fin-fishes and shell-fishes. The sea cucumbers are regularly caught as by-catch in trawlers and as trawlers are included in the closure, the by-catch of sea cucumber is restricted for at least 45 days during the ban period, even though the sea cucumbers are not the focus of seasonal closure.

d) Pulse fishing or rotational fishing

The pulse fishing strategy allows fishing for one or several years followed by an inactive period of several or many years (Friedman *et al.*, 2011) after considering the ecological and social risks. The shifting of livelihood in years of closure will not be acceptable to the fishers and traders and there would be pressure to prolong fishing beyond the ecological safe limits. In contrast, several decades of modest fishing have resulted in stable stocks in a few regions (Purcell *et al.*, 2013). In India, the moratorium may be relaxed for one year, but with restrictions on the fishery. By observing the behaviour of fishermen and traders and the response of the resources, decision could be taken on continuation of pulse fishing with changes in restrictions.

e) Spatial closure and no-take zones

It is imperative to identify certain areas as 'protected habitats' or 'no-take zones' as a measure of conservation. In the Gulf of Mannar, an area of 560 sq. km. encompassing 21 uninhabited islands is a Marine National Park since 1986. A Biosphere Reserve is located within the park, which is a protected area. Fishing and other human activities are prohibited within the Marine Biosphere Reserve. Although the impact of declaration of reserve in the conservation of resources have not been assessed, it is quite possible that three decades of protection would have helped in the recovery of stocks of many resources, including sea cucumbers. Also, being a Marine Protected Area (MPA), it is easy to identify certain locations as 'no-take zones', through community participation.

The Palk Bay, on the other hand, is characterized by vast stretches of seagrass meadows which are an ideal habitat for many marine invertebrates including the holothurians. Therefore creation of 'no-take zones' in the Palk Bay would not only help in conservation of sea cucumber population but also in the preservation of seagrass habitats. The 'no-take zones' need to be identified involving the local communities who were involved in sea cucumber fishing and have a rich knowledge on sea cucumber habitats and areas of abundance. A community level self-imposed regulation would be far-reaching and successful in restricting targeted fishing for sea cucumber in the designated no-take areas. Marine reserves may be particularly useful for sea cucumbers because effective spawning and fertilisation seems to require high densities of breeding population, which may not occur in most of the open fishing grounds (Bell *et al.*, 2008).

f) Gear limitation

Gear limitation will protect the resources as well as the environment. In addition to targeted collection of sea cucumbers by divers, the sea cucumbers also form incidental catches in destructive gears like pair trawl, *Thallumadi* (minitrawl) and *Roller madi* (a kind of trawl). These destructive fishing gears are already banned by the Government of Tamil Nadu. However, these gears are being illegally operated in the inshore areas and in seagrass habitats causing destruction to the seagrass beds and also to the sea cucumbers and other resources. The operation of trawl in the inshore areas, very close to the shore is banned under the Marine Fishing Regulation Act (1981), but this restriction is often violated by the fishermen. A strict vigilance and surveillance on the operation of banned fishing gears will reduce the damages caused to the seagrass beds and many benthic invertebrates including sea cucumbers.

g) Species protection

The IUCN has listed *H. scabra* as 'Endangered' (EN), *H. spinifera* as 'Data Deficient' (DD), and *A. miliaris*, *A. echinites* and *S. hermanni* as 'Vulnerable' (VU) in the Red List of Threatened Species. Of the 39 species recorded in Gulf of Mannar and Palk Bay, the fishery and trade is mostly restricted to two species, namely, the high valued *H. scabra* and medium valued *H. spinifera*. A few other medium valued species, namely, *A. miliaris*, *A. echinites* and *S.hermanni* are fished and traded occasionally. The most widely traded species are also available in relatively higher abundance, hence less abundant ones may be declared as protected species. Species-specific bans do not prevent serial depletion of other species further down the value chain as species of lesser value will be targeted by fishers, at the same or higher rate, when high-value species become scarce. Hence it might be advisable to set a shortlist of allowable species, and to implement various regulatory measures.

h) Habitat protection

The health of the habitat is a pre-requisite and decisive in having a healthy stock of animals. Pristine habitat would ensure higher survival, optimum growth and breeding. Many sensitive habitats including corals and seagrass beds are susceptible to changes both due to natural and man-made causes. The distribution and abundance of sea cucumbers are closely associated with benthic habitats like sandy and mudflats, coral reefs, seagrass meadows, mangrove swamps and rocky areas. Several species show specific habitat preferences. *Holothuria scabra* and *H. spinifera* are associated with sandy bottom and mudflats, while *Actinopyga* spp. show a preference for coral reefs and reef flats (James, 1994). The seagrass beds are also important habitats of *H. scabra* and several other species, since the larvae and juveniles of sea cucumbers rely heavily on seagrass for settling cues and early life stages (Mercier *et al.*, 2000). In India, the coral reefs are protected under the Indian Wildlife (Protection) Act, 1972, but not the seagrass beds. When trawling is done in the inshore seagrass areas, it results in the damage of seagrass beds. Also, the country trawl, locally called *Thallumadi* is invariably operated in the seagrass beds for catching shrimps. The operation of country trawl results in the removal of large quantities of seagrass, which affects the larval as well as adult stages of many invertebrate communities for which the seagrass ecosystem is an essential and preferred habitat. Therefore, efforts are needed to develop an understanding of the present status of sea cucumber habitats and to undertake habitat restoration measures.

i) Trade management

Although regular fishing and trade happened for several years prior to the ban imposed by the Government in 2003, there is not much information on the quantity of holothurians that were collected and traded. At present in the Gulf of Mannar and Palk Bay, illegal trade thrives and the fishers, middlemen, traders and exporters are all involved in a long market chain. If the government lifts the moratorium and permits regulated fishing, the concerned government agencies should ensure that the poor fishers get a fair share of the export value. The agencies should monitor the market chain within the country and also the export prices, so that the trade is well regulated. Also, monitoring the entire market chain from the fishermen to the exporters will enable the government agencies to set and levy appropriate taxes and duties. The Marine Products Export Development Authority (MPEDA) and the Customs Department should regularly monitor the export prices of sea cucumbers which is inevitable for a better trade management.

Potential for restocking

Hatchery and grow-out potential of sea cucumbers in India; developments and experience in other parts of the world

Insufficient management measures and weak governance have caused sustained over-fishing of high valued sea cucumber populations in many parts of the world and these have prompted research activities for stock restoration and sustainable livelihood activities based on culture of sea cucumber species (Erickson *et al.*, 2011; Robinson, 2013; Han *et al.*, 2016; Hair *et al.*, 2016).

The history of spawning and larval rearing of sea cucumber dates back to 1940, when the Japanese attempted seed production of temperate sea cucumber species *Apostichopus japonicus* owing to overexploitation of this species in Japanese waters (Imai and Inaba, 1950). Mass production of viable juveniles for restocking and sea ranching projects was initiated in Japan in the 1980s (Ito and Kitamura, 1997; Yanagisawa, 1998). In China also, research on hatchery technique of this species was initiated in the 1950s and major progress on artificial breeding was made in the mid 1980s, and the techniques was perfected by 1995 (Zhang and Liu, 1998). Now, China has emerged as the world leader in sea cucumber aquaculture with the production exceeding 170,000 tonnes, surpassing production from capture fisheries (Robinson and Lovatelli, 2015). Juveniles of *A. japonicus* are mass produced in hatcheries in controlled conditions and farmed to market size in a wide variety of production systems such as pond, tank and raft, intensive production in re-circulating aquaculture systems (RAS), as well as in floating cages and sea ranching, (Han *et al.*, 2016). By restocking of the natural habitat with hatchery-reared seed, the major sea cucumber consumer countries like China, Japan, Korea and Taiwan could successfully manage the sea cucumber stocks (Robinson, 2013).

Research on sea cucumber seed production in India

Research on aquaculture production of tropical sea cucumber species in India was initiated by ICAR-CMFRI in 1987 and the research team succeeded in the seed production of *Holothuria scabra* (Fig.4a) for the first time (James *et al.*, 1988; 1994). Since then seed production of this species has been repeated on a number of occasions and used for sea ranching purpose. A part of the seed produced was used for culture experiments at different locations as well as in enclosures made of different materials and sizes like velon screen cages, netlon cages, concrete rings and in tanks. The results of these were not promising for various reasons like poor water circulation in

Fig.4. Brood stock of holothurians (a. *Holothuria scabra,* b. *H. spinifera*)

the production system, development of toxic gases and poor durability of materials (James *et al.*, 1996). The culture experiments of juvenile *H. scabra* attempted in a prawn farm using concrete rings yielded encouraging results that proved the efficiency of sea cucumbers in cleaning the pond bottom by consuming the feed waste (James *et al.*, 1999). Among the tropical sea cucumber species, *H. scabra* is considered as an ideal candidate in many countries for stock enhancement programme for reasons like wide distribution, sedentary nature, simple production systems, low trophic level (consumption of organic matter/detritus) requiring no additional feed, low-cost and attaining marketable size in approximately 12 months (Battaglene, 1999).

In 2001, success was achieved in the seed production of another commercial and over-exploited sea cucumber species *H. spinifera* (Fig.4b) (Asha, 2005; Asha and Muthiah, 2002). *H. spinifera* was the second major contributor to the '*beche-de-mer*' production from Indian waters. It was once rated very high in the market and the most preferred species of the Chinese consumers, hence was locally named as *Raja attai*, and *Cheeni attai*. This species is declared as an endangered species in China (Chinese Species Information Service) and is considered as a highly priced species in Tanzania (Purcell *et al.*, 2012). Hence development of hatchery techniques of this species was expected to have greater importance for stock replenishment and farming. The chronological development with details of various larval stages up to juvenile of both the species are given in figures 5,6 and table 3.

Table 3. Time after fertilization and mean size for different developmental stages of *Holothuria scabra* and *H. spinifera* in laboratory condition.

Development stage	Time after fertilization	Mean size ± SE	
		H. scabra	*H. spinifera*
Gastrula	24 hours	270.7±2.5µm	265.4± 6.06µm
Auricularia (early)	2 days	481.2±9.8µm	489± 14.1µm
Auricularia (late)	10 days	1072 ±25µm	809± 50µm
Doliolaria	10 – 12 days	520 ±18µm	468± 23.3µm
Pentactula	13 – 15 days	371 ±21µm	330±16.7µm
Early juveniles	20 days	1.3±1.3mm	0.95 ±2.5mm
Juveniles	48 days	14.3±1mm	10.1±1.1 mm
Juveniles	55 days	18.2 ±0.9mm	16.1±0.9 mm
Juveniles	62 days	23.7±0.7mm	18 ±0.5mm

Through continuous research,, several improvements were made in the hatchery and culture protocols of the two species during the period 2001-2005. Determination of optimal spawning induction methods, larval feeding regime, microalagal diet,

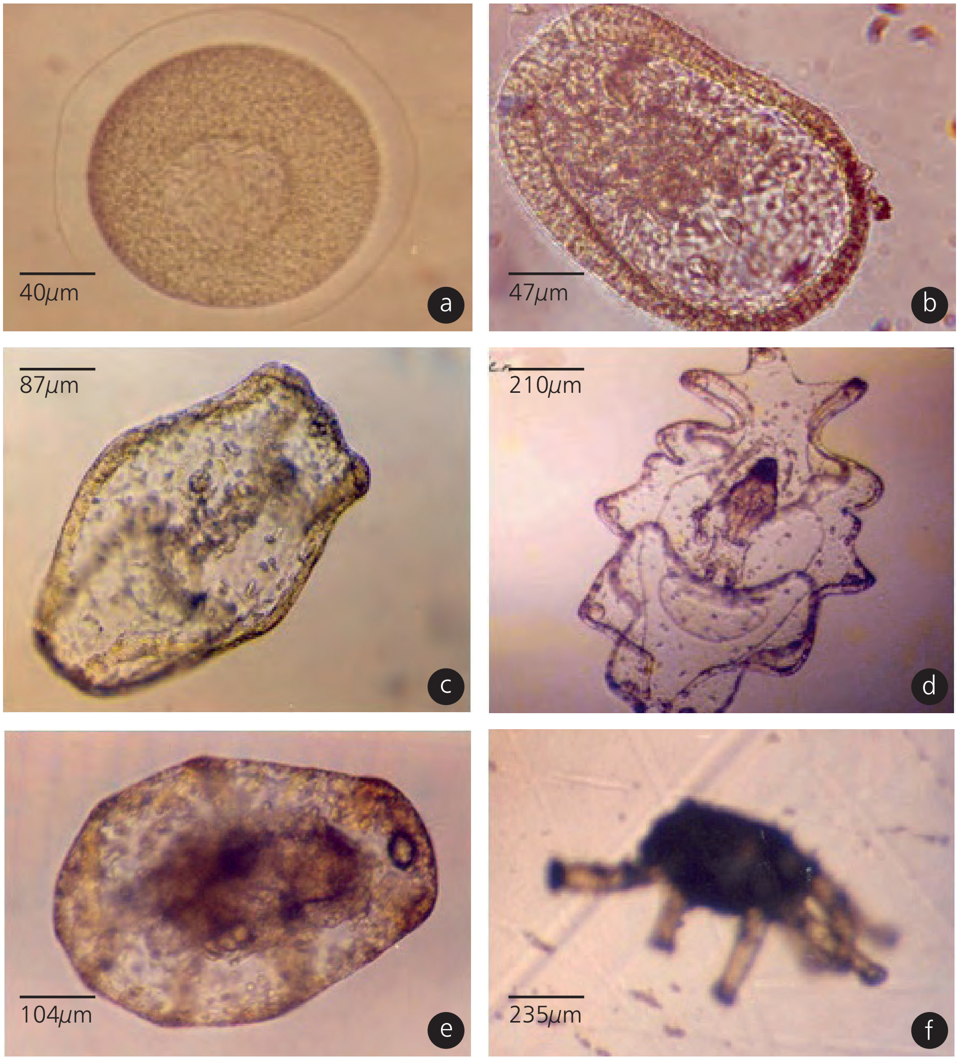


Fig.5. Developmental stages of *Holothuria spinifera* (a. Fertilized egg, b. Gastrula, c. Early auricularia, d. Late auricularia, e. Doliolaria, f. Pentactula)

environmental conditions, settlement preference, stocking densities at different stages of larval and early juvenile rearing have been worked out (Asha, 2004 ; Asha and Muthiah, 2005, 2006, 2007; Asha *et al.*, 2011; Asha and Diwakar, 2013). Sea ranching of 11,335 juveniles of *H. scabra* (mean size-23mm) in different locations of Gulf of Mannar area was carried out during this period (Asha *et al.*, 2007).

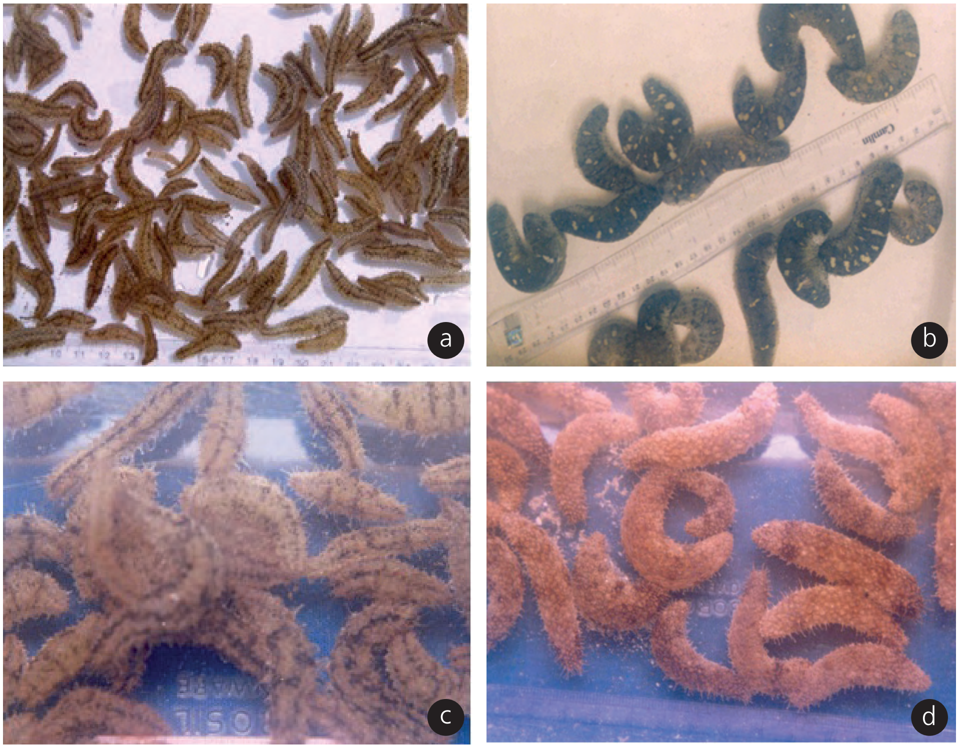


Fig.6. Juveniles of *Holothuria scabra* (a. one month old, b.120 days old) and *H. spinifera* (c. 85 days old and d. 120 days old)

Developments in sea cucumber aquaculture production in other parts of the world

After the initial success of *H. scabra* in the Indian waters, advanced research effort by the World Fish Center in the Solomon Islands (1997-2000), New Caledonia (2001-2008) and Vietnam (2003-2016) (Agudo,2006; Battaglene,1999; Pitt and Duy,2004) has helped refinement of mass production of juveniles of *H. scabra*. Further research on aquaculture techniques of this species (Mills *et al.*, 2012 ; Raison, 2008; Purcell *et al.*, 2012) helped successful development and dissemination of hatchery, nursery and grow-out technology, which are currently being followed by many countries (Hair *et al.*, 2016). The current production of *H. scabra* is limited to 130t per year through extensive production systems including sea ranching, sea pen farming and pond culture (Robinson and Lovatelli, 2015). Farming of *H. scabra* is providing an alternative livelihood source for coastal communities in countries ranging from Madagascar to Fiji (Robinson, 2013; Hair *et al.*, 2016). Globally, the techniques for seed production through hatchery system have been developed for 14 over-exploited commercial sea cucumber species (Appendix 1).

Advancement in nursery and grow out techniques of *H.scabra*

Nursery rearing

Several research advancements have been made on nursery and grow out rearing of *H. scabra* juveniles worldwide, which make the operation cost-effective and simple. Earlier experiments proved that sea cucumber juveniles in the nursery stages can be successfully reared in hatchery-based raceway systems, but because of the high cost of production and larger tank area at commercial scale production, these systems proved economically not viable. A range of new nursery systems has been trialled in many countries. In Madagascar, the juveniles are transferred directly to outdoor nursery ponds containing sediment from seagrass areas. In Vietnam and Philippines, fine-mesh nets (referred to as 'hapas') constructed from 1-mm mesh installed in ponds, raceways or in protected areas are proved efficient resulting in high survival and growth rates (Mille *et al.*, 2012; Robinson, 2013). An 'advanced nursery' stage has now been introduced in Vietnam, where in ponds with optimal seawater supply and organically rich muddy-sand are seeded with 2–5g juveniles from hapas at a high density of up to 50,000 juveniles/ha and reared up to 50g ensuring high survival and fast growth during the grow out stage.

Grow-out techniques

The grow out includes both extensive and intensive techniques. Sea ranching is currently one of the most extensive forms of sea cucumber aquaculture. Community based sea ranching enterprises in pen and pond have been practised in Fiji, Philippines, Madagascar, New Caledonia and Vietnam. Sea ranching has been developed in regions where communities have some degree of ownership over near-shore areas and involved in marine resource management. In Fiji and Philippines, sea ranching projects are co-managed by communities and local governments in large areas of seagrass beds (~5 ha) (Junio-Menez *et al.*, 2012a). In Papua New Guinea, community-based sea ranching trials indicated that minimizing the size at release of cultured juveniles, post release mortality, time taken to reach harvest size, material and labour cost will be helpful for sustainable and economically viable practice (Hair *et al.*, 2016). Natural disasters and poaching are the two major threats to the economic viability of sea ranching operations (Hair, 2012; Junio-Menez *et al.*, 2012b).

Sea pen farming is a semi-intensive form of small-scale aquaculture offering greater control over initial site selection, predation, monitoring and harvesting of stock, with no additional feed or fertilizers. In Madagascar, user rights and ownership of pen have been assigned to a group of farmers with capital inputs supplied by donor agencies initially until the farmers become established and self sufficient. Farmers constructed pens of 225 to 600 m^2 in near shore seagrass beds using locally available material and stocked hatchery-reared juveniles (10-15g) at $0.5/m^2$. The growth rate was 1.5g/d, depending upon the carrying capacity of the site (Robinson, 2013). In the Philippines, juveniles (5-7g) are often stocked in sea pens to facilitate monitoring of the stock after release. The juveniles registered a growth rate of 1.0-1.8g/d. Poaching and predation are the two bottlenecks faced by pen farming activities (Robinson and Pascal, 2012; Robinson, 2013).

Extensive research on pond farming has been conducted in Vietnam. Sandfish monoculture is proving to be a viable economic alternative for prawn farmers (Duy, 2012). Ponds in intertidal areas with good water exchange and sandy muddy substrate were stocked at $1/m^2$ with juvenile sandfish (of 2g) that were reared in nursery of hapa nets. The juveniles showed survival rates as high as 80 to 87 percent and growth rates ranged from 2.2 to 3.2 g/d, with the sandfish reaching a harvest size of 300 to 350g within 6 to 14 months (Duy, 2012). Pond culture of *H. scabra* juveniles conducted in Phillippines and Thailand on an experimental basis indicated that high growth rates are inversely proportional to density (Mills *et al.*,

Spawning of female *Holothuria scabra*

2012). Pond-based co-culture systems involving sea cucumbers and other pelagic groups for optimising space are gaining momentum in many countries. Trials with *Penaeus monodon* (tiger shrimp; Pitt *et al.*, 2004) and *Litopenaeus stylirostris* (Pacific blue shrimp; Purcell *et al.*, 2006; Bell *et al.*, 2007) showed some initial promise; however, larger–scale trials proved unsuccessful. Culture experiments with larger juveniles (approx. 50 g) tested with shrimp post-larvae gave promising results in Vietnam. Similarly rotational culture trials practised by a good number of producers in Vietnam, have shown high sandfish growth rates in ponds recently used for shrimp culture (Duy, 2012). Intensive, land-based sandfish culture in recirculating systems is currently being practised in South-Africa also (Robinson, 2013).

Sandfish are excellent candidates for integrated multi-trophic aquaculture (IMTA) -the practice of culturing several species together based on their mode of nutrition, with one species consuming the waste of another. Co-culture of sea cucumber with fin fishes like pompano, milkfish and sea bass was found promising in the trial conducted in the Philippines (SEAFDEC-AQD) with survival close to 100% (Mills *et al.*, 2012). Similarly, IMTA experimental farming trial conducted for the commercially valuable red seaweed *Kappaphycus striatum*, and sandfish has been demonstrated successfully in Zanzibar, Tanzania (Robinson, 2013).

Future prospects of sea cucumber farming in India

Through the pioneering success in the development of breeding and consistent seed production techniques of two species of sea cucumbers, (*H. scabra* and *H. spinifera*), India has proved its research potential and engrossment in developing and formulating the conservation strategies for over-exploited sea cucumber resources. For conserving the species, continued research effort has to be made on development of seed production techniques of other depleted species like *Actinopyga echinites*, *A. miliaris* and *Stichopus chloronotus* which once existed in the Gulf of Mannar and Palk Bay but have totally disappeared from the fishery over the years. High valued and unexploited sea cucumber species like *H. fuscogliva*, *H. nobilis* and *Thelenota ananas* having high international market values are available in Lakshadweep waters. Attempts may be made for hatchery production and farming of these species.

Future research on hatchery techniques in India needs to be focused on improvements of nursery rearing and grow out techniques of holothurian juveniles. By upgrading the existing larval and juvenile rearing techniques for cost-effective mass production of holothurian juveniles through hatchery system, community based sea ranching may be carried out followed by proper monitoring. It is also possible to use a part of the hatchery produce for farming into adults (through the pen, pond, mono or co-culture) and the farmed adults may be used for export. Thus, India may move towards providing regulated permits for collection of broodstock of threatened species for establishing hatchery and aquaculture programmes and certification that exports are from farmed stocks. The community-based management system should ensure protection of released juveniles until harvest and these could result in small, but dense, breeding populations that improve egg production for rebuilding sea cucumber stocks in neighbouring fishing grounds. In India, the Ministry of Environment, Forests and Climate Change may adopt a strategy by funding research programmes on hatchery seed production and sea ranching in a participatory manner involving the local communities, which in turn will help evolving strategies for ensuring conservation and sustainable fishery of sea cucumber resources.

Colour morph of *Holothuria scabra*

Implementation of management measures

Implementation of various regulatory measures is a challenge, but holds the key for sustaining the sea cucumber fisheries. The regulations should help sustainable utilization of resources, improving the socio-economic status of fisher communities and conservation of sea cucumber resources in the wild. An overarching goal in the management of sea cucumber fisheries is to safeguard the reproductive capacity of breeding stocks so that the resources are available to future.

As discussed in the preceding paragraphs, a wide range of options of regulatory and restocking measures are available; however, identification of right measure and planning is the first step in the process of implementation. All regulatory measures may not be applicable to our situation and hence careful selection of viable regulatory measures which are practical and implementable should be chosen. The regulatory measures would vary with the species that is targeted and the type of habitat in which it lives. Also, no single regulatory measure would help in achieving the goal; and therefore, a combination of more than one regulatory measures is to be carefully chosen. Strict surveillance and monitoring by the responsible agencies is essential to ensure effective implementation of various measures.

Co-management

Participation of all stakeholders holds the key for success in any fishery management plan. For sustainable management of sea cucumber fishery and conservation, a large number of stakeholders like the fishers, traders, processors, exporters, officials of the Department of Fisheries, Department of Forests, Indian Coast Guard, Coastal Marine Police, Wildlife Crime Control Bureau, Gulf of Mannar Marine Biosphere Reserve Trust (GOMBRT), Non-Government Organisations, research and academic institutions have defined roles to play and they should be involved at each stage of dialogue and implementation of plans. In co-management of sea cucumber resources, both the communities and the government share the responsibility and authority for managing the fishery, with various degrees of power sharing.

Any long-term management strategy should ensure involvement of local communities who are the custodians of resources in their locality. They are well aware of the resources and the importance of each of the resources and thereby the need for sustainable utilization. While aiming at conservation, the communities should have access to the resources, and the local communities should be assured that they have a stake on the resources, provided they do not violate the regulatory measures imposed by the government.

Capacity building

Capacity building at all levels, from fishermen to government officials is essential to develop skills and knowledge for effective implementation of sustainable fishery management practices and conservation of sea cucumber stocks. It is necessary to improve the capacity of fishers to opt for eco-friendly methods of fishing and to restrict fishing with regard to size regulations, in a regulated fishery regime. Government agencies need to develop capacity for use of scientific information to implement management interventions, for effective monitoring and surveillance of regulations, inspection of trade and data collection. The capacity building programmes create an environment for better management decisions. Informed stakeholders are in a better position to manage their resources in a community-based management system.

Regional co-operation

The Gulf of Mannar and Palk Bay are the predominant regions for sea cucumber harvest and trade in India. The resources of these regions are shared between India and Sri Lanka. While there is a moratorium on collection and trade of sea cucumber in India, there is no such regulation on the Sri Lankan side. As the distance by sea between the two nations is very short, the sea cucumbers that are illegally caught in India are supposedly sent to Sri Lanka from where it finds an overseas export market. Therefore, bilateral co-operation between the two nations is essential for strengthening the conservation efforts.

Ecosystem approach to management of Palk Bay and Gulf of Mannar

It is suggested that effective management of sea cucumber fishery could be achieved by following an ecosystem approach, in which multiple regulatory measures and management actions could be agreed upon and applied in a participatory manner in full consideration of the sea cucumber stocks, the ecosystems in which they live and the socio-economic systems that drive exploitation. In the ecosystem approach, it is crucial to get the commitment of governments, fishery managers and scientists to develop, apply and implement the management measures to sustain sea cucumber populations for current and future generations (Purcell, 2010). The Palk Bay and Gulf of Mannar are biodiversity hotspots, with critical habitats like coral reefs, seagrass beds, seaweeds, mangrove forests and rocky coast, which also serve as home for several endangered and vulnerable species. Considering the importance of these habitats and species, it is worthwhile considering managing the entire area through ecosystem approach jointly by India and Sri Lanka.

Model for sea cucumber fishery management

Due to the prevailing illegal trade, the efforts taken by the Government to achieve the goal of conservation of sea cucumber resources might be far reaching. Therefore, a more pragmatic approach would be to switch over from a 'total ban' to a 'regulated fishery' as this would help in (i) sustainable exploitation of sea cucumber resources; (ii) improve the socio-economic status of fishers who are dependent on sea cucumber for their livelihood; (iii) conservation of stock; and (iv) foreign exchange earnings. The recommended approach for sustainable uses of sea cucumber resources is given in Table 4 and the schematic representation indicating the past, present and future of sea cucumber fishery and management is given in Table 5.

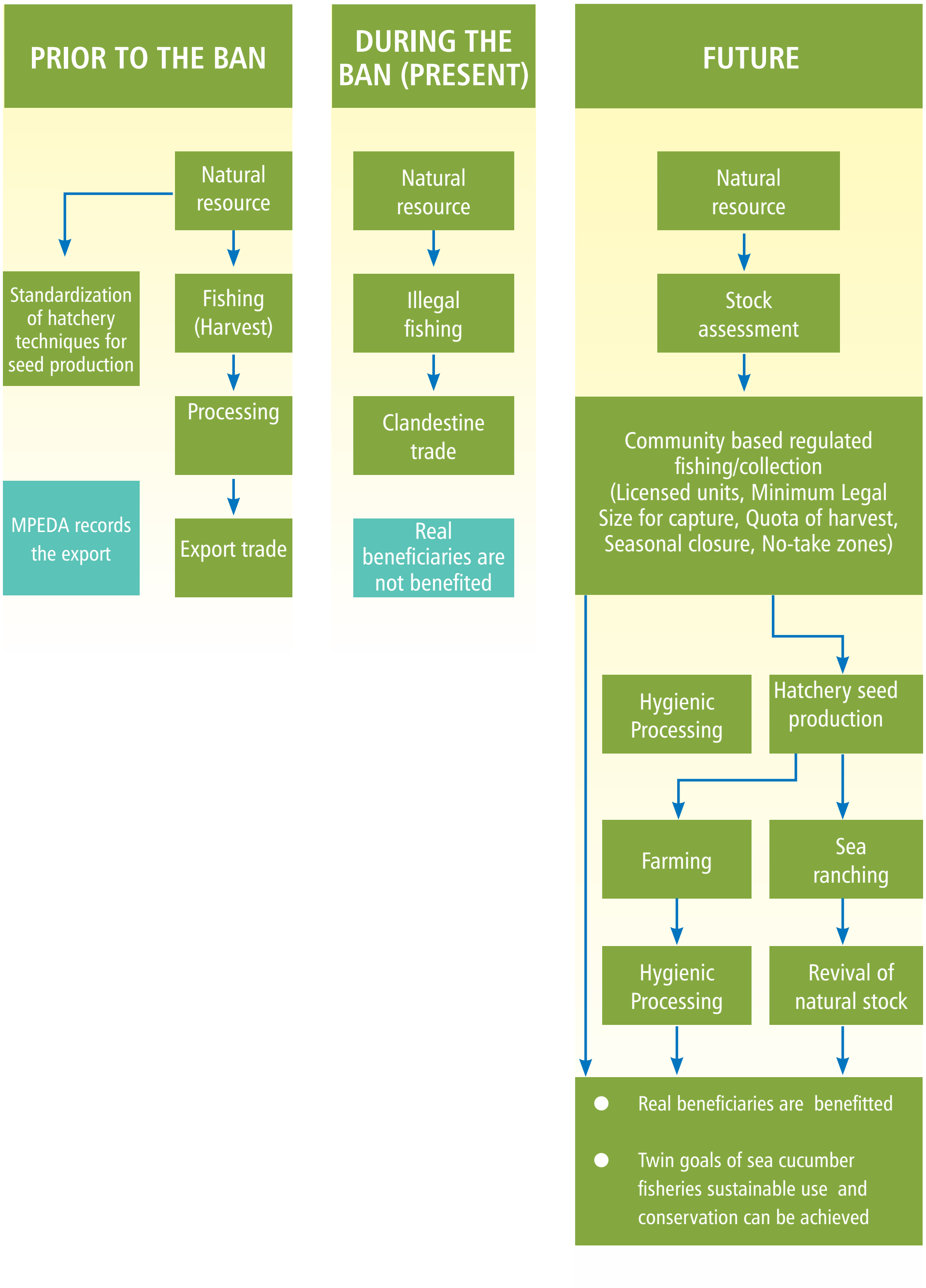
Table 4. Approach for sustainable uses of sea cucumber resources

Lifting of moratorium temporarily	Define the fisheries	Manage the fisheries	Conservation – Long-term sustainability
1.The moratorium on collection and trade of selected species of sea cucumbers can be relaxed for 1 or 2 years, on an experimental basis.	1.Developing an understanding of relevant species groups.	1. Educating the local communities on the importance of sea cucumbers –their habitat, biology etc.	1.Stock replenishment programmes through seed production in hatcheries and ranching.
2. If the fishery is found sustainable, the government can decide on relaxing the moratorium during subsequent years, through close monitoring of response of resources and trade.	2.Mapping the fishery grounds and find out the total extent of area.	2. Permitting fishing and trade with strict regulations like issue of licenses, catch quota and seasonal closure.	2.Identifying and implementing no-take zones and sanctuaries.
	3.Retaining enough stock in the fishing ground to enhance breeding and recruitment in the wild.	3. Establishing National level Committee to coordinate and formalise management.	3.Ensuring the health of habitat.

In order to achieve the goal of sustainable fishery and conservation of sea cucumber resources in Indian waters, it is suggested to:

- Strengthen the scientific information/knowledge base of different sea cucumber species available in the Indian waters, particularly on their population structure and biology.
- Undertake scientific programmes for periodic assessment of sea cucumber stock in the wild. The study should be a collaborative effort of relevant scientific institutions who are involved in stock assessment studies of marine animals. The scientific

Table 5. Past, present and future of sea cucumber fishery and management



information on stock, generated by research Institutions should be made available to the Government agencies for logical decision-making.

- Lift the moratorium on selected species of sea cucumbers by the Ministry of Environment, Forests and Climate Change, Government of India, initially for a period of one or two years, on an experimental basis.
- Constitute a National Committee by the government comprising of scientists, officers of the Forest Department and Fisheries Department and fishermen representatives for developing a framework for sea cucumber fishery management. The Committee would also coordinate with the scientific institutions for translation of research output to principles of scientific management.
- Have a totally regulated sea cucumber collection and trade, strictly following all the guidelines/regulatory measures laid down by the National Committee in the management guidelines.
- Carry out strict monitoring and surveillance of fishery and trade, particularly with regard to the quantity of each species of sea cucumber harvested by individuals or groups, size that is caught and the quantity that is traded.
- Undertake hatchery-based seed production programmes for sea ranching, to replenish the natural stock of sea cucumber.
- Involve the local communities in every stage of planning and decision making process.

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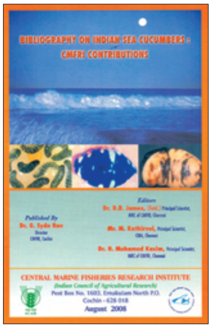

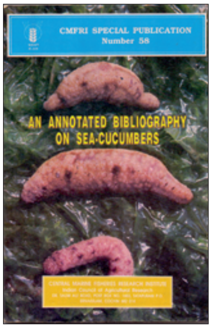

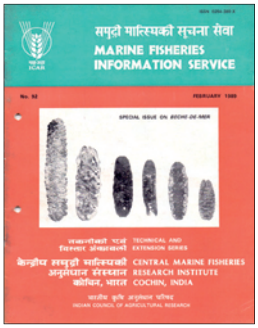

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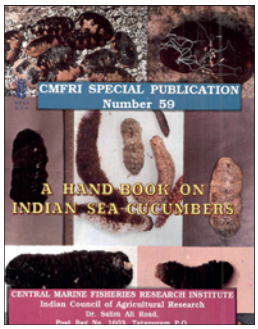

Appendix -1

Details of hatchery production of juvenile sea cucumber species globally (n/a = not available).

Country	Species cultured	Annual production of 1 g juveniles	Use of juveniles	Year of operation &Present Status
Australia (Northern Territory)	*Holothuria scabra*	62,000	Sea ranching; pond farming	2004-ongoing
Australia (Queensland)	*H. scabra*	500,000	Sea ranching	2003-2009-Nil
Australia (Queensland)	*H. lessoni*	330,000	Sea ranching	2004-2009-Nil
Australia (Queensland)	*H. scabra*	1000	Experimental	2004-2007-Nil
Canada	*Parastichopus californicus*	n/a	Pond farming	2009-ongoing
China	*Apostichopus japonicus*	>6 billion	Sea ranching; pond farming	1990-ongoing
Ecuador	*Isostichopus fuscus*	n/a	Experimental	2002-2008
Fiji	*H. scabra*	500	Experimental	2008-2010
FSM (Pohnpei)	*H. scabra*	10,000	Experimental	2009-ongoing
FSM (Yap)	*Actinopyga sp.*	n/a	Stock enhancement	2007- n/a
India	*H. scabra*	3000	Experimental	1988-2006
India	*H. spinifera*	n/a	Experimental	2001-2003
Iran (Bandar-e Lengeh)	*H. scabra*	n/a	Experimental	2011- n/a
Japan	*A. japonicus*	>3 million	Stock enhancement	1977-ongoing
Kiribati	*H. fuscogilva*	500-8000	Stock enhancement	1997-2009
Madagascar	*H. scabra*	200,000	Sea farming (pens)	2007-ongoing
Maldives	*H. scabra*	5 million	Sea ranching	1997-ongoing

Mexico	*I. fuscus*	300,000	Pond farming	2008-ongoing
Mexico	*I. badionotus*	n/a	Experimental	2013- n/a
New Caledonia	*H. scabra*	18,000	Experimental	2000-2006
New Caledonia	*H. scabra*	450,000	Sea ranching; pond farming	2011-ongoing
New Zealand	*Australostichopus mollis*	n/a	Experimental	2007-ongoing
Palau	*Actinopyga mauritiana*	500,000	Stock enhancement	2009-2011
Palau	*A.miliaris*	50,000	Stock enhancement	2009-2011
Philippines (Bolinao)	*H. scabra*	32,000	Sea ranching	2001-ongoing
Philippines (Mindanao)	*H. scabra*	15,000	Sea ranching; pond farming	2009-ongoing
Philippines (Bolinao)	*Stichopus horrens*	500	Experimental	2009-ongoing
Philippines (Dagupan)	*H. scabra*	20,000	Experimental	2009-2011
Philippines (Iloilo)	*H. scabra*	11,000	Experimental	2010-ongoing
Saudi Arabia	*H. scabra*	n/a	Sea ranching	n/a
Solomon Islands	*H. scabra*	n/a	Experimental	1996-2000
USA (Alaska)	*P. californicus*	n/a	Experimental	2010-ongoing
Vietnam	*H. scabra*	200,000	Pond farming	2001-ongoing
PapuaNew Guinea	*H. scabra*	n /a	Sea farming (pens)	n/a - ongoing
Sri Lanka	*H. scabra*	n/a	Experimental	2011-ongoing

Source: Purcell *et al.*, 2012; Robinson and Lovatelli, 2015.

Appendix -2

Regulatory measures adopted in different countries, experiences and outcomes

Sl. No	Regulatory Measures	Countries adopted	Experiences& Outcomes
1.	**Size restrictions/limits** A minimum individual length or weight of sea cucumbers that can be legally fished or traded.	Galapagos Islands (Ecuador)	The management officials and scientific institutions agree that size restriction regulation may not be as effective as others, since the size limit varies at one region from another for the same species (Toral-Granda, 2008).
		New Caledonia (France)	The fishers expressed that it is difficult to enforce thesize limit in fresh animals as it contracts and expands the body length. However, the process of consultation and interaction about the size limits seems to have improved the acceptance by fishers and processors (Purcell, 2004).
		Yap, Federal States of Micronesia	Yap has developed a fisheries management plan based on regulating weight rather than size. The quota has been set for "standard" species groups and "premium" species groups (shipments will be made and checked in 10 kilogram packages of '*beche-de-mer*') separately for more comprehensive quality control (Friedman *et al.*, 2008b). This particular measure is easy to monitor.
2.	**Temporary closures or seasonal closures** A cessation or prohibition of fishing for a short specified time period, generally for less than a year and often over the breeding season	Japan	As spawning season falls during spring, harvesting of sea cucumbers in most fisheries is allowed during the winter and there is a closed season for several months, starting in April. Semposhi Fishery Cooperative Association self-regulates their fishery season from March 1 to April 30 and from June 16 to July 20 (Akamine, 2004). Self-regulation/local management measures are being strictly followed and found to be very effective.
		British Columbia, Canada	In British Columbia, the annual *Parastichopus californicus* fishery lasts for about three weeks in October. The open season is set at this time because the size and weight of sea cucumbers are more in comparison to other seasons (Mercier and Hamel, 2008).

3.	**Gear restrictions/ limitations** A prohibition or limit on the use of certain types, sizes or number of equipment for collecting sea cucumbers.	United States of America	Due to increase in by-catch and damage of sea beds/sea cucumber there was a conflict among the local fishers on the use of "drag" or bottom trawl fishery for *Cucumaria frondosa* in Maine during 1988. To overcome this issue, a dragnet for sea urchins was modified for collecting *C. frondosa*. This particular regulation has significantly reduced the by-catch and well accepted by the fishers (Mercier and Hamel, 2008).
		Newfoundland and Labrador, Canada	In Newfoundland and Labrador, Canada, the exploratory sea cucumber fishery was initiated in 2001. Catch rates and by-catch were compared with two fishing methods, namely Labrador scallop buckets and Digby scallop buckets. Newfoundland sea cucumber drag design was approved by Fisheries and Oceans Canada (DFO) since the results of the study was positive. This gear was also used for scientific survey in estimation of population abundance and distribution. This example shows that fishing gears can be developed and regulated in cooperation with the fishery management agency and used in population studies (Mercier and Hamel, 2008).
		New Caledonia (France)	Though the prohibition of trawlers is recommended, it is difficult to enforce by compliance officers at inconvenient times or locations. Hence as of now there are no prohibitions on gears like drags, dredges or trawl nets,although these are not yet in use (Purcell, 2004).
		Seychelles and Madagascar (Western Indian Ocean)	In Seychelles, fishers need to be trained in SCUBA diving, whereas in Madagascar the use of SCUBA is legally prohibited. Enforcement, communication and, in some cases, training, are needed to ensure that fishery comply with gear restrictions, like the use of SCUBA (Conand, 2008).
4.	**Effort and capacity control** Capacity controls seek to restrict the total size of the fleet, while effort controls seek to restrict the fishing activity (FAO, 2003).	Galapagos Islands (Ecuador)	According to the Galapagos Special Law enacted in 1998, only small-scale fishers may take part in fishing activities within the Galapagos Marine Reserve (GMR). Maximum beam length for mother boats is restricted to 18 m. The number of fishers has been regulated by means of a moratorium (effective as on 31 March 2003) which allows only sons and daughters of active fishers to become new registered fishers of the GMR (Toral-Granda, 2008). This measure can be implemented in similar socio-economic, ecological marine reserve area elsewhere in the world.

		Pacific, Melanesia	Vanuatu's customary fishing controls - local management systems, Malekula Island (communities on the Maskelynes group of islands). The collection of Trochus, in individual reef, came under the control of family groups, and high value sea cucumbers such as sand fish, *Holothuria scabra* were protected by harvesting tabu's, even close to the village forefront that was accessed by the whole community. This stock was protected from fishing and helped in recovering of those resources. Restricting the number of fishers and capacity control is effective in protecting the sea cucumber breeding grounds and to maintain their population on reef areas (Friedman *et al.*, 2008a).
5.	**Catch Quotas** A catch limit set for a particular sea cucumber fishery, generally for a year or a fishing season. Quotas, also called "total allowable catch" (TAC), are usually expressed in tonnes of live-weight equivalent, but are sometimes set in terms of numbers of individual animals.	Japan	The Semposhi Fishery Cooperative Association set an annual quota of 50 t (seasonal quotas of 30 t in spring and 20 t in summer). Fishing is prohibited for the rest of the open season as soon as the annual quota of 50 t is reached by all fishers (Akamine, 2004).
		British Columbia, Canada	*Parastichopus californicus* is maintained in an area comprising about 25 percent of the British Columbia coastline (existing arbitrary quota of233 t). Another 25 percent of the coast is dedicated to experimental fishing, and the remaining half is closed until the biology of the species is well understood (Mercier *et al.*, 2004).
		Australia	The sea cucumber fishery on the Great Barrier Reef (GBR) in 2004 fixed the Total Allowable Catch (TAC) as 380 tonnes (127 t of white teatfish, zero catches of black teat fish and 253 t for all other species). In addition, the fishers in the industry agreed on species-specific limit reference points (sandfish, 15 t; golden sandfish, 10 t; prickly redfish, 40 't; surf redfish, 25 t; and deep water redfish, 25 t)' (Uthicke, 2004).
6.	**Market chain licensing and reporting** Requirements imposed on fishers, processors and traders to declare and report on their activities within the fishery.	Galapagos Islands (Ecuador)	The Galapagos Marine Reserve (GMR) has a Fishery Monitoring Programme(FMP), in which information is collected on fishing sites, fishing effort, total catch and fishing methods throughout the market chain. The chain starts in the GMR fishing site and ends with the exporter in mainland Ecuador. By the Special Law of Galapagos, fishers are obliged to provide all the required information to the FMP (Toral-Granda, 2008).

	Cuba	All fishing activities for Isostichopus badionotus are controlled and monitored strictly from landing to export. There is one exporting company authorized in Cuba (NENEKA C.A.) which ships "Class A" product to China, Hong Kong Special Administrative Region, and "Class B" product to China or the Republic of Korea. The impact of this measure is till date, there has not been any illegal shipment detected (Alfonso, 2006).
	New Caledonia	Licensing system is followed in both the Northern and Southern Provinces of New Caledonia. On personal visit by fisher to fishery service, every year they have to renew theirlicence at a nominal fee. In this process,they must also apply for a special "Concession" to harvest sea cucumbers. The licensing system monitors the fishers and provides updated information on new fishery regulations. The log sheets are also provided to the fishers in order to record the sea cucumber catch (both in terms of numbers and weights) (Purcell *et al.*,2009).
	Fiji	Fishers collect and sell product (fishers in the western lagoon of Vanua Levu and the Lau Group catch and process sea cucumbers into dried product). A local/island middleman passes it to regional agents and to national agent/ capital.This market chain has changed somewhat in recent years. Fishers collect sea cucumbers and transport directly to the regional centres for processing. In addition, some marine agents also buy fresh sea cucumbers from independent fishers and process them. The role of middlemen has been completely eliminated by which fishers can get reasonable consumershare (Friedman *et al.*, 2008a).
	Seychelles and Madagascar (Western Indian Ocean)	The licensing and monitoring of sea cucumber catch and trade in Seychelles is conducted at 3 levels: harvesting, processing and export. The status of sea cucumber resources is assessed based on the collected catch and effort data. Hence the licensing and monitoring measure is successfully implemented. Whereas in Madagascar, monitoring and controls have been difficult to implement (Conand, 2008).

7.	**Rotational harvest closures** A periodic temporal and spatial shifting of fishing effort, in a systematic way among demarcated fishing grounds.	Alaska,United States of America	Current sea cucumber management measures in Alaska, using rotational harvest strategies, have provided sustainable harvests and consistent quality of *Parastichopus* californicus. Divers rotate their effort between 16 harvest areas, throughout the fishing grounds (Ess, 2007). In southeast Alaska, each fishing area operates on a three year rotation and is harvested at a rate of 6 percent per year (Mercier *et al.*, 2004).
		Philippines (Sagay Islands)	The practice of rotational closure and harvest has increased the awareness among the community about sustainable fishing of the sea cucumber resources (Dacles, 2007; Gamboa *et al.*, 2007).
		Great Barrier Reef, Australia	As the rotational sectors are relatively large, fishers cannot easily deplete the resource within each sector during the year of rotation. Moreover the process of allocating plots and reaching agreement among fishers is easy (Uthicke and Purcell, 2004).
8.	**Marine Protected Areas No take zones** A marine protected area (MPA) is a portion of the marine benthos and water, with its associated biota, reserved to protect part, or all, of the enclosed environment (Kelleher, 1999). "No-take zones" (NTZs) or "fully-protected marine reserves" are a special class of MPA, which prohibit any extractive activities such as fishing. MPAs and No-take zones are one type of spatial closure.	Malaysia	The system of national marine parks and fishery zoning regulations in Peninsular Malaysia have met with some successes and Malaysia's National Coral Reef Management efforts are some of the most successful in Southeast Asia.In order to reduce conflicts and overfishing, different user groups were separated to different fishing zone (Choo, 2008).
		New Caledonia (France)	Although long-term reserves in New Caledonia tended to have greater sea cucumber populations than reserves established recently, they did not always lead to a huge build-up of sea cucumber breeding populations (Purcell *et al.*,2009).
		Solomon Islands	Arnavon Island Marine Reserve (AIMR) after the declaration of conservation area showed that the time needed for a species to recover from harvesting might be longer than expected. The important factors for species recovery is generation time, severity and extent of previous fishing, local oceanographic features, location and size of the reserve, infringement of the reserve and availability of nursery and adult habitat (Kinch *et al.*, 2008).

9.	**Territorial user rights in fisheries** The provision to certain users, e.g. fishers or sea ranching proponents, of exclusive privilege to exploit certain resources and/or access certain areas of seabed.	Japan	Only local fishery cooperative associations are eligible for the fishery right. Thus, no one except the fishery cooperative association members can collect sea cucumbers for any purposes. This measure restricts only few fishers to be involved in the sea cucumber fishery (Akamine, 2004).
		Australia	In the state of Queensland, access to commercial fishing of sea cucumber fishery on the Great Barrier Reef (divided in to154 fishing zones of approximately 100 to 150 nautical square miles) is limited to just 18 licenses (Uthicke, 2004).
		The Philippines	Fishing communities at several of the project's sites generally have de-facto rights over the adjacent shallow seabeds. But poaching and the temptation to harvest small sea cucumbers are potential problems that need to be resolved by formal access rights. The communities apply for permits from the local municipal government and village council
			to have exclusive access to inshore plots (5-10 ha) for sea ranching. The granting of access rights requires public consultations on proposed sea ranching, implementation mechanisms and arrangements including sharing of costs (e.g. labour, guarding of area) and benefits (*i.e.* harvest and access rights) (Purcell and Kirby, 2006)
		Pacific, Polynesia	American Samoans continued to claim exclusive fishing rights to their adjacent reefs (Hill, 1978). Similarly, in neighboring Samoa (formerly Western Samoa), the reef and lagoon areas are owned by the State, but customary ownership by the village of local fishing rights is recognized and remains firmly entrenched (Fairbairn, 1992). Despite these controls, overfishing has also occurred in Samoa, especially in urban and populated areas, even with customary ownership in place (Friedman *et al.*, 2008a).
		Madagascar	The traditional fishery has expanded in the last decades, however due to lack of well-defined access rights, conflicts were raised with local communities and led to heavy depletion of wild stocks (Conand, 2008).

Acknowledgements

The authors wish to express their sincere gratitude to Dr. A. Gopalakrishnan, Director, ICAR-Central Marine Fisheries Research Institute (CMFRI) Kochi for his constant encouragement and unwavering support in bringing out this document. The support and facilities provided by Dr. P. P. Manojkumar, Dr. P. K. Asokan and Dr. A. K. Abdul Nazar, Scientists In Charge-Tuticorin, Calicut Research and Mandapam Regional Centres of ICAR-CMFRI respectively, while preparing this document is also gratefully acknowledged. Some information has been used from the report of the project supported by the Bay of Bengal Large Marine Ecosystem (BOBLME) and executed by the ICAR-CMFRI. Special thanks are due to the BOBLME for sharing the information.

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Acronyms

AIMR	Arnavon Island Marine Reserve
B1,B2,B3	B vitamin complex
BOBLME	Bay of Bengal Large Marine Ecosystem
CIBA	Central Institute of Brackishwater Aquaculture
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMFRI	Central Marine Fisheries Research Institute
DD	Data Deficient
DFO	Fisheries and Oceans Canada
EN	Endangered
FAO	Food and Agriculture Organisation
FMP	Fishery Monitoring Programme
GBR	Great Barrier Reef
GMR	Galapagos Marine Reserve
GOM	Gulf of Mannar
GOMBRT	Gulf of Mannar Marine Biosphere Reserve Trust
HIV	Human Immunodeficiency Virus
ICAR	Indian Council of Agricultural Research
IMTA	Integrated Multi-Trophic Aquaculture
IUCN	International Union for Conservation of Nature
MLS	Minimum Legal Size
MPA	Marine Protected Area
MPEDA	Marine Products Export Development Authority
NTZs	No Take Zones
PB	Palk Bay
pH	Potential Hydrogen
RAS	Recirculation Aquaculture Systems
SCUBA	Self-Contained Underwater Breathing Apparatus
SEAFDEC-AQD	Southeast Asian Fisheries Development Center/Aquaculture Department
TAC	Total Allowable Catch
VU	Vulnerable
ZSI	Zoological Survey of India

Conservation and sustainable use of **sea cucumber resources in India** suggestions and way forward

This book is an outcome of the extensive research work carried out by the ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI) in the last five decades and the project on sea cucumbers implemented by the ICAR-CMFRI with financial support from the Bay of Bengal Large Marine Ecosystem (BOBLME) project in 2015. It is aimed to propose guidelines and principles for effective conservation measures ensuring the long-term sustainability of sea cucumber resources in this region.

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