Review of fisheries and management of sea cucumbers in the Indian Ocean

Chantal Conand[1,2,*], Michel Claereboudt [3], Chamari Dissayanake[4], Ameer Ebrahim[5], Stella Fernando[6], Rodney Godvinden[7], Thierry Lavitra[8], Marc Léopold[9], Twalibu K. Mmbaga [10], Thierry Mulochau[11], Shafiya Naaem[12], Stanley Shea[13], Devarajen Vaitilingon[14], Saleh Yahya[15], Kim Friedman[16,17]

[1] UMR ENTROPIE, Université de La Reunion, av. René Cassin, 97715 Saint Denis, France

[2] Museum National Histoire Naturelle, 57 rue Cuvier 75231 Paris, France

[3] Department of Marine Science and Fisheries, College of Agricultural and Marine Science, Sultan Qaboos University, Oman

[4] Department of Zoology, Faculty of Applied Sciences, University of Sri Jayewardenepura, Gangidawila, Nugegoda, Sri Lanka

[5] Fisheries Resource Management & Technical Fisheries Coordination, Seychelles Fishing Authority, Victoria, Mahé, Seychelles

[6] Instituto Nacional de Investigação Pesqueira, Maputo, Mozambique

[7] Seychelles Fishing Authority, Victoria, Mahé, Seychelles

[8] Intitut Halieutique et des Sciences Marines (IH-SM), Université de Toliara, Route du Port Mahavatsy, (601) Toliara, Madagascar

[9] UMR ENTROPIE, IRD, University of La Reunion, CNRS, University of New Caledonia, Ifremer, c/o IUEM, 29280 Plouzané, France

[10] School of Aquatic Sciences (SoAF), Box 6009 University of Dar es Salaam, Tanzania

[11] BIORECIF, 3 ter rue de l'albatros 97434 La Saline les Bains, La Réunion, France

[12] Maldives Marine Research Institute, Ministry of Fisheries, Maldives

[13] ADMCF/BLOOM, Suite 2405, Queen's Road Central, Hong Kong

[14] D.Bluquest Consulting, 71349 Beau Bassin, Mauritius

[15] Institute of Marine Sciences, University of Dar es Salaam, P.O. Box 668, Zanzibar, Tanzania

[16] Food and Agriculture Organization of the United Nations, Rome, Italy

[17] University of Western Australia Oceans Institute, Perth, WA, Australia

* corresponding author: chantal.conand@univ-reunion.fr

Abstract

Several sea cucumber species (Echinodermata: Holothuroidea) are fished, mostly for export of the dried product for Oriental consumers. Previous studies had analysed the historical trends at the world-scale until 2014. In the Western Indian Ocean (WIO) holothurian fisheries have a long history and several programmes have tried to ameliorate their management. Information has been recently gathered through a questionnaire and access to the most recent, yet unpublished available data (2015 to 2021) from different countries, through the evaluation of catches and/or processed product, present management systems, the imports of beche de mer and other products from Indian Ocean (IO) countries into the major market hub of Hong Kong SAR, and the Food and Agricuture Organisation (FAO) yearly statistics. The results are first presented for WIO countries, highlighting recent improvements in management. Imports from 16 WIO countries into the Hong Kong market (2017-2020 data) indicate the importance of the hub. The FAO world statistics are used to present the changes for the last few years, concentrating on the WIO countries. The recent trends show that demand for holothurians is still very high. Inconsistencies in the unit used in the reported statistics (fresh or dry weight) exist, and this needs to be addressed. The national data should be collected at the species level, to be able to follow the changes and the stock status. A regional approach is needed to encourage use of comparable management tools and follow future trends.

Keywords: holothurian, trepang, beche-de-mer, Indian Ocean, fishery, management

http://dx.doi.org/10.4314/wiojms.v21i1.10

Introduction

Several sea cucumber species (Echinodermata: Holothuroidea) are fished, mostly for export of the dried product (Beche-de-mer or trepang) for oriental consumers. Previous studies had analysed the historical trends at the world-scale (Conand, 1998, 2001, 2004, 2006a, 2006b, 2008). A paper by Conand (2017) showed that expansion during the past two decades outpaced management capacity. It was based on the last six years of the FAO capture data and Hong Kong statistics. Hong Kong remains the most important market for the imports and re-exports of the processed products, mainly the dry trepang, but also other more recently developed product forms, which raises difficulties for the analysis of catch trends. The catches are still increasing with additional countries developing export fisheries, changes in species targeted and new products traded. The exploitation is now qualified as 'serial' (Anderson *et al*., 2011) and 'contagious' (Eriksson *et al*, 2015a). A recent paper by Conand (2018a) focused on the changes during the last decade of the tropical fisheries and trade patterns. These papers confirmed overexploitation in the traditional Indian Ocean and West Pacific export countries and territories. They also showed the active fisheries in several Latin-American countries. Despite the management and conservation issues which have recently received more attention at international, regional and national levels, more measures are still needed at all these levels, to ensure sustainable exploitations of these resources. This paper presents the recent stutus of IO sea cucumber fisheries which have a very long history. Several programmes have tried to improve the management of these fisheries but they appear to be now mostly overexploited (Conand, 2017, 2018a). This up-date presents the most recent data available for this region and discusses the trends and possible management tools.

Material and methods

Previous studies have allowed interactions between scientists studying holothurians within and outside the IO. They include a Western Indian Ocean Marine Science Association MASMA project (2000 – 2014) (see Conand and Muthiga, 2007, 2010; Muthiga and Conand, 2014), several FAO publications and meetings focussed on holothurians (Lovatelli *et al*., 2004; Toral-Granda *et al*., 2008; Purcell, 2010; Purcell *et al*., 2012, 2013; FAO, 2013), and a number of publications have also shown the developing interest in these resources in the tropics (Conand, 2006a, 2006b, 2008; Uthicke *et al*., 2010; Eriksson *et al*., 2010, 2015b; Ochiewo *et al*., 2010; Friedman *et al*., 2008; Purcell *et al*., 2013, 2014, 2016; Pakoa and Bertram, 2013; Conand *et al*., 2016a; Conand, 2017, 2018; Léopold *et al*. 2019). Many publications, generally more focused on one country, are found in the yearly issues of the SPC Beche-de-mer Bulletin.

Information has been recently gathered through a questionnaire conducted to prepare an up-to-date review for the IO region, and through access to most recent, yet unpublished available data (2015 to 2020). The data used comes from: 1) The status of the holothurian fisheries in the different countries through the evaluation of the catches and/or the processed product, the present management and/or its recent changes; 2) The imports of beche-de-mer and other products coming from the IO countries, in the major market hub of Hong Kong SAR, where it appears under several categories; and 3) The FAO yearly statistics on this commodity, by country and globally.
The different data are presented, analysed and a synthesis has been prepared to show the main characteristics for the region and the problems encountered during the last few years. The relevant regulations in the different countries have also been compiled where this information is available.

Results

The situation of each of the fisheries will first be presented from the different countries, by geographic sub-regions in the IO, based on the responses from local experts to the questionnaire and the regional results presented earlier in Conand (2008), FAO (2013), Purcell *et al*. (2013), Eriksson *et al*. (2015b) and several local recent papers. The recent Hong Kong market data and FAO statistics, for the region are analysed. Finally, management tools utilised and the issue of illegal fisheries is discussed.

Situation in the different countries

Countries in WIO: Mainland

Information has been obtained on the present status of sea cucumber fisheries in Egypt, Oman, Tanzania and Mozambique. No recent information from Erythrea, Yemen, United Arab Emirates, Somalia, Kenya and Kenya was available since the syntheses by Conand (2008), FAO (2013), Purcell *et al*. (2013), Muthiga and Conand (2014), and Eriksson *et al*. (2015b).

In the Egyptian Red Sea, following the situation presented in Conand (2008) the resource is considered overexploited; the holothurian populations were monitored at intervals between 2000 and 2016 by Hasan (2019) who showed a decrease in number of species (from 13 to 7), abundance and densities (very low density in 2006 and 2016 after the high density recorded in 2000). The uncontrolled exploitation peaked around 2002; as depletion was observed an official ban was declared in 2001, but it was non effective and lifted in 2002, but re-decreed in 2003, with an increase of illegal fisheries, leading to depletion. Hasan and Johnson (2019) experimented with the restocking of populations of *Holothuria fuscogilva* by transplanting wild-captured juveniles in the Gulf of Aqaba and showed that it can be effective. Juveniles were translocated from a robust population into two sites where population density, growth rate and mortality were monitored for two years; the restocking was successful only at one site.

In Oman, the status of the fishery has often changed in the recent period: unregulated in 2004-2005 (Conand, 2008), overfished in 2010 (Al-Rashdi and Claereboudt, 2010), 3 tons of dried trepang were recorded in 2013 and 5 tons in 2015, banned in 2018 (decision 2018/69 AD prohibiting fishing), with seizure of illegal catches mostly of *H. scabra* and an extension of the ban for two years, in 2019, in order to prepare a management strategy (Al Jufaili *et al*., 2021). Trials for aquaculture have now started (Al-Rashdi and Claereboudt, 2018; Al-Rashdi *et al*., 2018).

For Tanzania, the information presented here concerns the mainland, as Zanzibar will be considered with the islands. During the MASMA project (Conand and Muthiga, 2007, Muthiga and Conand, 2014) several studies were conducted (Mgaya and Mmbaga, 2007). Despite a ban being implemented from 2003, some fishers continued to exploit the holothurians and the available data are from Mmbaga (2013, 2015). The main species harvested were *H. scabra* and *H. nobilis ;* the average CPUE (g/fisher/hour) values for *H. nobilis* are 0.5 in Kunduchi, 0.4 in Buyuni, 0.6 in Kitoni (near MPA) and 0.3 in Magemani, with the catch being made mainly by men (64:4, n= 68). A few women were seen collecting firewood and were involved in processing. The situation is complicated by the differences in regulations between the Mainland and Zanzibar, and illegal practices (Mmbaga, 2015). An up-date of the fishery status in this country will be useful. Co-culture trials for seaweed and sea cucumbers were started since 2011, and the synthesis from the experiments and the questions asked is detailed in Kunzmann *et al*. (2018).

In Mozambique, sea cucumbers are known as Magajojo and they are distributed throughout the coast. Sea cucumber fishing is not a new activity, it has been in existence since the 1950s. In 1983, the country earned exports worth ~600 000USD. The catch was 500 t in 1983, 700 t in 1993 (DNP, 1995), and had declined to 6 t in 1995 and 54 t in 1996 (DNP, 1997), and between 2000 and 2004, when the last reports are available, production has been >10 t per year (Conand and Muthiga, 2007). Unfortunately, it is difficult to know to what extent the variability in the catch is due to irregular reporting in the provinces or to over-exploitation, but given that there has been such a dramatic drop in the catch, overexploitation is probably a reasonable explanation.

The fishery intensified in the 1990s resulting in its virtual collapse mainly in the southern area of the country (Maputo and Inhambane) (Abdula, 1998). This fishery is most important and practiced in some Mozambican coastal provinces with rocky substrate like Cabo Delgado and Nampula. Despite not having had a directed fishery, the Chinese have always been the main buyers. Currently the fishery takes place in the northern part of the country (Cabo Delgado and Nampula province), where the fishermen have reported a decrease in catches forcing them to move to deeper zones (Fernando *et al*. 2012) and the main reasons for the decline of sea cucumber was an increase in the number of harvesters, and a change in approach to harvesting such as Tanzanian people in Palma (in northern Cabo Delgado province) using Scuba diving equipment and taking the most valued organisms.

The sea cucumber fishery is mainly smallscale, practiced by men using diving and hand catch on rocky substrates and coral reef shores at depths ranging from 10-20 m. In a few regions of the country children collect *H. scabra* over the seagrass beds (Fernando *et al*., 2012). The market is driven by demand, with fishing occuring only if there is a buyer. The fishermen generally do not do any kind of processing but sell the wet product to Chinese traders who then procure an export license from the National Fisheries Administration, but in some regions, there are fishermen who boil the sea cucumber. The main commercial species harvested in Mozambique are *H. scabra, H. nobilis, H. fuscogilva, Actinopyga echinites, H. atra* and *Actinopyga mauritian*a. Other species also ocurr in Mozambique waters such as *Actinopyga lecanora, Stichopus chloronotus,* and *S. variegatus* with unknown catch levels, and a few more species remain unidentified (Fernando *et al*., 2012).

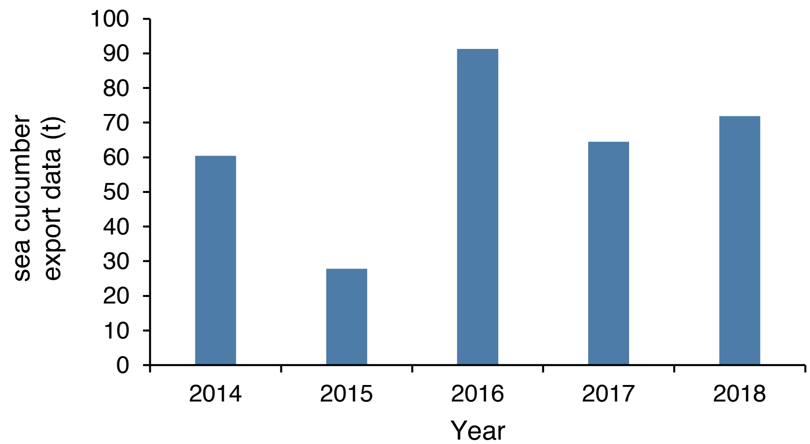

Figure 1. Annual exports of sea cucumbers from Mozambique.

According to Fernando *et al*. (2012) in Nampula and Cabo Delgado provinces the fisherman reported that the periods of high catch are related to the rainy season (October to April) in Nampula and dry season (July to August) at Cabo Delgado. CPUE ranges between 1 to 25 individual per fishermen per fishing day and daily profit ranges from 0.63 - 40. 63 USD. Stocks are severely depleted. The Mozambican legislation (REP-MAR- General Regulation on Maritime Fisheries, Decree 89/2020) establishes, in its annex II, a minimum size and weight for the catch of sea cucumber of 20 cm and 250 g, respectively, for all species of live/fresh sea cucumber. It prohibits the harvesting of the three species of *H. scabra, H. lessoni and Thelentota ananas,* including harvest of larvae or juveniles of any species, unless it is for aquaculture. Since some species contract when handled, it is difficult to carry out this control using size, so it is recommended, in parallel, to use the minimum weight (especially for species of the genus *Actinopyga* and for *H. fuscogilva*). In the legislation it is reported that the use of diving equipment is prohibited.

In recent years there has been a marked increase in the request for sanitary licenses for the export of this resource. There are two companies in Mozambique that export sea cucumber and the National Institute of Fishery Inspection (INIP) is responsible for issuing sanitary licenses and has been recording exports for the last 7 years. The exports are shown in Figure 1 (2014-2018).

There is no management plan for the sea cucumber fishery in Mozambique and no cooperation between stakeholders.

Countries in WIO: Islands

Recent information has been obtained from most islands, except Comoros which had been presented in FAO (2013).

Maldives. The sea cucumber fishery (locally known as "Huifilan'daa") is recent as it started in the mid-1980, with the export of a trial shipment of about 30 kg of prickly redfish (*Thelenota ananas*) to Singapore (Naeen and Ahusan, pers comm). They explain that the number of foreign buyers as well as the exporters engaged locally, as well as the number of species harvested increased as the fishery progressed. The diversity of holothurians has been described by Muthiga (2008), and Ducarme (2015, 2016). Nine species are now commercially harvested, processed and exported. The processed sea cucumbers are either taken to Malé, or directly to the exporters or to the agents of some of the major exporters based in the islands. Maldives bêche-de-mer was exported mainly to Singapore and Hong Kong SAR. However, in recent years, Sri Lanka has also become an importer of Maldives bêche-de-mer. The overall exports over the period (1988-2018) show a first phase of very sharp increase, followed by an important drop in 1994, then less significant variations. Since 2014, the export quantities ranged between 50 and 100 mt. It is clear that the high-valued sea cucumber stocks are heavily over-fished and drastic measures are required if the resource is to recover. At present, the only data available is from the export statistics, which report sea cucumber shipments as "dried sea cucumbers", "Fresh or frozen sea cucumbers", without categorizing them by species, or any differentiation between the wild-caught and farmed animals. Therefore it is strongly recommended that the species composition

Figure 2. Women collecting sea cucumbers at low tide on the easy coast of Zanzibar (Photo credit: M de la Torre-Castro).

of the exports be determined and tracked over time to identify shifts in harvested species.

Zanzibar. The situation in Zanzibar is complex, as the Tanzanian legislation is different for the islands and the Mainland. The fishery has a rather long history, starting more than a century ago; it declined as elsewhere during the World Wars and then Chinese traders initiated more intense harvesting during the 1960s (Eriksson *et al.*, 2010, 2015c). The organisation of the fishery ranges from small-scale near-shore activities (Fig. 2) to more mobile industrialised avtivities using scuba-diving (Eriksson *et al.*, 2010, 2012a.). Comparisons between the small-scale fisheries in Zanzibar (open access) and Mayotte (precautionary closure) have been presented by Eriksson *et al.* (2015c). These authors observe that in terms of resource value, catch and exports differ markedly, with more than 30 species caught in Zanzibar, and 90 % of the catch composed of low-value species. More recently, Eggersten *et al.* (2020) made a more precise comparison between these islands with an analysis of the economic value under contrasting management regimes, using three species, *H nobilis* (high value), *B. atra* (medium value) and *H atra* (low value). They conclude that these fisheries have high potential for providing social-economic benefits if properly managed.

According to to data from the Department of Fisheries Development exports of holothurians were 35.26 t in 2015, 26.39 t in 2016, and 29.62 t in 2017. The recent data does not however provide information on species or value.

In 2015, the Government of Zanzibar, through the Department of Fisheries Development issued directives that prohibited sea cucumber fisheries and promoted farming of sea cucumbers in Zanzibar. Thus, export of holothurians from farms is allowed. The lack of tracebility initially meant that it was difficult to ensure that the farms are not just transit points for fished specimens. However, random spot checks on farms by fisheries officers have helped to control this gap.

As a result of implementation of the Zanzibar mariculture sector development program a government-run multi-species hatchery was inaugurated in 2018, which aims at producing 1 million sea cucumber juveniles annually (Menezes, 2018), alongside finfish and crab production. Between 2017 and 2018 there were thirteen spawning trials producing over 7 million eggs (Y. Yussuf pers. comm.). Hatching rate ranged between 39 to 87%. Average survival rate of juveniles was 2.2%. Small scale trials on ocean based nursery system in rearing post-settled juveniles of *H. scabra* using floating hapas have been successful (Yussuf and Yahya, 2021). Some biological studies have been carried out in recent years, specifically on *H. scabra* (Yussuf and Yahya 2020). Trials are currently ongoing in Pemba Island, at small scale, on integrating seaweed and sea cucumber farming.

Mayotte. The commercially important species in Mayotte have been described in numerous papers, some of them recently (Pouget, 2004, 2005; Eriksson *et al*. 2012b, 2015c; Ducarme, 2018; Mulochau, 2018a). Following previous publications, the most recent inventory of the Echinoderms includes 45 holothurians species (Ducarme, 2018). Several studies by Eriksson *et al*. (2012a, 2012b, 2015b, 2015c) and Mulochau (2018a) have delt with their ecology, fishery and conservation. A moratorium on the fishery has been in place since 2004 (Prefecture de Mayotte 2004), but some illegal fishing has probably occurred.

Seychelles. Reports of sea cucumber fisheries in Seychelles date back to the 1800s. However, the fishery remained small-scale until the late 1990s when a rapid increase in catch was observed (Aumeeruddy and Conand, 2008). The increase in demand and price for "bêche-de-mer" led to an evolution in the fishery from the collector type by wading in shallow areas, to the use of scuba gears as fishers moved to deeper waters (Aumeeruddy and Payet, 2004). Historically in Seychelles, the targeted species were the black teatfish *H. nobilis*, the white teatfish *H. fuscogilva*, the flower teatfish *H. Microthele* sp., the blackfish *Holothuria atra* and the prickly redfish *Thelonota ananas* (Aumeeruddy and Payet, 2004).

In the late 1990s signs of decline in sea cucumber catches were observed and in 1999 the Seychelles Fishing Authority (SFA) introduced management measures for the fishery (Fisheries (Amendment) Regulations, 1999). Measures included issuing fishing and processing licenses and a limit in the number of divers per license. However, the management measures were precautionary due to a lack of baseline information on the status of the stock. The established measures were regarded as insufficient and a lack of catch data from fishers raised concerns over potential overexploitation of the resource. This led to the temporary closure of the fishery in 2001. The fishery was reopened the same year with new management measures. The number of fishing licenses was capped at 25, logbook and receipt books were issued to fishers and processors and catch reports were to be submitted to the SFA on a monthly basis (Aumeeruddy and Payet, 2004).

To improve upon the established measures, the SFA carried out a fishery independent resource assessment of the holothurian population between 2004 and 2005 (Aumeeruddy *et al.*, 2005). The assessment indicated that some species like sandfish *H. scabra* and redsurf *Actinopyga mauritania* were overexploited while the white teatfish and flower teatfish were fully exploited, and some other species were underexploited. One of these underexploited species was the high-valued black teatfish. Recommendations for management measures were made which included controls of the fishing effort to not exceed the recommended Total Allowable Catch (TAC), control in fishing effort for high value species close to the main islands, proposal to establish minimum size limits and the implementation of continuous periodic surveys to regularly assess the performance of management strategies (Aumeeruddy *et al.*, 2005). Some of the recommendations such as the TAC limits were highly contested by stakeholders involved in the fishery and were not adopted in the reviewed management measures.

As part of a project examining the sea cucumber fishery ecology, a fisheries independent stock assessment survey was carried out during 2011 – 2013. Abundance of some species like lollyfish and black teatfish were found to have declined when compared to the 2005 SFA survey. However, the blackfish (*A. miliaris*) indicated an increased abundance (Koike, 2017).

Another stock assessment was carried out in 2012 by MRAG, based upon the catch and effort data reported by fishers to SFA via the logbooks. The assessment comprised of a spatially disaggregated analysis of catch and effort data, the creation of a standardized commercial Catch Per Unit Effort (CPUE) series which was used as an indicator for relative abundance, and using surplus production models to estimate biomass and Maximum Sustainable Yield (MSY). From this assessment recommendations for management were made. These included, introducing catch limits based on the recommended TAC suggested in 2005 and improvement in the collection of catch and effort data to enhance the quality of data for more comprehensive stock assessments in the future. Following the assessment, new management measures were introduced, including minimum landing weight for white teatfish, flower teatfish, prickly redfish and black teatfish (MRAG, 2012).

Table 1. Breakdown of quota distribution in Seychelles, per species and per vessel.

	Flower teatfish	Prickly redfish	White teatfish	Total
Pieces per species	281,250	37,500	56,250	375,000
Pieces per vessel	11,250	1,500	2,250	15,000

Following the recommendation from the 2012 stock assessment, an agreement was reached between SFA and the stakeholders to review the management plan after three years. This led to another fisheries dependent stock assessment by MRAG in 2017. Evidence of significant population decline was observed especially for black teatfish in some areas (MRAG, 2017). Based on this finding, further measures were introduced including, reduction in the fishing season from nine months to eight months, a complete ban on fishing of the black teatfish and a defined TAC for three species and quota allocation.

The TAC was set in reference to the 2016 season, at a total of 375,000 pieces of sea cucumber. Under this TAC, allocations were only made on three harvestable sea cucumber species. The TAC and non-transferable quota were first introduced during the 2017/2018 fishing season. The breakdown of the TAC is highlighted in Table 1.

As per the Seychelles Cabinet Memorandum 2017-'New Management Measures for Sea Cucumber Fishery, the TAC is to be reviewed after three years or three consecutive opening seasons.' This exercice was carried out by the SFA in 2021, following the 2020/2021 fishing season. Table 2 and Figure 3 highlight the breakdown of the TAC consumed per species from the last four seasons (i.e., spanning from 2017 to 2021).

The R-squared (R^2) value is displayed for each species. The R^2 is a statistical measure that represents the proportion of the variance for a dependent variable (% Quota consumed) that is explained by an independent variable (Season).

Overall, the average quota for the White Teatfish and Prickly Redfish were well consumed. However, that of the Flower Teatfish (the species with the highest allocated quota) has been highly variable and averaging only 78 % over the period under review. The exact reasons for this remain unclear, although one possible factor could be the reduced natural abundance of this species. In order to determine the cause of this low quota intake for this species would require a more comprehensive analysis on a vessel-by-vessel basis.

A research project was conducted in 2017 and 2018 to strenghten the sea cucumber fishery co-management process through strong participation of fishers, skippers, and exporting companies in the research activities (Léopold and Govinden 2018). First, as part of a genetic study, 16, 19, and 25 microsatellite loci were isolated from White Teatfish, Flower Teatfish, and Black Teatfish DNA libraries, respectively (Oury et al. 2019a, 2019b). These loci were used for assessing genetic diversity and population structure of these taxa over the Mahé plateau and the Amirantes islands. The Flower Teatfish was structured in one single population (n=437 samples, 8 sites) while small, yet significant, genetic difference was observed among White Teatfish samples (n=348 samples, 7 sites). That spatial structure likely arose from the low abundance of White Teatfish over the fishing areas, which called for spatial management of White Teatfish resources that are protected by Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Second, the size at sexual maturity of the Flower Teatfish was estimated at 30.3 cm through a reproductive biology survey and macroscopic observations of the gonads of 93 specimens in the SFA lab (Cahuzac et al. 2019), which was informative to discuss a minimum catch size of that species. Third experimental dive fishing and commercial dive profiles showed that underwater visibility and depth impact catch rates, and, consequently, should be recorded in commercial logbooks for estimating CPUE index. Finally, an electronic logbook and an online database were experimented by SFA to facilitate fishery monitoring and fishery-dependent stock assessment. However, this monitoring system has not been deployed at the fishery scale yet due to technical constraints and acceptability issues among some skippers of the fishery.

Following lengthy discussions and presentations to the SFA Board of Directors, sea cucumber stakeholders and the Minister responsible for Fisheries, a decision was taken in 2021 to reduce the current allocated

Table 2. Breakdown of the consumed TAC in Seychelles, per species from the last four seasons. PR- Prickly Redfish, WT- White Teatfish, FT- Flower Teatfish

Season	Consumed PR	% Consumed	Consumed WT	% Consumed	ConsumedFT	% Consumed
2017-2018	32,130	86	47,862	85	193,103	69
2018-2019	37,554	100	50,249	89	177,929	63
2019-2020	37,061	99	66,491	118	268,047	95
2020-2021	38,494	103	53,241	95	243,169	86
Average	**36,310**	**97**	**54,461**	**97**	**220,562**	**78**

quota of the Flower Teatfish by 10 %. Therefore, the allocated quota set for the 2021-2022 sea cucumber fishing season is prescribed below in Table 3. It was also agreed that the quota and overall fishery would be reviewed following a scheduled independant stock assessment of sea cucumbers planned for late 2021 and early 2022. The Seychelles has adopted a co-management approach to the independent stock assessment exercise. Sea cucumber commercial divers participated in the data collection and data analysis segments of the survey, after undergoing extensive training by the SFA. Since fishing activities are mainly concentrated on the Mahé Plateau and the Amirantes groups, the same sites as for the 2005 assessment were surveyed (Fig. 4). This allowed a comparison over a 16-year time period. The specific survey points at each of the sites were selected using random stratified sampling where the Mahé Plateau and the Amirantes were stratified by habitat types, depths and the limits of the marine protected areas. Power analysis was then used to calculate the number of sites for each identified stratum based on fishing pressure and the sites were randomly selected within each stratum.

The survey was carried out in two phases; the first part was completed in November 2021, and the second in March 2022. The analysis and results of the stock assessment were recently finalized and presented to the Board of Directors of the SFA, as well as to the Ministry of Fisheries. The ultimate fate of the Seychelles' sea cucumber fishery will be disclosed to the sector through a National Sakeholder Workshop being planned for the first week of September 2022.

La Réunion. Several studies have been conducted on the biology and ecology of the main holothurians from La Reunion. An inventory of the 38 holothurian species has been published (Conand *et al.*, 2010;

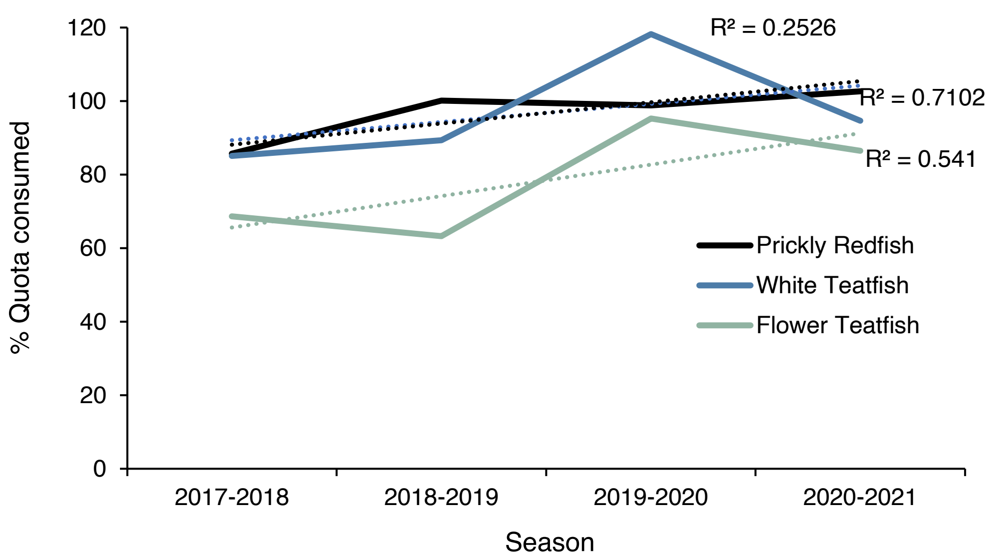

Figure 3. Line graph displaying the percentage quota in Seychelles consumed per species per season. Also displayed is the R^2 value for each species.

Table 3. Breakdown of quota distribution in Seychelles, per species and per vessel following a 10 % reduction of the Flower Teatfish in 2021.

	Flower Teatfish	Prickly Teatfish	White Teatfish	Total
Pieces per species	253,125	37,500	56,250	346,875
Pieces per vessel	10,125	1,500	2,250	13,875

Conand *et al.*, 2018); detailed information is also provided in a book on the echinoderms (Conand *et al.*, 2016a). Given the small size of the reefs, no fishery is authorised. Very recently, illegal fishing activities have been observed within the Marine Nature Reserve of Reunion Island. https://www.facebook.com/groups/1736481600015091/posts/2972490759747496

Eparses Islands (Scattered Islands, Canal du Mozambique). These isolated and inhabited islands are now a Natural Reserve and good sites for biodiversity inventories, but are also vulnerable to illegal fisheries (Conand *et al.*, 2016b). Several scientific programmes were conducted during the recent years in collaboration with the french TAAF. Inventories and/or abundances of the holothurians have been made for the different islands, such as for the Glorieuses Islands and Geyser Bank (Conand *et al.*, 2013a; Mulochau and Gigou, 2017; Mulochau, 2018b), Europa (Conand *et al.*, 2013b), and Juan de Nova (Mulochau *et al.*, 2015). A global inventory for the Echinoderms of the Eparses Islands includes the occurrence and habitats of 31 holothurians (Conand *et al.*, 2016b). Discussions between the Goverments of Madagascar and France for agreements and cooperation have taken place. Recent observations of illegal fishing (2021, pers. com.) have been made in the Glorieuses, Juan de Nova and Bassas da India. The TAAF regularly make fishing seizures around the Eparses Islands. Some catches were made on the Geyser Bank (Mulochau, 2018b), but the recent creation of the 'Réserve Naturelle Marine des Glorieuses' by TAAF will allow better monitoring.

Mauritius and outer islands. Sea cucumbers (*barbara* in Mauritian creole) have been exploited traditionally by the local Chinese communities for domestic consumption. The commercial exploitation started in late 2005 and after three years of commercial harvest

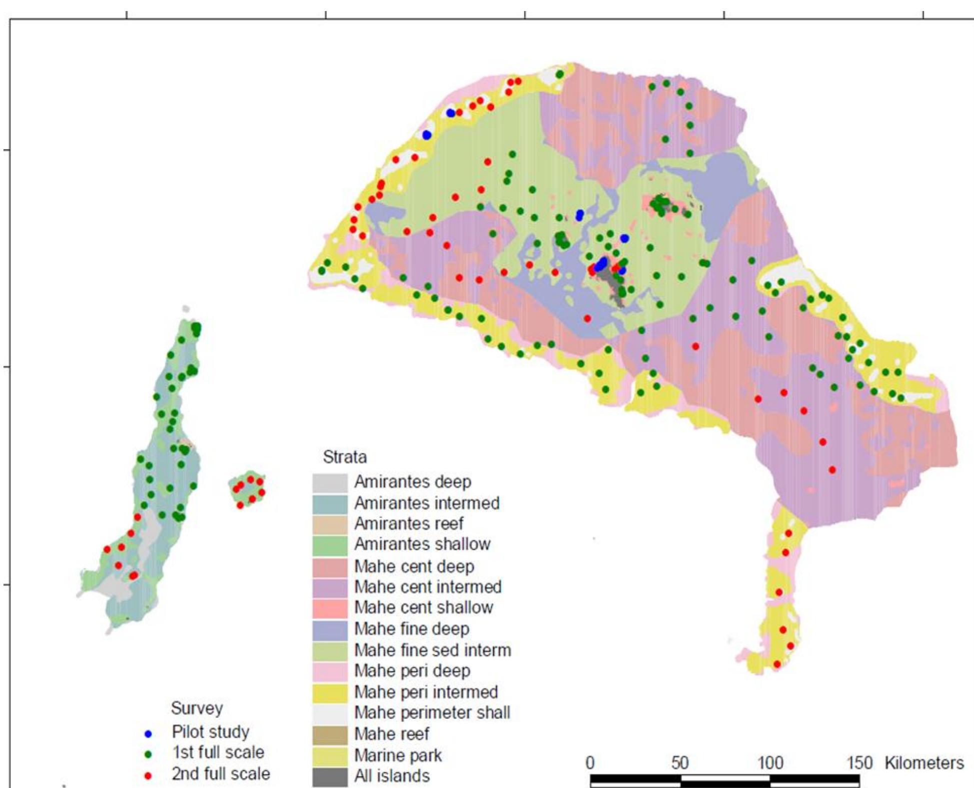

Figure 4. Sampling sites selected in Seychelles, based on the different stratifications for the 2005 resources assessment survey (Aumeeruddy *et al.*, 2005).

Table 4. Temporal relative abundances of nine species of sea cucumber around Mauritius and Outer Island lagoons. Note: data from 1998 are being used as measure of the virgin stock for Mauritius.

	Relative abundances in the lagoon of Mauritius				Relative abundances in the lagoon of Rodrigues		Relative abundances in the lagoon of Agalega	
	1998	2011	2013	2016	2007	2016	2008	2016
	n = 1129	n = 3411	n = 7488	n = 9963	n = 2734	n = 3397	n = 944	n = 2328
Average denssity (ind ha^{-1})	564	487	602	2640	854	1697	710	1290
Number of sites surveyed	2	16	23	12	16	10	8	8
Species composition (%):								
Holothuria scabra	0.44	0.00	0.01	0.00	0.04	0.00	0.00	0.00
Actinopyga echinites	3.45	1.08	0.75	0.10	0.15	0.09	0.00	0.00
Stichopus chloronotus	8.24	6.39	11.77	0.30	0.95	5.50	99.70	99.90
Thelenota ananas	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stichopus variegatus	0.09	0.18	0.00	0.00	0.07	0.00	0.00	0.00
Bohadschia vitiensis	36.49	3.22	4.73	1.70	0.37	0.98	0.00	0.00
Holothuria atra	24.89	29.14	51.94	12.20	91.19	72.70	0.30	0.10
Holothuria leucospilota	19.31	11.93	3.21	85.60	7.21	20.70	0.00	0.00
Holothuria pervicax	6.73	1.99	1.54	0.00	0.04	0.03	0.00	0.00
Sources	Luchmun *et al.* (2001)	Lampe (2013)	Lampe *et al.* (2014)	AFRC (2016a)	AFRC (2007)	AFRC (2016b)	AFRC (2008)	AFRC (2016c)

Note
- High commercial value
- Medium commercial value
- Low commercial value

destined for export market, the resource was considered as depleted. The commercial exploitation of sea cucumber resources started with the issuance of export permits to two companies in 2006 for a six-month trial period. Following this trial period, at least 12 other companies benefited from an export permit for the same duration and under strict quota conditions set and monitored by the government. The first full stock assessment of sea cucumber resource in Mauritius was conducted in February 2007 by staff of Albion Fisheries Research Centre amid concerns of over-exploitation of the stock. Following the surveys, a Total Allowable Catch (TAC) of 550 tons (wet weight) was equally distributed among 5 companies for a six-month period and a regulation was promulgated under the Fisheries and Marine Resources Regulations of 2008, stating a minimum size limit of 15 cm for all species and a three-month closed season from 01st January to 31st March. The total production reported from all operators in 2007 was 408 tons (wet weight). Overall the production data (in dry weight) from 2006, 2007, 2008 and 2009 were 94 t, 50 t, 21 t and 5 t respectively (AFRC, unpublished data), amounted to approximately USD 1.8 million and the main export markets were Hong Kong, Singapore and Taiwan.

A new regulation came into force in October 2009 introducing a two-year moratorium period to ban the collection of sea cucumbers in Mauritian waters, including the outer islands (Rodrigues, Agalega and St Brandon). Mauritius was the first country in the Western Indian Ocean to introduce and enforce a moratorium on sea cucumber fishing. A second moratorium period was introduced from March 2012 to February 2016 and following stock assessment surveys carried out in August 2016 in Mauritian waters, the moratorium was extended for another 5 years.

Table 4 shows a summary of the relative abundances of sea cucumber from stock assessment surveys carried out during and after the exploitation period in Mauritius and the outer islands. The surveys conducted by AFRC employed the standardised belt transect method comprising a main transect of 100 m and five 20 m sub-transects. Sea cucumbers were enumerated within a 2.5 m belt on either side of the transect line, with a total surface area surveyed of 1000 m^2. Data from the lagoons around Mauritius were compared with data from Luchmun *et al.* (2001), used here as virgin stock since the surveys were done prior to commercial exploitation. The diversity had also been assessed in shallow sites by Lampe-Ramdoo *et al*. (2014). Table 4 shows a net loss in diversity of sea cucumber in Mauritian lagoons following a 4-year period of intensive fishery. A Simpson Diversity Index (SDI) was applied to the data in 1998 and 2016, showing a net drop in SDI from 0.75 (in 1998) to 0.25 (in 2016). Sea cucumber species of high to medium commercial value, such as *H. scabra*, *Thelenota ananas* and *Stichopus herrmani* have almost completely disappeared during the exploitation period and had not recovered by 2016 (the last surveys done). Species such as *H. atra*, *H. leucospilota* and *S. chloronotus* were among the most abundant in the years following the closure of commercial exploitation. Interestingly, these species are among the few sea cucumber species that can reproduce asexually through fission. The increase in average density (see Table 4) seems to indicate that these species have taken over the habitats left by the depleted ones.

Baseline data, prior to onset of commercial harvest in 2006, from the lagoons of Rodrigues Island (Rowe and Richmond, 2004) indicated 29 species of Holothurioidea, of which 18 were of commercial importance. Surveys done in July and August 2006 (Mrowicki, 2006), reported 8 species of sea cucumber (6 being commercially important) with *H. atra* (72 %), *H. leucospilota* (11%) and *S. chloronotus* (11%) being the most dominant and widespread species. Subsequent surveys done by AFRC staff in 2007 and 2016 (see Table 4) showed the same trends as in Mauritius, with a decrease in diversity from 18 commercially important species in 2004 to 6 in 2016. The most thriving species, after the exploitation from 2006 to 2009 and ban imposed in 2009, were those that could also reproduce by asexual reproduction. They were found to occupy all the different habitat types surveyed (sand, rock/coral rubbles, coral, seagrass and macroalgae).

Three surveys were done from 2006 to 2019 on the diversity and stock assessment of sea cucumber in the lagoons and outer reef flats of St Brandon. In 2006, the Ministry of Agro Industry and Fisheries commissioned a 6-day trip to St Brandon to survey the diversity of sea cucumber prior to allowing one company to exploit the resource. Ten species of sea cucumber were recorded from north to south of the atoll; these were *H. nobilis* (high value species); *Actinopyga mauritiana*, *A. miliaris*, *Thelenota ananas* and *Stichopus chloronotus* (medium value species); and *A. echinites*, *Bohadshia marmorata*, *H. atra*, *H. fuscopunctata* and *H. pervicax* (low value species). Three species were most abundant, namely *S. chloronotus* (24,000 ind/ha), *H. atra* (20,000 ind/ha) and, *A. miliaris* (6000 ind/ha) although they were patchily distributed. Eeckhaut (2010) conducted a survey on the atoll in view of determining its suitability for sea cucumber farming. Eleven species of sea cucumber were recorded, namely *H. nobilis* and *H. fuscogilva* (high value species); *T. ananas*, *S. chloronotus*, *S. hermanni*, *A.miliaris* and *A. mauritiana* (medium value species); and *A. echinites*, *H. atra*, *Holothuria sp*. and *Bohadshia vitiensis* (low value species). The most abundant species were *H. atra* (50,000 ind/ha), *S. chloronotus* (patches of 20,000 ind/ha), and *B. vitiensis* (2000 ind/ha). The latest survey was done in March 2019 and commissioned by the Mauritian Wildlife

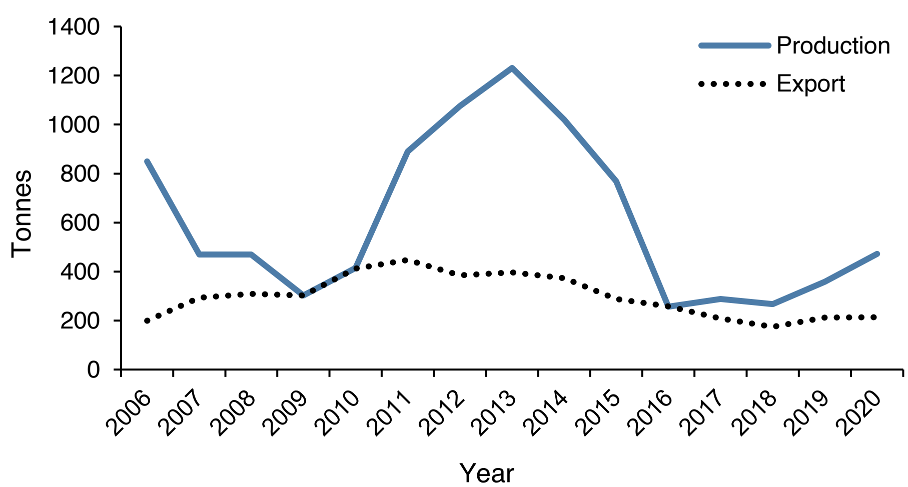

Figure 5. Recent yearly volumes of trepang production (data from MPEB) and exports from Madagascar (data from ASH).

Foundation (Ramah, 2019). Twenty-five sites on the atoll were surveyed and five species of sea cucumber were recorded, namely, *H. nobilis* (high value species); *S. chloronotus* (medium value species); and *H. atra*, *A. echinites* and *Bohadshia atra* (low value species). Two species were most abundant; *S. chloronotus* (25,000 ind/ha) and, *H. atra* (15,000 ind/ha). High value species such as *H. scabra* (sandfish) were not observed in all the surveys since they were conducted only during the day. Habitats suitable for sandfish were mostly observed on the northern part of the atoll (Eeckhaut, 2010).

Surveys done in 2008 and 2016, showed that the lagoons of Agalega have one predominant species, *S. chloronotus* (Table 4). Precaution should be taken while interpreting these data since no night surveys were done and it is possible that cryptic and nocturnal species were not recorded. The average density of *S. chloronotus* was 710 ind/ha in 2008 and increased to 1300 ind/ha in 2016, which is not as high as at St Brandon. *S. chloronotus* did not show any particular habitat preferences since it was observed on almost all substrates (coral rubbles, sand, and macroalgae). It is worth noting that local residents reported that about 30 t (wet weight) of sea cucumber were harvested in 2007 and since then, only the abovementioned species has recovered (AFRC 2008, 2016).

The sea cucumber stock in Mauritius and outer islands suffered from the 3 years of commercial exploitation. A drop in sea cucumber diversity was observed in all locations during the years following the open season. Some species have not recovered following a decade long moratorium and will probably never recover. An interesting observation is the increase in numbers of species such as *S. chloronotus* and *H. atra*, which, due to their ability to reproduce asexually are not affected by depensation. They can therefore proliferate quickly and occupy the habitats left by the other species that were locally depleted due to overfishing. Indeed, *S. chloronotus*, which is a species generally observed on coral rubbles of reef flats and upper slopes, was observed to occupy different habitat types such as coral rubbles, sandy patches, macroalga and seagrass patches.

Madagascar. The fishery is artisanal but the stocks of the high value species are mostly depleted and the fishers have adapted to find new sites and/or new species (Conand, 2008; Purcell *et al*., 2013). The recent data on the production and the exports are shown on Figure 5.

A slight increase of the exports was observed from 2006 to 2011, where the maximum export level of trepang was reached (448 t). From 2012, a continuous decrease of trepang exports was recorded to 174 t in 2018 (source: Autorité Sanitaire Halieutique ASH). In apparent contract, a large increase of trepang production was also recorded from 2011 and a maximum production of 1,231 tonnes was reached in 2013. This increase in production is linked to the illegal fishing of sea cucumbers (the use of scuba diving) especially in the northeast region of Madagascar. A slow increase is noted from 2019 and 2020.

The differences between the production data (source: Service Statistique du MPEB) and the export data (ASH) could be explained by local sales and illegal exports.

Countries in East IO

Recent information and contributions have been submitted by the co-authors for Sri Lanka, India and Western Australia.

Sri Lanka. The sea cucumber fishery has a long history in Sri Lanka (Adithiya, 1969; Conand, 2008) being seasonal in relation to mooson winds, and several recent papers show its present importance (Dissanayake and Wijayarathne, 2007; Dissanayake and Stefansson, 2010, 2012; Nishanthan *et al*., 2019, Dalpathadu, 2021).

An underwater visual census (UVC) carried out on the northwest and east coasts of Sri Lanka in 2008 reported the presence of 25 sea cucumber species. The results of this survey revealed that the overall average density (±SD) of sea cucumbers was higher in the northwest (350 ±648 ind ha^{-1}) than in the east (90 ± 130 ind ha^{-1}) and low-value species were predominant in both survey areas (79 ±125 ind ha^{-1} in the east, 244±488 in the northwest) when compared with the medium (10±34 ind ha^{-1}, 105±175 ind ha^{-1}, respectively) and highvalue category (<2 ind ha^{-1}, Dissanayake and Stefansson, 2010).

The detailed study by Nishanthan *et al*. (2019) based on data collected from November 2015 to January 2017, shows the fishing pattern, and the social and economic characteristics of sea cucumber fisher communities in the north, north-west and north-east regions of Sri Lanka. In total nine sea cucumber species are landed in these areas, using three methods: diving (SCUBA and breath-hold); gleaning; and surrounding nets. SCUBA diving is the dominant method and divers do both day and night fishing, reporting the highest catch rates (CPUE ± SD in numbers/person/day) compared to the other fishers. Gleaning is entirely carried out by fisherwomen in the northern region, while 28 surrounding nets are used targeting the low-value *Stichopus naso*. The CPUE varied with species, region and fishing method. *Bohadschia vitiensis* made up the highest percentage contribution (61.3 %) to the total sea cucumber landings during the study period. The high value teatfish species (*H. fuscogilva* and *H. nobilis*) are not reported any longer. Among all fishers, SCUBA divers reported the highest average net monthly income. Men play a dominant role in sea cucumber fishing (98 %), processing (99 %) and marketing (100%). Fishermen are in the age range of 25–67 yrs, having only primary education and mainly involved in the sea cucumber industry. The sea cucumber value chain consists of fishers (~ 2000), middlemen (12), processors (16), and exporters (7). A significant increase in overall price development from fishers to the exporters was reported for all nine species. Fishers received a proportionally higher share of the end-market price mainly for low-value *Bohadschia* spp. Although fishers receive disproportionately low returns compared to others, 47.8 % of fishers showed high satisfaction towards the prices they received from buyers. However, 83.6 % of fishers are not satisfied with existing management measures (Table 5). This information is important to strengthen the existing management measures in Sri Lanka.

Recently, Dalpathadu (2021) has evaluated the fisheries in the coastal waters of Trincomalee district, Eastern Sri Lanka, showing the population depletion of most species in the shallow waters. Logbook record-based surveys were conducted to cover the fishing season in 2019. The harvest was collected by skin diving from shallow nearshore waters and Scuba diving from coastal waters about 5 km away from the shore. *Thelenota anax* was the dominant species in the catch from both fishing grounds. The study revealed that the stock of *T. anax* along with other species in these coastal waters might be moving towards extinction if the fishery prevails without proper management.

A detailed study by Bondaroff (2021) analyses highly organised poaching and smuggling of sea cucumbers, which has been on the rise in Sri Lanka and the south of India. The 120 incidents analysed reveal 502 arrests.

Table 5. Holothurian fishery in Sri Lanka. A: informations from the north, north-west and north-east coast of Sri Lanka from November 2015 to January 2017. B: variation in CPUE for the different species (number/person/day), from the north, north-west and north-east coast of Sri Lanka from November 2015 to January 2017. Modified from Nishantan *et al.* (2019).

A_ Parameter	**Northwest**		**North**				**NorthEast**
	SCUBA	Snorkelling	SCUBA	Snorkelling	Gleaning	Netting	SCUBA
Fishing Effort	335	102	68	305	27	28	372
CPUE (nb/ person/day)	88	43	100	31	14	35	558
Distance to fishing (km)	29	15	10	8	2	16	31
Total income /person (US$) /day	68.9	23.2	21	12.1	5.1	9.8	80.7
nb of fishing days / month	14	15	14	15	4	20	15
Fishing months / Y	5	4.5	4.5	4.6	5	5	4.5
Net income /month (US$) /person	517	288	210	205	31	107	888
Total landings (Nbx 10^3)	2 926		2 017				12 303

B. Species	**North-West**		**North**				**North-East**
	SCUBA	Snorkelling	SCUBA	Snorkelling	Gleaning	Netting	SCUBA
H. scabra	109	43	3	10	14		
H. spinifera	25		17	4			72
T. anax	41						
S. chloronotus	3						
H. atra	1		32	6			
B. marmorata	3		2				
B. sp l	3		2				
B. vitiensis	1						486
S. naso	1		44	11		35	

He concludes that it should be treated as a form of transnational organised crime. Monitoring and enforcement efforts should be expanded and intergovernmental and interagency cooperation increased.

Finally, sandfish farming activities are rapidly developing in northern Sri Lanka. There are 2-3 functioning hatcheries at present, and two sea cucumber villages are proposed to be established. Sandfish fattening activities are currently carried out using lagoon pens (size range from 1 – 10 Ha) and there are 100 – 150 being operated at present. However, conflicts between sea cucumber farmers and fishers are very common as farmers collect small-sized sandfish from the natural environment. However, with the establishment of the proposed sea cucumber villages, more hatcheries will be established, and then the use of wild-collected individuals in farming activities will be banned.

India. Holothurians are mainly distributed in the Gulf of Mannar and Palk Bay, Andaman and Nicobar, Lakshadweep, Gulf of Kutch and along the mainland coast of India in variable numbers (Asha *et al.*, 2019). The fishery was artisanal in nature and was introduced by the Chinese more than a thousand years ago in the Gulf of Mannar and Palk Bay (Hornell, 1917). The industry comprised fishermen, who are divers, the processors who act as middlemen, and the exporters. The fishery was mainly dependent on high valued *H. scabra* and the medium valued *H. spinifera*, and occasionally on medium valued *Actinopyga miliaris*, *A. echinites* and *Stichopus hermanni* based on their availability (Asha *et al.*, 2017). Numerous studies have also been conducted by James (2004) after the industry came to a standstill when the Ministry of Environment, Forests and Climate Change of India imposed a total ban on the sea cucumber fishery in June 2001 and listed all holothurians as protected animals under the Schedule I of the Indian Wildlife, which severely affected the livelihood of the poor fishers of this region. A reliable long-term estimate was not available on the exploited as well as potential stocks of holothurians in Indian waters. A short-term survey conducted by the Zoological Survey of India (ZSI) along the Gulf of Mannar in 2007 reported the availability of seven species, with *H. atra* as the dominant one. Another survey conducted by the ZSI in 2011-12 also indicated the occurrence of nine and seven species in the Gulf of Mannar and Palk Bay, respectively (Venkataraman *et al.* 2012). A fundamental barrier to improved knowledge and management of sea cucumbers was the lack of data on population abundance/biomass and basic biological parameters of most of the species. The large dependent coastal population in the Gulf of Mannar and Palk Bay, high value of the species and the ease with which the sea cucumbers can be collected, allows illegal harvest, leading to potential biological and ecological vulnerability of the stocks.

Fourteen years of the sea cucumber fishing ban has caused considerable changes in the stock status. Scientifically supported information on the population characteristics of sea cucumber resources in the Gulf of Mannar and Palk Bay, two geographically distinct ecosystems, was very much needed for formulating sustainable management measures for these resources and the recent study by Asha *et al.* (2019) was aimed to fill the gap in this respect. It indicated variation in status and structure of sea cucumber resources in the Gulf of Mannar and Palk Bay. The difference is mainly linked to the unique environmental characteristics of both the ecosystems; hence, ecosystem-based management approaches should be given more emphasis while formulating conservation measures for these resources in the region.

The stock status of the sea cucumber population was assessed both by trawl and dive surveys following standard methods on a random basis. Comparatively, a higher average density of total sea cucumbers was estimated in the Gulf of Mannar (3853±152.3 nos. ha-1) than in Palk Bay (2428.5±504.6 nos. ha-1). The species diversity, average length and weight of individual species were also higher in the Gulf of Mannar. While comparing with previous post-ban surveys, this study also indicated wide fluctuation in the sea cucumber population status. Hence it is recommended to conduct fishery-independent and dependent surveys of the sea cucumber stock at a regular interval as per the standard survey and methodologies for the development of time series data on population metrics from this region. It is also suggested that long-term mark-recapture studies are implemented to assess the growth, dispersal, mortality rates and longevity of sea cucumber resources for better clarification on population structure in order to formulate management measures for the conservation and sustainable utilisation of the resources (Asha *et al.*, 2019).

The poaching and smuggling that is increasing in Sri Lanka and the south of India has been analysed by Bondaroff (2021). It is recommended that cooperation between countries is necessary for effective management.

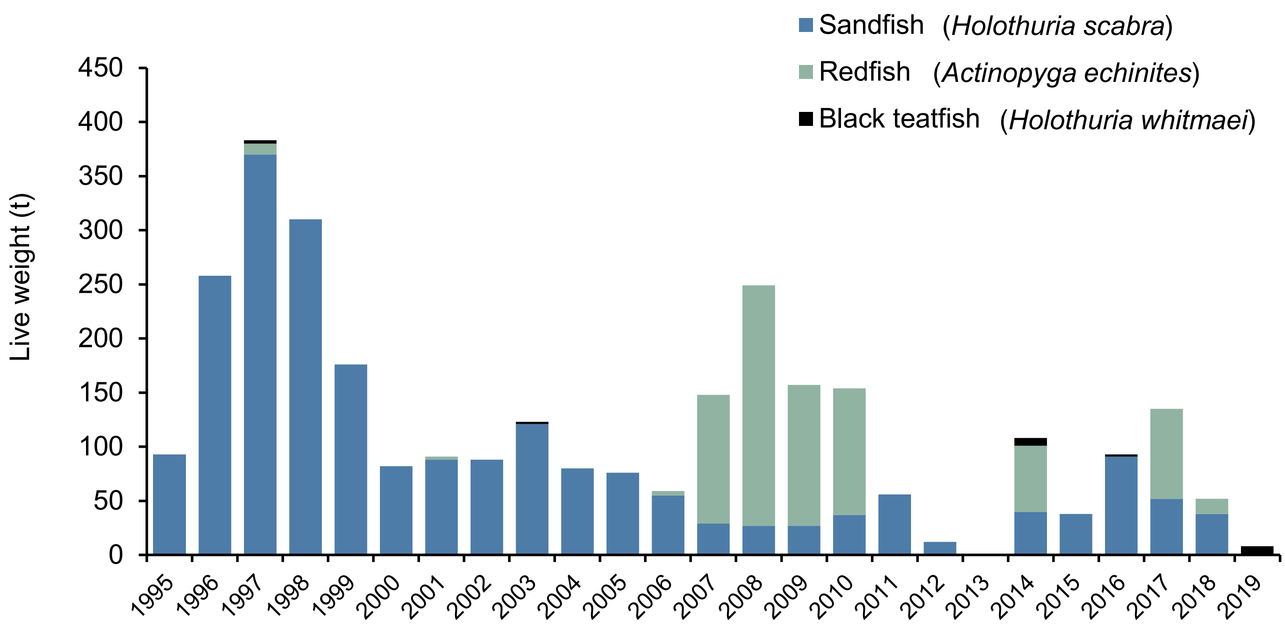

Figure 6. Annual total retained catches (tonnes) in the Western Australian sea cucumber fishery (WASCF) between 1995 and 2019. Adapted from Hart & Murphy (2021).

Western Australia. This reletively recent fishery for holothurians is a small commercial fishery as shown in Figure 6 where live weight captures since 1995 are presented (Gaughan *et al*., 2019; Newman et al., 2021; Hart & Murphy, 2021). As elsewhere, the fishery followed the 'boom and bust' scenario. Essentially based on the sandfish *H. scabra* initially, it decreased after ten years and targeting the redfish *Actinopyga echinites* allowed a new peak in 2008. The teatfish *H. whitmaei* only represents occasional captures. The holothurians are mostly collected by diving in remote areas, accessed only by boat. The stock status is managed through input controls including limited entry, maximum number of divers, species-dependent minimum size limits, and gear restrictions. The Pilbara area of this fishery has achieved Marine Stewardship Council certification.

In 2019, two species were targeted, with a total catch of 6.9 t (Fig. 6). This catch comprised 2.1 t of sandfish (*H. scabra)* and 4.8 t of deepwater redfish (*A. echinites*). This was lower than the 2018 total of 61 t (sandfish 36 t; deepwater redfish 25 t). The industry has adopted a rotational fishing strategy for both sandfish and redfish with limited catch taken for either species in 2012 and 2013, and no fishing for sandfish in the Kimberley in 2018 and 2019.

Details are given on the different stocks (Hart *et al*., 2022). For the Kimberley Sandfish (Sustainable – Adequate) based on the information and analyses available, the current risk level was estimated to be Medium, consistent with previous assessments of the fishery. For the Pilbara Sandfish (Sustainable – Adequate) based on the information and analyses available, the current risk level was estimated to be Low. For the Pilbara Redfish (Sustainable – Adequate) based on the information and analyses available, the current risk level was estimated to be Low. This is consistent with previous assessments of the fishery.

Given the hand only method of fishing, no bycatch is taken by the fishery and there are no known protected species interactions. This fishery harvests only a small amount of sandfish and redfish per annum. The effect from this harvesting on the rest of the ecosystem, given that the catch is spread over a wide region, would be insignificant.

Social and economic outcomes are also presented (Hart and Murphy, 2021): the social outcomes are at low risk level, as 4 to 6 crew are employed on a vessel, comprising a master, deckhand and divers. Additional individuals are employed for the processing of the product. These activities are mostly located in the Northern Territory and Victoria where the fishing fleet is based. The economic outcomes are also at low risk level, as the estimated annual value for 2019 was $29,325 based on a total live weight of 6.9 tonnes and $4.25 per kg. This is only a beach-price value and the processing sector adds significant value. Concerning

Table 6. Hong Kong imports 2017-2020. A- quantities in kg. B - values in HK$.

A-Quantities, Kg

Country	2017	RK	%	Country	2018	RK	%	Country	2019	RK	%	Country	2020	RK	%
Yemen	214 233	1	5.15%	Sri Lanka	196569	1	4.78 %	Sri Lanka	194495	1	6.58	Yemen	123472	1	7.38
Sri Lanka	176 170	2	4.24%	Yemen	179015	2	4.35%	Yemen	134507	2	4.55	Sri Lanka	118740	2	7.09
Madagascar	134 489	3	3.23%	Mozambique	88742	3	2.16%	Mozambique	57032	3	1.93	Madagascar	62690	3	3.75
Mozambique	119 675	4	2.88%	Madagascar	84509	4	2.05%	Seychelles	51969	4	1.76	Seychelles	44516	4	2.66
Maldives	76 114	5	1.83%	Maldives	69202	5	1.68%	Madagascar	47569	5	1.61	Tanzania	21873	5	1.31
Tanzania	54 865	6	1.32%	Seychelles	48991	6	1.19%	Maldives	42345	6	1.43	UAE	18621	6	1.11
Seychelles	51 820	7	1.25%	Kenya	39533	7	0.96%	Kenya	31533	7	1.07	Maldives	18175	7	1.09
Kenya	34 846	8	0.84%	Oman	25596	8	0.62%	Tanzania	27754	8	0.94	Kenya	13239	8	0.79
Oman	15 507	9	0.37%	Tanzania	25448	9	0.62%	Egypt	19786	9	0.67	Egypt	12140	9	0.73
Egypt	11 643	10	0.28%	Saudi Arabia	14110	10	0.34%	Saudi Arabia	10037	10	0.34	Saudi Arabia	4230	10	0.25
Saudi Arabia	8 879		0.21%	Mauritius	3880		0.09%	Oman	9756		0.33	Mozambique	2645		0.16
India	7 548		0.18%	Sudan	3739		0.09%	South Africa	6540		0.22	Mauritius	2551		0.13
UAE	7 245		0.17%	UAE	3281		0.08%	Somalia	6312		0.21	Oman	2215		0.13
Mauritius	4 786		0.12%	Somalia	2490		0.06%	Sudan	5935		0.20	South Africa	1348		0.08
Sudan	2 030		0.05%	South Africa	2615		0.06%	UAE	4128		0.14	Somalia	1250		0.07
Jordan	292		0.01%	Iran, islamic republic	945		0.02%	Mauritius	3675		0.12	Sudan	636		0.04
Somalia	405		0.01%	Egypt	853		0.02%	Ethiopia	1540		0.05	Qatar	171		0.01
South Africa	149		0.00%	Ethiopia	252		0.01%	Iran	663		0.02	Ethiopia	165		0.00
Ethiopia	110		0.00%	India	246		0.01%	India	616		0.02	Djibouti	0		0.00
Djibouti	70		0.00%	Pakistan	120		0.00%	Qatar	581		0.02	India	0		0.00
				Qatar	52		0.00%	Djibouti	42		0.00	Iran	0		0.00
total IO	**920 876**		**22.14%**	**total IO**	**790188**		**19%**	**total IO**	**656815**		**22%**	**total IO**	**448677**		**27%**
All countries	**4 158 818**			**All countries**	**4 116 795**			**All countries**	**2954775**			**All countries**	**1673908**		

B-Values, HK$

Country	2017	RK	Country	2018	RK	Country	2019	RK	Country	2020	RK
Yemen	65218	1	Sri Lanka	59572	1	Sri Lanka	68155	1	Yemen	60476	1
Sri Lanka	40442	2	Yemen	58104	2	Yemen	60491	2	Sri Lanka	53663	2
Madagascar	15562	5	Mozambique	3486	8	Mozambique	3851	8	Madagascar	9911	5
Mozambique	21582	3	Madagascar	31865	3	Seychelles	4665	7	Seychelles	15214	3
Maldives	14238	6	Maldives	16455	4	Madagascar	9727	4	Tanzania	12257	4
Tanzania	20855	4	Seychelles	3027		Maldives	16540	3	UAE	3113	8
Seychelles	4709	9	Kenya	3463	9	Kenya	2787		Maldives	6372	6
Kenya	2864		Oman	3323	10	Tanzania	3796	9	Kenya	2159	9
Oman	6273	7	Tanzania	7998	6	Egypt	7646	5	Egypt	3481	7
Egypt	3372		Saudi Arabia	12036	5	Saudi Arabia	6079	6	Saudi Arabia	1414	10
Saudi Arabia	5508	8	Mauritius	1289		Oman	997		Mozambique	442	
India	967		Sudan	671		South Africa	2061		Mauritius	219	
UAE	4466	10	UAE	4038	7	Somalia	2238		Oman	1131	
Mauritius	1131		Somalia	717		Sudan	3639	10	South Africa	349	
Sudan	92		South Africa	748		UAE	1735		Somalia	709	
Jordan	45		Iran, islamic republic	579		Mauritius	1878		Sudan	382	
Somalia	36		Egypt	215		Ethiopia	149		Qatar	86	
South Africa	391		Ethiopia	88		Iran	145		Ethiopia	53	
Ethiopia	75		India	70		India	156		Djibouti	0	
Djibouti	36		Pakistan	20		Qatar	436		India	0	
			Qatar	42		Djibouti	52		Iran	0	
total IO	207862		**total IO**	207806		**total IO**	197223		**total IO**	171431	

Table 7. Trade of sea cucumbers in tonnes and by product forms. From FAO data (FAO, 2021).

Commodity name	Flow	2015	2016	2017	%	Rank
1-SC live, fresh or chilled	**Import**	**5168**	**4782**	**6907**	30%	**2**
	Export	3858	3393	2519	9%	5
2-SC frozen	**Import**	**4934**	**4469**	**8402**	36%	**1**
	Export	4568	7031	9914	34%	2
3-SC dried, salted or in brine, smoked	**Import**	**5218**	**4968**	**6032**	26%	**3**
	Export	7732	8176	10214	35%	1
4-SC other than live, fresh or chilled	**Import**	**3031**	**3853**	**596**	3%	**5**
	Export	5769	4509	3378	12%	3
5-SC prepared or preserved	**Import**	**1346**	**1027**	**1361**	6%	**4**
	Export	3421	2706	2993	10%	4
TOTAL	**Import**	**19697**	**19099**	**23298**		
	Export	25348	25815	29018		

the Management Initiatives (Marine Stewardship Council MSC Assessment) the WA Sea Cucumber Fishery has been formally assessed against the sustainability standards. Sea cucumber stocks in the Pilbara Unit of Certification have passed the assessment, with the Kimberley region currently under review. A present conclusion is that the remoteness of the currently fished stock and the large tidal ranges where it occurs are natural barriers to uncontrolled expansion of fishing. Marine park planning has to date restricted this fishery from general use zones of some MPAs. Currently, lack of experienced fishers and suitable vessels is restricting catch to low levels.

Hong Kong statistics for the Indian Ocean region

Hong Kong is a very important hub for the trade and consumption of holothurian products (Conand, 2004, 2006b, 2008; To and Shea, 2012; Conand, 2017; To *et al*., 2018).

The Census and Statistics from Hong Kong SAR for holothurians comprise several categories for the imports as well as the re-exports. In an early review based on 16 years of information, the main five supply countries of dried product were from the Western Pacific (To and Shea, 2012). A change in commodity codes occured in 2012 including an important frozen category and other categories such as live product, and prepared and preserved product (Conand *et al*., 2014). A general figure showing the imports and re-exports of the dried and frozen product categories was published by To *et al*. (2018).

As the countries from the Indian ocean generally export dried product, this presentation (Table 6) is based on the last published Hong Kong import statistics, for the last 4 years from 2017 to 2020. Another change in categories had occured in 2016, therefore the data used here are from code 03081900 (sea cucumbers Holothuroidea, dried, salted or in brine, including those smoked; flours, meals and pellets of sea cucumbers fit for human consumption) for 2017 to 2020.

The Table 6-A shows the quantities (in kilograms) for each country of the Indian Ocean, imported into Hong Kong, the rank of the major exporters and the percent of the total world imports into Hong Kong. The total imports from the Indian Ocean have decreased during this period from 920 t in 2017 to 448 t in 2020. They represent approximately a fifth of the world total. The main exporters are Sri Lanka, Madagascar, Yemen and Mozambique. Table 6-B shows the values of these imports from the Indian Ocean countries in HK dollars, and the ranks of the major exporters with Yemen and Sri Lanka ranked as the main exporters.

A large part of these imports is then re-exported, as shown in Conand *et al*. (2014), Eriksson and Clarke (2015), and To *et al*. (2018). Locally, products in wholesale markets are typically displayed openly and in bulk, while retail markets offer a diverse array of dried and frozen products (To *et al*., 2018).

FAO statistics for the Indian Ocean region

Statistics for holothurians are collected by FAO (2021) from the countries according to the five different forms of the product (Table 7).

Table 7 shows the general statistics at the world level for imports and the exports for the years 2015 to 2017.

Table 8. Holothurian captures by country in the Indian Ocean for the years 2015 to 2019. The sum for the Western (WIO) and Eastern (EIO) Indian Ocean areas are calculated and their percent of world total presented. From FAO data (FAO, 2021).

Country	Species	FAO major fishing area	FAO code	2015	2016	2017	2018	2019
Egypt		Indian Ocean, Western	51	0	0	0	0	0
Kenya		Indian Ocean, Western	51	171	6	13	15	15
Madagascar		Indian Ocean, Western	51	1598	535	922	853	1150
Maldives		Indian Ocean, Western	51	0	0	99	0	0
Mauritius		Indian Ocean, Western	51	0	0	0	0	0
Mozambique		Indian Ocean, Western	51	0	0	0	0	0
Seychelles	Black teatfish	Indian Ocean, Western	51	8	10	2	2	5
Seychelles	Prickly redfish	Indian Ocean, Western	51	108	79	72	72	75
Seychelles	Sandfish	Indian Ocean, Western	51	0	0	0	0	0
Seychelles		Indian Ocean, Western	51	467	270	194	194	195
Seychelles	White teatfish	Indian Ocean, Western	51	108	81	66	66	70
Tanzania, Unit. Rep.		Indian Ocean, Western	51	0	0	0	0	0
Yemen		Indian Ocean, Western	51	32	27	23	23	23
Sum WIO		Indian Ocean, Western	51	2492	1008	1391	1225	1533
% WIO				6.14%	2.20%	2.80%	2.42%	2.59%
Indonesia		Indian Ocean, Eastern	57	309	477	805	1013	1035
Malaysia		Indian Ocean, Eastern	57	0	0	0	0	0
Sri Lanka		Indian Ocean, Eastern	57	2560	1190	1090	1100	2350
Sum EIO		Indian Ocean, Eastern	57	2869	1667	1890	2113	3385
% EIO				7.07%	3.64%	3.50%	4.17%	5.71%
Sum IO				5361	3683	4677	3338	4918
% IO				13.2%	5.8%	6.4%	6.6%	8.3%
World Totals - Tonnes - live weight				40544	45773	49983	50661	59262

The category 'frozen' is now the largest in tersm of tonnage of the imports, followed by the 'live, fresh or chilled' category. This is an important change due to changes in transport facilities. The traditional category 'dried, salted or in brine, smoked' is now the third largest category with 26 % of the total. For the exports, the traditional category 'dried, salted or in brine, smoked' is still the largest, followed by 'frozen'. There are sometimes difficulties or inaccuracies in the way that these statistics are compiled, as the processed dry product is less than 10 % of the weight of the freshly fished product (Conand, 1989; Purcell *et al*., 2009).

The FAO data are very important in showing the importance by country in terms of captures as presented in Table 8 for the years 2015 to 2019. The data for 2015 for Madagascar and Sri Lanka show very high levels compared to the following years, but again reached similar levels in 2019. The WIO countries, with more than1500 tonnes in 2019, represent 2.6 % of the world total, while the Eastern Indian Ocean countries represent 5.7%. On the whole for these recent years, the Indian Ocean countries have dropped from 13.2 to 8.3 % of the global total. Indonesia fishing zone 57 has shown an important increase during this period.

Discussion

Management of fisheries has developed during the 20th century with the Code of Conduct for Responsible Fisheries by FAO and partners developed in 1995 listing the main principles. The Ecosystem Approach (EAF) (FAO, 2003) is interdisciplinary and involves the overlap of the three objectives of stock productivity, biodiversity conservation and socio-economic issues. Sea cucumbers have been an issue for EAF management in international workshops organised by FAO (Lovatelli *et al*., 2004) and CITES (Bruckner, 2006). More recently practical measures were presented at a global level by Friedmann *et al*. (2008), Purcell (2010), FAO (2010), and Purcell *et al*. (2013). Given the interest in the book on the commercial species by Purcell *et al*. (2012) produced by FAO, a second edition is now being prepared which will include more species. The conservation of the species had been examined by IUCN (Purcell *et al*., 2014; Conand *et al*., 2014) and projects are currently being developed through the IUCN

Sea Cucumber Specialist Group. CITES has recently put the teatfish species on Appendix II (Shedrawi *et al*., 2019, Di Simone *et al*., 2019, 2021) and Non Detrimental Findings (NDF) are now published (Setyastuti and Wirawati, 2019). Management measures were presented at the global regions level in Toral-Granda *et al*. (2008), including a chapter on the Indian Ocean (Conand, 2008). The regional approach for the Indian Ocean was later developed during a WIOMSA project (Conand and Muthiga, 2007; Muthiga and Conand, 2014) and a workshop by FAO (2013) and partners followed by publications (Eriksson *et al*, 2015b).

The **institutional regulatory measures** at a country level for holothurian fisheries are well presented in Purcell (2010); they use the answers to three questions which characterize the particular fishery to be managed: 1) the type of fishery (small-scale or industrial); 2) the status of the stock (underexploited, fully exploited, depleted); and 3) the management capacity of the country for management (strong, and will use recommended measures, or modest, and will use minimum measures and actions). The different types of fisheries for the Indian Ocean have been described in Purcell *et al*. (2013) and are updated here in the country reports.

The different measures, not detailed here, are the following: size-limits (to protect juvenile holothurians); gear limitation; fishing effort; catch quotas; market chain licensing and reporting; seasonal and short term closures; bans or moratoria; marine protected areas (MPA); rotational harvest closures; and territorial user rights. Each measure to be implemented needs to be supported by biological or socio-economical surveys, regulations and education.

The data reported in the literature is often at different levels depending on country and the different stakeholders consulted (Conand, 2001). The problem of reliability of the data has often been raised. A main issue concerns the measure of the catches of the different species; as fresh weight (or length), but also eviscerated, or salted, which differs largely from the processed weight (or length) and needs the knowledge of the specific values of conversion to be useful (Conand, 1990; Skewes *et al*., 2004; Purcell *et al*., 2009; Muthiga and Conand, 2014). The dried product weight was the main unit used in the trade until recently, but the frozen products are now increasing, as shown by Hong Kong imports, and this category will also need conversion values. Despite regulatory measures, illegal fisheries have developed in many countries; Conand (2018b) gives the information for the main global regions during the period 2014-2018. Bondaroff (2021) insists that illegal fisheries should be treated as a form of transnational organised crime, and intergovernmental and interagency cooperation should be increased to address this. The last issue of the review 'Traffic' by Ong and Chin (2022) analyses the online trade advertisments from Malaysia and Singapore. These are mostly (75 %) for the dried product, coming from 15 countries; most frequesntly from Indonesia and Australia. These authors emphasise that robust regulations and tracability systems are necessary.

As in other echinoderm species, holothurian populations show large 'boom - bust' variations coming from environmental and human influences with the latter being predominant for commercial species (Uthicke *et al*. 2009). Serial exploitations are described and analysed for many countries and will provide data for bio-economic models (Anderson *et al*., 2011; Purcell *et al*., 2013; Eriksson *et al*., 2015b; Rawson and Hoagland, 2019; Wolfe and Byrne, 2022). Regional coordination for the management of holothurians is recommended for the future, as this seems to be the most appropriate scale based on the nature of the fisheries.

References

Abdula R. (1998) A summary about holothurians in Mozambique. SPC Beche-de-mer Information Bulletin 10: 34-35

Adithiya LA (1969) Beche-de-mer in Ceylon. Spolia Zeylan. Bulletin of the National Museum, Ceylon 31: 405-412

AFRC (2007) Survey of sea cucumbers in the lagoon of Rodrigues. Internal report from Albion Fisheries Research Centre, Ministry of Agro-Industry and Fisheries, Mauritius. 35 pp

AFRC (2008) Survey of sea cucumbers in the lagoon of Agalega. Internal report from Albion Fisheries Research Centre, Ministry of Agro-Industry, Food Production & Security, Fisheries Division, Mauritius. 21 pp

AFRC (2016a) Survey of sea cucumber in the lagoon of Mauritius. Internal report from Albion Fisheries Research Centre, Ministry of Ocean Economy, Marine Resources, Fisheries, Shipping & Outer Islands, Mauritius. 23 pp

AFRC (2016b) Survey of sea cucumbers in the lagoon of Rodrigues. Internal report from Albion Fisheries Research Centre, Ministry of Ocean Economy, Marine Resources, Fisheries, Shipping & Outer Islands, Mauritius. 21 pp

AFRC (2016c) Survey of sea cucumbers in the lagoon of Agalega. Internal report from Albion Fisheries Research Centre, Ministry of Ocean Economy, Marine Resources, Fisheries, Shipping & Outer Islands, Mauritius. 26 pp

Al Jufaili, Al Rashidi K, Al Kharusi I (2021) The Omani sandfish sea cucumber, *Holothuria scabra* Jaeger, 1833 (Holothuroidea: Holothuriidae): Fishery, length-Weight relationship and condition factor. International Journal Aquatic Biology 9: 115-123

Al-Rashdi KM, Claereboudt MR (2010) Evidence of rapid overfishing of sea cucumbers in the Sultanate of Oman. SPC Beche-de-mer Information Bulletin 30: 10-13

Al-Rashdi KM, Claereboudt MR (2018) Reproductive biology of the sea cucumber *Holothuria scabra* (Jaeger 1883) in MahoutBay, Arabian Sea, Oman. International Journal of Fisheries and Aquatic Studies 6: 100-108

Al-Rashdi KM, Claereboudt MR, Eeckhaut I (2018) Preliminary trials on hatchery and larval development of the sea cucumber, *Holothuria scabra* (Jaeger 1883), in the Sultanate of Oman. Asian Journal of Fisheries and Aquatic Research 2: 1-9

Anderson SC, Flemming JM, Watson R, Lotze HK (2011) Serial exploitation of global sea cucumber fisheries. Fish and Fisheries 12: 317-339 [doi.org/10.1111/j.1467-2979.2010.00397]

Asha PS, Vinod K, Ranjith L, Johnson B, Vivekanandan E (2017) Conservation and sustainable use of sea cucumber resources in India: suggestions and way forward. CMFRI Marine Fisheries Policy Series 7, Central Marine Fisheries Research Institute, Kochi, India. 80 pp

Asha PS, Ranjith L, Vivekanandan E, Johnson B, Subin CS, Sheik Mohamed M (2019) Spatial variations in the population characteristics of sea cucumber resources in Gulf of Mannar and Palk Bay, southeast coast of India. Indian Journal Fisheries 66: 1-11

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

Aumeeruddy R, Skewes T, Dorizo J, Carocci F, Coeur de Lion F, Harris A, Henriette C, Cedras M (2005) Resource assessment and management of the Seychelles sea cucumber fishery. Report for FAO Project No. TCP/SEY/2902. Seychelles: Seychelles Fishing Authority. 49 pp

Aumeeruddy R, Conand C (2008) Seychelles: a hotspot of sea cucumber fisheries in Africa and Indian ocean. In: Toral-Granda V, Lovatelli A, Vasconcellos M (eds) Sea cucumbers. A global review on fishery and trade. FAO Fisheries Technical Paper 516, Rome. pp 207-221

Bondaroff TP (2021) Sea cucumber crime in India and Sri Lanka during the period 2015–2020. SPC Beche-demer Information Bulletin 41: 55-65

Bruckner AW (ed) (2006) The proceedings of the CITES workshop on the conservation of sea cucumbers in the families Holothuriidae and Stichopodidae. NOAA Technical Memorandum. 244 pp

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

Conand C (1990) The fishery resources of Pacific island countries. Holothurians. FAO. Fisheries Technical Paper 272 Rome. 143 pp

Conand C (1998) Overexploitation in the present world sea cucumber fisheries and perspectives in mariculture. In: Mooi R, Telford M (eds) Echinoderms: San Francisco. AA Balkema, Rotterdam. pp 449-454

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

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

Conand C (2006a) Sea cucumber biology: taxonomy; distribution; biology; conservation status. In: Bruckner AW (ed) The proceedings of the CITES workshop on the conservation of sea cucumbers in the families Holothuriidae and Stichopodidae. NOAA Technical Memorandum USA. pp 33-50

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

Conand C, Muthiga N (2007) Commercial sea cucumbers: A Review for the Western Indian Ocean. WIOMSA Book Series 5. 66 pp

Conand C (2008) Population status, fisheries and trade of sea cucumbers in Africa and Indian ocean. In: Toral-Granda V, Lovatelli A, Vasconcellos M (eds) Sea cucumbers. A global review on fishery and trade. FAO Fisheries Technical Paper 516, FAO, Rome. pp 153-205

Conand C, Muthiga N (2010) The sea cucumber resources and fisheries management in the Western Indian Ocean: Current status and preliminary results from a WIOMSA regional research project. In: Harris *et al*. (eds) Echinoderms: Durham. Taylor & Francis, London. pp 575-581

Conand C, Michonneau F, Paulay G, Bruggemann H (2010) Diversity of the holothuroid fauna (Echinodermata) in La Réunion (Western Indian Ocean). Western Indian Ocean Journal of Marine Science 9: 145-151

Conand C, Mulochau T, Chabanet P (2013a) The holothurian (Echinodermata) biodiversity of the Glorieuses Islands (Eparses Islands, France, Mozambique channel). Western Indian Ocean Journal of Marine Science 12: 71–78

Conand C, Stohr S, Eleaume M, Magalon H, Chabanet P (2013b) The echinoderm fauna of Europa, Eparses island, (Scattered islands) in the Mozambique Channel (South Western Indian Ocean). Cahiers de Biologie Marine 54: 499-504

Conand C, Polidoro BA, Mercier A, Gamboa RU, Hamel JF, Purcell SW (2014) The IUCN Red List assessment of aspidochirotid sea cucumbers and its implications. SPC Beche-de-mer Information Bulletin 34: 3-7

Conand C, Ribes-Beaudemoulin S, Trentin F, Mulochau T, Boissin E(2016a) Oursins, étoiles de mer & autres echinodermes. Biodiversité de La Réunion. Les éditions du cyclone. 168 pp

Conand C, Mulochau T, Stohr S, Eléaume M, Chabanet P (2016b) Inventory of echinoderms in the Îles Eparses (Europa, Glorieuses, Juan de Nova) (Mozambique Channel, France). Acta Oecologica 72: 53–61

Conand C (2017) Recent trends in the world sea cucumbers fisheries and markets. Revista Biologia Tropical 65: 1-10

Conand C, Ribes-Beaudemoulin S, Trentin F, Mulochau T, Boissin E (2018) Marine biodiversity of La Reunion Island: Echinoderms. Western Indian Ocean Journal of Marine Science 17: 111-124

Conand C (2018a) Tropical sea cucumber fisheries: changes during the last decade. Marine Pollution Bulletin 133: 590-594

Conand C (2018b) Recent informations on worldwide illegal fisheries for sea cucumbers. SPC Beche-de-mer Information Bulletin 38: 68- 71

Dalpathadu KR (2021) Evaluation of the fisheries and resource of sea cucumbers in the coastal waters of Trincomalee district, Eastern Sri Lanka. International Journal Aquatic Biology 9: 297-308

DNP (1995) Estatísticas de pesca (1986-1994). Direcção Nacional de Administracao Pesqueira, Ministério da Agricultura e Pescas. 284 pp

DNP (1997) Estatísticas de pescas (1996). Direcção Nacional de Pescas, Ministerio da Agricultura e Pescas. 108 pp

Di Simone M, Horellou A Conand C (2019) Towards a CITES listing of teatfish? SPC Beche-de-mer Information Bulletin 39: 76-78

Di Simone M, Horellou A Conand C (2021) The listing of three sea cucumber species in CITES Appendix II enters into force. SPC Beche-de-mer Information Bulletin 41: 3-4

Dissanayake DCT, Wijayarathne MJS (2007) Studies on the sea cucumber fishery in the NorthWestern coastal region of Sri Lanka. Journal of Aquatic Science 12: 19-37

Dissanayake DCT, Stefansson G (2010) Abundance and distribution of commercial sea cucumber species in the coastal waters of Sri Lanka. Aquatic Living Resources 32: 303-313

Dissanayake DCT, Stefansson G (2012) Present status of the commercial sea cucumber fishery off the north-west and east coasts of Sri Lanka. Journal of the Marine Biological Association UK 92: 831-841

Ducarme F (2015) Field observations of sea cucumbers in the north of Baa atoll, Maldives. SPC Beche-de-mer Information Bulletin 35: 26-31

Ducarme F (2016) Field observations of sea cucumbers in Ari Atoll, and comparison with two nearby atolls in Maldives. SPC Beche-de-mer Information Bulletin 36: 9-14

Ducarme F (2018) Inventaire et état des lieux des populations d'échinodermes à Mayotte : biodiversité, écologie et perspectives. Rapport scientifique de la mission BEST RUP N°2486 « Inventaire et état des lieux des populations d'échinodermes à Mayotte ». 54 pp

Eeckhaut I (2010) Evaluation du potentiel des Iles Saint Brandon (Cargados Carajos Shoals; Maurice) en ce qui concerne l'élevage d'holothuries commercialisables (concombres de mer; bambaras). Rapport d'expertise. 13 pp

Eggertsen M, Eriksson H, Slater MJ, Raymond C, de la Torre-Castro M (2020) Economic value of small-scale sea cucumber fisheries under two contrasting management regimes. Ecology and Society 25 (2): 20 [doi.org/10.5751/ES-11436-250220]

Eriksson H, de la Torre-Castro M, Eklöf J, Jiddawi N (2010) Resource degradation of the sea cucumber fishery in Zanzibar, Tanzania: a need for management reform. Aquatic Living Resources 23: 387–398

Eriksson H, de la Torre-Castro M, Olsson P (2012a) Mobility, expansion and management in an East African Multispecies scuba diving fishery. PLoS ONE 7 (4): e35504

Eriksson H., Byrne M., de la Torre-Castro M. (2012b) Sea cucumber (Aspidochirotida) community, distribution and habitat utilization on the reefs of Mayotte, Western Indian Ocean. Marine Ecology Progress Series 452: 159-170

Eriksson H, Clarke S (2015) Chinese market responses to overexploitation of sharks and sea cucumbers. Biological Conservation 184:163-173

Eriksson H, Österblom H, Crona B, Troell M, Andrew N, Wilen J, Folke C (2015a) Contagious exploitation of marine resources. Frontiers Ecology Environment 13 (8): 435-440 [doi:10.1890/140312]

Eriksson H, Conand C, Lovatelli A, Muthiga N, Purcell SW (2015b) Governance structures and sustainability in Indian Ocean sea cucumber fisheries. Marine Policy 56: 16-22

Eriksson H, de la Torre-Castro M, Purcell SW, Olsson P (2015c) Lessons for resource conservation from two contrasting small-scale fisheries. AMBIO 44: 204–213

FAO (2003) FAO Yearbook of fisheries statistics. Rome. 255 pp

FAO (2010) Fishery and Aquaculture Statistics 2008. Rome. 107 pp

FAO (2013) Report on the workshop on sea cucumber fisheries: an ecosystem approach to management in the Indian Ocean (SCEAM Indian Ocean), Mazizini, Zanzibar, Tanzania, 12–16 November 2012. FAO Fisheries and Aquaculture Report 1038. Rome. 92 pp

FAO (2021) FAO Yearbook. Fishery and Aquaculture Statistics 2019/FAO annuaire. Statistiques des pêches et de l'aquaculture 2019. Rome/Roma. 110 pp

Fernando S, Murama J, Pires P (2012) Estudo da biodiversidade de recursos pesqueiros acessíveis à pesca artesanal nas zonas entre marés na província de Cabo Delgado. Instituto Nacional de Investigação Pesqueira. Boletim de Divulgação 52. 30 pp

Friedman K, Purcell SW, Bell J, Hair C (2008) Sea cucumber fisheries: A manager's toolbox. ACIAR Monograph 135. ACIAR, Canberra. 36 pp

Hart A, Murphy D (2021) Sea cucumber resource status. Report 2021. In: Newman SJ, Wise BS, Santoro KG, Gaughan DJ (eds) Status reports of the fisheries and aquatic resources of Western Australia 2020/21: The State of the Fisheries. Department of Primary Industries and Regional Development, Western Australia. pp 171-173

Hart A, Murphy D, Fabris F (2022). Western Australian sea cucumber resource. Resource assessment report (2022). Fisheries Research Report No. 324. Department of Primary Industries and Regional Development, Western Australia. 113 pp

Hasan MH (2019) Destruction of sea cucumber populations due to overfishing at Abu Ghosoun area, Red Sea. The Journal of Basic and Applied Zoology 80: 5 [doi.org/10.1186/s41936-019-0074-6]

Hasan MH, Johnson KS (2019) Restoration of stocks of the sea cucumber *Holothuria fuscogilva* in the Red Sea with transplanted wild juveniles. Journal of Water Resource and Protection 11: 959-980 [doi.org/10.4236/jwarp.2019.118057]

Hornell J (1917) Indian beche-de-mer industry: its history and recent revival. Madras Fishery Bulletin 11: 119-150

James DB (2004) A bibliography of Indian sea cucumbers. Technical Bulletin 2, Chennai-600

Koike H (2017) Fishery Ecology of Seychelles' Sea Cucumber Fishery. Unpublished PhD Thesis, University of Hawaii, Hawaii, the United States of America

Kunzmann A, Beltran-Gutierrez M, Fabiani G, Namukose M, Msuya FE (2018) Integrated seaweed – sea cucumber farming in Tanzania. Western Indian Ocean Journal of Marine Science 17: 35-50

Lampe K (2013) Holothurian density, distribution and diversity comparing sites with different degrees of exploitation in the shallow lagoons of Mauritius. SPC Beche-de-mer Information Bulleting 33: 23 - 29

Lampe-Ramdoo K, Moothien Pillay R, Conand C (2014) An assessment of holothurian diversity, abundance and distribution in the shallow lagoons of Mauritius. SPC Beche-de-mer Information Bulletin 34: 17-24

Léopold M, Thébaud O, Charles A (2019) The dynamics of institutional innovation: crafting co-management in small-scale fisheries through action research. Journal of Environmental Management 237: 187-199

Léopold M, Govinden R (2018) SEACUSEY: Co-management of the sea cucumber fishery in the Seychelles (2017–2018). SPC Beche-de-mer Information Bulletin 38: 85-87

Lovatelli A, Conand C, Purcell SW, Uthicke S, Hamel JF, Mercier A (2004) Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper 463. 425 pp

Luchmun JP, Mangar V, Mosaheb JI, Terashima H, Yamamoto M (2001) Holothurian distribution in the Lagoon at La Preneuse and Baie du Cap. Mauritius, Indian Ocean. Report of the Marine Ecology Research Institution 3: 13-25

Menezes A (2018) Development of Mariculture in Zanzibar, Tanzania. FAO Aquaculture Newsletter, 59: 41-42

MRAG (2012) Stock assessment for the sea cucumber fishery of the Seychelles. Final project report, MRAG Ltd, London. 50 pp

MRAG (2017) Assessment of Seychelles sea cucumber fishery. Final project report, MRAG Ltd, London. 75 pp

Mmbaga TK (2013) The effect of fishing on the ecology of sea cucumber (Holothuroidea: Echinodermata) *Holothuria scabra* and *Holothuria nobilis* in Tanzanian sea water. International Journal of Development and Sustainability 2: 1099-1126

Mmbaga TK (2015) Sea cucumber fishery characteristics in Tanzania. International Journal of Development and Sustainability 4: 661-701

Mgaya YD, Mmbaga TK (2007) Sea cucumbers in Tanzania. In: Conand C, Muthiga N (eds) Commercial sea cucumbers: A review for the Western Indian Ocean. WIOMSA Book Series 5. pp 53-59

Mrowicki RJ (2006) The abundance and distribution of holothurians (Echinodermata: Holothuroidea) in the shallow coastal lagoon of Rodrigues, Mauritius. MSc Thesis, University of Wales, Bangor, UK. 105 pp

Mulochau T, Conand C, Stöhr S, Eléaume M, Chabanet P (2015) First inventory of the echinoderms from Juan de Nova (Iles Eparses, France) in the Mozambique channel, South Western Indian Ocean. Western Indian Ocean Journal of Marine Science 13: 23-30

Mulochau T, Guigou A (2017) Holothuries d'intérêt commercial des récifs de l'archipel des Glorieuses (Îles Éparses, France), du canal du Mozambique) : abondances, tailles et impact de la pêche illicite. Revue d'Écologie (Terre et Vie*)* 72: 19-32

Mulochau T (2018a) Monitoring commercially important sea cucumber populations in the reefs of Mayotte (Indian Ocean). SPC Beche de Mer Information Bulletin 38: 21-28

Mulochau T (2018b) Commercially important sea cucumbers on Geyser Bank (Scattered Islands – Gloriosos – Indian Ocean). SPC Beche-de-mer Information Bulletin 38: 15-20

Muthiga N (2008) Field observations of sea cucumbers at North Male Atoll in the Maldives. SPC Beche-de-Mer Information Bulletin 27: 33-37

Muthiga N, Conand C (eds) (2014) Sea cucumbers, a poorly understood but important coastal resource: A regional analysis to improve management. WIOMSA Book Series 14. 74 pp

Newman, S.J., Wise, B.S., Santoro, K.G. and Gaughan, D.J. (eds) (2021) Status Reports of the Fisheries and Aquatic Resources of Western Australia 2020/21: The State of the Fisheries. Department of Primary Industries and Regional Development, Western Australia. 311 pp

Nishanthan G, Kumara A, Prasada P, Dissanayake C (2019) Sea cucumber fishing pattern and the socio-economic characteristics of fisher communities in Sri Lanka. Aquatic Living Resources, 32 :1-12

Ochiewo J, de la Torre-Castro M, Muthana C, Munyi F, Nthuta JM (2010) Socio-economic features of seacucumber fisheries in southern coast of Kenya. Ocean and Coastal Management 53: 192-202

Ong EJ, Chin ST (2022) A rapid assessment of online trade in sea cucumber and fish maw in Malaysia and Singapore. TRAFFIC, Southeast Asia Regional Office, Petaling Jaya, Selangor, Malaysia

Oury N, Léopold M, Magalon H (2019) Isolation and characterization of microsatellite loci from three widespread tropical sea cucumbers of the genus *Holothuria* (Echinodermata, Holothuroidea), and cross-amplification among them. Molecular Biology Reports 3501-3510.

Oury N, Léopold M, Magalon H (2019) Isolation and characterization of 42 microsatellite loci from the prickly redfish *Thelenota ananas* (Echinodermata, Stichopodidae). Molecular Biology Reports 5569-5574

Pakoa K., Bertram I (2013) Management state of pacific sea cucumber fisheries. SPC Beche-de-mer Information Bulletin 33: 49-52

Prefecture de Mayotte (2004) Portant interdiction de l'exploitation des holothuries sur le territoire de la Collectivité Départemental de Mayotte. Arrete No 32 SG/DAF 12004

Purcell SW, Gossuin H, Agudo NS (2009) Conversion of weight and length of sea cucumbers to beche-demer: filling gaps for some exploited tropical species. SPC Beche-de-mer Information Bulletin 29: 3-6

Purcell SW (2010) Managing sea cucumber fisheries with an ecosystem approach. In: by Lovatelli A, Vasconcellos M, Yimin Y (eds) FAO Fisheries and Aquaculture Technical Paper 520. FAO, Rome. 157 pp

Purcell SW, Samyn Y, Conand C (2012) Commercially important sea cucumbers of the world. FAO Species Catalogue for Fishery Purposes 6. FAO, Rome. 150 pp

Purcell SW, Mercier A, Conand C, Hamel JF, Toral-Granda V, Lovatelli A, Uthicke S (2013) Sea cucumber fisheries: global analysis of stocks, management measures and drivers of overfishing. Fish and Fisheries 14: 34-59

Purcell SW (2014) Value, market preferences and trade of Beche-De-Mer from Pacific Island sea cucumbers. PloS One 9: e95075 [doi:10.1371/journal. pone.0095075]

Purcell SW, Polidoro BA, Hamel J-F., Gamboa RU, Mercier A (2014) The cost of being valuable: predictors of extinction risk in marine invertebrates exploited as luxury seafood. Proceedings Royal Society 281 [doi.org/10.1098/jspb.2013.3296]

Purcell SW, Conand C, Uthicke S, Byrne M (2016) Ecological roles of exploited sea cucumbers. Oceanography and Marine Biology: An Annual Review 54: 367- 386

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

Pouget A (2005) Abundance and distribution of holothurians on the fringing reef flats of Grande Terre, Mayotte, Indian Ocean. SPC Beche-de-mer Information Bulletin 21: 22-26

Ramah S (2019) Saint Brandon marine ecological survey expedition. Cargados Carajos Shoals Expedition 08 - 20 March 2019. Internal report from Albion Fisheries Research Centre, Ministry of Ocean Economy, Marine Resources, Fisheries & Shipping. 26 pp

Rawson K, Hoagland P (2019) Sea cucumbers in a pickle: the economic geography of the serial exploitation of sea cucumbers. Ecology and Society 24 (4): 35 [doi.org/10.5751/ES-11150-240435]

Rowe FWE, Richmond MD (2004) A preliminary account of the shallow-water echinoderms of Rodrigues, Mauritius, Western Indian Ocean. Journal of Natural History 38: 3273-3314

Setyastuti A, Wirawati I (2019) Panduan penyusunan dokumen Non-Detriment Finding (NDF) teripang di Indonesia. Pusat Penelitian Oseanografi-LIPI.

Shedrawi G, Kinch J, Halford A, Bertram I, Molai C, Friedman K (2019) CITES listing of sea cucumber species provides opportunities to improve management of the beche-de-mer trade. SPC Fisheries Newsletter 159: 6-8

Skewes T, Smith L, Dennis D, Rawlinson N, Donovan A, Ellis N (2004) Conversion ratios for commercial beche-de-mer species in Torres Strait. Australian Fisheries Management Authority. Torres Strait Research Programme. 32 pp

To AW, Shea SK (2012) Patterns and dynamics of the beche-de-mer trade in Hong Kong and mainland China: Implications for monitoring and management. TRAFFIC Bulletin 24: 65-76

To AW, Shea SK, Conand C (2018) Trade patterns of bêche-de-mer at the global hub for trade and consumption – an update for Hong Kong. SPC Beche-de-mer Information Bulletin 38: 64-67

Toral-Granda V, Lovatelli A, Vasconcellos M (2008) Sea cucumbers. A global review on fishery and trade. FAO Fisheries Technical Paper 516. Rome. 319 pp

Uthicke S, Schaffelke B, Byrne M (2009) A boom-bust phylum? Ecological and evolutionary consequences of density variations in echinoderms. Ecological Monographs 79: 3-24

Uthicke S, Byrne M, Conand C (2010) Genetic barcoding of commercial Bêche-de-mer species (Echinodermata: Holothuroidea). Molecular Ecology Resources 10: 634-646

Venkataraman K, Venkitaraman C, Rajkumar R (2012) Status assessment of sea cucumber species in Palk Bay and Gulf of Mannar. Report submitted to Gulf of Mannar Biosphere Reserve Trust, Ramanathapuram, Tamil Nadu, India. 55 pp

Wolfe K, Byrne M (2022) Overview of the Great Barrier Reef sea-cucumber fishery with focus on vulnerable and endangered species. Biological Conservation 266 [doi.org/10.1016/j.biocon.2022.109451]

Yussuf YS, Yahya SA (2020) Size-distribution and length-weight relationship of a deep-water population of *Holothuria scabra* (Jaeger, 1833) in Zanzibar, Tanzania. Western Indian Ocean Journal of Marine Science, 19, 1: 113-121

Yussuf YS, Yahya SA (2021). Stocking Density, Growth and Survival Rate of Post-Settled Juveniles of *Holothuria scabra* (Jaeger 1833) Reared in an Ocean-Based Floating Hapa. Tanzania Journal of Science, 47,3: 1041-1054