World Sea Cucumber Fisheries: Status, Culture, Application, Effectiveness of Management and Extinction Threats

M. Aminur Rahman

Laboratory of Marine Biotechnology, Institute of Bioscience, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

E-mail: aminur1963@gmail.com

Abstract*—The sea cucumbers are marine invertebrates, typically found in the shallow benthic areas and deep seas across the world. They have high commercial value coupled with increasing global production and trade. The major products of sea cucumbers, informally named as bêche-de-mer, or gamat, have long been using for food and folk medicine in the peoples of Asia and Middle East. Nutritionally, sea cucumbers have an exciting profile of valuable nutrients such as Vitamin A, Vitamin B_1, Vitamin B_2, Vitamin B_3, and minerals, specifically calcium, magnesium, iron and zinc. A number of distinctive biological and pharmacological activities including anti-angiogenic, anticancer, anticoagulant, anti-hypertension, anti-inflammatory, antimicrobial, antioxidant, antithrombotic, antitumor and wound healing have also been attributed to various species of sea cucumbers due to the presence of valuable bioactive compounds with biomedical applications. We accumulated global aquaculture production, harvestings, economic data, and country-specific assessment and management reports to synthesize global trends in sea cucumber fisheries, evaluate potential drivers, and test for local and global exploitation patterns. Although some sea cucumber fisheries have existed for centuries, catch trends of most individual fisheries followed boom-and-bust patterns since the 1950s, declining nearly as quickly as they expanded. New fisheries expanded five to six times faster in 1990 compared to 1960 and at an increasing distance from Asia, encompassing a global fishery by the 1990s. Global sea cucumber production was correlated to the Japanese yen at a leading lag. Regional assessments revealed that population declines from overfishing occurred in 81% of sea cucumber fisheries, average harvested body size declined in 35%, harvesters moved from near- to off-shore regions in 51% and from high- to low-value species in 76%. Thirty-eight per cent of sea cucumber fisheries remained unregulated, and illegal catches were of concern in half. Nevertheless, development patterns of sea cucumber fisheries are largely predictable, often unsustainable and frequently too rapid for effective management. A ample discussion has been made on the potential ecosystem and human community consequences, effective aquaculture management strategies, and urge for better monitoring and reporting of catch and abundance, proper scientific research for stock enhancement and consideration of international trade regulations to ensure long-term and sustainable development and utilization of world sea cucumbers fisheries*.

Keywords: *Sea cucumber, bêche-de-mer, status, culture, application, exploitation, extinction risk*

1. Status, Culture, Application, Management And Extinction Risks

Over the past century, we have witnessed the decline of many traditional finfish fisheries as well as the expansion of existing and the establishment of new invertebrate fisheries [1]. The increase in invertebrate fisheries has been attributed to increasing demand [2, 3], the need for new resources to harvest [4, 5] and the increasing abundance of invertebrates because of their release from predation [6-8]. Despite an overall global increase in invertebrate catches and target species [9], many individual fisheries have shown severe depletion or even collapse. For example, sea urchin fisheries have followed a boom-and-bust cycle around the world [3, 10. 11], oysters have been serially depleted along the coasts of the United States of America and eastern Australia [12], and shrimp and crab populations have been serially depleted in the Greater Gulf of Alaska [13].

Sea cucumbers (class Holothuroidea) are elongated tubular or flattened soft-bodied marine benthic invertebrates, typically with leathery skin, ranging in length from a few millimetres to a metre [14, 15]. Holothuroids encompass 14000 known species [16] and occur in most benthic marine habitats worldwide, in

temperate and tropical oceans, and from the intertidal zone to the deep sea [17]. The fisheries of sea cucumber have expanded worldwide in catch and value over the past two to three decades [18, 19]. Global sea cucumber production increased from 130,000 t in 1995 to 411,878 t in 2012. Among other aquatic animals, overall production of dried sea cucumbers has increased rapidly (Figure 1). However, sea cucumber fisheries in Asian countries (China, Japan, India, Philippines, Indonesia and Malaysia) have been depleted due to overexploitation as well as lack of proper management and conservation

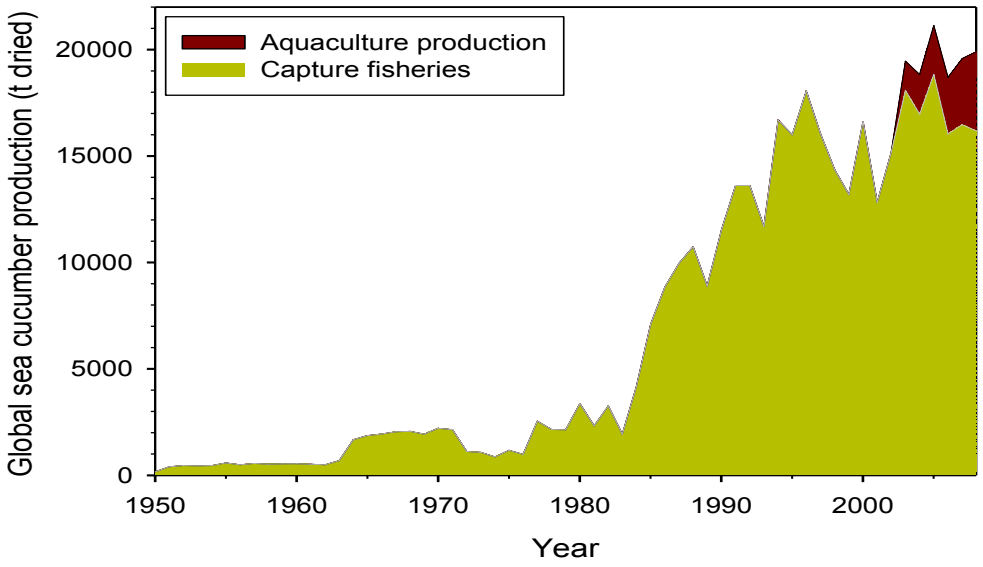

Fig. 1: World sea cucumber fisheries production from 1950 to 2012.

Indo-Pacific regions have harvested and traded sea cucumbers for over one thousand years, driven primarily by Chinese demand [20]. Harvesters typically capture sea cucumbers by hand, spear, hook, or net while wading or diving with snorkel or SCUBA (Self Contained Underwater Breathing Apparatus) gear. In some regions, and especially for less valuable species, sea cucumbers are trawled [21-23]. They are consumed both reconstituted from a dried form (called trepang or bêche-de-mer) and in a wet form, with muscles cut in strips and boiled [24].

In recent years, reports have documented both the rapid climb in value of traded sea cucumbers and the spread and increase in sea cucumber fisheries around the world [19, 25]. However, sea cucumber populations are particularly vulnerable to overfishing for at least two primary reasons. First, harvesters can easily and effectively capture shallow water holothurians [[26, 27]. Second, their late age at maturity, slow growth and low rates of recruitment make for slow population replenishment [28, 29]. Moreover, at low population densities, their broadcast spawning may induce an Allee effect [11, 30], resulting in population collapse and inhibiting recovery [26, 29]. Owing to these factors, overfishing has severely decreased the biomass of many sea cucumber populations [8, 31, 32]. Thus far, even with harvesting closures, sea cucumber stocks seem slow to recover [28, 33, 34]. Other broadcast spawning invertebrate populations that have been severely depleted, such as pearl oysters in the South Pacific, have not recovered even 50–100 years far ahead [35].

The Sea cucumbers are important ecologically as suspension feeders, detritivores and prey. In kelp forests [36] and coral reefs [37], they consume a combination of bacteria, diatoms and detritus [38, 39]. Their function as suspension or filter feeders can be substantial. For example, two species of holothurians alone represent nearly half of the filter feeding biomass in South African kelp. As suspension feeders, sea cucumbers regulate water quality by affecting carbonate content and the pH of the water [40]. Deposit feeding sea cucumbers change the size of ingested particles and turn over sediment via bioturbation, thereby altering the stratification and stability of muddy and sandy bottoms [40]. For example, on coral reefs, healthy sea cucumber populations can bioturbate the entire upper five millimetres of sediment once a year (4600 kg dry weight year/1000 m^2), significantly reducing the microalgal biomass in the sediment [41] and playing a substantial role in the recycling

of nutrients in oligotrophic environments where nutrients would otherwise remain trapped in the sediment [42]. Bruckner et al. [27] noted that the extirpation of holothurians has resulted in the hardening of the sea floor, thereby eliminating potential habitat for other benthic organisms. Holothurians are also important prey in coral reef and temperate food webs [37, 43] both in shallow and in deep water [40], where they are consumed particularly by fishes, sea stars and crustaceans [3].

In addition to the ecological importance of sea cucumbers, their fisheries are of great social and economic importance to many coastal communities. For example, just a few years after beginning in the Maldives, the sea cucumber fishery became the most highly valued fishery outside the tuna fishing season, representing 80% of the value of all non-fish marine products in 1988 [44]. Sea cucumber fisheries form the main source of income for many coastal communities in the Solomon Islands [45] and for 4000–5000 families in Sri Lanka [46]. Perhaps most importantly, sea cucumber fisheries are economically decentralized. Whereas their total global value is low compared to other higher volume fisheries [47], economic benefits are obtained immediately at the village level [48]. In contrast, other high-value fisheries, such as tuna fisheries, have higher initial cost and bring wealth to a more centralized group of people [8].

In spite of the ecological and social importance of sea cucumber populations, the assessment of their global status is challenging. There is generally a lack of abundance data; catch, import and export statistics are often incomplete; and the trade of sea cucumbers is complex [19, 25, 49]. Nonetheless, reports such as FAO [19, 25] and the SPC Bêche-de-mer Information Bulletin (http://www.spc.int/coastfish/en/publications/bulletins/beche-de-mer.html) have assimilated much of the available knowledge on the status and management of sea cucumber fisheries around the world. So far, there has been discussion of country specific sea cucumber fisheries and insight into the dynamics of the global sea cucumber trade [2, 8, 19, 47, 49, 50]. However, we lack a quantitative analysis of the typical trajectory, potential drivers, and combined spatial and temporal dynamics of sea cucumber fisheries around the world.

Sea cucumbers and their extracts have been well documented for their strong effectiveness against hypertension, asthma, rheumatism, cuts and burns, impotence and constipation [51-56]. Nutritionally, sea cucumbers have an impressive profile of valuable nutrients such as Vitamin A, Vitamin B1 (thiamine), Vitamin B2 (riboflavin), Vitamin B3 (niacin), and minerals, especially calcium, magnesium, iron and zinc [57]. A number of unique biological and pharmacological activities including anti-angiogenic [58], anticancer [59], anticoagulant [60, 61], anti-hypertension [62], anti-inflammatory [63], antimicrobial [64], antioxidant [65], antithrombotic [66], antitumor [67] and wound healing [68] have been attributed to various species of sea cucumbers. Therapeutic properties and medicinal benefits of sea cucumbers can be linked to the presence of a wide array of bioactive compounds, especially triterpene glycosides (saponins) [69], chondroitin sulfates [70], glycosaminoglycan [71], sulfated polysaccharides [72], sterols (glycosides and sulfates) [73], phenolics [74], cerberosides [75], lectins [76], peptides [77], glycoprotein, glycosphingolipids and essential fatty acids [57]. These high-value components and bioactive compounds as well as their multiple biological and therapeutic properties supports to exploring the potential uses of sea cucumbers for functional foods and nutraceutical products to a greater extent [15].

Sea cucumber fisheries have provided an important income source to coastal communities in many Pacific islands as well as food in some regions for decades if not centuries or millennia but are now worth only a fraction of historical values [78]. Sea cucumbers have been harvested for hundreds of years for trade with Asia and were probably one of the first real ‘exports’ from the Pacific islands. Unfortunately, the increase in demand and price, combined with the development of cash economies and growing coastal populations in many islands, has led to widespread overfishing of the resource across much of this region. This is particularly severe for countries that depend highly on sea cucumber fisheries and have few alternative income sources, such as the Maldives [44], Sri Lanka [46] and the Solomon Islands [45]. In other regions, sea cucumber fisheries may continue to be just one of many alternative income options (e.g. United States) or may became more important because of the overexploitation or restrictive management of more traditional fisheries (e.g. eastern Canada: [5]). There is a high level of interest in adoption of aquaculture techniques to restore production levels, but different capacity levels require implementation of different techniques. Some Pacific island countries and territories have completed successful research trials of hatchery and release techniques, and now have capacity to scale up this activity. Factors that work in favour of successful aquaculture include pristine marine environments, long

familiarity with sea cucumbers as a commodity, and traditional marine tenure systems that in some places can provide a basis for management of released sea cucumbers. Challenges include lack of technical capacity, unproven effectiveness of sea cucumber releases, poaching and illegal harvesting.

2. Conclusions

Before sustainable management measures can be enforced, it is vital that stocks are allowed to recover to a near pristine biomass level. Only then can management regimes such as TACs, closed seasons, restricted areas and size limits, be effective in achieving maximum benefits from the resource. Sea cucumber populations have been overexploited, which calls for immediate closure of the fishery to enable stocks to recover to levels where they can be managed sustainably. Whatever management measures are officially enacted, the underlying success of management will depend on effective enforcement. The area where sufficient governance exists, two important steps to manage existing and future holothurian fisheries have been suggested, such as: (i) the expansion rate of new fisheries had best be reduced to a level where management has time to react to early warning signs of resource depletion and (ii) lacking changes in regulation, the catch trajectory and patterns of serial spatial, species and size expansion or depletion are largely predictable. Knowledge of the impending sequence of events can therefore be pre-emptively incorporated into the management of new and existing high-value marine fisheries. Overall, this review highlights the urgent need for better monitoring and reporting of harvesting and abundance data, proper scientific stock enhancement and ecosystem impact assessment and appropriate aquaculture and conservation strategies to ensure more sustainable management and utilization of global sea cucumber fisheries in a very significant and worthwhile manner.

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