Sea Cucumber Fisheries: Market Potential, Trade, Utilization and Challenges for Expanding the Production in the South-East Asia

M. Aminur Rahman[1*] and Fatimah Md. Yusoff[1,2]

***Abstract*—**During the recent decades, invertebrate fisheries have expanded in catch and value worldwide. One increasingly harvested group is sea cucumbers (class Holothuroidea), which have been fished, with more than 50 species commercially exploited worldwide. They are highly valued bioresources in Asia and sold as trepang or beˆche-de-mer (the product after gutting, cooking, salting and drying sea cucumber), and is exported worldwide to Asian dried seafood markets. Market preferences of these natural resources contribute to shape their exploitation and production. In South-East Asia, important sources of sea cucumber are: Indonesia, the Philippines, Vietnam, Thailand and Malaysia, with Hong Kong and Singapore being major export countries. They are traditionally consumed raw, dried and boiled in many tropical and subtropical countries. In addition, sea cucumbers have also been popular as a traditional food tonic in China, Korea and Taiwan for thousands of years. Sea cucumbers are considered to exert wound healing and reduce arthritis pain, hence are widely used in Asian folk medicine and human health therapeutics. Sea cucumbers are an ideal fishery resource for which the collection and processing methods are easy, requiring no specialized skill or equipment and, once processed, bêche-de-mer has a shelf life of many years. Historically sea cucumbers were exploited opportunistically as part of a multi-species fishery because, once processed, they could be stockpiled until traders passed through the region. In the international seafood trade, sea cucumbers are regarded as a specialty product that falls within the same niche market as other high-value luxury seafood products, including shark fin, fish maw and abalone. However, supply of sea cucumber in South-East Asia is declining due to overfishing and unstrained harvesting. Despite significant volume is being produced from sea ranching and pond culture, this is not enough to offset rapidly declining collection from the wild. This and the increasing demand for the product have kept prices at attractive levels. The marketing system for sea cucumber in South-East Asia is generally inefficient, and marketing channels are multilayered. Information asymmetry encourages proliferation of redundant players in the distribution system, while high transaction costs keep the overall marketing margin high but the price received by collectors low. Unlocking the full potential of the sea cucumber industry calls for a set of well-conceived strategies that would sustain supply from the wild, increase the supply from aquaculture, improve primary processing and remove the inefficiencies in the distribution system. Emerging systems for more-efficient processing of the product should also be explored to address issues of economies of scale and improve returns on investment for good 'manufacturing practice' (GMP) and 'hazard analysis critical control point'(HACCP)-compliant facilities as well as the incomes of fishers and farmers. Nevertheless, a better understanding of the trade, value and market preferences of Pacific island beˆche-de-mer could identify critical postharvest processing techniques and management strategies for fisheries and aquaculture.

***Keywords*—** Sea cucumber, Bêche-de-mer, South-East Asia, Potential, Trade, Utilization, Production, Challenges

I. INTRODUCTION

Sea cucumbers are echinoderms from the class Holothuroidea. There are some 1,717 known species [1], with the greatest number being in the Asia Pacific region [2] and many of these animals are indeed shaped like soft-bodied cucumbers. All sea cucumbers are ocean dwellers, though some inhabit the shallows and others live in the deep ocean. They live on or near the ocean floor—sometimes partially buried beneath it. Sea cucumbers have the characteristic leathery skin and an elongated body containing a single, branched gonad. Holothurians measure generally between 10 and 30 centimeters long, with extremes of some millimeters for *Rhabdomolgus ruber* and up to more than 3 meters for *Synapta maculata*. The largest American species, *Holothuria floridana*, which abounds just below low-water mark on the Florida reefs, has a volume of well over 500 cubic centimeters (31 cu in) and 25–30 cm (10–12 in) long [3].

All sea cucumbers are ocean dwellers, though some inhabit the shallows and others live in the deep ocean. They live on or near the ocean floor—sometimes partially buried beneath it. They can also be found in great numbers on the deep seafloor, where they often make up the majority of the animal biomass [4]. At depths deeper than 8.9 km, sea cucumbers comprise 90% of the total mass of the macrofauna [5]. The body of some deep water holothurians, such as *Enypniastes eximia*, *Peniagone leander* and *Paelopatides confundens* [6] is made of a tough gelatinous tissue with unique properties that makes the animals able to control their own buoyancy, making it possible for them to either live on the ocean floor or to actively swim [7] or float over it in order to move to new locations [8] in a manner similar to how the group Torquaratoridae floats through water.

Sea cucumbers feed on tiny particles like algae, minute aquatic animals, or waste materials, which they gather in with 8 to 30 tube feet that look like tentacles surrounding their mouths. They are generally scavengers, feeding on debris in the benthic zone of the ocean. Exceptions include some

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

[2]Department of Aquaculture, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.

pelagic cucumbers and the species *Rynkatorpa pawsoni*, which has a commensal relationship with deep-sea anglerfish [9]. Some sea cucumbers position themselves in currents and catch food that flows by with their open tentacles. They also sift through the bottom sediments using their tentacles. Other species can dig into bottom silt or sand until they are completely buried. They then extrude their feeding tentacles, ready to withdraw at any hint of danger. The animals break down these food particles into even smaller pieces, which become fodder for bacteria, and thus recycle them back into the ocean ecosystem. Earthworms perform a similar function in terrestrial ecosystems. Sea cucumbers, particularly eggs and young larvae, are prey for fish and other marine animals.

Sea cucumbers can breed sexually or asexually. They are typically dioecious, with separate male and female individuals, but some species are protandric. Sexual reproduction is more typical, but the process is not very intimate. The animals release both eggs and sperm into the water and fertilization occurs when they meet. There must be many individuals in a sea cucumber population for this reproductive method to be successful. Depending on conditions, one organism can produce thousands of gametes. The reproductive system consists of a single gonad, consisting of a cluster of tubules emptying into a single duct that opens on the upper surface of the animal, close to the tentacles [10].

Many of these are gathered for human consumption and some species are cultivated in aquaculture systems. The harvested product is variously referred to as trepang, bêche-de-mer or balate. They are also enjoyed by humans, especially in Asia, and some species are farmed as delicacies. Sea cucumbers also serve a useful role in the marine ecosystem as they help recycle nutrients, breaking down detritus and other organic matter after which bacteria can continue the degradation process [2].

II. Potentials, Trades, Utilizations Challenges And Improvements

In the recent decades, many traditional finfish fisheries are receiving increasing assessment and regulation, slowly leading to more sustainable exploitation and rebuilding worldwide. In their wake, invertebrate fisheries are rapidly expanding with little scientific as well as the expansion of existing and the establishment of new invertebrate fisheries [11, 12]. However, the increase in invertebrate fisheries has been ascribed to meet-up the increasing demand [13, 14], the need for new resources to harvest [15, 16] and the increasing abundance of invertebrates because of their escaping from predation [17–20]. Despite an overall global increase in invertebrate catches and target species [21], many individual fisheries have shown severe depletion or even collapse [12]. Among the high-valued marine invertebrate fisheries, sea cucumbers have expanded worldwide in catch and value over the past two to three decades [22–24]. 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 [25, 26]. Holothuroids encompass 14000 known species [27] (although most fished species are within the order Aspidochirotida) and occur in most benthic marine habitats worldwide, in temperate and tropical oceans, and from the intertidal zone to the deep sea [28]. Production of world sea cucumber fisheries increased from 130,000 t in 1995 to 411,878 t in 2012 [29]. Among other aquatic animals, overall production of dried sea cucumbers has increased rapidly. However, sea cucumber fisheries in South-East Asian countries have been depleted due to overexploitation as well as lack of proper knowledge, effective management and conservation strategies. Other threats to sustaining the sea cucumber resources include habitat loss, lack of accurate statistics, global warming and new uncontrolled uses such as for pharmaceuticals and nutraceuticals.

Sea cucumbers are consumed predominantly by Chinese and other Southeast Asians such as Singaporeans, Vietnamese, Koreans, Malaysians, and Japanese. During the recent decades, sea cucumbers have been exploited with more than 50 commercially important species in 70 countries around the world in industrial, semi-industrial and small-scale fisheries that stretch from polar to temperate and tropical zones [30]. The important sources of sea cucumber in South-East Asia are Indonesia, the Philippines, Vietnam, Thailand and Malaysia, with Singapore and Hong Kong being major export destinations [31]. The major product in the sea cucumber is the boiled and dried body-wall, commonly known as 'bêche-de-mer' or 'gamat', for which there is an increasing demand for food delicacy and folk medicine in the communities of Asia and Middle East [32–34]. There is also a trade in sea cucumbers for home aquaria and biomedical products [35]. Sea cucumbers have been well recognized as a tonic and traditional remedy in Chinese and Malaysian literature for their effectiveness against hypertension, asthma, rheumatism, cuts and burns, impotence and constipation [32, 36, 37]. 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 [28]. A number of unique biological and pharmacological activities including anti-angiogenic [38], anticancer [39], anticoagulant [40, 41], anti-hypertension [42], anti-inflammatory [43], antimicrobial [44], antioxidant [45], antithrombotic [46], antitumor [47] and wound healing [48] 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 [29, 34, 49, 50]. However, the multiple biological, nutritional and therapeutic properties of sea cucumbers with respect to their potential and significant uses for functional foods, nutraceutical and pharmaceutical products and human health benefits have recently been well-documented [29, 51, 52]. Sea cucumbers are also one of the delicacies of fine Chinese cuisine and are of cultural importance.

Due to overfishing, supply of sea cucumbers in South-East Asia is declining day by day. Despite significant volume is being produced from sea ranching and pond culture, this is not enough to offset rapidly declining collection from the wild. This and the increasing demand for the product have kept prices at attractive levels. Nevertheless, high prices do not translate to improved income for coastal households as individual catch size remains small and the cost per unit of fishing effort high [31]. The market offers high premiums for well-dried, good-quality sea cucumber. However, primary processing, which is the sole determinant of product quality, remains mostly at the village level, which employs traditional practices. The nature of the fishery itself, which is characterized by small catch volumes per day, leads to diseconomies of size, constraining large processing facilities that are compliant with 'good manufacturing practice' (GMP) and 'hazard analysis critical control point' (HACCP) standards from engaging in the business. The market also operates in the absence of officially formulated grades and standards that would guide transactions along the value chain. The marketing system for sea cucumber in South-East Asia is generally inefficient, and marketing channels are multilayered. Information asymmetry encourages proliferation of redundant players in the distribution system, while high transaction costs keep the overall marketing margin high but the price received by collectors low [31]. Unlocking the full potential of the sea cucumber industry calls for a set of well-conceived strategies that would sustain supply from the wild, increase the supply from aquaculture, improve primary processing and remove the inefficiencies in the distribution system. Emerging systems for more-efficient processing of the product should also be explored to address issues of economies of scale and improve returns on investment for GMP- and HACCP-compliant facilities, as well as the incomes of fishers and farmers. In the demand side, globalization of demand and the increasing number of new sea cucumber products are interesting developments. Of course, supply and demand issues cannot be viewed in isolation. Understanding how one affects the other is at the core of a good marketing system analysis.

The critical status of sea cucumber fisheries worldwide is compounded by different factors including the lack of financial and technical capacity to gather basic scientific information to support management plans, weak surveillance and enforcement capacity, lack of political will and socio-economic pressure exerted by the communities that rely on this fishery as an important source of income. The fast pace of development of sea cucumber fisheries to supply the growing international demand for bêche-de-mer is placing most fisheries and many sea cucumber species at risk. The pervasive trend of overfishing, and mounting examples of local economic extinctions, urges immediate action for conserving stocks biodiversity and ecosystem functioning and resilience from other stressors than overfishing (e.g. global warming and ocean acidification), and therefore sustaining the ecological, social and economic benefits of these natural resources [53]. However, when the wild stocks decline, high market demand for food, nutraceuticals and pharmaceuticals raises the price of the product and, as a result, culturing is most likely to become viable commercially [54]. However, development patterns of echinoderm fisheries are largely expectable, often unsustainable and frequently too rapid for effective management. An ample discussion has been made on the potential ecosystem and human community consequences, appropriate 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 sustainable development and utilization of global sea echinoderm fisheries to a greater extent [55].

The absence of reliable market and trade information in South-East Asia is a huge challenge. Updated price data, which could serve as the basis for formulating sound production and marketing decisions, do not exist. In the Philippines, information asymmetry persists—certain market players have greater access to information, giving them undue advantage, especially in price bargaining. Distribution systems become multilayered, since those who have the latest information (especially on prices) can embark on pure arbitrage. While there are cases where product moves only along three layers (collector→processor→exporter), there are also instances where the product moves along two or three additional layers involving local traders and commission agents. These appear redundant and contribute to marketing inefficiency rather than adding real value to the product [31]. Another important challenge relates to primary processing, the single most important determinant of product quality and one for which the market pays a very high price. Primary processing methods currently in use are highly variable; no standard protocol is being followed, resulting in highly variable product quality [31]. The absence of officially formulated and well-implemented grades and standards for sea cucumber is another challenge. This is crucial since such measures could guide transactions along the value chain [31]. Fishers and village-level processors may not find the incentive to improve primary processing if they know that exporters would end up classifying good-quality product as lower grade based on arbitrary standards developed by the exporters themselves [31].

III. Conclusions and Recommendations

South-East Asia is a major source of sea cucumber supplied to the world market. However, the fishery is mostly artisanal, carried out by low-income households. Sea cucumber is generally an incidental catch in finfish fishing, although fishery activities where it is targeted are becoming more significant. The hotspot case studies show for instance that, despite the adoption of management plans in some countries, the lack of enforcement capacity poses considerable constraints on the effectiveness of adopted management measures, besides exacerbating illegal, unreported and unregulated fishing and trade. Owing to the declining catch from the wild, a number of possibilities proposed by Perez and Brown [31] and Rahman and Yusoff [55] can be explored to meet the ever-increasing demand, as follows:

- promoting aquaculture involving technically established protocols that can be explored to address demand and supply gaps
- establishing direct market linkage between producers and exporters to reduce market inefficiencies
- expanding research to develop culture protocols for other high-value species
- improving support for efforts designed to generate new products from sea cucumber
- exploring new export destinations, especially in countries with significant Chinese populations
- establishing regularly updated statistics and information systems for sea cucumber
- formulating and implementing official grades and standards
- improving village-level small-scale primary processing
- exploring strategies that could lead to the achievement of economies of scale in large-scale modern processing methods/facilities that observe international standards for processed food products.

The lack of capacity to gather the basic information needed for management plans, weak enforcement, the high demand from international markets and the pressure exerted from resource-dependent communities figure as important factors responsible for the critical status of sea cucumber fisheries. It should therefore needs to undertake immediate actions to stop the trend of sequential depletion of sea cucumber production if we are to conserve stocks biodiversity and sustain the ecological, social and economic benefits of these high-valued marine bioresources to a greater extent.

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