- *Management*

The world market demand for Anguillid eel is high, which is reported to be around 58,000 mt. Since the Japanese eel and European eel are under the control of the IUCN, the development of sustainable Anguillid eel fisheries could be an excellent prospect to increase the source of income of small-scale fishers. The eel fishery business chain could be connected institutionally between supply and demand. However, the challenge that needs to be confronted is the damage created to the watersheds threatening the sustainability of eel seeds for aquaculture, which is still capture-based. The critical point that policymakers need urgent attention to is the protection of the eel ecosystems by minimizing the injuries to lakes or watersheds, pollution of public waters, development of dams, and controlling seed consumption.

Box 4. Issues that identified during the October 2018 Regional Meeting on Enhancing Sustainable Utilization and Management Scheme of Tropical Anguillid Eel Resources in Southeast Asia

Inadequate statistical data on eel resource utilization and systematic data collection scheme
Harmonized data on catch, species, life stages, fishing gear, and fishing effort (*e.g.* duration of fishing operation, number of fishing gears, number of fishers, biological data) should be compiled to understand the current status of glass and elver/ yellow eel fisheries, and for stock assessment
Limited information on eel farming and the quantity of glass eels used
Data collection system for eel aquaculture activities (*e.g.* number of eel farmers, eel culture production, quantity of glass or elver eels used as inputs) should be established by developing and promoting registration schemes including licensing and reporting system for eel farmers
Geographic range of information on tropical anguillid eel species is insufficient
Information on natural habitat, spawning ground, and migration routes are fundamental for conservation and management of the eel stocks, thus, the geographic range of the tropical anguillid eel species in the region should be examined based on the description of fishing areas, reproductive biology, and migration patterns
Limited stock assessment studies on tropical anguillid eels
Stock assessment, *e.g.* using CPUE analysis as an abundance index, should be conducted for tropical anguillid eels, and that the appropriate level of exploitation and indicators for managing eel stocks should be established
Limited effective conservation and management measures for tropical anguillid eels
Development of conservation and management measures for tropical anguillid eels should be established for each country taking into consideration the results of the abovementioned stock assessment studies
Mixed statistics on international trade of tropical anguillid eels
Existing trade data on anguillid eel species under the UN Comtrade Database include other eel species like swamp eel and snake eel, there is a need to disaggregate such data to improve the trade statistical data reports by harmonizing trade data collection, coding, and reporting and by segregating tropical Anguillid eels from other eel species which require capacity building on eel species identification

In order to establish effective and sound conservation and management of tropical anguillid eel resources in the ASEAN region, the ASEAN Member States and SEAFDEC should address several issues that were identified during the Regional Meeting on Enhancing Sustainable Utilization and Management Scheme of Tropical Anguillid Eel Resources in Southeast Asia organized in October 2018 (**Box 4**).

3.1.3 Sea Cucumbers

Sea cucumbers are commercially important marine invertebrates. Dried sea cucumbers or *beche de mer* or *trepang* fetch high prices in Chinese markets, especially in Hong Kong, Taiwan, and Singapore. The prices are primarily based on the type of species, size, and processing quality. However, during the COVID-19 pandemic, sea cucumber prices went up due to the decreasing supply and high demand (Godfrey, 2019). Efforts on the sustainable management of wild sea cucumber resources have become more crucial than ever. Purcel *et al*. (2013) mentioned that the ineffective management of sea cucumber fisheries has led to the decline of stocks, especially in developing tropical countries where sea cucumber fisheries are considered small-scale. High demand and prices in global markets for luxury seafood, like *trepang*, caused extra pressure on wild harvest which is anticipated to even increase in the near future.

Sea cucumber production

- *Capture fishery*

According to the current data from FAO (2019) for Southeast Asia, only Indonesia and Philippines have shown consistent and active capture fisheries production of sea cucumbers since 1950. At present, Indonesia is the top producer of wild sea cucumbers, with a generally increasing trend since 1986 at record high harvests of more than 7,000 mt in 2005 and 2017 (**Figure 82**). Tuwo (2004) highlighted that harvesting sea cucumber rapidly increased after the 1990s, where the number of fishing vessels targeting sea cucumbers multiplied by more than 10-fold in 2003; however, the catch per unit effort (CPUE) decreased from about 500 sea cucumbers per vessel per day in 1997 to only about 33 sea cucumbers per day in early 2003. In terms of total volume, however, Indonesia still holds a significant chunk in global exports, although not consistently increasing year after year.

From 1985 to 1993, Philippines was the top producer of wild sea cucumber at 3,000–4,000 mt (**Figure 82**). This high production has contributed about 16 percent to the volume of the globally traded sea cucumbers at that time (Akamine, 2005). However, wild sea cucumber production declined

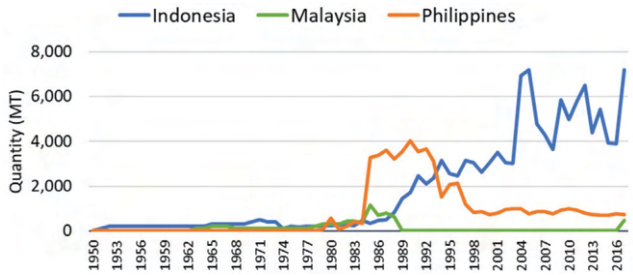

Figure 82. Capture fisheries of production of sea cucumbers in Southeast Asia by quantity (mt) from 1950 to 2017 (FAO, 2019a)

dramatically to 600–800 mt from 1998 to the present. Also, because most of the catches were considered low quality (*e.g.* low-value species, small sizes, poor processing practices), export prices have declined.

In Malaysia, there seem to be no recorded harvests since 1989 according to the FAO data, but sea cucumbers, especially those from the genus *Stichopus*, locally called *gamat*, had been constantly targeted to produce cosmetic products like soap. Although based on the local Annual Fisheries Statistics of 2009–2020, Malaysia produced less than 1,000 mt per year since 2015, those catches from such fisheries had not been reflected in global statistics, such as FAO, because the collection activity in Malaysia is only considered as "by-catch" from other fishing activities, and licenses that are specific for sea cucumbers have not yet been awarded.

Furthermore, the current FAO capture fisheries database also failed to show possible significant wild sea cucumber harvests from the other AMSs, like in Cambodia, Myanmar, Thailand, and Viet Nam, even though, all these countries have long history of sea cucumber harvesting. In Thailand, for example, the collection of sea cucumber had been practiced for many years, especially along the coasts of the Gulf of Thailand and Andaman Sea. However, despite no reliable data and information on the actual status of sea cucumber populations in the country, the decrease in the number of animals has become more apparent in recent years (Viyakarn *et al*., 2020). Because of this, the Ministry of Agriculture and Cooperatives has requested the Department of Fisheries in early 2000 for information on the status of the sea cucumber fishery in Thailand (Bussarawit & Thongtham, 1999). Among the many sea cucumber species in Thailand, 11 of the 102 listed species were considered economically important, with *Holothuria scabra* being the most valuable (Munprasit, 2009). In Viet Nam during the early 1990s, a single fishing vessel can catch about 1.4 mt of sea cucumbers during a single month's voyage from the Truong Sa Archipelago in the South China Sea. However, a recent survey in 2019 revealed that in Kien Giang Province located at the Gulf of Thailand, sea cucumber catches has declined by 60–90 percent compared to 10 years ago (Van Khanh *et al*., 2020).

- *Aquaculture*

The aquaculture of sea cucumbers started before the 1980s in China, Japan, and India. In Southeast Asia, the small-scale culture of sea cucumbers began in intertidal areas using wild-caught juveniles. However, the advent of the early hatchery technology for the sandfish *H. scabra* in the early 2000s has jumped-started some of the earliest aquaculture ventures using hatchery-bred juveniles in the region. Current FAO data reports that only Indonesia, Malaysia, and Viet Nam have aquaculture production of sea cucumbers, with Indonesia being on top with about 2,000 mt in 2015 but declined to < 500 mt starting 2016 onwards (**Figure 83**). Meanwhile, Malaysia and Viet Nam were producing less than 100 mt annually since 2011. However, actual production volumes may not have all been reflected in the FAO database.

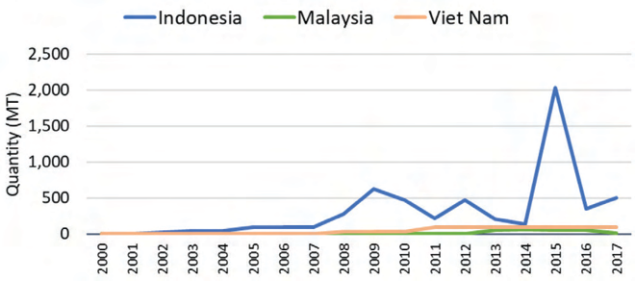

Figure 83. Aquaculture production of sea cucumbers in Southeast Asia by quantity (mt) from 2000 to 2017 (FAO, 2019a)

The farming of sea cucumbers in Indonesia has not been widely documented, although many of the aquaculture efforts and studies were published in the local Bahasa language. However, some recent studies already discussed the development of sea cucumber aquaculture in the country in the recent decade, especially after the establishment of the sandfish hatchery in 2011 at the Marine Bio Industry (LIPI) in north Lombok, Indonesia, and attempts of pond culture have been demonstrated in Sekotong, West Lombok (Indriana & Firdaus, 2020). Although it is interesting to see the FAO aquaculture data for Indonesia as early as 2005, this may suggest that early aquaculture ventures in Indonesia made use of wild-sourced juveniles for farming.

In Malaysia, the Department of Fisheries (DOF) had been conducting successful studies on hatchery production of three species of sea cucumbers, namely: *Stichopus horrens*, *S. vastus*, and sandfish *H. scabra* (Zaidnuddin, 2009; Vaitilingon *et al*., 2016). Farming activities in pens only involved the sandfish species and were carried out only in the waters of northern Sabah from Kudat to Sandakan. However, production levels are on a subsistence scale because these areas were mostly still dependent on wild-caught juveniles. Currently, the Government of Malaysia is investing in hatchery developments, and an example of this is the DOF hatchery in Bukit Malut, Langkawi Island, Malaysia which was completed in 2015. Efforts for pond culture of sandfish were also tested in partnership with

private partners within the last decade but were eventually discontinued, primarily because of high investment costs but with low potential yields.

In the Philippines, hatchery production and aquaculture development for sea cucumbers, particularly for the sandfish *H. scabra*, started in the mid-2000s and intended to restore the depleted wild populations through sea ranching and stock enhancement, as well as to increase the supply of good-quality *trepang* through integrated and adaptive culture-based systems (Juinio-Meñez *et al*., 2017). Hatchery production of sandfish juveniles has been established by research institutions and universities in strategic locations in the country. SEAFDEC/AQD was also at the forefront of aquaculture technology development and refinement (SEAFDEC, 2017b). The Philippines also pioneered the development, design, and culture protocols for the ocean-based floating nursery system for sandfish using hapa nets (Juinio-Meñez *et al*., 2012; Altamirano & Noran-Baylon, 2020; Altamirano *et al*., 2021). The farming of sandfish in a sea ranch by local communities was demonstrated in a five-hectare pilot site in Bolinao, Pangasinan in northern Philippines in 2009 with technical support from the Marine Science Institute (MSI) of the University of the Philippines Diliman (Juinio-Meñez *et al*., 2013). Although the economic benefits from the demonstration site were very modest at that time, it showed the prospects of scaling up production using sea ranch networks across coastal communities in the country. The Government of the Philippines, through the Department of Science and Technology (DOST), had been investing resources for research and development on sea cucumbers as an emerging species since the early 2000s, covering fields in aquaculture development, genetics, environmental science, and biotechnology (Juinio-Meñez *et al*., 2017; Ravago-Gotanco & Kim, 2019). Recently, sea ranch sites are multiplying in the central and eastern Philippines and the southern region of Mindanao, although no commercial-scale harvests have been officially recorded yet.

Similar to most ASEAN countries, the culture of sea cucumber in Thailand has been equally challenging. Although no dedicated facilities had been made exclusively for sea cucumber production, the hatcheries at the Shrimp Genetic Improvement Center (SGIC) in Chaiya District, Surat Thani, Thailand, had been producing sandfish *H. scabra* juveniles at experimental scales from 2012 (Sithisak *et al*., 2013).

Local farmers in Viet Nam has already been producing sandfish at 2.6 to 2.8 mt per hectare of marine ponds by alternately culturing with shrimps from 2008 to 2009 (Duy, 2012). This progress was made possible because sandfish juveniles were already being produced, albeit on a small scale, in the hatcheries of the Research Institute in Aquaculture (RIA) 3 in Nha Trang, Viet Nam. Recent aquaculture efforts in Viet Nam are in the co-culture of sandfish with other high-value crops like the Babylon snail (*Babylonia areolata*) and sea grapes (*Caulerpa lentillifera*) – all with good economic prospects (Dobson *et al*., 2020).

Trade

From 1996 to 2011, Indonesia (17 %) and the Philippines (13 %) were the top two exporters of dried and frozen sea cucumbers to Hong Kong, while the remaining 70 percent was a collective of other 101 countries worldwide (To & Shea, 2012). However, the same report also showed that there was a dramatic decline in volume from 1996 versus 2011 with a 67 percent reduction for Indonesia and 40 percent reduction for Philippines. In addition, a more recent report during 2012–2016 revealed that Japan was the number one exporter of dried sea cucumbers to Hong Kong at 11.5 percent, followed by Indonesia as the second (10.4 percent), and Philippines (6.0 percent) at fourth place. Fiji came in at third with 7.2 percent and Madagascar entered fifth with 5.6 percent (To *et al*., 2018). This decline for Indonesia may be attributed to the relatively low quality of *trepang*, often classified as moderate to low, caused by poor processing methods and technology like those being traditionally used in Sulawesi, Indonesia (Aprianto *et al*., 2019).

In most Southeast Asian countries, the preferred high-value sea cucumber species are *H. scabra* and *Stichopus horrens*. The top 10 commercially important sea cucumber species in the region are listed in **Table 62**. However, most of these commercially important species were already considered endangered by the International Union of Conservation of Nature (IUCN), namely: *Thelenota ananas*, *H. lessonii*, *H. whitmaei*, *H. fuscogilva*, and *H. nobilis* (Purcell *et al*., 2014). In fact, the latter three species belonging to the teatfish group were recently included in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) with strict trade regulations (Shedrawi *et al*., 2019).

Table 62. Most valuable sea cucumber species in Southeast Asia (SEAFDEC, 2017b)

Scientific Name	Common name	Local price (USD/kg, dried)
H. scabra	sandfish	*30–105*
H. nobilis/*H. whitmaei*	black teatfish	*17–105*
Holothuria fuscogilva	white teatfish	*17–88*
Actinopyga lecanora	stonefish	*7–66*
Stichopus horrens	dragonfish	*24–58*
Stichopus hermanni	curryfish	*58*
Actinopya echinites	deepwater redfish	*12–54*
Thelenota ananas	prickly redfish	*12–51*
Thelenota anax	amberfish	*4–51*
Bohadschia argus	leopardfish	*9–27*

The actual market prices for sea cucumbers are based not only on the type and species of the product but also on the size and processing quality. Harvested sea cucumbers are processed and dried into what is called *beche de mer* or *trepang* before they can be sold and exported. Unfortunately, the declining supply and high demand for sea cucumber have driven local fishers to harvest even the smallest size that only sells for a very meager amount. Besides, prices of such small animals even drop because of inferior processing methods. Generally, smaller sandfish (*e.g.* < 300 g) warrant a much lower overall price tag than larger (*e.g.* > 500 g) animals. When sold, the larger sandfish will elicit much higher product recovery after processing, larger marketable dry weight, and much higher premium prices of about 180 percent more than small sizes (Pardua *et al*., 2018).

Issues and Challenges

In most countries of the Southeast Asian region, wild sea cucumbers are harvested by multiple methods including simple hand collection, diving with the use of artificial breathing devices, and using fishing vessels (*i.e.* trawlers). In the past, traditional sea cucumber collection by hand-picking during low tide may have had the lowest impact on the sea cucumber population. Nonetheless, the localized impact could be multiplied exponentially when the whole village and their families are involved (Choo, 2012). In addition, such impacts are aggravated by other causes like habitat destruction, pollution, and overexploitation.

In Malaysia, the increase in total sea cucumber landings in 2011 was associated with trawlers when the modified nets were introduced to specifically target sea cucumbers. The bottom rubber rollers of traditional trawl nets were replaced by heavier bottom sinkers, which can plow deeper into the sea bottom and dig out more sea cucumbers. Such fishing vessels are also equipped with a facility for boiling sea cucumbers. Consequently, fishery statistics have shown that the population of sea cucumbers has declined in various locations in Malaysia, especially in the recent decades (Ibrahim & Zaidnuddin, 2015).

In the Philippines, the government has imposed since 2013 a regulation on sea cucumbers harvesting, at least for the sandfish. There is now a set of standards on the quality of dried sea cucumbers, and imposing a 5-cm minimum size limit for the dried sandfish product (BFAR, 2013), which translates to about 350 g of live animal. However, the implementation across the country has been relatively loose because sea cucumbers have remained to be open access resource (Jontila *et al*., 2018). Also, Deauna *et al*. (2021) indicated that the sea cucumber resource in the Philippines is in a state of overexploitation, but the capacity to enforce the necessary regulations is quite low.

In Viet Nam, sea cucumber harvesting has been done for years, especially around the island of Phu Quoc, which is at the border with Cambodia in the Gulf of Thailand. In that area, it is a common knowledge that sea cucumbers had been harvested at 3 mt per day in the past decade. However, at present, it was reduced to only 300 kg per day. Another productive area is the Truong Sa Archipelago in the South China Sea, where a single boat in the early 1990s can catch about 1.4 mt during a single month's voyage. Now, huge declines in catch have been reported because of high harvesting rates (Hung & Dinh, 2008).

Due to the declining populations of the high-value species in the recent decade, local fishers were forced to harvest even the less economically valuable species. In Thailand, for example, it was recorded that in the late 1990s, low-value species like *H. atra*, *H. leucospilota*, *Stichopus chloronatus*, *S. variegatus*, and *Bohadschia marmorata* had been harvested (Bussarawit & Thongtham, 1999). Similarly, a 2019 survey in Viet Nam showed that almost 80 percent of catch from the coasts of Kien Giang Province are now composed of medium to low-value species like *H. leucospilota* and *H. atra*, an indication that the high-value species are already overfished (Van Khanh *et al*., 2020). In Lyson Island on the central coast of Viet Nam, 30 percent of fishers are now exclusively targeting sea cucumbers at Truong Sa using scuba diving as the primary fishing method (Hung & Dinh, 2008), which will further put pressure on wild sea cucumber populations.

Conservation Efforts

The main challenge in the conservation of sea cucumber resources in the Southeast Asian region is the lack of reliable quantitative data on the existing and past status of the resource. The declining trends of populations of various sea cucumber species in the region are often reported anecdotally because of the inherent difficulty in monitoring within the vast coastal areas of the countries that are mostly archipelagic. Fortunately, many assessment studies of the natural populations of sea cucumbers have been recently conducted using inventory assessments and population genetics in Indonesia (Rahardjanto *et al*., 2020), Philippines (Ravago-Gotanco & Kim, 2019; Lal *et al*., 2021), Thailand (Ninwichian & Klinbunga, 2020; Viyakarn *et al*., 2020), and Viet Nam (Van Khanh *et al*., 2020). Data from these studies can fill in the critical gaps in the quantitative information that is relevant in the management of fisheries, aquaculture, and conservation of sea cucumber resources. It is also seen that many more such surveys and fisheries impact assessments will be conducted in the future.

Way Forward

In the past decade, there has been a significant increase in terms of research and development devoted to sea cucumbers in various fields. In Indonesia, the aquaculture

for sandfish is still being evaluated in ponds at various sites in Lombok and Sulawesi (Indriana & Firdaus, 2020; Tuwo *et al*., 2020). Efforts to evaluate the economics of the small-scale fisheries in the southern islands of Indonesia had also been promoted (Prescott *et al*., 2017). An important aspect of sea cucumber processing methods and technologies have also been explored, especially in the Sulawesi area, where *trepang* production is significantly important (Aprianto *et al*., 2019). Future directions in research and development in Indonesia is seen to focus more on the seed production and farming of sea cucumbers.

Similarly, research will continue on hatchery production in Malaysia for *Stichopus horrens*, *S. vastus*, and sandfish *H. scabra* with support from the government. Further activities on the demonstration of farming in pens and ponds is seen to continue for sandfish, especially in Sabah with potential engagements of the private sector.

In the Philippines, the trend of research has been in aquaculture production, primarily for the sandfish *H. scabra*. Recent studies had focused on the refinement of hatchery and nursery techniques for sandfish through the enhancement of larval and juvenile feeds (Sibonga *et al*., 2021; Magcanta *et al*., 2021). Refinement of floating hapa nursery systems for juvenile culture have been studied by assessing the various environmental factors such as quality of biofilm as early food sources, and evaluating the best practices and operational management (Altamirano & Noran-Baylon, 2020; Altamirano *et al*., 2021; Gorospe, *et al*., 2021; Sinsona & Juinio-Meñez, 2019). Also, studies and assessments for grow-out systems in pens and sea ranching had been conducted (Dumalan *et al*., 2019; Villamor *et al*, 2021). Foreign assistance, especially in collaborative research, is also active for sea cucumbers in the country, especially those from the Australian Centre for International Agricultural Research (ACIAR). In addition, the focus of research has expanded to other sea cucumber species like *Stichopus horrens*, *Holothuria fuscogilva*, and *Phyllophorus* sp. The Government of the Philippines also established the Niche Center in the Regions (NICER) Program specific for sea cucumbers to enhance further research and development for these commodities (de la Peña, 2020). In particular, SEAFDEC/AQD in the Philippines will be continuing its efforts in optimizing seed production and farming protocols for the sandfish and targeting to publish practical manuals on sandfish production operations. Research and development studies in collaboration with national institutions and international funding partners will continue in addressing knowledge gaps in various phases of the culture of sandfish.

Although the farming of sandfish in ponds has been demonstrated for almost two decades in Viet Nam, farmers still resorted to the culture of shrimps because of relatively shorter culture periods and higher profits. Recently, aquaculture in ponds using multiple species has shown some very good prospects and increased income by integrating sea grape (*Caulerpa lentillifera*) and Babylon snail (*Babylonia areolata*) into the culture with the sandfish *H. scabra* (Dobson *et al*., 2020). Future efforts on sea cucumber aquaculture will be towards the diversification of farming methods, whether intercropping among various species or co-culture in the same culture pond. Also, there have been advancements in the hatchery technology for sandfish by using micro-algae concentrates in larval rearing of sandfish in the hatchery, which can significantly reduce the overall operational and production costs (Duy *et al*., 2016).

In Thailand, the current research on sea cucumbers seems to focus more on the physiological aspects like the study on the functions of sex steroids in gonad maturation and neurotransmitters in larval development and growth (Thongbuakaew *et al*., 2021; Nontunha *et al*., 2020). Research on aquaculture of sea cucumber is being conducted including those that evaluated the co-culture trials for sandfish with red tilapia in experimental inland tanks (Sithisak *et al*., 2013). Recent research also focused on some bioactive compounds from sea cucumbers with potential medical applications, particularly for critical diseases like cancer (Yurasakpong *et al*., 2020) and Parkinson's disease (Chalorak *et al*., 2018).

The Southeast Asian region has seen some promising developments in sea cucumber resources in the past few years. With the increasing demand for sea cucumber products, more efforts are now being dedicated to the aquaculture and farming of these species and would continue in the coming decades. The preliminary results of pilot farming sites in countries like the Philippines, Malaysia, and Indonesia are viewed to increase and scale up, while production of sandfish in ponds of Viet Nam is bound to increase even more. Meanwhile, efforts on establishing accurate statistics on wild sea cucumber resources in the region will be instrumental in implementing the crucial conservation and management interventions of the threatened wild stocks across Southeast Asia.

3.1.4 Seahorses

Seahorse trade is significant in Southeast Asia for traditional Chinese medicine (TCM) and thus, seahorses are being exported mainly to Hongkong Specialist Administrative Region (SAR), Taiwan, and mainland China (Foster *et al*., 2017; Foster *et al*., 2021; Kuo *et al*., 2018; Stocks *et al*., 2019). Seahorses *Hippocampus* spp. were among the first marine species to come under global restrictions listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). All seahorses are allowed for export provided that the specimens are sourced sustainably and legally within CITES rules. Nevertheless, the global trade of seahorses from 2016–2017 defied export bans under the