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

CITES action and national legislations of countries with Thailand followed by Philippines as the top sources of dried seahorses (95 %) exported to Hong Kong SAR based on interviews with traders in Hong Kong SAR (Foster *et al*., 2019). According to CITES data, two-thirds of live trade from 2005–2014 went to the USA and 11 % to France. Seahorses born in captivity to wild parents—and traded live—made up 90 % of reported wild exports in the CITES database for 2008–2014.

Issues and Challenges

Exploitation for trade is one of the biggest threats to many species, especially for marine species (Kuo, *et al*., 2018). Effective trade regulations should facilitate the conservation of marine fish populations. However, the illegal trade of seahorses continues even with the implementation of export bans (O'Donnell *et al*., 2012; Foster & Apale, 2016; Foster *et al*., 2017). Based on field surveys carried out in 1998–2001, Philippines was confirmed as the major exporter of dried and live seahorses with an estimated catch for the dried trade at 10,000 kg/year, but highly variable estimates of catch for the aquarium trade ranged from an average of 145,000–1,000,000 seahorses/year depending on the data source (Pajaro & Vincent, 2015). Seahorses are obtained by fishers via free or compressor diving and scoop/push nets and some are caught in non-selective fishing gears including trawls, beach seines, and push nets. Information on the biology, fisheries, and trade of seahorses had been gathered in the Philippines by conducting interviews with fishers and traders across 17 coastal provinces, where fishers reported that the mean catch per unit effort was between one and ten seahorses per day for gleaners, spear/skin divers, compressor divers, and fish nets, and up to as high as 100 seahorses for micro-trawlers (Foster *et al*., 2021).

A case study of the dried seahorse trade in Thailand conducted by Kuo *et al*. (2018) suggested that the trade may be underreported based on the economic value of the seahorses and the large discrepancy between declared export volumes and catch estimates. External datasets from the CITES trade database (2004–2013), the Census and Statistics Department of Hong Kong SAR (1998–2014), and from the Customs Administration of Taiwan (1983–2014) had been used to examine the changes in international trade of seahorses from Thailand. The estimated value of dried seahorses could be worth USD 26.5 million per year versus the total declared annual export value of around USD 5.5 million and USD 1.0 million in 2013. In Viet Nam, Foster *et al*. (2017) reported the complex trade of seahorses due to large domestic consumption for seahorse wine and tonics, and a sizable amount for export. The reported purchase volume of dry seahorses was more than three times of wet seahorses.

The extraction rate of seahorses may be unsustainable and prone to overfishing due to the slow-moving, limited home ranges, and low fecundity of seahorses (Foster & Vincent, 2004; Vincent *et al*., 2011). Seahorses are sensitive to habitat destruction brought about by large-scale environmental impacts including coral bleaching, frequent typhoon, tsunami, and earthquake damages that could impede the recovery of their populations (Shimozomo *et al*., 2015; Anticamara and Go, 2017). Consequently, population recovery of seahorses may be further impeded due to habitat destruction brought about by large-scale environmental impacts including coral bleaching, frequent typhoon, tsunami, and earthquake damages (Shimozomo *et al*., 2015; Anticamara & Go, 2017). Furthermore, heavy degradation of the world's ocean caused by anthropogenic activities is harming the species and habitats across both terrestrial and aquatic ecosystems due to land-based pollution, over-extraction of resources, and changing environmental conditions (Butchart *et al*., 2010; Halpern *et al*., 2015; Maxwell *et al*., 2016; Mora *et al*., 2006). The exploitation of seahorses using trawlers combined with damaged and degraded habitats had been reported in the Philippines, Thailand, and Viet Nam (Foster & Apale, 2016; Foster *et al*., 2018; Foster *et al*., 2019; Foster *et al*., 2021; Stocks *et al*., 2019).

- *Breeding of Seahorses*

Commercial breeding of seahorses started in China in the 1970s, but technical problems on their vulnerability to diseases and correct diet were encountered. Moreover, economic failure in the 1980s led to the widespread closure of seahorse farms in China. In Southeast Asia, Viet Nam started to culture *H. kuda* (Pham, 1993). Research in India on the rearing of *H. trimaculatus* used 2,000 l tanks for broodstocks and 30 l larval rearing tanks (Murugan *et al*. 2009), while in the Philippines illuminated floating bamboo and nylon mesh cages had been used for grow-out (Garcia & Hilomen-Garcia, 2009).

The reproductive biology of seahorses has been explored by offering various types of feed. In Malaysia, Nur *et al*. (2015) reported that while post-larvae shrimp gave the best reproductive performance of *H. barbouri*, frozen mysid can also be used as feeds. In the Philippines, trials conducted at SEAFDEC/AQD showed improved reproductive performance of *H. comes* fed with mysid shrimp alone or in combination with *Artemia* and *Acetes* (Buen-Ursua *et al*., 2015). Significantly higher brood sizes and shorter parturition intervals were obtained from seahorses fed with mysid shrimps as a single diet or combined with either *Artemia* or *Acetes*. In Viet Nam, Troung (2011) reported on the successful culture of seahorses and feeding them with frozen *Mysids* and *Acetes* with some vitamins A, C, and E added to the feed to improve gonad quality and strengthen fish larvae. In India, Murugan, *et al*. (2009) observed significantly higher reproductive efficiency and a lower number of deformed larvae when *H. trimaculatus* were fed with amphipods.

Technologies developed by SEAFDEC/AQD for the larval rearing of newborn and juvenile seahorse, *H. comes* include the use of UV-treated seawater and copepods as a replacement for brine shrimp as food for newborn seahorses (Buen-Ursua *et al*., 2011). The survival of 2–6 months old juveniles has also improved with mysid shrimps and *Acetes*. In Viet Nam, Troung (2011) reported feeding the seahorse with copepod three times per day from birth to 40 days old, while enriched *Artemia* nauplii were fed to fry from 10 days onwards. In India, Murugan *et al*. (2009) used copepodites to improve survival rates in 9 and 12 days old juvenile *H. trimaculatus*. Rearing *H. barbouri* in illuminated cages showed that the seahorse fed on copepods attracted to the night illumination (Garcia *et al*., 2012). From 2009 to 2011, the demonstration project in Sulawesi, Indonesia examined the potential to culture *H. barbourin* as an ornamental marine species for coastal management and conservation efforts (Williams *et al*., 2014). Culture units (8 m × 5 m) had been constructed in the family's yard areas to enhance the incomes for the families.

- *Resource Enhancement and Management*

SEAFDEC/AQD has conducted studies on the development of resource enhancement strategies for seahorses. Results of the transport trials for 5–7 cm in stretched height (SH) juveniles suggested an optimum stocking density of 3 ind/l for transport duration up to 12 h. In the Philippines, baseline assessment of the natural stock of seahorses showed an increasing number of stocks over the years (2012–2019), wherein the communities have played important roles in the stewardship of the protected areas. Appropriate protection of the natural habitat suggests the possible sustainability of the wild seahorse stocks. The fishing communities are being involved through information, education, and communication (IEC) and hands-on training during field sampling, seed production, and nursery rearing of seahorses (Buen-Ursua, unpublished).

The exploitation of seahorses is unsustainable, prompting urgent management of the natural resources. To reduce pressure on seahorse populations, management is required for both target fishers of seahorses and incidental catch. It is necessary to reduce the impact of the large trawl fleet which is consistently catching seahorses while simultaneously destroying habitats (Stocks *et al*., 2017; Foster *et al*., 2018). Marine reserves are also essential and should be well implemented. The Project Seahorse, an interdisciplinary and international organization committed to conservation and sustainable use of the world's coastal marine ecosystems, has made significant contributions to seahorse conservation being the first to study seahorses underwater, discover their huge trade, identify the threatened status of seahorses and the first to launch the seahorse conservation measures. One conservation measure targeting behavior to mitigate wildlife trade is reducing consumers' demand. On a smaller scale, seahorse conservation efforts could include persuading artisanal fishers to catch a minimum size of > 10 cm in height and release smaller sizes (Foster & Vincent, 2005).

Thailand has several fisheries regulations already in place, but conversations with local communities indicated that enforcement of these restrictions may still be an issue. Although the Government recently enacted strict measures against illegal commercial fishing, grounding unregistered trawlers, and banning illegal fishing gear, addressing these biodiversity losses would require extensive fisheries regulations, policy action, and enforcement of existing laws to protect natural resources (Loh *et al*., 2016).

In Viet Nam, exploitation of seahorses had caused declines in their populations, thus requiring the development of adaptive management measures (Giles *et al*., 2006; Stocks *et al*., 2017). Management interventions are necessary to reduce the impact of trawl fleet that catch seahorses and destroy habitats; surveys at major ports by border guards and fisheries surveillance officers; well implemented marine reserves; and reductions in fishing effort, whether seasonally or permanently (Foster & Vincent 2016; Stocks *et al*., 2019).

Way Forward

The exploitation for the trade of seahorses has led to the decline of their wild populations. Trade regulations had been undermined by the persistence of indiscriminate extraction as target species or by bottom trawls. Seahorses are vulnerable to exploitation due to their inherent biology of being slow-moving, limited home range, and low fecundity, which is further aggravated by various natural disasters that cause damage to the habitats. Urgent management of the natural resources is required to mitigate the exploitation of this species. Strict compliance with fishing regulations must be put in place such as the banning of trawlers and other illegal fishing gear. Reducing consumers' demand may also contribute to fishing pressure by implementing a minimum size of at least 10 cm. Survey and monitoring of seahorse catch need strong cooperation with concerned authorities of the respective AMSs. Measures would certainly require prompt cooperation and willing compliance by the fishers and the implementing authorities.

3.1.5 Corals

Coral reefs are the most structurally complex and taxonomically diverse marine ecosystems on earth (Knowlton, 2001; Jackson *et al*, 2001), and occur in more than 100 countries and territories (Souter *et al*., 2020a). Although coral reefs cover only 0.2 % of the seafloor, they support at least 25 % of marine species, providing habitat for tens of thousands of associated fishes and invertebrates (Knowlton, 2001; Jackson *et al*., 2001) and underpin the safety, coastal protection, well-being, food, and economic security of hundreds of millions of people (Souter *et al*., 2020a).