

Management of Catadromous Eel Resources in Southeast Asia Toward Sustainability: a Synthesis

Dina Muthmainnah, Ni Komang Suryati, Isao Koya, Virgilia T. Sulit, and Takuro Shibuno

Although the fisheries of catadromous eels are known to be practiced in many countries in Southeast Asia, e.g. Cambodia, Indonesia, Myanmar, Philippines, Thailand, and Viet Nam, the statistical information on eel production from these so-called eel-producing countries had been very limited exacerbated by the inadequate classification of the eel species caught and cultured in these countries. In an effort to address such concern, the Inland Fishery Resources Development and Management Department (IFRDMD) of the Southeast Asian Fisheries Development Center (SEAFDEC) based in Palembang, Indonesia conducted baseline surveys to gather information on the systems of data collection on production from eel fisheries and aquaculture practiced by the said countries. The surveys formed part of the five-year project “Enhancement of Sustainability of Catadromous Eel Resources in Southeast Asia,” which was implemented by IFRDMD from 2015 to 2019 with funding support from the Japanese Trust Fund (JTF) as well as that of a parallel activity funded by the Japan-ASEAN Integrated Fund (JAIF). Results from the surveys were then used to establish the data collection scheme for eel production of Southeast Asia, with the main objective of assessing the management of the eel resources toward sustainability. The target eel species are the Anguillid eels, such as *Anguilla bicolor* (*A. bicolor bicolor* and *A. bicolor pacifica*), considering that these species comprise most of the region’s production of Anguillid eels that are bound for the export market in the East Asian region. These species of catadromous eels have been considered as replacement for the declining European and Japanese eel supply in the world’s eel market, as the taste of *Anguilla bicolor* is almost the same as that of the European and Japanese eels.

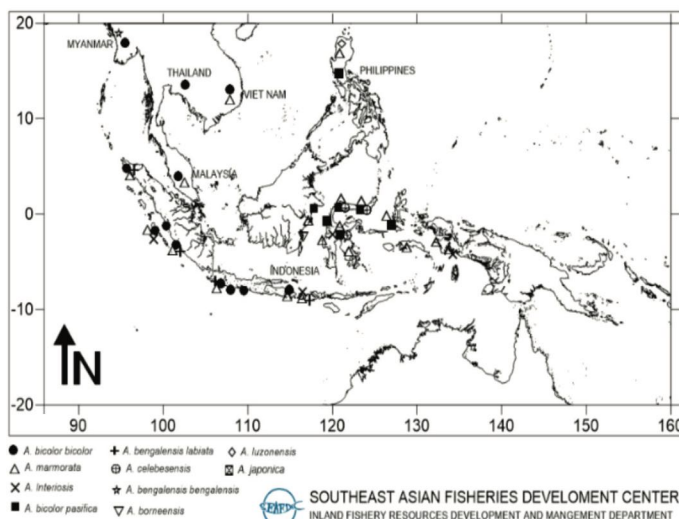


Figure 1. Geographical distribution of Anguillid eels in Southeast Asia

The baseline surveys were carried out to determine the present status of eel fisheries in the ASEAN Member States (AMSS) since many countries do not compile national statistical data on the tropical Anguillid eels. As a result, baseline data from Cambodia, Indonesia, Myanmar, Philippines, and Viet Nam were compiled that included the information on the status and trends of Anguillid eel harvest (SEAFDEC, 2019). From the data obtained, it could be gleaned that the eel samples from Indonesia, Myanmar, and the Philippines comprise six species/subspecies, namely: *Anguilla bicolor bicolor*, *A. bicolor pacifica*, *A. marmorata*, *A. bengalensis*, *A. interioris*, and *A. luzonensis*.

Reports on the JTF Project and JAIF activity on the sustainable utilization and management of Anguillid eel resources have indicated that in Southeast Asia, various species of catadromous eels, especially the *Anguilla* spp. are found in Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Thailand, and Viet Nam (Figure 1). In order to obtain the necessary information on eel fisheries from these countries, baseline surveys were carried out, and catch data were collected from enumerators or consolidators (eel collectors) for glass eels, elvers, and yellow eels to investigate the abundance and trends of tropical eel resources (SEAFDEC, 2019; SEAFDEC, 2020). Representatives from local government units as well as aquafarmers in the sites where eel fishing and culture activities are being practiced were also interviewed.

The rapid decline of temperate eels in the world market during the recent years had resulted in the drastic rise of the value of tropical eels, leading to the dramatic rise of the capture of glass eels (juveniles of eel) in the tropical zone, and prompting some countries to adopt measures to avoid the over-exploitation of glass eels (SEAFDEC, 2020). For example, the Government of Indonesia had issued a regulation prohibiting the export of less than 150 g eel seeds from any areas in the Indonesian territory. Similar policies prohibiting the export of eel seeds have also been enforced by other Southeast Asian countries. Moreover, conservation and management policy issues on tropical eel resources for their sustainability had become a priority not only in Indonesia but also in other Southeast Asian countries.

Status and trend of Anguillid eel fisheries and trade in Southeast Asia

For the sustainability of the region's Anguillid eel resources, it has therefore become necessary for the Southeast Asian countries to establish policies that would strike a balance between the utilization and management of these tropical eel resources. Nonetheless, considering that knowledge on tropical eel species in the region is still limited, the IFRDMD Project was therefore implemented in the AMSs to determine the current status of eel fisheries, establish the collection methods for statistical data on eel fisheries and aquaculture production, and promote management plans for conservation and sustainable use of the tropical eel resources (SEAFDEC, 2020). The surveys on the trends of catadromous eel fisheries carried out in 2015 – 2019, resulted in the compilation of valuable information that depict the status and trends of eel fisheries in the Southeast Asian region (Table 1).

The compiled status and trends of eel fisheries and eel resources in the Southeast Asian region (Figure 2) indicates that Indonesia and the Philippines played significant roles in eel fisheries landings (SEAFDEC, 2019). From 1980 to 2017, the estimated reported landings of Indonesia had increased

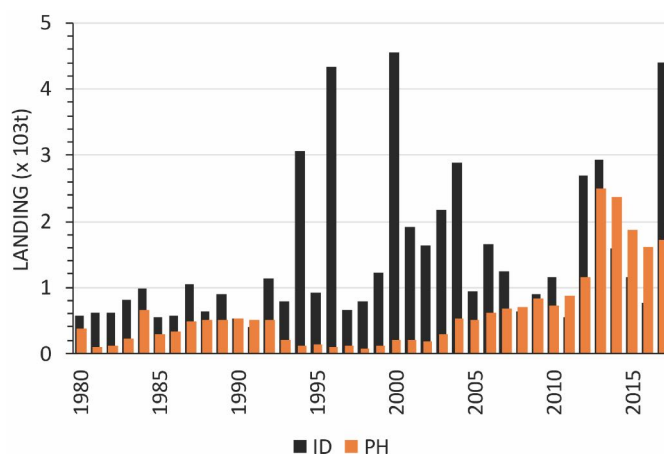


Figure 2. Annual landing data of Anguillid eels (nei) in Indonesia and Philippines (1980-2017)

Source: SEAFDEC (2019)

but fluctuated since 1990, while that of the Philippines had steadily increased since 2000 but then gradually decreased after 2013.

Moreover, the surveys were also able to determine the commercial distribution and trade of catadromous eels in the Southeast Asian region (Table 2).

Table 1. Status and trends of eel fisheries in the Southeast Asian region

Countries surveyed	Outputs/Remarks
Cambodia, Indonesia, Myanmar, Philippines, Thailand, Viet Nam	<p>Compilation of data on:</p> <ul style="list-style-type: none"> the trends and intensity of eel capture including glass eel catch the target species and stages of Anguillid eels used as seeds for eel culture the technical information on the target species and stage of Anguillid eels used as seeds for eel culture the fisheries of Anguillid eel stages (glass eels and/or yellow eels) that are used as seeds for eel culture
	<p>Analysis of current status and trends in the AMSs:</p> <p>Cambodia</p> <ul style="list-style-type: none"> no tropical Anguillid eel fisheries but one eel culture exists <p>Indonesia</p> <ul style="list-style-type: none"> 11 eel aquafarms registered in 2017 more than 2,500 fishers operate fisheries of glass eels and elvers/yellow eels the main target species for eel fisheries and culture is <i>A. bicolor bicolor</i> and its glass eel, elvers and yellow eels are used as seeds for eel culture <p>Myanmar</p> <ul style="list-style-type: none"> no specific fisheries catch tropical Anguillid eels one aquafarm operates eel grow-out target species for eel fisheries and aquaculture is <i>Anguilla marmorata</i> and its yellow eels are used as seeds for aquaculture <p>Philippines</p> <ul style="list-style-type: none"> 28 aquafarms registered more than 4,000 fishers operate fisheries of glass eels and elvers/yellow eels <p>Thailand</p> <ul style="list-style-type: none"> eel capture fisheries not practiced one eel aquafarm is known to exist <p>Viet Nam</p> <ul style="list-style-type: none"> more than 1,320 eel aquafarms exist, 90 % at family scale about 300 fishers are involved in eel capture fisheries
	<p>General Remarks</p> <ul style="list-style-type: none"> Based on national landing data reported in the FAO global fishery and aquaculture production statistics (2019), Indonesia and the Philippines have been playing significant roles in sustaining river eel fisheries in this region, where the estimated reported landing from 1980 to 2017 of Indonesia increased and fluctuated since 1990, while that of the Philippines had steadily increased since 2000 then gradually decreased after 2013

Source: Adapted from SEAFDEC (2019); SEAFDEC (2020)

Table 2. Commercial distribution and trade of Anguillid eels from the Southeast Asian region

Countries surveyed	Outputs/Remarks
Cambodia, Indonesia, Myanmar, Philippines, Thailand, Viet Nam, and to some extent the other AMSs	Compilation of data on: <ul style="list-style-type: none"> the commercial distribution and trade of catadromous eels the commodity chains and demand-supply relationships of eel seeds for aquaculture the status of eel trades and markets in the AMSs the amount and route of existing eel trade
	Analysis of current trade status in the AMSs: Myanmar <ul style="list-style-type: none"> only one eel farm rearing Anguillid eels (mainly <i>A. marmorata</i>) and rice-paddy eel almost all eel products are exported to China, especially before the Chinese New Year Indonesia <ul style="list-style-type: none"> since the rearing from glass eels to elvers needs high-level skills and conditions, only limited number of eel aquafarms (11) could operate eel farming from glass eels most eel aquafarms are in Java Island at various scales of operation large-scale eel aquafarms are funded by foreign companies to rear eels baked eel “unagi-kabayaki” exported to East Asian countries small and middle-scale eel aquafarms trade their products in domestic markets in Indonesia
	General Remarks <ul style="list-style-type: none"> Export data on catadromous eels are available globally, and the general export data of river eels (nei) and elver (live) indicated that Indonesia, Myanmar and the Philippines play significant roles in eel trading in the Southeast Asian region, although the export of Indonesia decreased in 2013, and also that of Myanmar and the Philippines in 2014, but after 2010, Myanmar and the Philippines provided the major contribution to the eel trade

Source: SEAFDEC (2019); Suryati, et al. (2019)

The existing information regarding the amount and route of eel trade in Indonesia, Malaysia, Myanmar, Philippines, Thailand, Viet Nam, and other AMSs compiled by IFRDMD, indicated that in the general export data of river eels (nei) and elvers (live), Indonesia, Myanmar, and the Philippines are the major players in the trading of eels (Figure 3). While the export quantity of Indonesia decreased in 2013, those of Myanmar and the Philippines had decreased in 2014 (SEAFDEC, 2019). Nonetheless, after 2010, the major contributors from the Southeast Asian region to the eel trading arena were Myanmar and the Philippines.

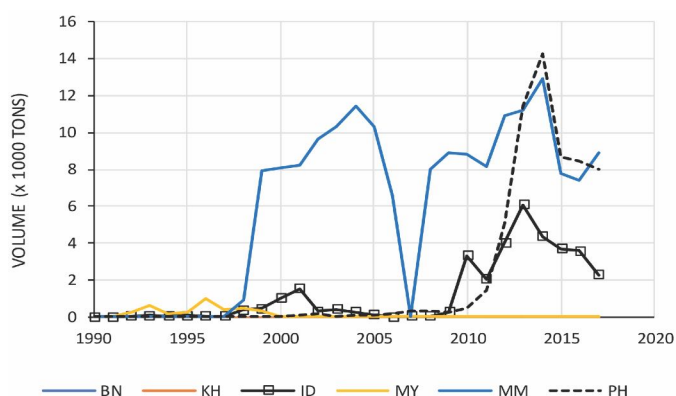


Figure 3. Annual export of eel and elvers (live) from the AMSs (1990 - 2017)

Source: SEAFDEC (2019)

Species identification of catadromous eels in Southeast Asia

In order to enhance the capacity of the countries in the identification of Anguillid eel species in Southeast Asian and in determining the composition of eel catch and aquaculture production, the use of DNA technique had been promoted in the AMSs. However, the studies to address these issues are currently ongoing with the objective of thoroughly finding the ways and means of identifying the eel species found in the region (SEAFDEC, 2020). Meanwhile, IFRDMD provides the technical assistance for the preparation of samples and materials for the said analysis. Nevertheless, through ocular surveys of Anguillid eels in the AMSs, the results showed that the dominant species are *A. bicolor* and *A. marmorata*. Moreover, from the samples of Anguillid eels in Southeast Asia, it could be gleaned that the eel species/subspecies found in Indonesia are *Anguilla bicolor bicolor*, *A. bicolor pacifica*, *A. marmorata*, *A. bengalensis*, and *A. interioris* which were identified based the results of studies conducted in Indonesia’s Palabuhan Ratu, Aceh, Tasikmalaya, Bengkulu, and Poso. The eel species found in the Philippines are: *A. bicolor pacifica*, *A. marmorata*, and *A. luzonensis*; and one species was identified in Myanmar: *A. bicolor bicolor*.

In the evaluation of the species diversity of tropical Anguillid eels in Indonesia, Philippines, and Viet Nam using the genetic data from 5’ region of mtDNA D-loop region, five species and subspecies of glass eels were present in the samples

from Indonesia, four in the Philippine samples, and four in the samples from Viet Nam. These provide the information needed for future studies of the tropical Anguillid eels that would contribute to the development of strategies for the management of the eel resources in the Southeast Asian region.

Statistical data collection methodologies

The concerned Southeast Asian countries indicated that data and information on Anguillid eel fisheries exist in their respective official statistical records, *e.g.* Indonesia, however, these are mostly fragmented making them not accurate and useful for stock assessment of the country's eel resources. In an effort to improve the catch statistics on anguillid eels, especially in response to the requirements of CITES for not listing Anguillid eels in the CITES Appendices, IFRDMD initiated an independent data collection system for Anguillid eels with the help of the eel collectors in Palabuhan Ratu and Bengkulu in Indonesia who have been asked to report the daily catch and effort of their Anguillid eel fisheries. Meanwhile, the current practice of collecting catch statistics on Anguillid eels at each stage of their development, in the SEAFDEC Member Countries had been analyzed for improvement taking into consideration the experience of Indonesia, especially regarding the collection of information on the indices of effort for monitoring the trend and fluctuations of the catch of eel seeds in the region (Muthmainnah *et al.*, 2016).

In an attempt to come up with continuous data, the catch and fishing effort (CPUE) data from Indonesia and the Philippines were used to determine the trend of tropical eel stocks by observing the change in the CPUE. However, considering that long-term fishing effort data of the catch is necessary for analyzing the trends and status of the fishery resource, and since such data are not readily available, the five-year data collected through the Project's surveys was analyzed, but the results did not clearly indicate any trend that could suggest a decline in abundance based on the CPUE. Nonetheless, the basic information compiled on the characteristics of the fisheries for tropical Anguillid eels in the AMSs could still be useful for future stock assessment and management of the eel resources.

The increased attention given to tropical Anguillid eels is meant to compensate the decline of the populations of temperate Anguillid eels, especially in the East Asian eel market (Arai, 2015). Such a situation had prompted many aquaculturists to establish eel farms, *e.g.* in Java Island, Indonesia for the aquaculture of tropical Anguillid eels being eyed for export to the East Asian countries. To date, eel aquafarming still relies heavily on wild-caught seeds in their various stages, such as glass eels (**Figure 4**), elvers and yellow



Figure 4. Fisher collects the glass eel using a scoop net (*above*), the captured glass eel (*below*)

eels, and these eel seeds could be captured in various places in many Southeast Asian countries, *e.g.* Indonesia, Myanmar, Philippines, Viet Nam. But the amount of tropical Anguillid eel seeds caught and used as seeds for eel aquafarming is yet to be established.

Further analysis of the data compiled from Indonesia, indicated two different patterns of the commodity chains of eel seeds from both Sukabumi Regency and Bengkulu Province of Indonesia to the eel farms in Java Island (Muthmainnah *et al.*, 2020). In order to sustainably utilize the Anguillid eel resources and the state of exploitation of eel seeds in



Figure 5. Anguillid eel resources in Southeast Asia as exemplified by the Anguillid eel resources in Sulawesi, Indonesia and eel fishing ground in the Province

Southeast Asia, it has become necessary for the countries to take immediate actions for developing their respective national catch statistics on Anguillid eel fisheries as these would facilitate the establishment of appropriate management strategies for the Anguillid eel resources of Southeast Asia (Figure 5).

Conservation, management and sustainable utilization of catadromous eel resources

The IFRDMD Project had also initiated the compilation of preliminary information regarding the relationship between upward migration of eels and the construction of structures in the rivers of some countries, based on a pilot study carried out in one hydropower dam in Indonesia, the PLTA Poso II located in Poso River and operated by P.T. Poso Energy. The study involves the construction of a fish ladder as a precautionary approach which the company had adopted to maintain the sustainability of eel resources especially in Poso Lake (Ditya *et al.*, 2021). As part of the company’s Corporate Social Responsibility (CSR) program on eel conservation, Anguillid eels had been stocked in the lower part to the upper side of the dam to study the survivability of eels crossing the dam. The company had also restocked 200 kg of elvers in Peura Village near Poso Lake, while silver eels were restocked at the river mouth of Poso.

The progress of the pilot study had been continuously monitored to enable the IFRDMD to establish the relationship between upward migration of eels and construction of infrastructures in rivers, and the construction of fish ladders to mitigate the issues on disruptions of the migration route of eels in rivers for the completion of their life cycle (Figure 6), as what is being done by the Poso Energy Company. The life cycle of the Anguillid eels could be severely affected by

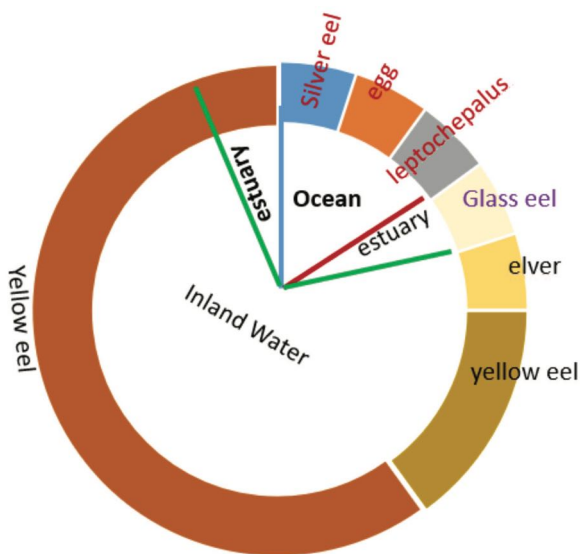


Figure 6. Habitats of the life stages of Anguillid eels

the construction of infrastructures in rivers and other water bodies, as a big part of their life stages is spent in inland waters. Although only an estimation, it has been presumed that more than 50 % of the life cycle of Anguillid eels is spent in inland waters, and it is also in these areas that interactions with human activities and interventions usually take place.

In the life cycle of the Anguillid eels, the glass eels enter the river mouths and estuaries where they grow to become elvers and yellow eels in these inland water environments, until they become silver eels and migrate to the oceans. It is in the inland water environments that the eel seeds are vulnerable to damages due to human activities as well as natural disasters. Generally, in the Southeast Asian region, interest has been rising on the collection of glass eels and elvers as these have been extensively used for the aquaculture of Anguillid eels to produce adult eels that could compensate for the dwindling eel supply in the market. The estimated production from capture fisheries of Anguillid glass eels and yellow eels in Southeast Asia is shown in Figure 7. The present target eel species is *Anguilla bicolor* (*A. bicolor bicolor* and *A. bicolor pacifica*) produced by Indonesia and the Philippines. East Asian countries, *e.g.* China, Japan, Taiwan, and South Korea have been the biggest importers of cultured Anguillid eel and used to replace and compensate for the declining supply of the European and Japanese eels (Arai, 2015). Besides, the taste of *Anguilla bicolor* is almost similar with that of the European and Japanese eels.

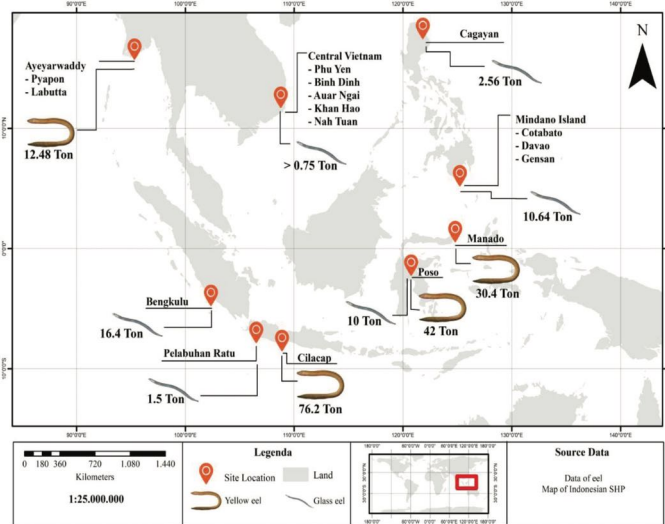


Figure 7. Production from capture fisheries of glass eels and yellow eels of Anguillid eels in Southeast Asia

In Southeast Asia, eel collectors gather glass eels from fishers, rearing the glass eels for a few days in temporary rearing tanks, then transporting the eel seeds to eel aquafarms. Finally, eel aquafarmers rear the glass eels to marketable size, and as soon as the eels reach the size for consumption, these are harvested and processed into food products such as the grilled *unagi* or *kabayaki*. While glass eels and elvers are shipped to

eel farmers, the yellow eels are shipped to local and overseas markets. The distribution channel for eels is concentrated on the consolidators because of the need to transport or trade eels in their live state. The production and utilization of the tropical Anguillid eels in aquaculture by selected Southeast Asian countries has also been established (Table 3).

Issues and Concerns

A major concern encountered in the region's Anguillid eel fisheries is the general status of the eel fishers: mostly small-scale and continue to survive below the poverty line. This condition deprives them from having considerable access in utilizing the fishery resources, and because of lack of capital for acquiring the necessary fishing gear, they usually do not

Table 3. Production and utilization of tropical Anguillid eels used for eel aquaculture by some AMSs

Countries surveyed	Catch tropical Anguillid eels and utilization of eel seeds in aquaculture
Cambodia	Although there is no capture fisheries that exploit the country's tropical Anguillid eel resources, its culture activities make use of elvers imported from the Philippines. In 2017, Cambodia imported about 1.0 t of elvers from the Philippines comprising 70 % and 30 % <i>A. marmorata</i> and <i>A. bicolor pacifica</i> , respectively. However, some fishers reported to have caught Anguillid eels from the country's rivers using crab traps set at night and hauled the next morning, but the main target of this fishery operation is not only the eel species but other fishes too. Some fishers also use hooks to fish in the shallow waters of rivers, fishing the whole day or using longline during the low tide.
Indonesia	Among th Southeast Asian countries, Indonesia remains very active in the capture fisheries and aquaculture of the tropical Anguillid eels There are four main fishing areas for eel fisheries in Indonesia: Palabuhan Ratu Sub-district, Manado District, Poso District, and Cilacap District, where glass eels, elvers, and yellow eels of <i>A. bicolor</i> or <i>A. marmorata</i> are dominantly caught. There is variation in the fishing gear used and time of capture of glass eels and elvers. In Palabuhan Ratu Sub-district, glass eels are mainly caught between September and December using scoop net. While in Cilacap District, elvers and yellow eels are mainly caught by scoop net or PVC trap from October to November. Glass eels, elvers, and yellow eels in Poso District are mainly caught by fyke net or barrier trap from July to August. In Manado District, glass eels are caught by scoop net but the peak fishing season is still unknown. In Palabuhan Ratu, glass eel fishing activities usually start at night from around 6:00 p.m. until 5:00 a.m. in the morning. Glass eels are abundant from October to March with a peak occurring in January. Eels for consumption are usually caught in April-September by <i>anco</i> or lift net. The eel fishery system in Palabuhan Ratu in Sukabumi has been in existence for decades but still requires proper management for the sustainability of the eel resources. Meeting the market demand for glass eels for the development of eel aquaculture has recently resulted in the shift of procuring eel seeds from capture fisheries to cultured eels. Nevertheless, success in eel aquaculture still remains largely dependent on the availability of seeds that rely heavily on nature. The country's production from farming of <i>A. marmorata</i> and <i>A. bicolor</i> in 2017 was 478.50 t which increased to 515.18 t in 2019 (KKP, 2020). Almost all production from these areas are exported to China, Korea, Japan, Taiwan, and other countries.
Myanmar	There are no specific fisheries for Anguillid eels in Myanmar. Yellow eels of 90 % <i>A. bicolor</i> and 10 % <i>A. bengalensis</i> are accidentally caught by stow net, crab trap, or longline hook in the rainy season. <i>A. bicolor</i> is the main species farmed in Myanmar by only one aquafarmer, with production that reached 15.0 t in 2017, and exported to China by truck through the border.
Philippines	Fishers of the Philippines catch the eel species, <i>Anguilla marmorata</i> from glass eels, elvers, and yellow eel stages in the waters of Luzon and Mindanao Islands. Glass eels are caught between April and August mainly by using fyke net, stow net, scoop net, or push net. The annual catch of glass eels has been fluctuating yearly since 2007. In 2017, the catch was about 2.0 t from Luzon and 10.0 t from Mindanao. The fishing gears used to catch the elvers/yellow eels are seine nets, bamboo traps, hook line, and spear gun, usually between December and February, and the annual catch from both islands in 2017 was about 0.3 t. The production volume of the 28 eel aquafarmers in the Philippines, based on local official data in 2017, showed that <i>A. marmorata</i> and <i>A. bicolor</i> from Mindanao was about 100.0 t and about 20.0 t from Luzon. The country's production of <i>A. bicolor</i> is exported to Japan, Korea, and Taiwan, while that of <i>A. marmorata</i> is bound for China and Taiwan.
Thailand	Only elvers/yellow eels of <i>A. marmorata</i> and <i>A. bicolor bicolor</i> are caught in Thailand usually in May to October as accidental catch when fishers operate fish traps. Elvers/yellow eels are captured in three areas: Ranong Province, Satun Province, and Phangnga Province. To meet the development needs of eel aquaculture in several provinces, glass eels are imported from China while elvers/yellow eels come from Indonesia. The country's eel production from aquaculture is exported to China.
Viet Nam	The composition of the country's glass eel production is 95 % <i>A. armorata</i> and 5 % <i>A. bicolor pacifica</i> . Glass eels are mainly caught in Phu Yen Province although there are also few catches in Bin Dinh Province, Auar Ngai Province, Khan Hoa Province, and Nah Tuan Province. The main fishing gears used to catch glass eels are towing net and scoop net. The peaks of the fishing season in Phu Yen Province occur from November to May. The total annual catch of glass eels ranges between 0.60 and 0.75 t (or 4,000,000-5,000,000 individuals). Several fish farmers are rearing eels in Phu Yen Province and Khan Hoa Province (Thuc & Van, 2021). The country's largest eel farm is located in Khan Hoa Province which produces 200,000-300,000 individuals of elvers/yellow eels. Compared with those of the other Southeast Asian countries, people in Viet Nam consume large amounts of Anguillid eels.

Source: SEAFDEC (2019); SEAFDEC (2020)

have sufficient ability to catch this pricey fish. As a result, fishers depend heavily on middlemen who lend them the needed capital, and so fishers are also bound to sell their catch directly to middlemen who have provided them the capital or fishing gear prior to undertaking fishing operations.

Eel farming could have also provided a solution not only to the unstable supply of eel products in the market but also in terms of creating prospects to increase the income and sustainable livelihoods of fishers (Siriraksophon *et al.*, 2014). However, this is still not attained as eel aquaculture in the region is still at its infancy. Although there are companies that operate eel aquafarms in eel producing countries, their products are directly exported to eel-consuming countries. For example, the value of the Anguillid eel exported to Japan during the past four years could easily averaged USD 2.3 million per year.

Another very crucial concern is in the sustainable management of the Anguillid eel resources in the Southeast Asian region, considering the limited ability of many eel-producing countries to estimate the status of their tropical eel stocks by pursuing stock assessment (Arai, 2015). As this endeavor would require that the data-poor eel fisheries production is improved using simple methods of data collection, efforts should be made to improve such data collection systems and come up with the real status and trend of eel production from capture fisheries and aquaculture. Moreover, for the sustainable management of the tropical Anguillid eels, it is also necessary that the capability of the eel-producing countries is enhanced to enable them to identify the eel species caught and cultured.

Although IFRDMD has already compiled the information on five Anguillid eel species in Indonesia (Palabuhan Ratu, Aceh, Tasik Malaya, Bengkulu and Poso), *i.e.* *Anguilla bicolor bicolor*, *A. bicolor pacifica*, *A. marmorata*, *A. bengalensis*, and *A. interioris*; three species in the Philippines, *i.e.* *A. bicolor pacifica*, *A. marmorata*, and *A. luzonensis*; and one species in Myanmar, which is *A. bicolor bicolor*, such information could be used for visually identifying the species of the eel samples. However, there is still a need to analyze more samples from other sites and countries, and be able to identify the other species of tropical eels found in the Southeast Asian region.

The development of simple aquaculture method could be one of the possible solutions that could reduce the market price of eels. In Indonesia for example, the price of glass eel could be around IDR 1.0–3.0 million/kg glass eels or USD 70–250/kg. This price could still increase depending on the availability of marketable stocks, especially that the production of glass eels depends on the catch from the wild and correlates with the season and location. Added to this is the high mortality during eel seed transfer, especially if the distance between the fishing and collection areas of the glass eels is far from the aquafarms, thus necessitating the development of improved eel transport techniques.

While research on the breeding of the tropical Anguillid eels is still being developed, another concern in eel aquaculture is the availability of cheaper feeds for hatchery operations. The current price of feeds is still quite expensive at about USD 2.5–4.0/kg, as the feeds should have high protein contents (40–50 %) and some ingredients for the feed formulation are still imported. Strategies should therefore be developed to reduce the price of feeds through the adoption of improved feed development technologies (Muthmainnah *et al.*, 2020).

Furthermore, challenges in Anguillid eel conservation had also been raised on many occasions and fora, as many factors have led to the deteriorating state of the habitats of eels. For example, the continued construction and installation of development structures, overfishing, diseases, climate change, and water pollution among others. The construction of dams or weirs in many rivers of the AMSs to supply the water needed for crop irrigation and for running hydroelectric power plants, has created obstructions of the flow of water that hinders the migration pathways of many aquatic species as they complete their life cycles. In the case of eels, such developments block the movement of eels going upstream or undergoing reverse migration to complete their life cycle.

Infrastructures constructed along rivers could also delay fish migration contributing to the decline and even possible extinction of fish species that depend on longitudinal movements along the stream during certain phases of their life cycles. Nowadays, the construction of fish pass or fish passage has been promoted to address possible river blocking that significantly addresses the possible deterioration of fish habitats that could eventually improve the survival rates of aquatic species. As many countries in Southeast Asia had been planning to construct or have already constructed dams and weirs, it is necessary that such construction comes with the installation of fish passes or fish passages or fish ways. For the already constructed dams and weirs, efforts should be made to build fish ways for the sustainability of the freshwater aquatic resources.

Most of the eels produced in the Southeast Asian region are bound for the export market, but locally, eels are not known as a nutritious food fish. Notwithstanding the market price of eels that seems to be prohibitive and unaffordable by the local people, eel products could be promoted domestically so that the local people could learn to patronize the products. In Indonesia for example, eel products are being introduced to local communities through processing to produce food that is suited to the people's palate. Packaging of Anguillid eel products have also been altered by avoiding designs that make eels appear like a snake. Such efforts could also be undertaken in the other Southeast Asian countries so that eels could be consumed locally, thus, increasing the demand. The promotion of information, education and communication (IEC) should be enhanced through sharing of publications, leaflets and other

audio-visual materials on Anguillid eels. The organization of meetings, training sessions, and field visits could also enhance the knowledge and capacity of the AMSs in the conservation, management and sustainable utilization of the catadromous eel resources.

Way Forward

There are still many challenges that need to be addressed for the sustainability of the Anguillid eel resources in the Southeast Asian region. Aside from the issues and concerns mentioned above, other constraints that hinder the sustainable management and utilization of Anguillid eels could include enhanced habitat protection, improved governance, development of measures that mitigate natural factors, e.g. climate change, diseases, as well as anthropogenic concerns, e.g. overexploitation, pollution. Efforts are therefore being made by SEAFDEC to extend the activities of the project that were terminated in 2020, through the implementation of new projects starting in 2021 that aim for the sustainable utilization and management of the Anguillid eel resources.

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About the Authors

Dr. Dina Muthmainnah is the Head of Research and Development at SEAFDEC/IFRDMD and Senior Researcher of the Research Institute for Inland Fisheries and Extension, Ministry of Marine Affairs and Fisheries, Palembang, Indonesia. She was the Project Leader for 2015-2016 of *Enhancement of Sustainability of Catadromous Eel Resources in Southeast Asia*. Currently, she is the Project Leader of *Sustainable Utilization of Anguillid Eels in the Southeast Asia Region for 2020-2021*.

Ms. Ni Komang Suryati is the Head of Research and Development Unit for Biological and Taxonomy at SEAFDEC/IFRDMD and Researcher of the Research Institute for Inland Fisheries and Extension, Ministry of Marine Affairs and Fisheries, Palembang, Indonesia. She was the Project Leader for 2017-2019 of *Enhancement of Sustainability of Catadromous Eel Resources in Southeast Asia*.

Mr. Isao Koya was the former Assistant Trust Fund Manager of the Japanese Trust Fund (JTF) at SEAFDEC from June 2016 until December 2020. He was also the Project Coordinator for the *Enhancing Sustainable Utilization and Management Scheme of Tropical Anguillid Eel Resources in Southeast Asia* funded by the Japan-ASEAN Integrated Fund (JAIF). He is now back at the Fisheries Agency of Japan in Tokyo.

Ms. Virgilia T. Sulit is the Managing Editor of *Fish for the People* based at the SEAFDEC Secretariat in Bangkok, Thailand.

Dr. Takuro Shibuno was the former of SEAFDEC/IFRDMD Deputy Chief in January 2018-March 2020. He is now back to Japan Fisheries Research and Education Agency (FRA of Japan).