Benchmarking the Adoption of Fish Enhancing Devices in Southeast Asian Waters: the coastal waters of Thailand in focus

Nopporn Manajit, Nakaret Yasook, Santiphong Putsa, Rattana Tiaye, Taweekiet Amornpiyakrit, Isara Chanrachkij, and *Virgilia T. Sulit*

The coastal waters of Southeast Asia are blessed with high productivity of fishery resources because of rich ecosystems such as dense mangrove forests and sea grass beds, as well as extensive coral reefs with clean tropical sea environment. These waters are critical to a broad range of aquatic organisms during their life cycle, *i.e.* from breeding, spawning, nursing to growing, hosting the feeding zones of aquatic species that are economically important, and serving as important source of recruitment of a wide diversity of fishery resources. However, most of the commercially important fishery resources in the coastal waters of the region had declined due to many factors that include overfishing, illegal fishing, destructive fishing practices, and environmental degradation. Fish aggregating devices, like artificial reefs had been established as significant tool for fishing ground development and for increasing the fish production from coastal areas, but the cost of installation of such devices is considerably high, especially in terms of investment, and necessitated that the management of such installations should be the responsibility of government agencies. Many artisanal fishers have therefore been adopting much cheaper types of resource enhancement devices and managing such devices by themselves with assistance from the public and private sectors.

Upon the adoption of the 2001 Resolution (RES) and Plan of Action (POA) on Sustainable Fisheries for Food Security in the New Millennium (SEAFDEC, 2001), and specifically following on the need to: "*work towards the conservation and rehabilitation of aquatic habitats essential to enhancing fisheries resources"* (RES#9), and to *"optimize the use of inshore waters through resource enhancement programs such as promoting the installation of artificial reefs and structures, encouraging coordinated and effective planning for coastal fisheries management programs, …*" (POA#4), SEAFDEC embarked on several programs and projects that aim to address overfishing and environmental degradation in the Southeast Asian waters, which include among others, programs on enhancing the coastal fishery resources through the development of strategies for the modification of coastal habitats to restore and increase their productivity (Ebbers, 2003). Modification of fishing grounds to increase fish production, *e.g.* installation of artificial reefs and other man-made structures has long been practiced in the Southeast Asian region for the rehabilitation and enhancement of degraded fish habitats. This article which focuses on the use of fish enhancing devices in Thailand (Manajit, *et al*., 2019), is based on the paper presented during the "International Conference on Fisheries Engineering 2019: Realizing a Healthy Ecosystem and Sustainable Use of the Seas and Oceans" organized by the Japanese Society of Fisheries Engineering, 21-24 September 2019, Nagasaki University, Japan.

From artificial reefs to fish enhancing devices

Various designs of the artificial reefs (ARs), also sometimes known as stationary fishing gear (SFG) or fish aggregating devices (FADs), had been developed and adopted in the Southeast Asian region with the main objective of enhancing the fishing grounds and improving fish production. Generally in Southeast Asia, however, the deployment and installation of ARs are the responsibility of the respective governments considering the high cost involved in construction, installation, and management of the ARs.

In Malaysia, for example, its ARs Program which is mainly under the Department of Fisheries Malaysia (DoFM) had been allocated a total budget of about 155 million Malaysian Ringgits (RM) from 1976 to 2010 (Ali and Sulit, 2012), where at the time of reporting USD 1.00 = RM 3.30. Such ARs Program is intended mainly for fishery use (conservation and fishing), as well as for non-fishery use (resource enhancement). Results from the monitoring of such ARs have indicated that the coastal fishery resources have been enhanced, as the ARs provide firm substrates for fauna and flora to grow. The ARs have also served as protection against encroachment of the inshore fishing grounds by trawlers (Ali *et al*., 2011). In order that ARs would continue to play the role of enhancing and conserving the fishery resources, it is necessary that proper management of the AR sites is sustained (Zainudin, 2016). Meanwhile, big ARs have also been deployed in the waters of Malaysia to eliminate trawler encroachments in nearshore areas while allowing more species of marine flora and fauna to settle outside and within big ARs (Ali *et al*., 2013).

In the case of Thailand, installation of ARs had been deployed in its coastal waters through the effort of the Royal Initiative Project on Coastal Fishery Resource Rehabilitation with the involvement of various stakeholders including the public and private sectors, and the academe, and making use of concrete pipes, concrete blocks, train cars, military tanks, and garbage trucks as ARs. Results of the monitoring carried out by the Department of Fisheries (DOF) of Thailand have shown that through the deployment of ARs, the fishery resources

in Pattani and Narathiwat Provinces of Thailand had been restored. The DOF would continue to monitor the situation of the ARs to make sure that these structures attain the objective of contributing to the sustainability of the resources and improvement of the socio-economic conditions of fishing communities (Somchanakij *et al*., 2016).

In a study he carried out, Ali (2004) suggested that the actual combination of ARs and FADs would continue to allow the aggregation of several varieties of fish species. Introduced in the coastal waters of Peninsular Malaysia by researchers from the SEAFDEC Marine Fishery Resources Development and Management Department (SEAFDEC/MFRDMD) in collaboration with the Department of Fisheries Malaysia, this modified structure called the Artificial Reef Fish Aggregating Devices (ARFADs) had shown to be more durable and provide more stable and enriched fish habitats, so that ARFADs (**Figure 1**) is meant not only to aggregate multiple fish species but also to enhance the fishery resources in coastal areas. Although construction of ARFADs could also be costly because of the materials used but not as expensive as the big ARs, in the long run, it would still turn out to be more economical. In the development of ARFADs, expensive but durable materials are necessary, such as the anchor, line, and aggregating devices that are able to withstand strong wind, waves, and currents, and resist the corrosive action of seawater.

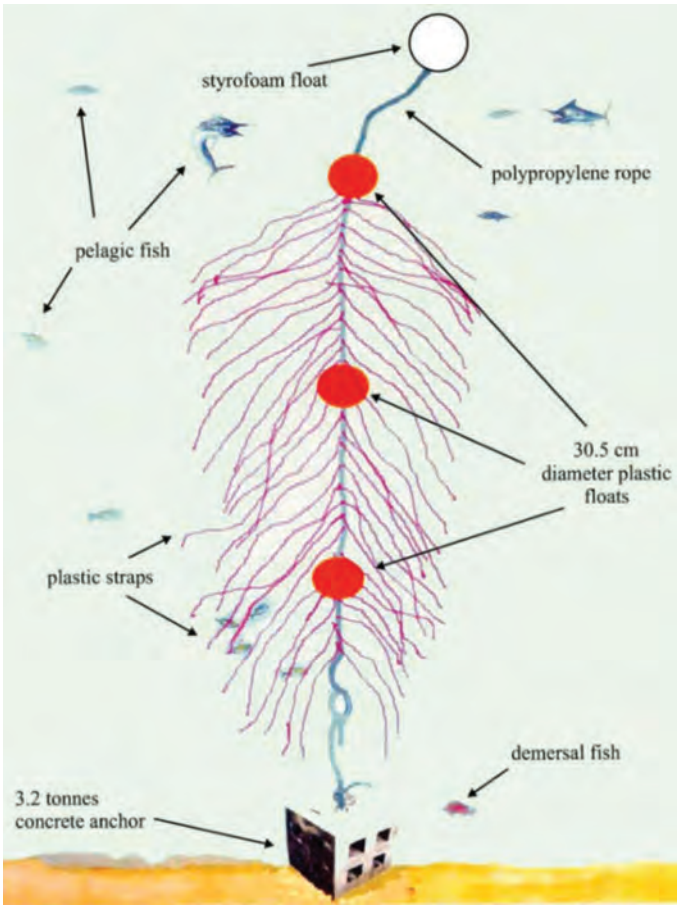

Figure 1. Suggested design of an ARFAD
Source: Ali (2004)

Generally, an ARFAD has three components: floats, attractors, and anchored mooring (**Figure 1**). The upper part of the structure, consisting of the floats, appendages and mooring line, is commonly referred to as a fish aggregating device. It is used to attract pelagic fishes because of the presence of attractors made of plastic strips and attached to the mooring line, also known as anchor line and made of polyethylene rope. The anchor line connects the floats to a heavy molded concrete anchor set at the bottom of the sea. This anchor not only keeps the FAD in position but also serves as an AR to demersal fishes.

ARFADs could therefore be effective for artisanal fisheries as fishing effort is relatively low, and once deployed in suitable sites, ARFADs could function like ARs turning unproductive areas into rich ecosystems that are beneficial to the fishing communities for subsistence fishing and recreational purposes. Nevertheless, in order to guarantee the sustainability of the ARFADs and ensure that their resource enhancement functions outweigh their contribution to resource harvesting, fishing effort must be strictly regulated in areas with ARFADs (Ali, 2004). The use of selective fishing gear, *e.g.* hook and line, is encouraged for catching the marketable sized fishes that have aggregated at the ARFADs.

Through the SEAFDEC/MFRDMD as well as SEAFDEC Training Department (SEAFDEC/TD), the task to explore the development of appropriate tools that would enhance the coastal fishery resources had continued through the years. Moreover, SEAFDEC also made sure that the awareness of stakeholders is enhanced, especially on community management of the fisheries that aim to, among others, shift the stakeholders' role from being resource users to resource managers through the installation of fish aggregating devices (FADs) that requires cheaper investment than artificial reefs.

Thus, the development of an innovative fisheries management tool had been explored in the Philippines and other countries in Southeast Asia including Thailand, which is a form of FAD and is known as fish enhancing devices (FEDs). Although the use of FEDs still involves the deployment of FADs in fishing grounds, fishing is regulated, if not totally prohibited, especially in the area of the FADs. Also called "floating artificial reefs," FEDs have additional structures other than those of the standard anchored FADs. Currently, many countries in the Southeast Asian region, *e.g.* Philippines, Malaysia, Indonesia, Thailand, have been adopting FEDs for fishery resources enhancement. **Table 1** summarizes the differences and similarities of the various structures used to enhance the fisheries habitats in coastal waters of the region.

FADs which are recognized as one type of ARs had been used to lure fish in large quantities and facilitate the efficient capture of fish. Placed at the surface or mid-depth of sea water, FADs which originated from small-scale fishers in the Oceanic-Pacific countries, where these are also called

Table 1. ARs, FADs, ARFADs, FEDs used in Southeast Asia: differences and similarities

	Function	Materials used	Installation area	Type
ARs[1]	• Enhance the resources (flora and fauna) • Aggregate demersal fishes • Create fishing ground • Serve as habitat protection	• Concrete, ferroconcrete • PVC • Tires • Fiberglass • Metal • Others	• Shallow water	• Bottom structures
FADs[1]	• Aggregate pelagic fishes • Create fishing ground	• Sticks • Plastic strips • Bundle of bushes or fronds • Canvas • Concrete block or drum, sandbag, rocks, stones	• Shallow to deep water	• Floating, anchored
ARFADs[1]	• Enhance the resources (flora and fauna) • Aggregate pelagic and demersal fishes • Serve as habitat protection	• Concrete for anchor • Plastic strips for attractors	• Shallow water	• Floating and anchored
FEDs	• Supporting buoy maintains buoyancy and provides marking • Attract fishes through polyethylene (PE) ropes attached to main line • Serve as habitat protection through the shades and hiding places provided • Sinkers and anchors fix the position of the structure	• Plastic buoys, floats, plastic gallons, etc. • Polypropylene (PP) rope • PE or PP rope (branch line, appendages), and PE net panels • Concrete block or drum	• Shallow to deep water	• Floating and anchored

[1] *Source: Ali (2004)*

"payao," are made of floating bamboo raft and anchored by weight under the raft. Tree branches and coconut palm leaves are used as fish shelter especially for small fishes and the big fishes are lured to feed on the small fishes. At present, "payao" is commonly used in the Philippines, Indonesia and Thailand, although this type of FADs varies in each country considering the locally-available materials used to make the FADs, *e.g.* bamboo, tree branches, coconut palm leaves. The most expensive parts of FADs are the anchors and chains.

In the Philippines, "payao" is placed at water depths of more than 2,000 m, and used to lure tuna, *e.g.* yellow fin tuna that are then captured by purse seine. When SEAFDEC implemented the program "Rehabilitation of Fisheries Resources and Habitats/Fishing Grounds through Resource Enhancement" from 2001 to 2005, experiments were carried out on the suitable designs/models of the resources enhancement tools in collaboration with the SEAFDEC Member Countries. As a result, the program came up with a resource enhancement tool modified from FADs, which is now the so-called "Floating Artificial Reefs" or Fish Enhancing Devices (FEDs) for use in coastal areas (**Figure 2**). Thailand was reported to be the first Southeast Asian country to adopt the use of such FEDs.

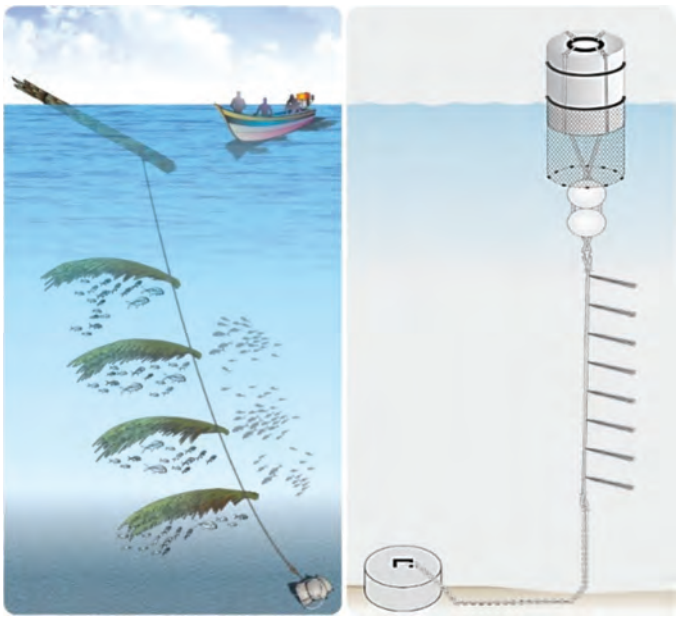

Figure 2. FADs *(left)* and FEDs *(right)*

Series of on-site training sessions on FEDs construction and installation had been carried out by SEAFDEC/TD since 2004, not only in the SEAFDEC Member Countries funded by the Japanese Trust Fund, *e.g.* Malaysia, the Philippines, Viet Nam, but also in the coastal areas of Thailand promoted and funded by the Department of Fisheries (DOF) of Thailand (*e.g.* Chonburi, Prachuab Kiri Khan, Chumporn and Phuket, Chanthaburi, and Trat Provinces) through the fishers' groups in the coastal zones. These sessions had provided the participants with the necessary information on FEDs that included the objectives, utilization, and methods of construction. The local fishers were also trained to monitor, manage the fishing activities near the FED areas, and repair the FEDs by themselves.

The training sessions also promoted the use of economical materials for FEDs, including used ropes and nets taken from abandoned fishing gears and nets for the accessory parts. This would make full use of discarded fishing equipment and reduce the cost of constructing the FEDs, an approach which

is similar to the concept of constructing the traditional FADs that emphasizes on the use of locally-available materials. As a result, the utilization of FEDs with various designs has widely spread throughout the coastal provinces of Thailand.

Benchmarking the use of FADs in Thailand

In order to update the compiled information on the structure and design of FEDs, as well as the significant issues and concerns in FEDs construction and design in different types of fishing grounds, SEAFDEC/TD in cooperation with the DOF of Thailand conducted a survey on FEDs used in small-scale fisheries from October 2017 to January 2018, covering 47 fishing communities in 15 coastal provinces of Thailand, *i.e.* in the Gulf of Thailand and Andaman Sea (**Figure 3**). Coordinated by the Fisheries Provincial Officers, the survey was meant to obtain the general information on the FEDs installed in each province. Interviews with the local fisheries officers and fishers were carried out to obtain the necessary information including the designs, materials used, construction, installation areas, and utilization of FEDs. Photographs of existing FEDs were also taken and their dimensions measured.

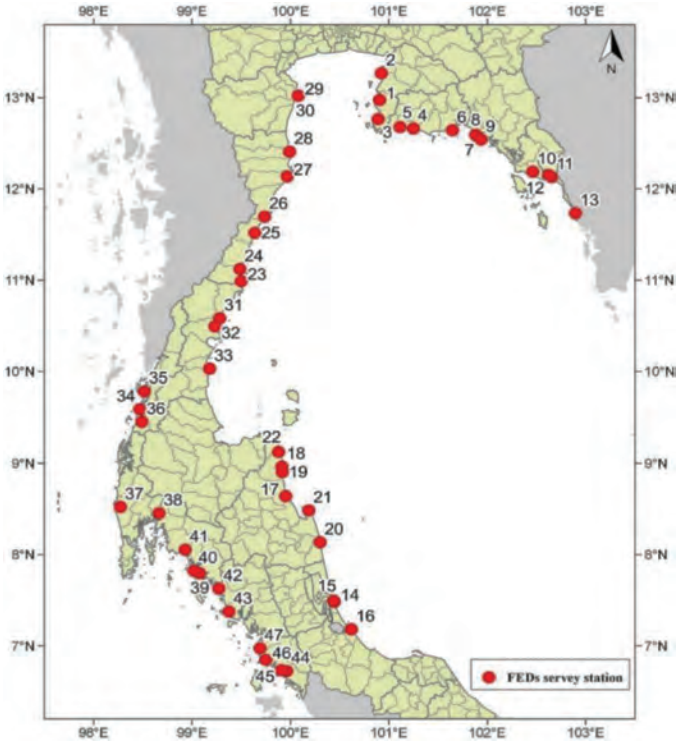

Figure 3. FEDs survey sites along the coastal areas of Thailand (indicated by red dots)

Results and Discussion

The results of the survey have confirmed that FEDs have been used by fishers as an innovative tool for fisheries management in the coastal communities of Thailand, and that the FEDs deployed were made of various materials and designs. The fishers' groups chose the patterns of their FEDs based on their artisanal fishers' wisdom, the objectives of installing FEDs, geography of the areas, water depth, and suggestions from supporting agencies, considering that the fishing communities received funding support from various agencies including private companies and government agencies, such as the Petroleum Authority of Thailand (PTT), Erawan Group, Amarin TV, DOF of Thailand, Department of Marine and Coastal Resources (DMCR) of Thailand, among others.

From the survey and actual observations, it was found that the FEDs were mostly placed in conservation areas at 0.1 to 1.6 nm away from the shoreline, and at water depths that range from 2 to 17 m. Moreover, it was also noted that the resource enhancing tools adopted in Thailand could be categorized into two types: the traditional FADs and the modern FEDs. For the traditional FADs, the materials for the buoy and attractor sections are made from locally available natural materials such as bamboo sticks which also function as buoy and marker, while coconut fronds or palm leaves are used as attractors and function also as provider of shades and hiding places for the fish. Although the materials used are low cost, these were found to be very effective in attracting fishes, but the life span of their use is only between 3 and 6 months. Furthermore, Anna *et al*. (1999) also reported that "palm leaves used in the traditional FADs provide less effective shelter than rope". The results from Ali *et al*. (2004) also indicated that the average lifespan of coconut leaves is 1-2 months. For the modern FEDs, instead of using natural materials, polyethylene, plastic or fiberglass materials are used for buoys. Although such materials contribute to high investment costs, their lifespan is longer compared with that of the traditional FADs.

Figure 4. Types of enhancing devices found in Thailand

Box 1. The types of enhancing devices used in Thailand (see **Figure 4**)
1. **Traditional FADs:** the attracting parts are made of natural materials such as coconut leaves, palm leaves and bamboo pole
2. **Anchored FEDs (Emerged type):** the attracting devices are synthetic rope (PE or PP rope)
3. **Anchored FEDs (Submerged type):** a kind of rope FEDs set up at mid-water layer or at a desired depth
4. **Pillar FEDs:** the attracting parts are made of synthetic rope tied up with a pillar and submerged to settle at seabed
5. **Other types of FEDs** including the AR-FEDs such as concrete pipe FEDs: could be either a single concrete pipe or multi-pipes, with or without attracting parts

In summary, various characteristics of FEDs with respect to the structure, design and installation were observed during the survey along the coastal areas of Thailand. These enhancing devices could be categorized into five (5) based on their patterns (**Figure 4** and **Box 1**).

From the survey, it was also observed that anchored FEDs were mainly found in 14 provinces (29 fisher groups) in the Gulf of Thailand and the Andaman Sea. The use of traditional FADs (No. 1) spreads over ten (10) provinces (19 fisher groups). Concrete pipe FEDs functioning as AR-FEDs (No. 2) were found only in 4 provinces (5 fisher groups) in the Andaman Sea, while the anchored FEDs submerged type (No. 3) were found in 3 provinces (4 fisher groups), and the pillar FEDs (No. 4) were deployed only in Trat Province (3 fisher groups). Moreover, in Trat Province, the fishers modified the design of FEDs to make these more suitable in the area considering the depth of the sea water. Furthermore, wrecked spirit houses and used motorcycle tires were also deployed as FADs and FEDs in Chumphon and Ranong Provinces, respectively.

From the results of the interviews with fishers, FEDs have been effective as tool to enhance the fishery resources and to protect the resources from the encroachment of destructive fishing gear into the coastal areas used by artisanal fishers for their fishing activities. Most fishers from the survey sites were satisfied with the presence of FEDs in their respective areas because the FEDs had remarkably enhanced and restored the coastal resources. The fishers also found aggregations of various aquatic species after the FEDs installation, *e.g.* barracuda, Spanish mackerel, black pomfret, longfin trevally, shortbody mackerel, yellowstripe scad, talang queenfish, fourfinger threadfin, groupers, snappers, catfish, including the blue swimming crab and splendid squid. Thus, the fishers are able to catch more fish to increase their income, while some fishers also earn additional income from carrying out eco-tourism activities like sports fishing and diving near the installed FEDs. Similar to the conclusion of Ali *et al*. (2004) that after a few years of the deployment of new design of FADs called "Artificial Reef Fish Aggregating Devices (ARFADs)," the FADs had turned into new habitats for many demersal fish species and sanctuaries of fish and other marine organisms. Furthermore, the fisher communities also observed that during the construction of FEDs, the cooperation among members of the fishers' groups had been strengthened. Therefore, FADs or FEDs would not only address resource deterioration but also ensure the sustainable livelihoods of coastal fishers.

Conclusion and Recommendations

Considering that the local fishers would be tasked to manage and maintain the FEDs, they should organize themselves into groups to take the leading role of regulating and controlling the use of fishing gear near the FEDs. Regulations should then be enforced that prohibit the irresponsible use of fishing gear and over-exploitation of the resources near the FEDs. This would also eliminate the same problems that were encountered during the FADs installation without any regulation. The fisher's groups are also expected to establish financial systems following the fisheries cooperative concept. The income earned from the fisheries cooperatives could then be used for the construction and installation of new units of FEDs.

Fish aggregating devices (FADs) and fish enhancing devices (FEDs) are well recognized as devices that help gather the living aquatic resources. The design and shape of FADs could differ from country to country, considering the behavior of target species and the conditions of the coastal waters. As alternative devices of FADs, FEDs could also be made of used fishing gear materials, such as ropes, nets and buoys that are still reusable to reduce the cost of FEDs construction and increase the reuse of waste materials that contribute to the accumulation of marine debris in the oceans. Reusing waste fishing gear materials could also help in addressing the concerns on micro-plastics in the oceans, as the FEDs synthetic materials could turn into micro-plastics, although this aspect should be a subject of further research studies.

Way Forward

Capacity building programs should be strengthened and promoted to enhance the knowledge and skills of stakeholders on co-management which is crucial for the management and maintenance of the FEDs to last longer. Accordingly, local users of the FEDs and stakeholders would be able to efficiently increase their fishing activities to support their families and improve community economic development.

Information on the use and management of FEDs in other Southeast Asian countries should also be compiled to be able to come up with a regional synthesis on FEDs including the issues and concerns. Guidelines for the proper installation and management of FEDs should also be developed similar to the guidelines for the installation of ARs.

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About the Authors

Dr. Nopporn Manajit is the Senior Researcher of Fishing Technology Section, Research and Development Division of SEAFDEC Training Department based in Samut Prakan, Thailand.

Mr. Nakaret Yasook is the Fishing Gear Technologist of Fishing Technology Section, Research and Development Division of SEAFDEC Training Department based in Samut Prakan, Thailand.

Mr. Santiphong Putsa is the Fishing Gear Technologist of Fishing Technology Section, Research and Development Division of SEAFDEC Training Department based in Samut Prakan, Thailand.

Ms. Rattana Tiaye is the Fisheries Management Scientist of Fisheries Management Section, Research and Development Division of SEAFDEC Training Department based in Samut Prakan, Thailand.

Dr. Taweekiet Amornpiyakrit is the Head of Fishing Technology Section, Research and Development Division of SEAFDEC Training Department based in Samut Prakan, Thailand.

Mr. Isara Chanrachkij is the Head of Research and Development Division of SEAFDEC Training Department based in Samut Prakan, Thailand.

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