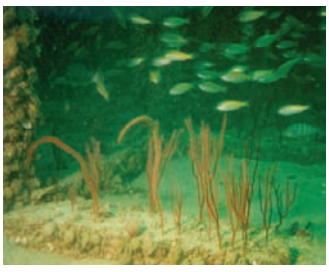
Enhancing Management of Fishery Resources
through Intensified Efforts in Habitat Conservation and Rehabilitation

Ahmad Ali, Raja Bidin Raja Hassan and *Yuttana Theparoonrat*

Since the coastal fishery resources in the Southeast Asian region have been characterized as overfished, the need to develop conservation measures has been considered urgent in order that coastal fisheries can continue to satisfy the demand for and sustain the supply of food fish. In this regard, national and regional efforts had put emphasis on enhancing fishery resources management through habitat conservation and rehabilitation. Specifically, efforts have been exerted in addressing the need to increase the traditional incomes of fishers, protect the coastal waters from destructive fishing gears, set up fish enhancing devices, rehabilitate the coral reefs, and create new fish *refugias* to replace the natural refuges that had been destroyed or no longer exist. The existing and present national and regional efforts in enhancing management of fishery resources through artificial reefs (ARs) programs that include the installation of fish enhancing devices, establishment of fish *refugias* and marine protected areas, stock enhancement, as well as the issues and lessons learned as consequences of these programs, are discussed in this article.

The coastal waters of Southeast Asia comprise a rich ecosystem characterized by the existence of areas with extensive coral reefs and seasonal up-welling, as well as the presence of dense mangrove forests enriched with nutrients from land. These areas are critical to a broad range of aquatic organisms during their life cycle from breeding, spawning, nursing and growing, hosting the feeding zones of aquatic species that are economically important, and serving as important source of recruitment of a wide diversity of fish species. In view of the economic benefits that these areas could provide, human settlements have mushroomed in coastal areas leading to the significant deterioration of the quality of the ecosystem as a result of continued and increasing human activities. More specifically, the commercially important fishery resources in the region have declined due to many factors that include overfishing, illegal fishing, use of destructive fishing practices, and environmental degradation. Massive clearance of mangrove forests for aquaculture, urbanization, industrialization, wood fuel, timber and the like, could bring about large temporary economic benefits to certain groups of people or the governments but in the end, the breeding, nursery and feeding areas of many aquatic species such as fishes, crustaceans, and mollusks have been destroyed and lost. For example, sand mining destroys the natural habitats of many commercial fish species while the use of dynamites in fishing could seriously destroy the coral reefs which serve as the natural habitats for the highly economic and commercially important demersal fishes such as groupers, humphead wrasse, snappers and others.

In addressing such concerns, most countries in this region have deployed artificial reefs (ARs) to restore the depleting coastal fisheries resources, prevent encroachment of trawlers, reduce conflict between commercial and traditional fishers, and increase the opportunities for small-scale fishers to improve and sustain their incomes from fishing. Other measures have also been promoted such as the installation of fish enhancing devices, promotion of stock enhancement through re-stocking, development of fish *refugias*, seasonal closure of breeding grounds, and establishment of marine protected areas or marine parks. Fish *refugia* is the spatially and geographically defined inland, marine or coastal areas in which specific management measures are applied to sustain important species (fisheries resources) during the critical stages of their life cycle. The establishment of fish *refugia* had been intensified in Thailand, Vietnam and Cambodia. Other man-made structures including aquaculture facilities, breakwaters, oil platforms, oil and gas pipe lines, stationary fishing gears, and jetties have also enhanced the biodiversity of aquatic organisms including fish. Thus, strengthening the linkages between resource enhancement activities and integrated coastal fisheries management with particular



Above: Fishes aggregate and improve the environment in AR areas *(Photo: Japanese Institute of Technology on Fishery Port, Ground and Communities (JIFIC) in Sato, 2009)*; and **Left:** Monitoring the environment in ARs *(Yuttana, 2009)*

emphasis on decentralized rights-based fisheries has been promoted in the Southeast Asian region for the sustainable development of coastal fisheries for food security.

However, it should be considered that the use of ARs can result in positive social and economic benefits if fishing effort is regulated but it could result in further overfishing if uncontrolled. Therefore, ARs should be installed under a strict management system within certain regulated areas. AR programs need proper planning and management at the national and regional levels while the implementation of any AR-related activity must be based on scientific knowledge and multi-discipline expertise. In the process, it is necessary to strike a balance between the objectives and benefits of the AR projects in terms of the environmental, economic and social aspects in fish production for food security.

SEAFDEC Initiatives and Activities on Fishery Resource Enhancement

During the ASEAN-SEAFDEC Millennium Conference in 2001, it was emphasized that the degradation of aquatic environment in the ASEAN region would lead to the declining of fisheries productivity and reducing the food fish supply for the local people. Therefore, the 2001 Conference recommended that efforts on resource enhancement activities should focus on: (1) integrated installation of artificial habitats in inshore waters with careful pre-assessment of the environmental and socio-economic impacts; (2) re-stocking exercises with careful assessment of the economic feasibility and environmental impacts; (3) establishment of Marine Parks to protect fragile ecosystem; and (4) development of management practices to effect seasonal closures of spawning areas in accordance with sustainable management requirements.

Specifically, in order to enhance the fisheries resources, the 2001 Conference presented several recommendations which included the need for respective countries to take measures for restoring critical inshore habitats which have been extensively degraded by various human activities; assess the feasibility and environmental impacts of artificial reefs and other man-made structures in inshore waters; promote re-stocking activities; encourage culture-based fisheries in inland waters; enhance marine engineering capabilities in the construction, installation and placement of resource enhancement structures; enhance the inshore habitats through artificial reefs for successful re-stocking program; conduct research on released species' potential recapture rate and impact on the ecosystem; ensure optimal recapture of the released stock through effective management measures, including predator control; develop marine parks in limited areas to protect the fragile coastal ecosystem; and promote the seasonal closure of specific areas to protect broodstock and juveniles of certain commercially viable species under rights-based fisheries management as alternative measures to marine protected areas.

Hatchery-bred abalone settling inside PVC pipe after release into the waters *(Photo: AQD 2010)*

SEAFDEC has been implementing resource enhancement project, where three main activities were carried out, namely: survey and data collection on the environment in ARs, set-net and marine cages in Malaysia and Thailand together with another SEAFDEC program on management of sustainable coastal fisheries; workshop on ARs and stationary fishing gear, design and construction and marine protected areas in 2003 and 2004 (in Thailand), 2009 (in Malaysia and Thailand), and 2010 in Japan; and short-term Regional Training Course in Resource Enhancement Methodologies in 2003.

Meanwhile, the SEAFDEC Aquaculture Department (AQD) initiated an activity on ARs in 1991 at Malalison Island in Culasi, Antique of western Philippines, where a project on community-based fishery resources was implemented. The project was aimed at developing the local fishers into a strong and independent association to be able to effectively manage the Island's resources. The project has been turned-over and now managed by the Fishermen's Association of Malalison Island. With an ultimate goal of rehabilitating the Island's fish and marine benthic communities, AQD had been monitoring the status of the flora and fauna communities since the start of the project in 1991 (Balgos, 1995).

In 2000 and 2001, the SEAFDEC Marine Fishery Resources Development and Management Department (MFRDMD) through the SEAFDEC Program on Marine Conservation and Stock Enhancement, had successfully completed a study on the construction and setup of durable fish aggregating device for coastal fishers, and published a "Guide to Make and Set Durable Artificial Reef Fish Aggregating Devices (ARFADs) for Coastal Areas" (Ahmad *et al.*, 2004). Moreover, the SEAFDEC Training Department (TD) also conducted program on Rehabilitation of Fisheries Resources and Habitat/Fishing Ground through Resource Enhancement from 2001 to 2005. The program focused on experiments on the suitable designs/models of the resource enhancement tools for coastal areas and on the

use of synthetic fiber for the construction of the devices for long lasting durability in seawaters, and subsequently the technique was introduced to various fishing communities in Thailand and Malaysia.

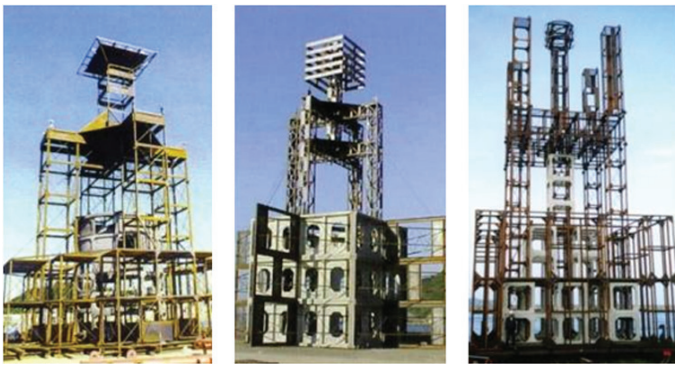
Furthermore, stock enhancement is one of the regular programs of AQD which has been conducted since 2000, focusing on mollusks such as abalone, top shell, window-pane shell, and giant clam as well as on sea horses. Under this project, stock enhancement which refers to the stocking of hatchery-produced seeds for the public good without the intention of benefiting an exclusive user groups, is envisaged to be socially desirable and recognized as one of the important tools for fishery management. The stock enhancement project of AQD covers research on seed production, permanent marking, packing techniques and transportation methods, workshops, monitoring and evaluation as well as training and raising public awareness through intensified information campaign and publications.

Fishery Resource Enhancement and Habitat Rehabilitation Activities in Japan and Southeast Asian Countries: Synthesis

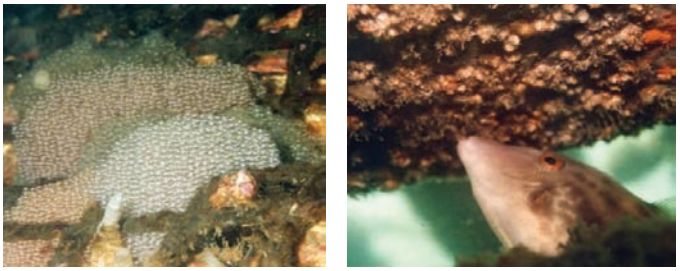
Japan

Japan is the most experienced and advanced country in terms of using ARs to maximize fisheries production through specific design appropriate for installation in seaweed beds, spawning grounds, shelters, among others. Stationary fishing gear especially set-net as introduced by Japan and now adopted in many countries does not only serve as a tool for catching fish but also provides substrate and shelter for high diversity of flora and fauna. Set net has therefore been considered an environment-friendly and selective fishing gear.

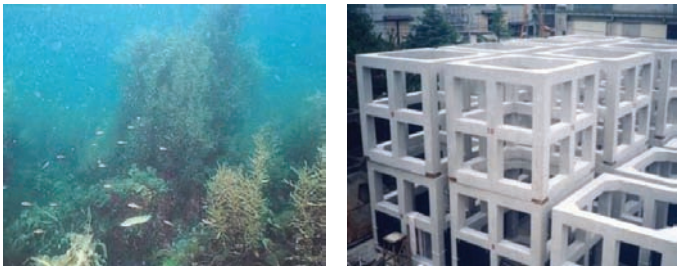
Many countries in this region have learned from the experience of Japan on ARs and set-net technology, and are now trying to implement their own projects. Japan has designed various ARs depending on the management and purpose, such as ARs to protect the main resources, create seaweed beds, promote coastal fishing activity, and



Samples of AR structures in Japan
Source: Takagi, et al., 2009



Left: Eggs of greenling *Hexagammos otakion* on ARs
Photo: JIFIC in Sato, 2009; and
Right: Black scraper nibbling on attached organisms in ARs
(Photo: JIFIC in Sato, 2009)



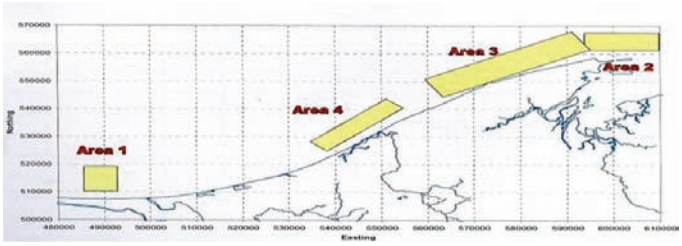
Examples of AR structures in Japan:
Left: to create seaweed beds;
Right: to promote coastal fisheries *(Source: Sato, 2009)*

propagate new resources. Sato (2009) reported that in a study in Japan which aimed to monitor the distribution of marine life around ARs, the results have shown that planktons usually swim around the sheltered areas near ARs, sessile organisms and other periphytons settle in ARs but could vary depending on the environment and materials used in constructing the ARs, and the change in the distribution of benthos around ARs was strongly related to the change in the sediments of the sea bottom. He added that ARs play important roles in enhancing the living environment of the marine resources by serving as spawning and feeding grounds for many fishes as well as providing shelters and resting areas for many species of fishes.

Brunei Darussalam

The Artificial Reefs Project of Brunei Darussalam was initiated in 1985 using discarded vehicle tires with the main objectives of enriching the marine resources, protecting the marine habitats and creating new fishing grounds. Other materials used to construct ARs included concrete piles, wield pipes and abandoned oil-rig platforms. The structures created by the country's oil industry such as oil

Triangular pyramid ARs in Brunei Darussalam



Marine protected areas with ARs installed in Brunei Darussalam

platforms, oil pipe lines and shipwrecks abandoned during the World War II, have also become new habitats for various fish species as well as other flora and fauna. Recently, small sized ARs measuring 2.5x2.5x2.5 m and triangular pyramids measuring 4x4x6 m have been deployed in 10-30 m deep coastal waters.

However, most ARs made from tires and triangular stainless steel had been buried in the sea bottom due to natural processes. Therefore, site selection is necessary before deploying ARs. Nevertheless, the deployment of abandoned oil platforms was in accordance with the Guidelines for the Decommissioning, Abandonment and Restoration of the Oil and Gas Industry Asset 2009. Until at present, no specific monitoring of the biological and socio-economic aspects of the country's ARs was carried out due to lack of expertise and manpower. Meanwhile, two marine protected areas were established in Selirong Island and Pelong Rocks in 2003, and fishing activities are restricted in areas with off-shore facilities including oil rigs.

Cambodia

Using concrete modules and logs, the Artificial Reefs Program initiated in Cambodia in 1991 aimed to provide habitats and improved the fish stock in the Great Tonle Sap Lake at depths of less than 10 meters and later, some related activities used rocks and tree trunks. While there is less concern on installing ARs in marine than in inland waters, 13 protected areas called fish sanctuaries have already been established in the Great Lake since 1979. These sanctuaries serve as refuge for freshwater fishes to spawn between flood seasons. Any kinds of fishing activities in the sanctuaries are forbidden except for research purposes but with permission from the Fisheries Administration of Cambodia. Mangrove forests along the country's coastline are also protected and developed as fish sanctuaries.


Marine protected area in Koh Sdach ND, Koh Rong archipelago, Cambodia

Other measures had also been undertaken by the Ministry of Environment under the Royal Decree on the Creation and Designation of Protected Areas. Since 1993, the Ministry had established 23 protected areas in collaboration with the United Nations Environment Programme (UNEP) to conserve wildlife and their habitats, four National Parks in the coastlines (366,250 ha), one wildlife sanctuary (357,500 ha), and multiple use area covering 27,700 ha. Legislations have been established since 1997 to promote the conservation of natural resources and coastal development as well as to implement community-based on natural resource management. The coral reef ecosystem within these areas has been reserved for spawning, feeding and nursery grounds of marine aquatic species.

In order to reduce the impact of fishing activities in coastal and marine environment, the country has promoted licensing of fishing boats and fishing gears, elimination of trawling activities in less than 20 m deep coastal areas, and improving control and monitoring system. Moreover, the country also prohibits the use of destructive fishing gears and rehabilitates degraded coastal resources and ecosystem through its Management Strategy Plan which includes co-management, installation of ARs and establishment of seasonal protected *refugias* in collaboration with the UNEP/Global Environment Facility (GEF) South China Sea Program, International Union for Conservation of Nature (IUCN), Ministry of Fisheries of Vietnam, Fisheries Administration of Cambodia, and the Ministry of Environment Cambodia.

Indonesia

Efforts undertaken by the Government of Indonesia in habitat conservation and rehabilitation included the implementation of activities that focused on rehabilitation of coral reefs using multi-design ARs, where the development of ARs has been initiated by the Fishery Agency (DKI) of Jakarta Province in 1980-1988 by sinking the former frames of buses and rickshaws. In 1990-1993, the Directorate of Fishery of the Ministry of Agriculture developed ARs using car tires which were installed in six provinces, namely: North Sumatra, Lampung, Central Java, East Java, West Java, and Bali. The Directorate of Fisheries Research and Development also supported the development of ARs using cube-shaped hollow-concrete materials and car tires arranged in pyramids. Reports showed that installation of ARs resulted in some biological and ecological impacts as some ARs were able to attract marine life and various

Various AR modules used in Indonesia

species of reef fishes. In 2000, ARs were installed in some areas in NTB (West Nusa Tenggara), Bali, Central Java, West Java, and Jakarta, for various purposes such as tourism, habitat improvement, and as means of inhibiting the trawlers from getting closer to the coastal areas.

In the waters of the Saleh Bay, West Nusa Tenggara, installation of ARs was conducted in 2004 by the Research Institute for Marine Fisheries – Research Center for Capture Fisheries. The Bali Provincial Government also re-developed ARs in Tukadse waters, Karangasem regency from 2004 until today in an effort to improve marine tourism. Until 2010, the DKI of Jakarta Province continued to submerge every year considerable number of concrete ARs valued up to billions of Indonesian Rupiah and in various forms for the main purpose of rehabilitating and improving the fish stocks. The private sector also do their part in installing ARs in an effort to promote tourism, especially in the waters of Pemuteran, Buleleng, Bali.

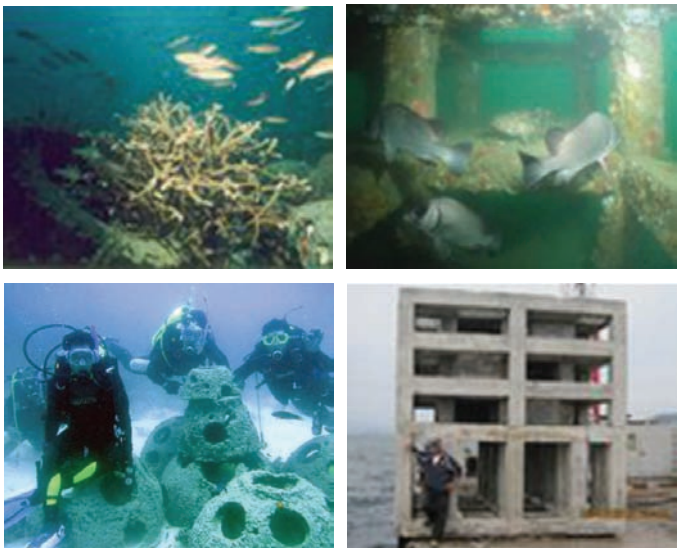
Malaysia

The 1963 Fisheries Act of Malaysia includes regulations on fisheries exploitation through very strict limited entry or input management regime. In the waters less than three nautical miles from the shorelines of any state of West Malaysia and several islands, trawl fishing and purse seining are not allowed except fishing operations that make use of traditional gears under the Fisheries (Maritime) Regulation 1967. In 1980, the restricted water areas increased from three to five nautical miles from the shorelines of all states of West Malaysia and several islands. Some of the islands were later gazetted in 1994 as Marine Parks of Malaysia under the country's Fisheries Act of 1985.

Locations of Marine Parks in Malaysia

The Fisheries Act 1985 also covers all aspects of fishing, Marine Parks, sea turtles, artificial reefs, and the use of destructive fishing methods. The establishment of Marine Parks was meant to provide special protection to the aquatic flora and fauna, specifically to protect, preserve and manage the natural breeding grounds and habitat of aquatic life with particular regards to rare or endangered species; to allow for the natural regeneration of aquatic life where such life has been depleted; to promote scientific study and research; to preserve and enhance other undamaged state and productivity of the environment; and to inculcate among the people the importance of avoiding irresistible damage to the environment.

Collection of marine organisms and fishing are prohibited within 2 nautical miles from the coastline of the Marine Parks except in an island where the protected area is only one nautical mile from the island. At state level, some islands especially in Sabah and Sarawak are also gazetted as protected areas where fishing and other unfriendly activities are prohibited. Under the new Fisheries Policy (1982-1983), the areas restricted from fishing were expanded and clearly defined into four zones. '**Zone A**' from shoreline to five nautical miles, reserved for traditional owner operator vessels; '**Zone B**' from five nautical miles and above from shoreline, for commercial gear of owner operated vessels below 39.9 GRT (Gross Registered Tonnage); '**Zone C1**' from 12 nautical miles and above from shorelines for commercial gears of owner operated vessels 40 GRT and above; and '**Zone C2**' for from 30 nautical miles and above from shoreline to the border of EEZ of Malaysia for commercial gears with vessels 70 GRT and above. Malaysia also enforces prohibitions on the use of destructive fishing gear and practices, and reduction of fishing capacity of trawlers in coastal waters. While the management of mangrove forests had been placed under the jurisdiction of the Forestry Department, plans to utilize mangrove swamps for any projects require mandatory Environmental Impact Assessment (EIA) and approval from the Department of Environment. The government also considers that introduction of ARs in the coastal waters would help in restoring the depleted coastal fisheries resources, prevent encroachment of trawlers, reduce conflicts between commercial and traditional fishers, conserve and rehabilitate the destroyed habitats, and increase the opportunities of small-scale fishers to improve and sustain their incomes from fishing.



Top left: Coral growth on tire AR modules;
Top right: Groupers and sweetlips inside soft bottom AR structures;
Bottom left: Reef ball ARs
Bottom right: Biggest ARs deployed in 2010 near Langkawi Island in Kedah, Malaysia, measuring 3.8x3.8x3.8 m and weighing 42 metric tons

During the initial stage, ARs were constructed and deployed by the Department of Fisheries Malaysia (DOFM) for conservation purposes. However, starting in 1985, the Fisheries Development Board of Malaysia locally known as LKIM began to be involved in constructing ARs for the purpose of aggregating fish to help the traditional fishers in harvesting more fish and increase their incomes. This structure was locally called unjam-unjam (Dianatul Azni, 2008). There are many designs of *unjam-unjam*, some are cuboids, cylindrical, pelagic, ceramics, FRC, piles, and others. The Marine Park Department was also seriously involved in the deployment of ARs focusing mostly on coral reef rehabilitation within the Marine Parks areas not more than two nautical miles from the islands. The Malaysian Maritime Enforcement Agency (MMEA) which is directly involved in enforcing the Fisheries Act 1985 had also deployed ARs using the confiscated fishing vessels.

Left: Pack of grey bamboo shark, *Chiloscyllium griseum* crowding under soft bottom ARs in Besut Terengganu, Malaysia illustrating the success of the structure as refuge for this species
Right: Aggregation of adult Harry sweetlips (*Plectorhinchus gibbosus*) inside soft bottom ARs suggesting such ARs as preferred breeding ground for this species

According to Jothy (1982), installation of ARs during the 70s was initially meant to achieve two-pronged objectives, namely: (i) to increase the productivity of the marine environment in general and thereby, the resources of food fish through the development of sanctuaries on sea beds for fish and other related marine life; and (ii) to promote the recovery of the fishery resources in coastal areas that have been seriously depleted as a result of ill-managed fishery exploitation. In order to achieve these objectives, a number of activities had been carried out on an '*ad hoc*' basis by researchers from Fisheries Research Institute (FRI) in Penang (Wong, 1991). In 1978, the ARs project was recognized as a development project of the DOFM under the Third Malaysia Plan (1976-1980). During the early period of the AR program, only discarded tires were used because these were free and readily available, relatively inexpensive to assemble into units for making modules, provide excellent substrates for attachment, indestructible in seawater, and reduce previous disposal problems by burning. Moreover, the successful use of tires as ARs which had been widely published in proceedings, journals and books, had encouraged the local fishery researchers of Malaysia to conduct experiments on ARs.

The development of tire ARs was continued until 1995, and up to 1994 the sites of tire ARs had increased to 75 where 3,145,856 pieces of tires were used. However, after 1995, the use of tires was forbidden because of claims by many parties that automobile tires could leach toxic matters to the marine environments. In this regard, Ahmad *et al.* (2008) conducted surveys using side scan sonar to monitor the status of tire ARs in Terengganu waters and found that all tire ARs deployed on open sea floor were destroyed through natural ocean processes especially from strong current and erosion of bottom sediments. Some tire ARs placed between islands was still in good condition but was colonized only by a few marine organisms and had attracted small assemblages of fish.

In 1989, PVC ARs were introduced near Pulau Langkawi in Kedah, but since PVC was not suitable for ARs especially in open sea because these can be easily destroyed by various fishing activities, the DOFM stopped using PVC since 1992. However, the Department of Marine Parks Malaysia continued the use of PVC as substrates for coral reef colonization within marine park areas especially in calm and close areas such as near jetties or sheltered bays. The first prefabricated ARs using reinforced concrete was launched in Malaysia in 1986, where two types such as concrete drainage culvert and concrete pipes were used. Since then, several modifications were made on the size and shape of ARs. Later, concrete lobster ARs was constructed and deployed in 1990 and the squid ARs in 1992. At the initial stage, the squid ARs attracted large number of squid

to aggregate, mate and lay their egg especially the *Sepia pharaonis* species. However, after the monsoon season almost all structures were found scattered on the sea floor which could be probably due to the fishing operations of illegal trawlers.

Another type of concrete ARs which were meant for recreational fishing was established in 1993 and in 1995 by a pioneering marine ranching project following the technology developed in Japan. The project was not successful due to many technical problems especially the construction which was not in accordance with the marine engineering construction guidelines. The lobster ARs made from ceramics were introduced in 1992, but achieved only about 40% of its objectives as the modules got buried in the sea floor. The DOFM therefore stopped the use of ceramics for the construction ARs since 1993. Derelict and confiscated fishing vessels made from wood were also used as ARs, but provided only short term benefits to fishers since the wooden hulls were attacked and destroyed by the dorado worms as well as by other natural processes such as strong and turbulent currents.

The reef ball ARs were deployed in various parts of Sarawak waters since 1998 by the DOFM and the Department of Forestry of Sarawak. In Peninsular Malaysia reef ball ARs were not widely used but were only deployed in Marine Park areas in Kedah and Terengganu for coral reef enhancement. These ARs were only suitable on hard bottom sea beds and not suitable to prevent illegal trawlers from getting into the soft bottom sea beds. The first oil platform converted to ARs in Malaysia was installed in 1968, but was observed to have collapsed in December 1975 and officially handed to DOFM in 2005. Now, these ARs are located in new sites in Sarawak waters at depths of about 21 meters, about 6.21 nautical miles from the coastline and used mainly for recreational fishing and scuba diving.

Starting in 2006, the DOFM focused on the design and construction of big sized reinforced concrete ARs for installation in hard and soft bottom sea beds. The structures considered various factors such as the fish behavior, marine engineering aspects, physical oceanography, and the target species, which were gathered from previous studies as well as references from various sources. The structures were constructed according to the British Standard 8110, and until the end of 2010, fifteen new designs of concrete ARs weighing between 6 to 42 metric tons/module and measuring between 1.6 to 3.8 m (length, width and height) were developed. The ARs were cuboids bio-active, ARs meant for soft bottom (4 designs), and two designs of the tetrapods ARs, recreational ARs, cube ARs, cuboids ARs, and lobster ARs (Ahmad *et al.*, 2010).

All monitoring activities in AR areas were conducted every 3-6 months after deployment to record the changes in the fishery resources as well as physical stability of the reef modules by researchers cum divers from the Research Division of DOFM based in Penang (Fisheries Research Institute), Terengganu (SEAFDEC/MFRDMD) and Sarawak (Fisheries Research Institute Sarawak Branch). More than 60 scientific and information papers, posters, pamphlets, book, videos, post-graduate thesis and proceedings have been published since the ARs program began in 1975, most of which were authored by researchers from the Research Division of the DOFM and universities in Malaysia. Artificial reefs deployed in 2006 have become a nursery and breeding ground not only for fish but also for lobsters and crabs. Fully gravid species were found within the AR structures during a series of visual observations conducted by researchers from DOFM and universities. The structures also function as substrates for highly diversified marine fauna and flora. More than 20 commercial fish species were recorded and among them are the high grade snappers (*Lutjanus* spp.), groupers (*Epinephelus* spp. and *Cephalopholis* spp.), Carangoides (*Caranx* spp.), stingrays, and spiny lobster (*Panulirus* spp.). In a study conducted by DOFM researchers, cuboid ARs deployed about 4 nautical miles from the coastline of Terengganu attracted both reef and commercial species of fishes including sharks and rays. More than 1800 tails of commercial species aggregated close to each module of the cuboid ARs which became the highest number recorded in Malaysia since 1975. The ARs also served as hindrance for illegal trawlers because the cod end of trawlers could get entangled with the ARs. In the latest findings in 2010, tetra-pod ARs deployed near a sea turtle sanctuary in 2006 has become a safe resting place for green turtles during the inter-nesting period. Adult green turtle *Chelonia mydas* was observed resting closed to the ARs in July 2010.

Myanmar

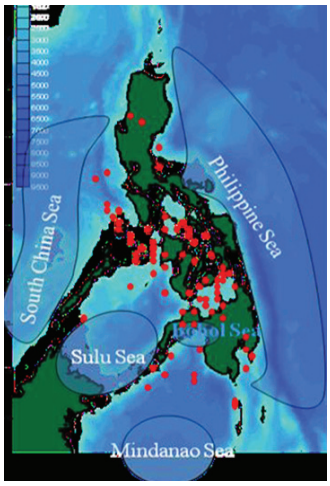
Rehabilitation of habitats by ARs has not yet been introduced in Myanmar considering that the country's coastal zones are still intact. However, other measures have been undertaken for habitat conservation and rehabilitation, which included controlling the fishing effort through proper licensing of fishing gear and fishing vessels, closed area, closed season, limitations on mesh size, and prohibition of destructive fishing activities. A total of ten fishing grounds identified as nursery areas of certain species have been gazetted as closed season for three months from June to August. Regulations on closed area are also implemented in three areas to avoid conflicts between traditional fishers and trawlers, where trawlers are not allowed to fish within these areas for the whole year. Under the Myanmar Marine Fisheries Law, fishing gears destructive to the environment and fisheries resources are banned, which include the pair

trawl, push net, purse seine net less than one inch mesh size, trawl net cod-end mesh size less than three inches and trammel gill net less than 1.5 inches; as well as fishing operations that make use of electric, poisons, chemicals, and explosives. Enforcement of the law is being carried out by the Myanmar Navy, Coast Guard, DoF Myanmar, Customs Department and police. Myanmar is the only country in the region which had gazetted a huge area from Ross Island to Lampi Island as Shark Protected Area under its Fisheries Law. Based on such regulation, shark fishing is totally prohibited in the area which caters only the tourism industry such as shark-watching for divers.

Philippines

AR projects in the Philippines started in 1977 using scrap tires and bamboo for experimental purposes by the Silliman University, University of the Philippines Marine Science Center, and Bureau of Fisheries and Aquatic Resources (BFAR). The project received assistance from the US Peace Corps and Japan Overseas Cooperation Volunteers in collaboration with local organizations including fishers' associations, civic organizations, diving groups, the Ministry of Human Settlements and the Natural Resources Management Center (Balgos, 1995). Encouraged by the successful experimental ARs, more projects using tires and bamboo were launched between 1985 and 1987 in all the regions of the country with the objective of enhancing the catch of small-scale fishers, where catch was decreasing while cost of fuel was increasing.

However, because of the short life span of bamboo ARs, any impact of these modules was not sustained. Therefore, bamboo ARs were later changed to concrete ARs. In 1990, the Philippine Council for Aquatic and Marine Research and Development (PCAMRD) launched a National Coral Reef Management Conservation Program which addressed the management of natural stocks in coral reefs with emphasis on community-based management (Balgos and Salacup, 1994). Tire and concrete ARs were deployed near several islands, and some ARs were deployed near a marine sanctuary in Negros Occidental in central Philippines. Fishing was not allowed during the year after deployment, while monitoring of fish and other fauna was conducted through fish visual census.



Locations of ARs in the Philippines

Concrete ARs used in the Philippines

In 1991, the construction of ARs for fishery resource and habitat enhancement was one of the measures adopted by the Fisheries Sector Program of the Department of Agriculture. The project involved the Provincial Fisheries Management Units responsible for the implementation, monitoring and evaluation of the project together with BFAR, the Department of Environment and Natural Resources (DENR), and various agencies and NGOs. The project installed ARs made from tires, concrete and bamboo in various places along the 500 km coastline in twelve bays of the country. Monitoring of the project was however, not conducted properly while most structures were observed to be poorly constructed.

Through BFAR, the Philippines formulated various management and conservation programs and policies such as the Coral Garden Project; Strengthening of the 'Bantay-Dagat Program'; implementation of monitoring control and surveillance program; and establishment of the Fisheries and Aquatic Resource Management Council (FARMC). All these programs aimed to conserve, manage and rehabilitate damaged reefs in identified sites; uplift the standard of living of the fisherfolk in local fishing communities; and identify and promote resource enhancement activities. Marine reserves have also been established and promoted in the Philippines by NGOs, local governments and the academe.

Singapore

Protection and conservation of fisheries in Singapore are regulated under the Fisheries Act (Chapter 111), where the use of poisons, explosives and trawl net are strictly prohibited. In order to enhance its marine resources, an AR program was initiated with the use of concrete blocks, tires and fiberglass. The first ARs were launched in 1989 under the ASEAN-US Coastal Resource Management Project using hollow concrete cubes and tires in pyramid modules, which were installed in 15 m deep waters in areas adjacent

Left: Concrete ARs used in Singapore; and
Right: Reef Enhancement Unit being promoted in Singapore

to a natural patch reef. The objective of this project was to restore and enhance the fish communities of degraded reefs (Chou, 1991).

Results from the monitoring activities showed significant increase in fish abundance and species diversity, and about 68 species from 26 families had been recorded. Fish abundance, density and size were higher at concrete ARs than in tire ARs. Adult fish like batfish and snappers have been observed close to the concrete modules while juveniles of various fishes preferred the tire ARs (Low and Chou, 1999). To enhance the coral reefs, a special fabricated AR unit called Reef Enhancement Unit (REU) made of fiberglass impregnated with sand and calcium carbonate was used, and deployed at a depth of 3 m. The results of this study showed that fiberglass is a viable alternative material for artificial reefs (Chou and Lim, 1986).

Thailand

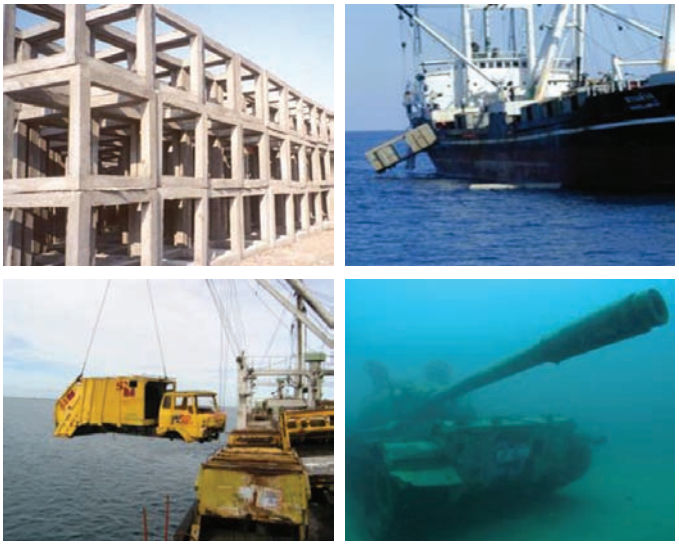
The rapid development of commercial gears such as trawl net and purse seine operated close to the coastline and the use of destructive fishing gears such as push nets and fine mesh cod-end trawlers seriously affected the livelihood of small-scale fishers in Thailand. A large area of mangrove swamps had also been cleared for other purposes such as aquaculture and human settlement. The Government therefore had to undertake various management measures to rehabilitate the coastal resources such as installation of ARs, introduction of stationary gears, and proclamation of marine protected areas.

The country's AR program started in 1978 using tires, concrete (cylinder, pyramid and cube), rocks, wood, unused train wagon, garbage trucks, and army tank with the main objectives of rehabilitating the coastal fishing grounds, providing habitats and shelters for juveniles, increasing the small-scale fishers' incomes, providing substrates for primary and secondary production, deterring trawlers from encroaching into nursery grounds, and reducing conflicts among fishers and resource users. The ARs were deployed at the depth of 4-18 m along the coast of the Gulf of Thailand and Andaman Sea. During the initial stage, most of the ARs were deployed and scattered in wide areas which proved to be less effective as most structures were buried especially on muddy sea bottom, damaged by pair trawlers, and entangled with gill nets.

Three main agencies are responsible for the country's ARs program, namely: the Department of Fisheries of Thailand (DOF), Department of Marine and Coastal Resources, and the Royal Thai Navy. During the research and development period (1979-1985), the ARs program of Thailand focused on research and experiment to identify the suitable materials, design, deployment techniques, and durability of the structures. Monitoring the status around the ARs showed significantly high diversity of fish with more than 50 species recorded. Moreover, the most suitable and durable ARs are the square concrete cubes, although there were no differences in terms of species diversity and catch in all the AR designs.

Under the country's National Social and Economic Development Plan IV (1988-1992), the Small-scale Fisheries Development Project was launched by the DOF, which included coastal small-scale fisheries development, installation of ARs, and fishery resource rehabilitation. The project was implemented from 1988 until 2003 in order to conserve the marine and environmental resources. Moreover, at least 50 km^2 from each province was designated as fishing grounds for traditional fishers in order to reduce conflicts.

The construction and installation of ARs began at large scale in 1985 when the Government started allocating annual budget for the ARs project. In 1985-2010, the DOF installed small-scale ARs in 334 sites covering an area of 478 km^2 and large-scale ARs in 33 sites covering 1,435 km^2 at the cost of Baht 673 and 568 million, respectively. In the southern part of the Gulf of Thailand, the ARs project started since 1983 and initiated by National Institute of



Arritificial reefs in Thailand, made of concrete, Train goods wagon, garbage truck, and war tank

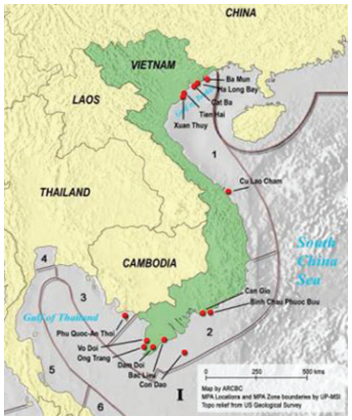
Coastal Aquaculture of Songkhla Province for experimental purposes. Between 1983 and 2004, a total of 64 new AR sites had been established at a total cost of Baht 206 million. Starting in 2002, most of the ARs and coastal resources rehabilitation projects in Pattani and Narathiwat Provinces were placed under the Royal Initiation of Her Majesty the Queen. The materials used for the ARs were tires, concrete pipes, dice blocks, and goods wagon, and placed between 9.5-12 km from the coastline of Pattani and Narathiwat Provinces. Later in 2002-2004, another 32 new sites of ARs were established at a cost of Baht 41 million.

In terms of fisheries management, near-shore areas within 3 km from shorelines had been identified as protected areas since 1972 from commercial gears such as trawlers and push nets under the Fisheries Act. Closed season from 15 February to 15 May was also imposed in 1984 covering an area of 26,400 km^2 in the Gulf of Thailand, which had been identified as spawning ground for important demersal and pelagic species. Such regulation prohibited fishing operations by all types and size of trawlers (with the exception of beam trawlers), all types of purse seines (except for anchovy purse seine operating in day time), and gill nets with mesh size less than 4.7 cm.

Vietnam

ARs were not widely used for habitat rehabilitation in Vietnam due to the high costs involved. A few studies was however, conducted by the Research Institute for Marine Fisheries in 2003-2004 in Ha Long Bay to rehabilitate the natural reefs and experiment on the proper methods to construct and deploy ARs in highly turbid areas. Nonetheless, the National Plan on Environment and Sustainable Development (NPESD) and the Biodiversity Action Plan (BAP) of Vietnam promote the establishment and management of marine protected areas (MPAs). Thus, the first MPA was established in 2000 in Central Vietnam funded by World Bank, IUCN and the Asian Development Bank (ADB).

After two years, the MPAs had demonstrated as means of recovering fish population. The MPAs then expanded to other areas of the country with support from the Danish International Development Agency (DANIDA) in collaboration with the local government units and NGOs. The project "Support to the Marine Protected Area Network in Vietnam" started in 2003 consisting of two sub-projects in order to address priority needs at both national and provincial levels. The project at national level developed the existing network of MPA sites through capacity development as well as strengthened policy and legal frameworks. At the provincial level, one site was selected as second MPA site. Results of the assessment showed that the management system through the MPA enhanced local awareness of resource protection and management, reduced pressures on the ecological systems, and raised awareness and understanding of the local people of the link between natural resources management and improved local livelihood system.



Marine protected areas in Vietnam

Conclusion

Inadequate funding and absence of policies created many problems on ARs, fish sanctuaries, MPAs, marine reserves, and other enhancement and rehabilitation programs in the region. Most of the common issues were on weak law enforcement, inadequate coordination among government agencies, less manpower and technical knowledge, and lack of monitoring and evaluation. There was a general lack of understanding of the purposes of ARs, whether for fishing or enhancing the coastal resources. Personnel involved also lack technical experience and knowledge especially in marine engineering and oceanography, resulting in faulty installations and poor quality of the ARs. Very few AR sites had been studied and most countries lack good data on fish recruitment, survival of juveniles, engineering, physical performance, standing stocks, bio-fouling, and socio-economics. As for marine stock enhancement, such activities are generally costly while experiences in tropical countries like in Southeast Asia where fisheries are multi-species had been mostly unsuccessful. Thus, there is a need for techniques on stock enhancement applicable for tropical fisheries in this region. Successful resource enhancement activities (*e.g.* ARs, MPAs, stock enhancement) require decentralization of management functions and responsibilities as well as rights-based fisheries which should be in place and functioning with due consideration of the involvement and participation of communities and fishers. MPAs and ARs can be complementary tools for conservation, management and enhancement of fisheries resources. A combination of integrated programs using ARs, closed season, limited entry, habitat protection and restoration, fish sanctuaries, mangrove reforestation; and increased community awareness of the need to conserve the resources could be promoted for the purpose of resource enhancement.

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About the Authors

Mr. Ahmad Ali is a Senior Researcher of SEAFDEC Marine Fishery Resources Development and Management Department (MFRDMD) in Kuala Terengganu, Malaysia, and is the National Research Coordinator for Artificial Reefs Program for Malaysia since 2006. He is a Ph.D. candidate (Fisheries Oceanography) at the Institute of Oceanography, University Malaysia in Terengganu.

Mr. Raja Bidin Raja Hassan is a Senior Researcher and Head of the Fisheries Oceanography and Resource Exploration Section of SEAFDEC/MFRDMD.

Dr. Yuttana Theparoonrat is the Head of the Coastal and Small-scale Fisheries Management Division of SEAFDEC Training Department in Samut Prakan, Thailand.