Big Artificial Reefs for Improved Enhancement of Fishery Resources: Experience of Malaysia

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In the development of its Artificial Reefs (ARs) Program for fishery use (resources conservation and fishing) and non-fishery use (marine resources enhancement), Malaysia had allocated about 155 million Malaysian Ringgit (RM) from 1976 to 2010. About 36% of the allocated budget was channelled through the Department of Fisheries Malaysia (DoFM) while more than 63% was allocated through the Fisheries Development Authority of Malaysia (FDAM) and less than 1% through other agencies. Many agencies in Malaysia have been involved in the construction, deployment and management of the ARs also known as ***tukun tiruan*** in Bahasa Melayu. In the early part of the country's ARs Program, the use of small and medium sized ***tukun tiruan*** had been promoted, while in the latter part and for various reasons, FDAM (2001-2010) and DoFM (2006-2010) focused on big-sized ***tukun tiruan***.

The Artificial Reefs (ARs) Program of Malaysia has two-pronged objectives, *i.e.* for fishery use (conservation and fishing) and for non-fishery use (enhancement). For conservation purposes, the ARs have enhanced coastal fishery resources by providing firm substrate for marine fauna and flora to grow. In addition, Malaysia had been using ARs to deter the encroachment of prohibited inshore areas by trawlers notwithstanding a regulation of the Department of Fisheries Malaysia (DoFM) that prohibits fishing activities within 0.5 nm from AR sites. The country's ARs that are intended for conservation are being collectively managed by various agencies, *e.g.* DoFM, Department of Fisheries Sabah (DoFS), Department of Marine Park (DMP), Sarawak Forestry Corporation (SFC), Fisheries Development Authority of Malaysia (FDAM), Malaysian Maritime Enforcement Agency, fishermen's associations, and recreational anglers. Fishing activities are not allowed within 0.5 nm from AR sites. However, for some ARs that serve as aggregating structures for scattered schools of fish, fishing activities are allowed near these ARs.

For non-fishery use, ARs have provided firm substrates for marine fauna and flora to grow, thus, enhancing the marine resources for recreational and eco-tourism activities (*e.g.* SCUBA, snorkelling activities). Fishing activities are allowed only near ARs that have been installed outside Marine Protected Areas. Construction and management of these ARs is conducted by various agencies, *e.g.* DMP, National Hydraulic Research Institute of Malaysia (NAHRIM), academic institutions, chalet operators, Malaysian Nature Society (MNS), Reef Check Malaysia, and other private companies. Construction and deployment of ARs or *tukun tiruan* in Bahasa Melayu have been carried out under the various phases of the Malaysian Plan (**Table 1**). The overall ARs Program of Malaysia from 1976 to 2010 entailed a total budget of more than 155 million RM, of which about 63% was provided through FDAM, about 36% through DoFM, and the remaining less than 1% through other agencies.

Table 1. Budget allocations to DoFM and LKIM for construction and deployment of ARs (1976-2010)

Malaysian Plan	Duration	Budgetary Allocations (in Malaysian Ringgit (RM)*	
		DoFM	FDAM
3rd Malaysian Plan	1976-1980	116,000	-
4th Malaysian Plan	1981-1985	524,000	199,657
5th Malaysian Plan	1986-1990	8,240,000	2,123,880
6th Malaysian Plan	1991-1995	9,400,000	3,831,275
7th Malaysian Plan	1996-2000	2,751,953	11,435,632
8th Malaysian Plan	2001-2005	2,524,344	60,377,893
9th Malaysian Plan	2006-2010	32,004,162	21,224,385
Total Budget Received		55,560,459	99,192,722
Years of operation		34 years	27 years
Ave Budget Received		1,600,000/ year	3,600,000/ year

**Exchange rate: 1USD=RM3.3*

Construction and management of the deployed ARs in Malaysia is being carried out through collective efforts of various agencies, namely: Fisheries Development Authority of Malaysia (FDAM), Department of Fisheries Malaysia (DoFM), Department of Marine Park (DMP), Malaysian Maritime Enforcement Agency (MMEA), Standards and Industrial Research Institute of Malaysia (SIRIM Bhd.), National Hydraulic Research Institute of Malaysia (NAHRIM), Universiti Sains Malaysia (USM), Income Revenue Board of Malaysia (IRBM), Department of Fisheries Sabah (DoFS), Sarawak Forestry Cooperation (SFC), among others. The contribution of these agencies to the development of ARs in Malaysia is shown in **Table 2**.

Table 2. Malaysian agencies involved in construction and deployment of ARs (1976-2013)

Agencies	Duration	Materials used for ARs
Department of Fisheries Malaysia (DoFM)	1976-2010	reinforced concrete, tires, polyvinyl chloride (PVC), old fishing vessels, ceramics, others
Sarawak Forestry Cooperation (SFC)	1977-2013	reef ball
Department of Fisheries Sabah (DoFS)	1980s	tires, old vehicles, old fishing vessels, others
Fisheries Development Authority of Malaysia (FDAM)	1983-2010	reinforced concrete, tires, ceramics, fiberglass reinforced concrete (FRC), fiberglass, others
Department of Marine Park (DMP)	1994-2012	reinforced concrete, bio-rocks, decommissioned war ships, old fishing vessels, PVC, fiberglass, others
Malaysian Maritime Enforcement Agency (MMEA)	2005-2012	confiscated fishing vessels
National Hydraulic Research Institute of Malaysia (NAHRIM)	2009	reinforced concrete
Standards and Industrial Research Institute of Malaysia (SIRIM Bhd)	2010-2012	ceramics
Universiti Sains Malaysia (USM)	2011	reinforced concrete (for sea cucumber)
Income Revenue Board of Malaysia (IRBM)	2013	steel

Big versus Small-Medium Size ARs

DoFM classifies the fabricated concrete ARs based on size, weight, materials and design, *i.e.* big size ARs should have a minimum size of 2m x 2m x 2m and weigh more than 10 metric tons (MT). Examples of big size ARs are shown in **Fig. 1**, **Fig. 2**, **Fig. 3**. DoFM had installed 68 big size ARs in the waters of Malaysia with 10-72 AR modules per site (**Fig. 4**, **Fig.5**).

During the initial stage of ARs development in Malaysia, DoFM constructed and deployed ARs mainly for conservation purposes, but starting in 1983 FDAM was seriously involved in the construction of ARs for the main purpose of aggregating fish to help traditional fishers in catching more fish and increase their incomes. The AR structures then were of small-medium sizes, *i.e.* cuboids, cylindrical, ceramics, piles, FRC, and others. The Department of Marine Parks was also involved in the development of ARs which were deployed for the purpose of rehabilitating the coral reefs in the country's marine park areas, which are not more than 2 nm from the islands. MMEA also did its share of AR deployment using fishing vessels that were confiscated for conducting illegal fishing in Malaysian waters (Ali *et al*., 2011).

Fig. 1. Soft-bottom anti-trawler AR (size: 3.75m x 3.75m 3.85m; weight: 32 MT)

Fig. 2. Soft-bottom juvenile enhancement AR (size: 3.75m x3.75m x 3.85m; weight: 32 MT)

Fig. 3. Soft-bottom cuboid AR (size:3.0 m x 3.0 m x 3.85 m; weight: 22 MT)

Fig. 4. Map of Malaysia showing the sites where big size ARs had been installed (Number of sites: 68; No of modules/site: 10-72)

Fig. 5. Installing a cube anti-trawler AR by DoFM

Under the Artificial Reefs Program of Malaysia, installation of ARs was meant to increase productivity of the marine environment through the development of fish sanctuaries in sea beds, and promote the recovery of fishery resources that had been seriously depleted due to irresponsible fishing activities. In the early phase of the Program, only discarded tires were used until 1990s when reports indicated that tires could leach toxic matters into the marine environment, and since then Malaysia prohibited the use of tires as ARs.

Later, PVC materials were used to construct ARs but this was also found to be not suitable especially in open waters where many PVC ARs were lost or destroyed. The first pre-fabricated ARs using reinforced concrete were developed by Malaysia in mid 1990s, comprising two types: concrete drainage culvert and concrete pipes.

Other types of ARs were also developed, *e.g.* concrete lobster ARs, squid ARs, reef-ball ARs. However, due to severe weather conditions and fishing operations of illegal trawlers, most of these small-medium size ARs were abandoned. This led to the design and construction of big size reinforced concrete ARs for installation in hard and soft bottom sea beds (Ali *et al*., 2010).

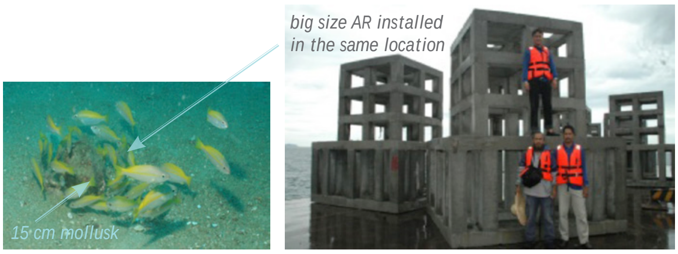

Fig. 6. Big size AR installed in location where schools of fish were known to aggregate

Fig. 7. Deployment of big size AR resulted in the aggregation of more fishes of high commercial value

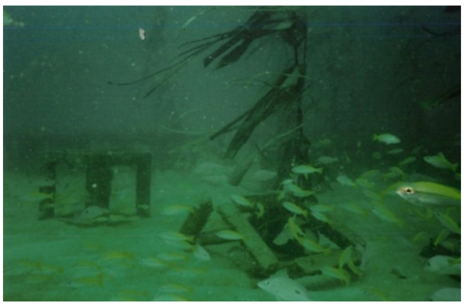

Fig. 8. Small-medium size ARs almost disintegrating while less schools of fish aggregate

Fig. 9. Encroaching trawlers often lose their trawl nets and codends when these become entangled with big AR structures

At the onset, researchers from DoFM observed that schools of big-eye snappers (more than 30 tails) were swimming close to a 15 cm mollusk (**Fig. 6**), thus, came the thought of installing a big size AR in that same location, and as a result, about 2,000 tails of *Lutjanus* spp. were observed to aggregate outside and within the big size AR (**Fig. 7**). While before, when small-medium size ARs were used, the structures could not last long while aggregation of fish was observed to be less (**Fig. 8**) compared to the situation with big size ARs. Nevertheless, one of the most critical advantages of deploying big size ARs is the deterrence of encroaching trawlers from getting close to inshore areas as their trawl nets and especially the codends could be entangled with the ARs (**Fig. 9**) leading to big losses in their fishing operations (Ali *et al*., 2011).

Deployment and Monitoring of Big Size ARs

Construction of ARs by DoFM follows the British Standard 8110 (column and beam rebar – Y12x4, link – R8@ 200 mm c/c, slab reinforcement – BRCA10/Y10). The concrete cover is 50 mm using ready-mixed concrete from batching plant, *i.e.* concrete grade 50 for soft bottom ARs and grade 40 for other types of ARs. Cube test is done 7-28 days after construction. The types of big size fabricated reinforced concrete ARs developed by DoFM from 2006 to 2013 are shown in **Table 3**.

To ensure adherence to specifications, AR construction works were supervised and monitored by officers from DoFM (Engineering Division, Licensing and Resource Management Division) together with researchers from MFRDMD and officers from state fisheries offices. After testing for sturdiness and before deployment of the ARs, site selection is conducted, *i.e.* using side scan sonar to create a visual profile of the sea bed of the possible area, using Phleger corer to obtain ocean bottom cores (1.2 m in length), using Smith Mc Intyre Grab to collect samples

Table 3. Big size ARs fabricated by DoFM using reinforced concrete (2006-2013)

AR types	Concrete grade used	Year produced	Specifications (m x m x m)	Weight (MT)
Soft-bottom 1	40	2006	3.0 x 3.0 x 3.6	14
Soft-bottom 2	50	2007, 2008	3.0 x 3.0 x 3.6	19
Soft-bottom 3	50	2009, 2010	3.75 x 3.75 x 3.85	23
Soft-bottom anti-trawler	50	2010	3.75 x 3.75 x 3.85	32
Soft-bottom juvenile enhancement 1	50	2010	3.75 x 3.75 x 3.85	42
Cube	40	2009	2.5 x 2.5 x 2.5	16
Cube juvenile enhancement	40	2010	2.5 x 2.5 x 2.5	20
Cube anti-trawler	40	2012	3.5 x 3.5 x 3.5	22.5
Cuboid	40	2007	2.0 x 2.0 x 3.0	10
Cuboid juvenile enhancement	40	2010	2.0 x 2.0 x 3.0	12
Cuboid bio-active	40	2010	2.0 x 2.0 x 3.0	14
Soft-bottom juvenile enhancement 2	40	2013	3.85 x 3.85 x 3.85	42
Soft-bottom cuboid	40	2013	3.0 x 3.0 x 3.85	22
Soft-bottom recreational	40	2013	3.5 x 3.5 x 3.85	25

of ocean sediments, using sub-bottom profiler to measure height of any objects on the sea floor, and using echo-sounder to detect schools of fish.

A pontoon or barge is used to transport the ARs from jetty to deployment sites. During the installation processes, free fall deployment method is applied using 50-80 metric tons crane equipped with special mechanical release device. At each site in Malaysian waters, 14-128 modules were placed 2-5 m apart from each other. For the purpose of deterring illegal trawlers, some modules were placed randomly over a larger area and spaced at about 100-200 m from each other. Location of every module is recorded using Global Positioning System (GPS). Soon after deployment is completed at each site, divers are dispatched to inspect and record the condition and position of the modules on the sea bed. The exact coordinates are submitted to the National Hydrography Center of Malaysia for national reference and future usage.

Success Story: Malaysian Big Size ARs

Visual observation was conducted using close-up and wide angle video and camera images to record physical stability of the reef modules, biofouling and encrustation of sessile organisms, fish behavior especially with regard to their interaction with the ARs as well as fish species. Big size ARs have been observed to be superior to small-medium size ARs in terms of their ability to attract more marine fauna and flora. Four years after deployment of big size ARs in Malaysia, recreational activities have increased near AR locations, with ARs fully covered by various species of soft corals and teeming with colorful small and large fishes as well as other crustaceans and invertebrates (**Fig. 10**, **Fig. 11**, **Fig. 12**, **Fig. 13**). In the socio-economic survey conducted, more than 97% of the respondents agreed that deployment of big ARs had decreased incidence of trawlers encroaching nearshore areas while more species of marine flora and fauna have settled outside and within big ARs. More than 78% of respondents reported that their incomes had increased considerably after the deployment of big ARs (Ali *et al*.,2013).

Conclusion and Way Forward

Based on the successful ARs Program of Malaysia, it can be deduced that larger size ARs are superior to small and medium size ARs especially in attracting more flora and fauna to settle within, on and outside the ARs. Moreover, big ARs have played excellent dual roles in resource

Fig. 10. Various species of soft corals covering big ARs

Fig. 11. Situation of big tetrapod ARs, four years after deployment

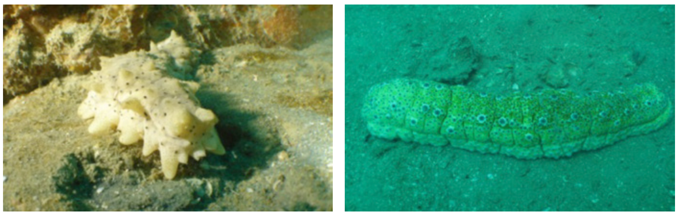

Fig. 12. Species of sea cucumbers settling near big ARs

enhancement and management, not only in terms of creating new habitats and recovering threatened stocks but also in deterring encroachment of trawlers in inshore areas thereby mitigating the conflicts between large-scale and small-scale fishers, with the latter increasing their incomes from fishing operations. Most modules placed on coarse sand sea beds were found to be stable while no scouring had occurred. The AR design allows the free flow of water current above the base of the modules facilitating water current flow with little resistance at the bottom of the modules. Good ARs design has therefore, contributed to making the AR structures attractive to more flora and fauna.

Considering that waters in various areas of Malaysia could be deep, DoFM is looking for new technology on ARs, especially the use of steel for the construction of big size ARs. Based on the study visits conducted by the first author from MFRDMD to the National Research Institute of Fisheries Engineering in Choshi Japan in 2013, he observed that the highest steel AR of Japan as of 2010 was 40 m and weighing 92 MT which could be deployed in water depths of 63 m targeting sea bream, horse mackerel, as well as yellow tail. DoFM is therefore exploring the possibility of adapting such technology in Malaysia. In order to facilitate discussions and exchange of information on new AR technology, DoFM plans to organize the second workshop on Artificial Reefs for Enhancement of Fisheries Resources in the Southeast Asian Region in 2015 with the collaboration of SEAFDEC and the Fisheries Research Agency (FRA) of Japan. Technologies developed through the ARs Program of Malaysia could be disseminated to the other countries in the Southeast Asian region. It is for this reason that the proposed workshop in 2015 will consider inviting more participants from the Southeast Asian countries.

Fig. 13. Commercially-important fishes settling in big ARs

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