Artificial Reefs

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Artificial reefs (AR) are natural or manmade external objects or stable structures placed in the sea to provide an artificial fish habitat and thereby to attract, aggregate and regenerate fishery resources. Artificial reefs are used worldwide to increase the productivity and fisheries potential of relatively barren or unproductive areas. They are also used as effective fish attracting devices during certain times of the year. Reefs when properly located and structured not only concentrate fishes but also increase the biological productivity of the area. Reefs also often serves as spawning and nursery areas for fishes and shellfishes.

History of Artificial reefs

Maritime countries all over the world has a rapidly increasing interest in artificial aquatic habitat enhancement technologies and 40 countries on 6 continents are using it today (Grove and Sonuj 1983). Artificial reefs and fish aggregating devices have been mainly used for three purposes; commercial fishing in Japan, sport fishing in United states and small scale fishery in a few Asian countries including India. Properly constructed reefs transform itself to convenient fishing grounds in a short span of time. FAD's have proved to be effective in commercial tuna fishing in the South East Asian countries.

Japan leads the world in the development of artificial fish habitat technologies for fisheries. The oldest record of an artificial reef in Japan dates back to 17th century when a reef was developed by dropping rocks into the sea. The declaration of EEZ (Exclusive Economic Zone) brought continuous decline in the fish production from distant fishing grounds. This prompted the country to invest extensively in the AR programme not only to increase the fish production but also to conserve the resources. At present Japan has the most intense and technologically advanced AR programme in the world. The total expenditure during 1988-1993 was in the order of $ 3 billion (Akira 1991).

In the United States, the earliest recorded history of AR construction dates back over 150 years. Reef building in the United States was initially promoted for sport fishing interests. Today AR's are constructed for sport fishing, commercial fishing, resource management, environmental mitigation, waste disposal and recycling, sport diving and tourism (Stone et al 1983). In Thailand AR's deployed adjacent to the coastal villages show increase in biomass and species diversity and substantial increase in the catches of traditional fishermen (Sinanuwong, 1991). In Philippines the use of Payaous increased the tuna catches tremendously. Payaous had improved exports and fishermen's status, reduced conflicts between artisanal and mechanized fishermen and increased local consumption of Tuna. (Apreito 1991). In Srilanka and Maldives use of FAD's are still in the experimental stages only.

Artificial reefs in India

In India artificial reef building technology was conceived and adopted by traditional fishermen. The potential of using AR's to increase the fisheries potential was first realized by NGO's working in the fisheries sector like South Indian Federation of Fishermen's Societies (SIFFS) Trivandrum, Programme for Community Organization (PCO) Trivandrum, Layola Social Service Centre Trivandrum, Murugappa Chettiar Research Centre (MCRC), Chennai and Centre for Research on New international Economic Order (CReNIEO), Chennai. These NGO's were largely responsible for mobilizing the fishermen and launching AR's close to a number of fishing villages in the South west and South east coast of the country in the 90's.Central Marine Research Institute (CMFRI), Kochi was involved in reef building programmes by monitoring the fish catches and assessing the productivity levels of the reefs along the Trivandrum coast. During the early 90's CMFRI installed one AR in Minicoy, Lakshadweep and another one in Tuticorin to study the resource generation in the reefs. Murugappa Chettiar Research Centre

during these period installed on Hut shaped reef off Chennai. This reef was made of high density poly ethylene pipes. CReNIEO also installed on AR off Chennai using Concrete rings, Coconut leaves and tree trunks. Coconut leaves are tied to a rope and the rope was tied to the reef module on the bottom and to a marker buoy on the surface. Fishermen used lift nets to catch the fish from the reef area.

During 1996 Trainers Training Centre (TTC) of CMFRI conducted a national workshop on ARs and sea farming technologies at Kochi. This workshop discussed the reef building technology in detail and also recommended to the Central government to increase the allocation for reef building activities along the coast. During the year 1997 CMFRI installed two more artificial reefs off Vizhinjam. One reef was developed for lobster resources. Modules of this reef were developed by placing stoneware pipes arranged in a triangular fashion. Each module was 4'x4' size and 100 modules were used in one reef. The second reef developed was for the fish resources made of triangular concrete modules. The lobster reef was installed about 500 meters away from the breakwater whereas the fish reef was installed about 1 kilometer away from the breakwater. Both the reefs are performing very well and are abound with fish resources. During 1998 CMFRI with the cooperation of the State fisheries department installed the largest AR (10000 M^2) off Poovar in association with Loyola Social Service Centre, Trivandrum. More than 150 modules were used in this reef.

Till 1998 most of the reef building activities were restricted to the southern parts of Kerala and during 1999-2000 CMFRI installed another large reef (10000 m^2) off Dharmadom in Kannur district of Kerala.This project was implemented with the involvement of the local bodies and fishermen community. The reef site was selected by them and the installation was completed during March 2001.This reef was considered as one of the Successful reefs as it generated plenty of resources. During 2001-2002 CMFRI developed two AR's off Moodady and Thikkody in Kozhikode district of Kerala in association with the State fisheries department. Each reef was of 7500 m^2 areas made of 100 modules each. The Moodady reef was a fish reef whereas the Thikkody reef was a lobster reef of 100 modules made of PVC pipes built in a triangular concrete base. At both the places the fishermen themselves did reef building and the local body authorities provided the necessary support. As a novel exercise reef enrichment materials (Coconut leaves) were dumped in the reef area to attract fishes and shellfishes into the reef. The Thikkody reef built in the traditional lobster fishing grounds showed resurgence in the lobster fishery of the area.

During the year 2002-03 another reef was installed by CMFRI off Muttom in the Kannur district of Kerala. This reef (10,000 m^2) was installed off Palakode in Muttom at a depth of about 24 meters close to a recent shipwreck in the area. This reef was also installed by involving the traditional fishermen of the area. Fish reef modules were alone used in this reef. Reef enrichment materials (6000 coconut leaves) were used to increase the biological productivity of the area. The AR building technology in India is an emerging one and needs strong support from the planners in a large way.

Artificial Reefs developed by Central Marine Fisheries Research Institute

Central Marine Fisheries Research Institute has designed and developed 50,000 M^2 reefs along the Kerala coast over the last 7 years in the following localities.

Reef and Funding Agency	**Year of Installation**	**Area m^2**
Vizhinjam I.Trivandrum (CMFRI)	1997	2,500
Vizhinjam II.Trivandrum (CMFRI)	1997	2,500
Poovar, Trivandrum, (Department of Fisheries. Govt. of Kerala.)	1999	10,000
Dharmadom, Kannur, (Department of Fisheries. Govt. of Kerala.)	2000	10,000
Moodady, Kozhikode. (Department of Fisheries. Govt. of Kerala.)	2001-2002	7,500
Thikkody,.Kozhikode, (Department of Fisheries. Govt. of Kerala.)	2001-2002	7,500
Muttom, Kannur, (Department of Fisheries. Govt. of Kerala.)	2003	10,000
Total Area		**50,000**

Artificial reef modules are designed considering the following features of the reef site

- Depth of the water column.
- Nature of sea bottom (Sandy and muddy bottoms require different types of modules)
- Type of resource being targeted

The depth of the water column and the reef height has a direct relationship. It is generally accepted that the reef height should be at least one tenth of the water column height, for example if the depth of the water column is 15 m the height of the reef should be at least 1.5 m. Less than this the effectiveness of the reef decreases.

Muddy bottoms experience drifting of mud during monsoon months and the modules are prone to sink in mud eventually. In such circumstances periodic depositing of reef modules are required to maintain the effectiveness of the reef. Where as in sandy bottom modules are more stable and its effectiveness also remain year after year. Triangular modules of 1.5Mx1.5Mx1.5m with a 0.60x0.60m window on all sides are found more suitable to areas where strong water currents prevail during the monsoon months. Triangular modules maintain its position in the sea bottom irrespective of the way it reaches the bottom. Cubical modules also serve same purpose but are more costly. Concrete pipes, well rings and used tyres are all very cost effective materials in reef building. The following types of modules are designed and used in reef building in India.

- Triangular modules
- Rectangular box type modules
- Circular modules
- Tetra pods
- Concrete rings
- Old tyres fixed on a concrete bed
- Triangular or rectangular modules with PVC or stoneware pipes fitted inside.
- HDPE pipe structures

While designing resource specific reefs modules are designed to fulfill the behavioral requirement of the targeted species, for example while designing lobster reef module stoneware or PVC pipes are used in the module to provide hiding space to the animal. Lobsters normally reside in crevices where an easy escape opening is available. Hence both ends of the pipe are kept open so that it can escape in the event of a predator attacking it. Lobster reef provide new habitats for the juveniles to settle, grow and populate the entire reef. In fish reefs fishes aggregated initially will stay back because of the plentiful food availability and eventually breed and populate the reef and later form fishery resource in the adjoining fishing grounds.

Fabrication of reef modules

Reef modules are fabricated on shore very close to the reef site so as to minimize the cost of transportation. Modules are to be carried from the shore to the transportation platform by the fishermen and hence the weight should be minimal. Modules are fabricated either by reinforced concrete or ferrocement. When concrete is used 4mm weld mesh is used for reinforcement and in the case of Ferro cement chicken mesh is used for reinforcement. To reduce the thickness of the modules to 4-5CM, 0.5” granite jelly is used in the concrete. Each slab of the module is fabricated separately and joined later after completing the curing of the concrete. Curing is normally done for 12 days. Each slab of 1.5Mx1.5m is provided with a middle window of 0.60Mx0.60m.Dried slabs are joined together to form either triangular modules or rectangular box type modules as the case may be. While fabricating the modules care may be taken to maintain the cement, sand, jelly ratio as 1:2:4 for greater strength. While joining the slabs 2 mm tying wire is used for strong corners.

Fabrication of reef modules

Triangular modules ready for transportation (Poovar, Trivandrum)

Specially designed modules for lobster resources

Low cost modules (Old tyres mounted on concrete slabs, Poovar, Trivandrum)

Triangular modules on the beach (Muttom, Kannur)

Fishermen carrying the modules to the raft (Dharmadom, Kannur)

Modules being loaded onboard a catamaran (Vizhinjam I,Trivandrum)

Module loaded Catamaran pushed beyond wave breakers (Vizhinjam II, Trivandrum)

Catamarans with modules being towed to the reef site (Poovar, Trivandrum)

Arranging the catamarans on the raft before towing (Kozhikode)

Modules sliding down to reef site (Thikkody, Kozhikode)

Enriching the reef with materials of plant origin increases the productivity

Coconut leaves being transported to the reef site

Coconut leaves are deposited in the reef site in bundles anchored with stones

Creating awareness among the fishermen is a pre requisite for reef building

Reef building succeeds when it is a community activity

Transportation and Installation

Transportation and installation of the modules are the most important part in the reef building. While building small scale reefs funds are always a constraint and hence heavy machinery is not used at all. Moreover reef building along the Indian coast is nurtured as a community activity. This ensures greater participation of the fishermen community whose livelihood depends on the availability of fish resources. Reefs have a primary function of conserving the resources and hence reef building creates a sense of responsible fisheries among the fishermen.

Reef sites are normally 3-12 km away from the shore and transporting modules on boats has its own limitations. Although catamarans were used extensively in the transportation of modules in the south a major constraint faced was the number of modules a catamaran can carry (Normally only one module was placed onboard a catamaran causing inordinate delay in transportation). Considering these difficulties a bamboo raft was designed for module transportation in the northern Kerala. Eight oil barrels of 200 l capacity was used to float the raft of 3mx3m size and 2 modules were placed on the raft, which was towed to the reef site using a 15 HP outboard motor fitted plywood boat. Bamboo poles are used by 8 people to transport the module from the shore to the raft and then towed to the reef site. After reaching the reef site the modules are either lowered to the bottom by using a strong nylon rope or slided to the bottom from the top. While lowering the modules greater accuracy is achieved in reef building whereas while sliding down the modules are dispersed in the reef in a scattered manner. The earlier method is more costly. Using marker floats on 4 corners of the proposed reef marks the reef area. Marker floats helps the fishermen to locate the reef correctly while installation as well as in the subsequent period. Modules are placed from one end of the marked area to the other end. Reef modules are normally placed on the outer sides of the reef leaving the middle area free for depositing reef enrichment materials subsequently. Reefs require annual maintenance by way of dumping enrichment materials to maintain high productivity in the reef.

Enriching the reef and enrichment materials

Artificial reefs are artificial habitats where large-scale aggregation of the fishes takes place due to the availability of plentiful food organisms in the newly developed habitat however as time progress the size of the population increase and the food availability decreases. This results in decreasing the productivity of the reef. The best way to overcome this problem is by enriching the reef by dumping plant materials like coconut leaves, coconut stumps, palm leaves, freshly cut branches of trees or additional modules into the area. Plant material when decays, especially coconut or palm leaves, exudes a typical smell which attracts the fishes and fish food organisms to the reef area. This sudden availability of food in the reef provides sufficient food to the larvae and fingerlings of many organisms. The fishermen knew this since time immemorial and this is widely practiced both in fresh water as well as marine environments for aggregating fishes. This is also widely practiced by fishermen for catching the cuttlefishes and squids in north Malabar coasts.

Fishing Methods in the AR

The following gears are commonly for exploiting the resources available in the reef area

1. **Hooks &line**

   Hooks and lines used in the reef are mainly three types

a. **Long lining:** Long lining is mainly used for the flat needlefish *Abelennes hians, Carangoides* Spp., *Lethrinids, Snappers, Groupers, triggerfish, Rachycentron canadum* etc. There are three types of long lines *i.e.* Surface long lines, small bottom long lines and big bottom long lines.
b. **Mid-water Hand lines:** This is mostly used for catching small sized mid water fishes. The gear consists of 25-50 hooks tied at intervals to a main line. This gear is mainly used for catching fishes like scads, mackerels, trevellies and small tunas. The bait used is commonly artificial.
c. **Bottom hand jigging:** The gear consists of a lead rod of 300 g over which a silver or golden or multi coloured glittering cloth piece is rolled completely acting as a bait.4-5 hooks are firmly tied at one end of the bait and the main line passes through a hole on the other end. Single fishermen operate many lines at a time to cover a wider area. This gear is exclusively used for catching cuttlefishes.

2. **Gill Nets**

Gill net is a rectangular piece of netting with large mesh size. While in water column the net acts like a barrier and while the fishes, without noticing the barrier, tries to pass through it gets entangled in the gills (gilling). There are different variations of gill nets available all along the coast and depending upon the area in the water column where they are operated or the resource for which they are operated this gear is known in different names at different places. Netholi vala (Anchovy net), Ayila kollivala (Mackerel net), Chala vala (Sardine net), Kanatha vala (Tuna net) etc are all variations of gill nests

3. **Trammel nets**

These are triple layered nets with the outer layers having big mesh size (250mm) and the middle layer having a smaller mesh size (50mm). Locally known as discovala, this gear is commonly used for catching prawns, Skates, rays and flat fishes from the reef area.

4. **Seine nets**

This gear has wings and towing wraps in the front and a bag in the rear end. The wings direct the fishes to the bag as the boat moves forward. Locally known as thattumadi this gear is mostly used for pelagic fishes like anchovies, squids etc.

Fishing Season

Fishing in the AR is normally restricted to a 6-month period starting from October and ending in March. After the post monsoon season there is a gradual decrease in the catches in the inshore waters starting from October, locally known as *Panjamasom (means months of starvation)*. It is during these months that the fishermen depend on the ARs for their livelihood. Fish catches in the reef decreases from February and by March catches will be very poor. Whereas fish catches in the open waters increases from

February onwards and fishermen move from reef area to open waters during these period. Thus the traditional fishermen regulate the exploitation of the resources in the reef area and open waters judiciously throughout the year. This conservation minded exploitation protects the resources to a greater extend. However, when the mechanized fleet invades the coastal waters this balance disappears.

Major resources exploited from the artificial reef area

D'Cruz (1995) reported that *Atule mate* belonging to the family carangidae dominated the species composition of the fish catches from the Valiathura reef (41.25%) followed by *Priacanthus spp* (12.97%), Mackeral (10.30%), Balistids (6.5%) and others forming the rest. Cuttlefish one of the important resource available in the reef formed 0.60%. In reefs where enriching is done, the cuttlefish catches can be increased many times. In general resources from the reef mostly consists of *Atule mate, Priacanthus spp, Rastroliger kanagurta, Abalistes stellatus, Odonus niger, Abalennes hians, Lethrinus nebulosus, L.lentjan, Deccapteres Russellii, D.macrosoma, Carangoides spp, Lutjanus lutjanus, Carangoides gymnostethus, Megalopsis cordyla, sepia pharaonis, Epenepheleus malabaricus, E.tauvina, Acanthurus spp, Dussumeria accuta, Sillago sihama* and others. Although the abundance of these species varies from month to month these are the major resources forming the fishery in the ARs.

Socio economic aspects of ARs

Artificial reefs increase the fish availability in the coastal waters and thereby increase the employment opportunity of the artisanal fishermen. AR's also play a greater role in conserving the resources by preventing mechanized vessels fishing in the inshore waters and depriving the livelihood of small and marginal fishermen. AR's are more significant in areas where traditional fisher folks face resource depletion due to over fishing or mechanized fishing. Reefs provide additional habitat for fishes as well as fish food organisms to attach and grow. Additional food invariably attracts smaller fishes to the reef which will eventually attract larger fishes. These fishes reproduce and populate the reef forming fishery resource to the traditional fishermen using hooks and lines and other minor gears. Artificial reefs are thus required to ensure a stable and dependable livelihood to the traditional fishermen and also to ensure the conservation and management of our valuable coastal fishery resources.

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Awareness program on the '*Impact of the aggregating devices on cuttlefish fishery*'
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