Artificial reefs - definition, history and status in India

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Introduction

World fisheries today face threats from several quarters, including non-judicious fishing practices influenced by irrational growth in demand, destruction of aquatic habitats through pollution and destructive fishing methods, rupture of trophic food webs by increased exploitation of particular fishery resources, increased incidences of natural disasters and the impacts of climate change. With increasing concern over global marine fish production, and the scenario being not very different in India, there is an urgent need to evolve resource-, area-, and habitat-specific management tools to revive, sustain or improve Indian marine fisheries and marine ecosystems. The immediate and primary objective of a management strategy would ideally look towards enhancing fish catches.

Fig. 1. Mechanized fishing vessels docked at Kasimedu, Chennai

Fisheries in many parts of the world have undergone drastic changes, with onsiderable reduction in the mean sizes of common, commercially exploited resources, increase in catches of smaller, low-value resources and bycatch, and massive collapses caused by rapidly growing fisheries often unforeseen by our assessment methods, leading to disastrous social and economic consequences. The slow and steady depletion of high-value demersal

resources (Garcia and Newton, 1997) is also a matter of great concern, as this is usually directly linked to the degradation of benthic habitats.

Sustainability is a deceptive goal because human harvesting of fish leads to a progressive simplification of the ecosystem in favour of smaller, high turnover, low trophic-level fish species that are adapted to withstand disturbances and habitat degradation, and present fisheries management is unable to reverse this trend. Some questions to ponder are –

- What has happened to our coastal waters?
  Increased exploitation and investments and pro-development installations, increasing discharges and inputs (thermal / saline/nutrients /debris).
- What is happening to our traditional fishers?
  Severely stressed
- Are we fishing down the food chain?
  Yes, it has already begun a few decades back
- Are we seeing the end of top predators and welcoming foragers?
  Yes, several fisheries and catch compositions have changed and large predators declined.
- Do we call it size reduction or the emergence of smaller varieties as a substitution?
  It is a combination of both and at times it is existential.
- How has the traditional fisher or the majority of fishers adapted to these changes?
  Shifted to capital intensive efforts with reduced CPUE and thus affecting livelihoods.
- Is sustainability meant to be showing higher catches of multiple species and changed compositions?
  No, sustaining the composition, balance of numbers and trophic levels and prey-predator ratios, retaining the primal states is.
- Where are we going with the continued harvest, increased efforts and hungry mouths?
  Reduced fish stocks and catches, overexploitation, very less fish to catch and feed.
- Is the competition bringing the survival instincts of best efficient techniques, faster, bigger nets, smaller mesh, better echo locatory supports and capital investments.
  Yes, more investments for better capture rates and efficiencies and value additions, but reducing margins and the artisanal fishers get handicapped.
- What happens to the marginalized and weaker fisher and most of all the surviving fishes?
  Increasingly vulnerable, and they live in stress and misery.

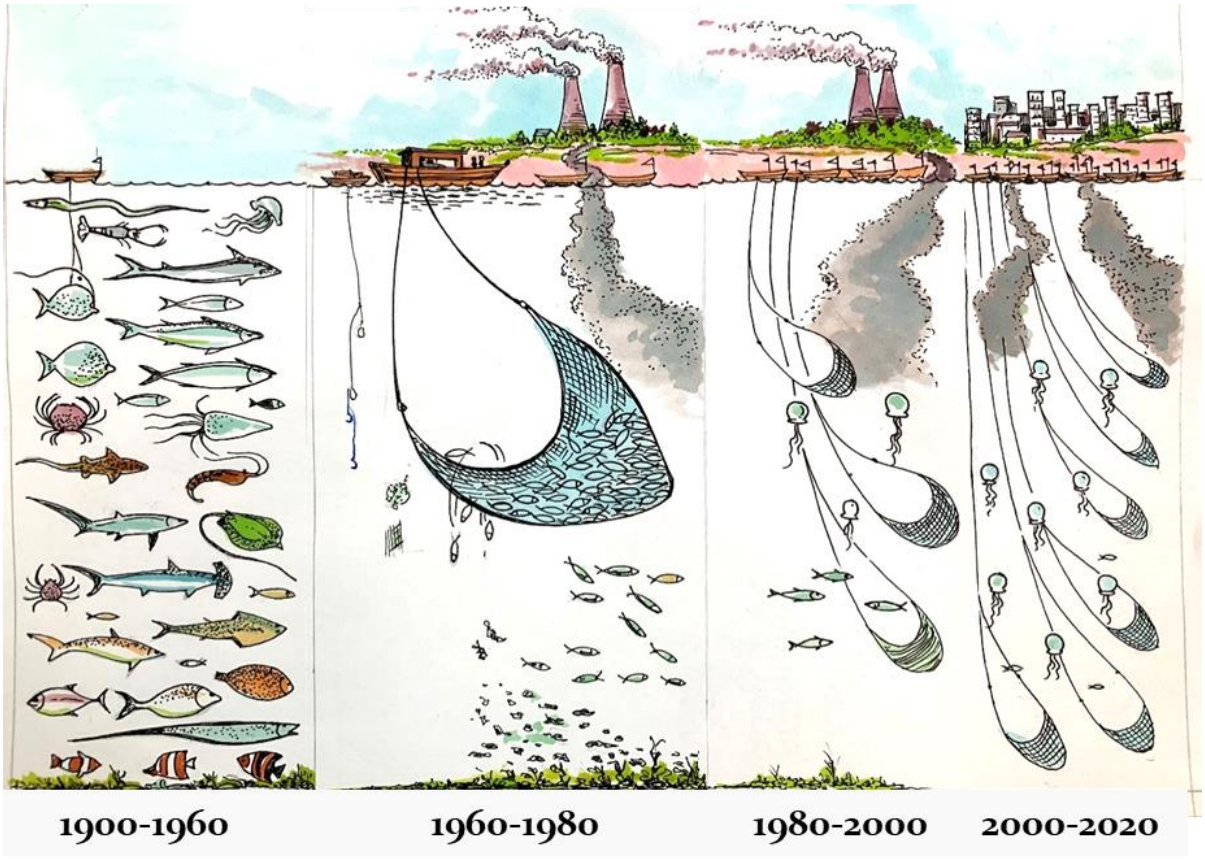

Fig. 2. Illustration of changes in the fishing scenario in coastal waters from 1900-1960 to 2000-2020 based on fishers' perception

- Have we compromised biodiversity and future economic options?

  Yes, the non-selective gears bring in several non-targeted species and in multitudes this has altered the ecosystem and habitat functioning and thus the balance and resilience within are shaken.

- Would the food fish deficit and high prices lead to long term local over exploitation?

  Yes, only to the extent of availability and economic feasibility.

- Does all these lead to the last resort of the landless poor (Pauly 1994)

  Yes

- Why do we need artificial reefs?

  We need more fish habitats, which are lost, restore the balance of fish diversity, populations, production and revive fishing and increase fish resilience towards increasing climate change.

Fig. 3. Fishing boats used at Kovalam, Tamil Nadu and Sassoon Dock, Mumbai and hooks used in hook & line fishery in Mumbai

Artificial Reefs

Artificial reefs are structures set on the sea bed to enhance the growth of marine floral and faunal benthic communities which simulate natural settings for promoting fish aggregations in terms of attracting migrant populations for breeding/feeding opportunities and also provide the base for the propagation of resident populations within sheltered structures. Artificial reefs promote habitat recovery/enhancement and boost aquatic biota. Artificial reefs are submerged (or partly exposed to tides) structures deliberately placed on the seabed to mimic some functions of a natural reef, such as protecting, regenerating, concentrating and/or enhancing populations of living marine resources. This includes the protection and regeneration of habitats. They serve as habitats that function as part of the natural ecosystem while doing “no harm.”

There is often a misunderstanding on the use of Fish Aggregating Devices (FAD)/Artificial Fish Habitats (AFH) and Artificial Reefs (AR). While FADs and AFHs are temporary aids to aggregate certain varieties or species mostly in surface or mid-water realms, ARs are more long-term habitat reconstruction programs to protect, produce and process a near similar natural reef like faunistic community built up and sustain it for several years.

Fish Aggregating Devices are structures or devices deployed in aquatic bodies to lure fish. They may be permanent, semi-permanent or temporary, made of natural or artificial materials. The practice of deploying FADs is rooted in the general knowledge of the tendency of fishes to aggregate under or in the vicinity of floating objects. These devices have been in use for over thousands of years. The earliest known FADs were driftwood, branches of trees and palm fronds etc.

While FADs provide an easy means of attracting fish towards easy exploitation, the deployment and proliferation of FADs have influenced harvesting practices and become the concern of fisheries managers (FAO, 2015). FADs increase the chances of selective fishing from spawning aggregations or juvenile aggregations, causing an eventual recruitment overfishing or growth overfishing. Sasikumar *et al.* (2015) report that the extensive use of FADs for cuttlefish fishing along the Karnataka coast has led to recruitment overfishing of the species in the eastern Arabian Sea, with a reduction in the number of recruits from 93.2 million in 2008 to 35.6 million in 2013. The use of synthetic non-biodegradable material in place of natural plant materials adds to the load of marine debris and pollution in the coastal waters.

Fig. 4. Traditional fish aggregating devices using coconut fronds, palm leaves, *Thespesia* spp. and *Acacia nilotica* tree branches, granite stones, etc.

In coastal marine ecosystems, ARs offer a platform for coral populations and increase the abundance of reef-dependant biota, including fishery resources. Their primary action being on the potential recovery of natural reef habitats that have been, or are on the verge of being affected by a collage of natural and anthropogenic events, artificial reefs can also prove to be a means of expanding favourable habitats through the deployment of coral-implanted reefs. The advantage of this would be developing fishing grounds close to shore, easily accessible to traditional and non-destructive fishing methods.

Artificial reefs exclude FADs, artificial islands, cables, pipelines, platforms, mooring, and structures for coastal defence (eg. breakwaters, dikes, etc.) which are primarily constructed for other purposes. Artificial reefs are management tools, which if applied in the right perspective, can prove to be great promoters of habitat recovery and enhancement and aquatic biota population boosters. Artificial reef technology has been used widely across the globe for both habitat and ecosystem enhancement and commercial fishery enhancement.

Advantages of an Artificial Reef

Artificial reefs provide suitable shelter for several groups of reef dependant fishes, particularly those that aggregate in such habitats for breeding. These structures easily attract smaller organisms which are vital sources of food for different marine species. They also serve as visual reference points for fish that forage away from the reef. A major advantage of fishery development through artificial reefs would be the reduction in scouting time and fuel consumption necessary for the fishermen to locate fish gatherings. These reefs, if properly constructed and properly buoyed, can be used to enhance existing rough bottom habitats and develop quality fishing grounds close to access areas. A well-planned and constructed reef is a mutually beneficial enterprise for both fish and man. The construction of a reef or fish haven can change a barren, relatively unproductive substrate into a dynamic, highly productive environment. Increasing the amount of rough bottom habitat provides immediate shelter and subsequent food for a complex of organisms which may have been otherwise lost in the process of its struggle for existence.

Types of reefs:

Protection: Beach and shoreline protection structures assembled in the sea bed to stall the wave swells and reduce the impacts on the sea shore.

Conservation/sanctuary: Create habitats and reserves for the settlement of select species or ranching select species and develop settlement colonies.

Production: Multimodule assembly of reefs built for the settlement, aggregation and multiplication and fishery sustenance and fisher livelihoods.

Recreation: Modules and deployments designed for fish assemblages for the SCUBA and diving enthusiasts and promote ecotourism**.**

Breeding and nursing /ranching: Specially designed reef modules for the juveniles and seed holding and nursing environment, to promote stocking and population revival.

Fishery and livelihood: Low scale short-term reef installations with simple models and fewer numbers with diversified and natural structures.

Creation of artificial sea mounts: Creation of large piles and dumps specially designed, to make artificial mounts or structures to create eddies and enrichments in the columnar region. These are normally very tall structures deployed on the continental shelf at greater depths.

Upwelling reefs for nutrient mixing: Introducing wall-like structures on the sea bed at the wave-breaking zones to induce a shift of sedentary nutrient mixtures to the surface and

water column thus providing base and supplements for the growth and multiplication of primary and secondary producers.

Creation of current shadows/wake region: Developing specifically designed modules to be deployed in areas with more sea currents and flow speeds**.** Assembly of the modules is suited to create more current shadows and wake regions according to the flow directions, which can support plankton colonies.

Multiple purposes: A combination of modules aimed to contribute to production, conservation, recreation, or other functions as is desired.

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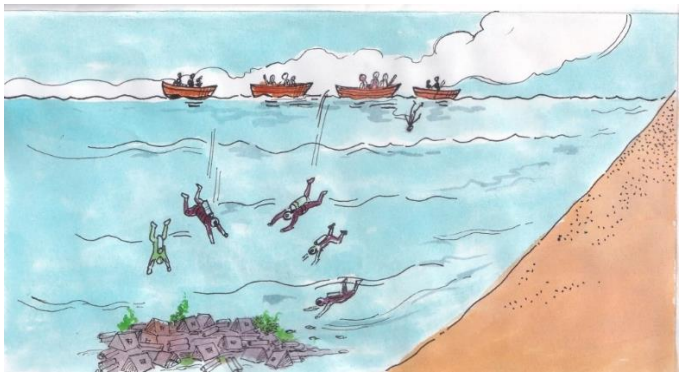
b.



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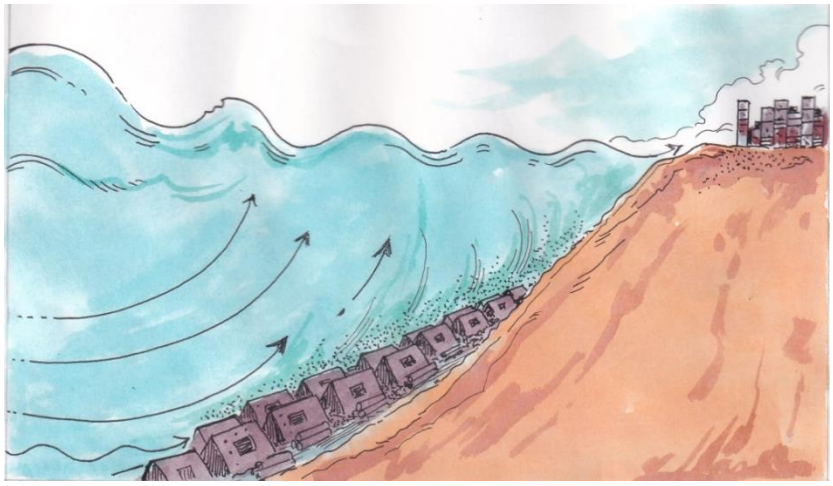

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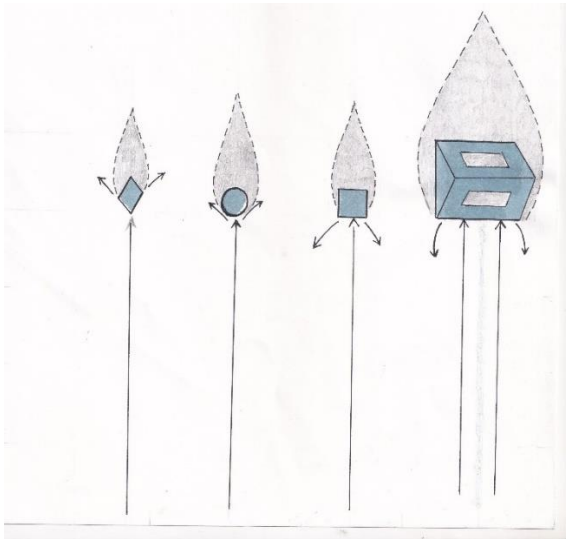

f.

Fig. 5. Artificial reefs deployed for various purposes – [a] ARs for protection [b] ARs in a Marine Protected Area (MPA) [c] ARs for recreation and tourism [d] ARs forming seamounts or cones [e] ARs reefs for upwelling [f] ARs forming shadow/wake regions

Artificial reef R&D and deployment in India

Since its inception in 1947, the Central Marine Fisheries Research Institute (ICAR-CMFRI), has been working on marine living resources, fisheries, sustainability, fisher census and livelihood, mariculture and marine environment. The Institute has produced several methodologies, technologies, products, research findings and publications in these directions.

Over the years, in the coastal states of Tamil Nadu, Gujarat and Maharashtra and many similar states where the commercial fishery has been predominantly supported by large predator fish communities and demersal fish species, increasing fishing intensity particularly focussed on large demersal groups has resulted in a continuous decline of these resources and the emergence of smaller fishes. Eventually, there has been a transition in the dependence of coastal fisheries from larger fishes to smaller ones, causing irreparable changes in the community structure and ecosystem functioning. The increasing pressure on the available fish stocks, anthropogenic inputs, climate change-related stress and increasing sea food demand and nutritional requirement has only aggravated the marine fisheries scenario with increasing pressure on the critical habitats and fisher livelihoods.

Since 1980, ICAR-CMFRI has been working on habitat enhancement and improvement of coastal productivity and livelihoods, through FADs, artificial reefs and fish stock revival and restorations. Initially, several NGO's working in the fisheries sector like the South Indian Federation of Fishermen Societies (SIFFS), Programme for Community Organization (PCO), Trivandrum, Loyola Social Service Center, Trivandrum, Murugappa Chettiar Research Centre (MCRC), Chennai and Centre of Research on New International Economic Order (CRENIO, Chennai) were responsible for mobilising fishermen and launching ARs in a few fishing villages in the south-west and south-east coasts of India. CMFRI initiated R&D works on artificial reefs in the 1990s. An experimental deployment was conducted in Minicoy, Lakshadweep and Tuticorin during the early 1990's by CMFRI. A National Workshop on Artificial reef building technology and farming was conducted at the Trainers Training centre (TTC) at CMFRI, Kochi in 1996.

Two reefs were deployed off Vizhinjam in 1997 by ICAR-CMFRI. Subsequently deployments were conducted with funding support from the Department of Fisheries, Government of Kerala, during the 1999-2003 in Poovar in Trivandrum, Dharmadom in Kannur, Moodady in Kozhikode, Thikkody in Kozhikode, and Muttom in Kannur districts, covering an area of nearly 50,000 sq. m. Different AR structures deployed in the coastal waters south of Chennai in the 2000s demonstrated the potential role of AR in resource enhancement and increased economic benefits. Catches from the deployed sites comprised of high-quality fishes, fetching fishermen better economic returns per unit effort (Vivekanandan *et al.*, 2006). Tamil Nadu has, in recent years, become a major player in the practice of artificial reef deployment in coastal waters, under technical guidance from CMFRI. Since 2006, the Department of Fisheries, Government of Tamil Nadu, has deployed artificial reefs in 125 coastal sites spread across 10 districts along the Tamil Nadu coast, with technical assistance from Madras Regional Station of CMFRI, Chennai. Since 2011, the IFAD-assisted Post

Tsunami Sustainable Livelihoods Programme (PTSLP) of Tamil Nadu Corporation for Development of Women (TNCDW), Government of Tamil Nadu, has also come forward to deploy artificial reefs along the Tamil Nadu coast, with 18 sites completed by CMFRI and 42 sites done by the National Institute of Ocean Technology (NIOT). Other NGOs and agencies have together deployed artificial reefs in another 22 sites in Tamil Nadu during 2000-2020.

CMFRI, in association with NTPC (CSR funding) and State Fisheries Department, deployed artificial reefs at Mutyalammapalem village in Visakhapatnam District Andhra Pradesh. A total of 210 (70 each 3 models) AR modules covering an area of 1000 m^2 were deployed (at 15 m depth) along the Mutyalammapalem coast of Andhra Pradesh in May 2015.The total area covered by 210 units is 1000 m^2 with a surface area of 2781.8 m^2. CMFRI has also undertaken Artificial fish habitat-based marine ecosystem restoration in the inshore areas off Bhadreswar, Kutch District, Gujarat on consultancy mode for Agriculture, Farmers Welfare and Co-operation Department, Government of Gujarat, with the deployment of 225 reef modules in 12 clusters off Bhadreswar.

CMFRI has also been conducting studies to assess the state of maturation of artificial reefs deployed at different sites along the Tamil Nadu coast, and collect information to assess the impact of artificial reefs on the natural habitat and its biodiversity. The team at the Madras Regional Station is conducting focused research and monitoring and evaluating the works on the development of suitable reef designs, structures and densities in the promotion of habitat formation in the near coast, for the past two decades in Tamil Nadu. Several patterns, materials and sites have been studied and site-specific programmes have evolved. Recently, the Institute was awarded patent rights for Patent 197/CHE/2012.

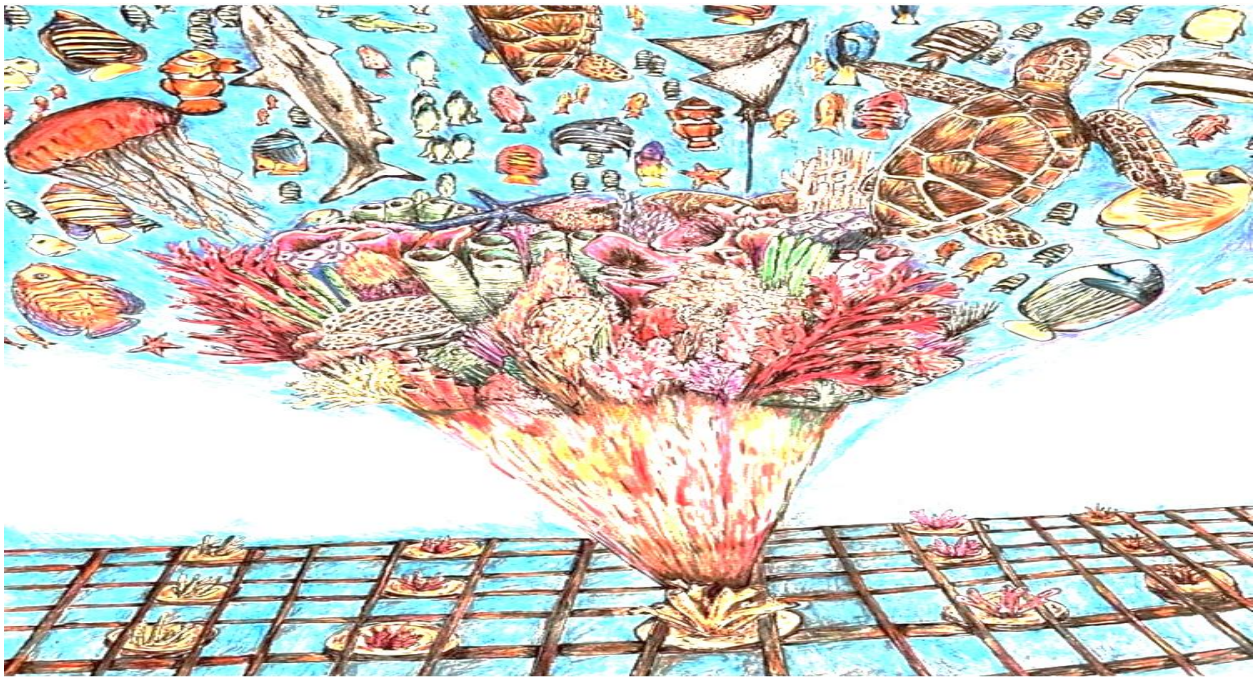

Fig. 6. An artist's view on the production cum conservation impacts from a small habitat restored on the sea floor