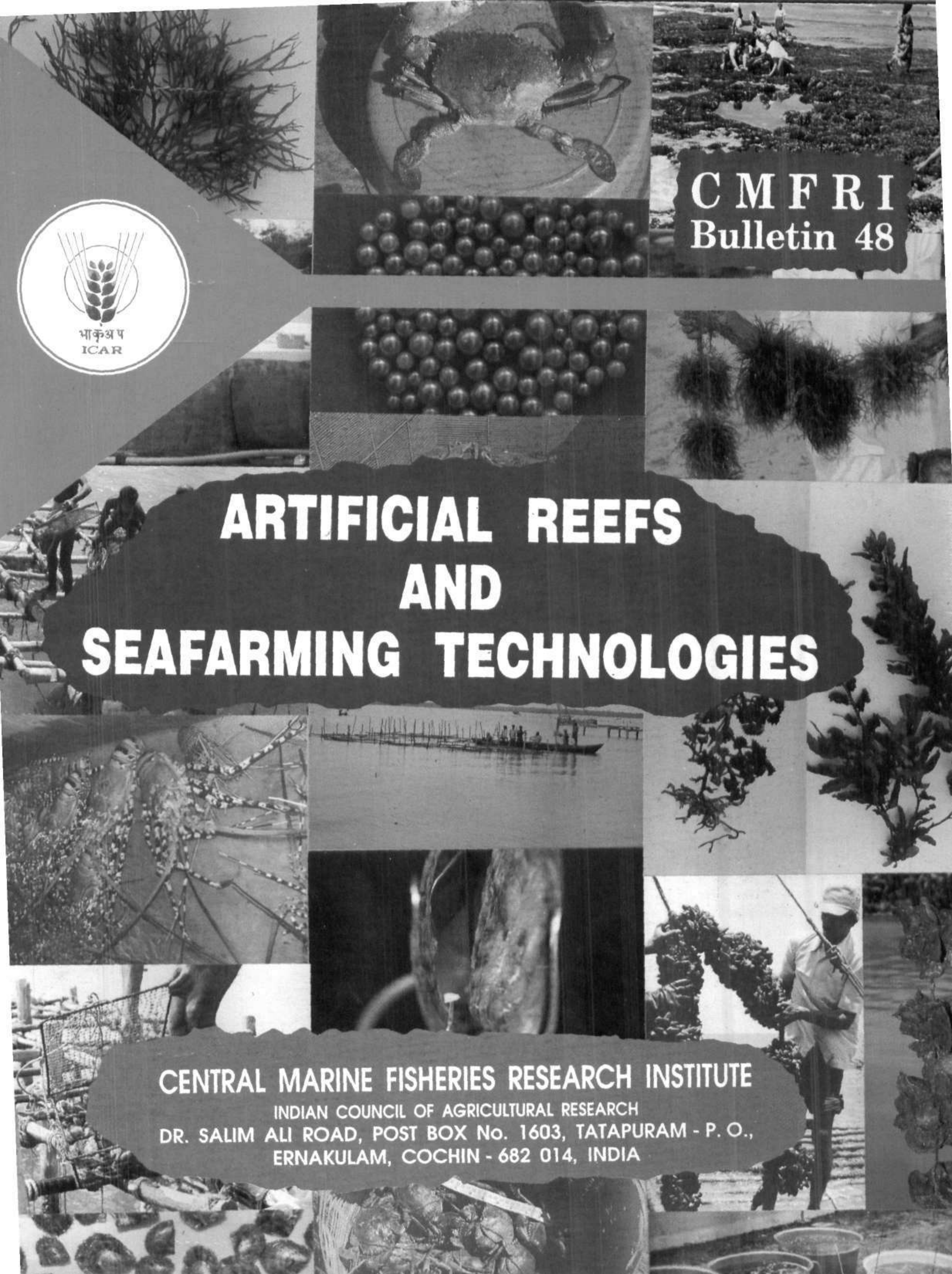

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DR. K. RENGARAJAN

Editor

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ARTIFICIAL REEF AND ITS ROLE IN MARINE FISHERIES DEVELOPMENT

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Introduction

Floating bamboo bundles and piles of stones kept on the sea bottom have long been used by traditional fishermen as fish gathering devices in various parts of the world. These objects provide living space, shelter for protection from the predators thus functioning as (i) a habitat for organisms. The attached algae and other sessile organisms serve as food especially for young ones. Thus the area where such objects are placed function as (ii) a feeding ground. These objects also act as a suitable substratum for attachment of eggs in some cases thus functioning as (iii) a spawning ground. Based on these principles artificial reefs are constructed in different parts of the world either to create a new fishing ground or to improve the production potential of the existing grounds. Although the construction of artificial reefs has been taken up as a Government sponsored programme in many countries, particularly in the Southeast Asian countries on a commercial scale, in India the work is still in a preliminary stage with only a few voluntary organisations and fishermen society taking some interest. In Japan for instance, annually $ 100 million is spent on artificial reef technology under Government's subsidiary project called the Coastal Fisheries Structure Improvement Project. Annually, about 60 million cubic feet of artificial reefs have been installed in recent years. According to the surveys taken since the beginning of the National Artificial Reef Programme, the productivity index in Japan has been estimated to be as high as 50 kg of fish per cubic metre of reef volume. India with a long coast line of over 6100 km can also significantly increase its marine fish production by constructing artificial reefs in certain selected places along the coast.

Types of Artificial Reefs

Artificial reefs may be broadly classified into two categories *viz.* (i) Artificial reefs set on the bottom and (ii) Artificial reefs floating on the surface or subsurface.

Artificial Reefs set on the bottom

Traditional fishermen have been constructing artificial reef on the floor of the sea by sinking boulders, discarded building materials, etc. in certain parts of the world and they have noticed an increase in fish catch. This is primitive method of artificial reef construction. Scientific method of artificial reef construction includes designing of suitable structures from materials such as steel and concrete, based on the results of the studies carried out on fish behaviour and oceanographic observations. Thus, the design, material and final dimension of the reef units are based on the species targeted, oceanographic characteristics of the area and other related considerations. The final structure of the artificial reef placed on the floor of the sea is thus a product of an interdisciplinary approach involving various branches of the science particularly engineering, oceanographic and biological.

Fish behaviour and reef design

Fishes respond to reef structures in different ways. The degree of such response has been termed as 'reefiness'. The behaviour pattern of certain species of fish allows one to design a suitable structure so as to attract that particular species. About 150 species of fishes have been recognized as showing clear response to reefs based on the behavioural studies carried out in Japan. Fishes orient their movements either through visual perception or through lateral line sensing of pressure variations in currents impinging upon the reef. The instinct called 'taxis', constitutes the fundamental linkage between the design of the reef structure and the fish. The various 'taxis' are (i) *geotaxis* - the fish tends to balance its body relative to the ground with the belly downside and the back to the light from above, (ii) *rheotaxis* - the fish tends to orient itself parallel to the current, (iii) *thigmotaxis* - the fish navigates relative to an object through physical contact or using its lateral line sensor, (iv) *phototaxis* - the fish responds to light and (v) *chemotaxis* - the fish responds to smell.

Fishes may be classified into five different categories depending upon their interaction with the bottom-set reefs.

Type I. Fish which always attaches a major portion of its body to solid objects *e.g.* eel.

Type II. Fish which attaches a part of its body *i.e.* pectoral fin or ventral surface to solid object *e.g.* rock trout, lionfish and grouper.

Type III. Fish which may not attach its body to solid objects, but needs to have solid objects close by all the times *e.g.* black seabream, parrot bass, opaleye ad coral-fish.

Type IV. Fish which does not necessarily need the presence of solid objects, but which will assume a steady position if some are there nearby *e.g.* horse mackeral, mackeral and yellow tail.

Type V. Fish which does not need the presence of solid objects at all, but it can assume a regular steady position in response to the stimulation of a floating object *e.g.* tuna, pike, salmon and trout.

Intensity of attraction of fish towards bottom-set artificial reef

The intensity of attraction of fish towards the artificial reef set on the bottom may be categorized as small, medium and large.

Small : Mackeral, mullet.

Medium : Seabream, surgeon-fish, filefish, parrot bass, grouper, yellow tail, cod.

Large : Eel, goby, flatfish, flounder, flathead, angler, lionfish, bullhead, rock trout, goatish.

Functions of Artificial Reefs in the life cycle of fishes

Artificial reefs play an important role in the lives of fish and have the following functions.

Artificial Reefs as habitat

It has been noticed during underwater observations that on seeing the diver the fish which were freely moving near the artificial reef structures, penetrated into the interior of the structures clearly indicating that the reef serves as a hiding place for such species. At times the fish remains at stationary position without even searching for food (*e.g.* rocky reef fish).

Artificial Reefs as feeding ground

The installation of artificial reefs creates a base for the attachment of algae and sessile organisms. These algae and sessile organisms serve as food especially for young fishes. In otherwords young fishes are attracted towards such places as food is available in plenty. Fishes like parrot bass and filefish feed on sessile organisms whereas grouper, flounder and eel confine themselves to the second higher level of the food chain by feeding on small fish. A close association between the seaweeds and fish larvae has been observed by many workers. Seaweeds have bountiful biota and have long been considered as an important nursery ground for fish and shellfish larvae. It has been reported that more than 150 species of fish appear in these seaweed beds. However, most of these species do not have any commercial value. Only about 30 species are commercially important. These species include seabass, wrasse, filefish, black rock fish, rock trout and greenling. Almost all these species spend a part of their larval stages in *Zostrea*. Some species like common horsemackerel, yellow-tail, amber jack, parrot bass, opal eye, rudderfish, rabbitfish, leatherfish, filefish, black rock fish, greenling and rock trout have been reported to occur in drifting seaweeds. However, most of these species leave the drifting seaweeds and move to a new habitat when they reach a particular size.

It has been reported that due to the formation of rip current in the vicinity of the artificial reefs the intensity of plankton distribution is very high which results in the attraction of plankton feeders in large numbers.

The density of sessile organisms in the reefs reaches its maximum after ten years of reef installation. It has been observed that the growth rate is faster initially at 60 m or deeper and after four or five years the areas at 30 - 60 m tend to have more rapid growth rate of the sessile organisms. Also, it has been reported that the growth rate of sessile organisms is faster in sandy bottom rather than in muddy bottom areas. Further the growth tends to be more rapid in open sea areas than in inner bay areas. It has been well established that the artificial reefs which have the highest growth density of sessile organisms, tend to be more effective in attracting fishes.

Diurnal changes in fish attraction

It has been reported that horsemackerel swarm in the bottom during day time, but disperse to the surface or midwater layers during night time. The swarming behaviour of larval yellow-tail and seabass in the artificial reefs is at its maximum during day time. Nocturnal fishes such as lionfish, remain in the crevices during day time, but become active in the evening and swarm around the reefs during night in search of food.

Underwater sound and its impact on fish behaviour

It has been observed that the lateral line sense organ of fish can detect a low sound of a few Hz, lower than 120 Hz. A low frequency sound will make the fish to position itself towards the direction of the origin of the sound and will make it to be alert to any subsequent changes of the sound's origin. When the speed of the sound is faster than the speed of the movement of an individual fish or schools of fish, many species react frantically and disperse. The range of the transmitted distance of the underwater sound varies according to the intensity of sound pressure at the origin of the sound. The lowest limit of auditory sense for fish is generally about -10 to -20 dB for bony fish. The maximum distance at which most can hear the sound of sessile organisms is generally a few hundred metres. Visual senses which must depend upon water clarity can never reach this distance.

Floating artificial reefs

It is well known that various species of fishes seek shelter among floating seaweeds especially during their early stages. Such behaviour of the fish is utilized in the exploitation of various fishery resources by providing suitable artificial floating shelters in the form of floating artificial reefs. While bottom-set artificial reefs are being extensively used in many parts of the world for exploitation of the coastal fishery resources, there has no such effort to exploit the offshore fishery resources. However, Japan has made a pioneering attempt in this direction by establishing a fish farm called "Tosa Kuroshio Fish Farm" in the form of a floating artificial reefs at a depth of 550 m approximately 40 km off Kochi city. The floating artificial reef has been designed and constructed by the engineers of Nippon Steel Corporation of Japan.

The reefs main hull is a steel disk 6 m in diameter with a weight of 12 tonnes and the floating hull with a overall height of 7.8 m. The reef is equipped with a water sprinkler system which is powered by a series of solar batteries mounted on the top of the reef. This sprinkler system has been designed to improved fish aggregation. The reefs mooring cable is a non-corrosive polyethylene-coated parallel wire cable with a diameter of 60 mm and a length of 485 m. The total length of the chain used is 830 m.

Experimental bottom-set Artificial Reefs constructed at Tuticorin

An experimental artificial reef was constructed at Tuticorin during July-August 1989 at a depth of 6 m using discarded Jeep tyres. Three designs of modules were fabricated on board M. V. *Cadalmin* IV (Fig. 1 & 2). Each module consisted of three tyres which were fastened together with polypropylene rope of 6 mm thickness. Design No. 1 was in the form of a tripod with the tyres standing vertically. Each module of this design was provided with maximum interspace between the blocks and the module occupied a floor area of approximately 2.3 m. A total number of 13 modules of this design was fabricated and released. Design No. 2 was fabricated in the form of a cylinder with no interspace between the blocks, but with provision for free flow of water from one end to the other. Design No. 3 was in the form of well with no inter-space between the blocks and the water in the module attaining more or less a stagnant condition. The bottom area covered by each module in Design No. 2 and 3 was less than 1 m^2. The height of the structure was about 1 m in the case of Design No. 1 and 2 and only 0.8 m in the case of Design No. 3. The modules were carefully released with the help of a winch of the Vessel and their position on the floor was set right by divers. The artificial reefs thus constructed covered an area of approximately 50 sq. m.

Fig. 1. Artificial reef module being fabricated with old tyres on board M. V. *Cadalmin IV*.

Within a period of one month from the time of construction of the artificial reefs good growth of algae was observed on the reef structures. The maximum length of the algal filament was 27 mm when observed after 15 days. This increased to 48 mm in 37 days. The algae belonged to Rhodophyceae and Phaeophyceae and were mainly represented by the genera namely *Acanthophora, Graciliaria* and *Padina*. The animal community was represented by various group of invertebrate organisms. However, the animals belonging to Porifera, Bryozoa, Polychaeta, Isopoda, Amphipoda and Cirripedia were found to have colonised the reef structures in large numbers. It was observed that the colonisation by polychaetes and cirripedes was very rapid. Initially, the composition of both the polychaetes and cirripedes was also almost in equal proportion. However, as the period advanced, the settlement of barnacles on the reef structures increased at a faster rate.

Underwater observations on the biota of the artificial reef was carried out by diving with SCUBA and inhabitation and behaviour of fish and shellfish were studied. The inhabitation by fish was recorded for the first time during the third month after the installation of the reef structures. Four distinct groups of fishes were recognised based on the degree of their attraction to the reef structures. Group 1. *Serranus* sp. preferred to live within the crevices of the reef structures; Group 2. *Lutianus* spp. preferred to swim in the stagnant water body of the well-type module without touching the reef structures; Group 3. *Caranx* spp. were observed to hover in large numbers about 2 m above the reef structures and Group 4. The blennids *Dasson* sp. and *Petroscirtes lienardi* were observed in the subsurface and found to cling to the marker rope whereas baby crabs (*Portunus pelagicus*) were found to live on the marker float, hiding themselves under the seaweeds grown on the float.

Fig. 2. Reef modules are ready for lowering into the sea.

In addition to the underwater observations, experimental fishing also was carried out in the vicinity of the artificial reef periodically by perch traps (Fig. 3). *Lethrinus* spp. with a size range of 138-210 mm and *Lutianus* sp. with a size range of 122-172 mm dominated the catch during the first year. But during the subsequent samplings the number of these species gradually declined and during the third year after installation of the artificial reefs the samplings were dominated by *Serranus* sp.

It was noticed during the underwater observations that *Serranus* sp. was attaching a major part of its body to the reef structure. As the shape of the tyre module was curved, the fish was found bending its body. On seeing the diver the fish was moving to another module and attached to it. Thus it appears that large concrete structures with wide openings and cavities may provide a favourable habitat for serranids which prefer to have strong physical contact with the object unlike Lutianids which prefer to swim freely within the reef-created stagnant water. A knowledge of the behaviour patterns of certain species of fish will thus enable us to design a reef tailored to attract that particular species.

Fig. 3. Perch trap being released in artificial reef area for collecting fish.

Conclusion

Artificial reefs when constructed on a large scale covering a vast area with scientifically designed structures will increase fish production significantly by creating a fertile ecosystem in such areas. As stated earlier the structures used for the construction of the artificial reefs primarily function as a base for the growth of algae and settlement of sessile organisms. The organisms thus settled on the reef structures reproduce there resulting in higher density of zooplankton in such areas which ultimately leads to the formation of a good feeding ground for various marine organisms. Further, suitably designed concrete structures will provide favourable habitat for spiny lobsters and various species of demersal fishes resulting in the aggregation of such groups in artificial reefs. Thus artificial reefs play important roles in marine fisheries development by (i) creating nursery ground, (ii) providing favourable habitat for fishes and shellfishes and (iii) conserving the fish stocks from over-exploitation.

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