Artificial reefs

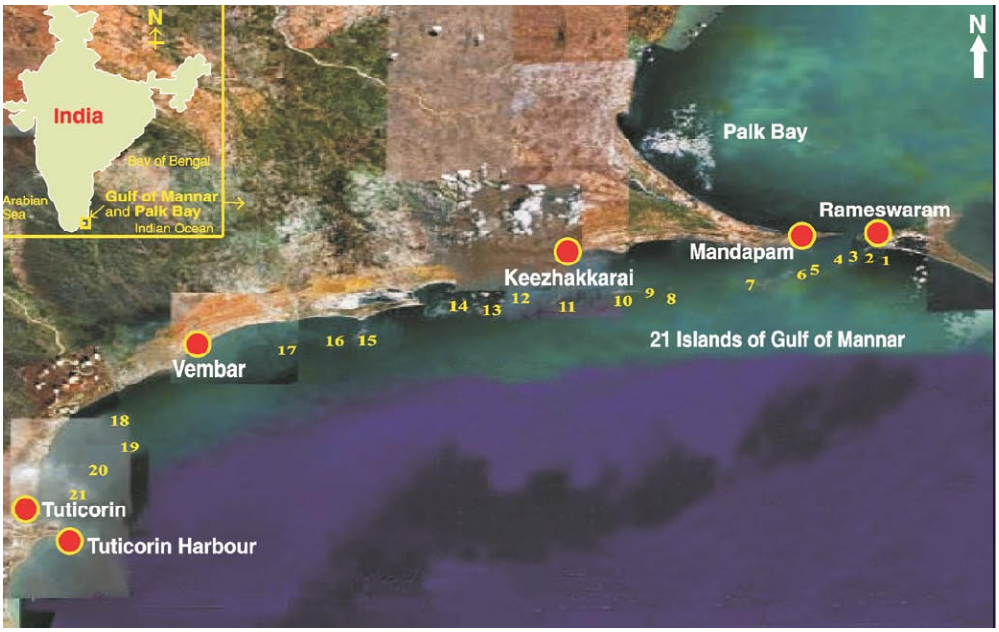
Increasing biodiversity and long term coastal fisheries in the Tuticorin region, Tamil Nadu, India

J.K. Patterson Edward *(Suganthi Devadason Marine Research Institute – SDMRI, Tuticorin, TN, India)*
Rob J. Leewis *(Netherlands Centre for Biodiversity Naturalis, Leiden, the Netherlands)*

Contents

Summary

In 2002, the community-based artificial reef programme began, aiming to restore a lost fishery and to increase marine biodiversity within the frame of a Netherlands-Indian coastal cooperation. The artificial reefs were locally constructed and placed in the Gulf of Mannar (Tamil Nadu). The effects were intensively monitored. The results are clear and undeniable, revealing that artificial reefs enhance coastal fishery stocks, coral recruitment and help form new food chains. It became clear, that although artificial habitats are mostly designed for a variety of biological functions, they primarily serve social functions by providing services and resources to different user groups. This ultimately enhances the socio-economic status of the poor, traditional fishermen, who gradually became more enthusiastic about the positive effects of the artificial reefs.
The higher yield of fish catches and the monitoring of the artificial reefs, essential for evaluating the results of the programme continued also after the Dutch assistance ended in 2006, are signals of success of this reef project.



The Gulf of Mannar *with the locations of its 21 uninhabited islands. In total 105 artificial reef modules were placed and monitored in three locations around the Koswari (#20) and Vaan Islands (#21), near Tuticorin. (source: Patterson Edward, J.K. et al, 2008)*

1. Introduction

The Gulf of Mannar is one of the four major natural reef areas in India and is located at the southeastern part of Tamil Nadu. The 140 km Gulf of Mannar stretch extending from Rameswaram to Tuticorin, located between Lat. 8º 47' N and 9º 15 N and Long. 78º 12' E and 79º 14' E includes 21 uninhabited islands, which are surrounded by coral reefs (Figure 1). In 1986, the Government of Tamil Nadu declared the Gulf of Mannar a Marine National Park, including all 21 islands and surrounding shallow coastal waters covering an area of 560 km^2. In addition to this, in 1989 the Gulf was also declared as "Marine Biosphere Reserve" covering an area of 10,500 km^2 from Rameswaram to Kanyakumari (= the southern most tip of India).

The Gulf of Mannar is influenced by seasonal monsoons - southwest monsoon and northeast monsoon. The islands are located at an average distance of 8-10 km from the mainland. Narrow fringing reefs are mostly located at a distance of 100 to 350 m from the islands, patch reefs rise from depths of 2 m to 9 m and extend up to 1 - 2 km in length with a width as much as 50 m. Large areas of reefs along the Gulf of Mannar are generally in poor condition due to a number of destructive activities – such as coral mining and destructive fishing practices carried out by several hundred people who live along the coast and depend on reef resources for their livelihood.

In 2002 the Suganthi Devadason Marine Research Institute (SDMRI, based in Tuticorin = Thoothukudi) in collaboration with the Coastal Zone Management Centre in The Netherlands, began a community-based artificial reef programme, to study efficiency of artificial reefs in enhancing the lost fishery. This programme was part of a cooperation between India and the Netherlands to strengthen integrated coastal zone management. The aim was to increase the resilience of the coastal habitats and its people through coastal measures involving no net environmental loss. The programme aimed to increase the biodiversity and fishery catches helping to combat the poverty of local fishermen.

2. Material and methods

Study Locations

Three stations were located around Vaan and Koswari Islands in Tuticorin coast. 37 artificial reef modules were deployed in site 1 (5.6 m depth), 37 modules in site 2 (3.6 m depth) and 31 modules (3.2 m depth) in site 3.
There were two main target fishery villages for the project: Vellapati (close to Vembar) and Tharuvaikulam near Tuticorin.

Deployment of artificial reefs modules

In the present study, the artificial reef modules were made of Ferro-cement. This material was cheap, locally available, and easy to handle. The modules were constructed as three slabs for easy transportation and deployment. Each slab was 137 x 90 cm in size with 12 holes of two different diameters: 18 and 11 cm (see Figure 1).

Parameters measured

Physico-chemical parameters (temperature, salinity, dissolved oxygen, pH, transparency) and nutrients (calcium, magnesium, phosphate, nitrate and nitrite) in the water were assessed continuously. Sediment samples were collected using cylindrical cores for the study of (macro) benthos and particle size composition. Plankton samples were collected using plankton nets for the analyses of phytoplankton and zooplankton species and plankton biomass.
SCUBA divers surveyed the species composition and cover of the epifauna on the artificial reef modules. The epifauna species are benthic (bottom) animals that live on the surface of a substrate, such as rocks, pilings, marine vegetation or on the (sea) bottom. They were identified and samples collected by scraping the animals off the surface with the help of a special "Epifauna sampling scraper". Epibenthic invertebrates were surveyed by counting quadrants of 15 by 15 cm.
In addition, plates such as cement slabs, tiles and pieces of wood were placed horizontally on the artificial reef modules and secured with plastic wires. After 10 days, the plates were retrieved and brought to the laboratory for the identification of newly established epifauna.

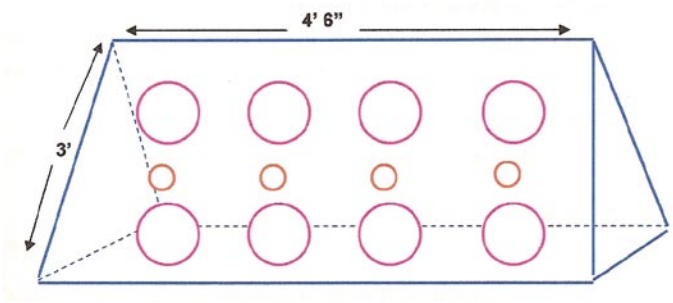


Figure 1: ***Module design, transport of modules parts (slabs) on rafts & assembling the modules parts*** *to the deployment in three locations at a water depth between 3.2 and 5.6 m. (photos: SDMRI)*

Catch Per Unit Effort (CPUE) was assessed by fishing once a month around the artificial reef sites using nets constructed like Mayavalai and Nandu valai (both are modified gill nets with different mesh sizes, used in the target villages). The species caught were numbered and recorded.
Gut content of all finfishes caught in the nets and traps was analysed to find out whether their diet came primarily from the reef or from elsewhere.
The diversity and quantity of fin fish and shellfish landed by different types of gear was recorded.
Collected data was statistically analysed by (ANOVA) Analysis of Variance to establish any significant difference in the mean of various parameters observed at the control and artificial reef stations. In addition, the statistical Duncan's multiple range test was also applied.

3. Results

The variations in the physico-chemical water quality parameters for the period up to 2008 were not significant. Also, statistical analysis showed no significant difference between the means of physical parameters in the control and the artificial reef sites, but most of the chemical parameters were found to be higher in comparison to the baseline data.
Data provided in this report cover the period 2002 – 2008. Monitoring the artificial reefs continued in order to improve the evaluation of the results, after the cooperation with the Dutch ended in 2006.

Plankton
Plankton biomass was observed to be very low in the 2002 baseline surveys. Plankton increased gradually from 2003 to 2008. Statistical analysis shows a significant difference in the plankton biomass by wet weight between stations. The reason for the higher dry and wet weight at station 2 was probably the proximity of a natural reef area. The presence of many plankton-feeding fish species such as *Siganus* sp. in the area, may be the main reason for the lower dry weight of plankton in the artificial reef sites.

Sediment Analysis

During the baseline study in 2002 the percentage of sand was very high (above 60%) in all stations and the percentage of clay was low (below 9%). The recent data reveal a reduction in the percentage of sand and an increase in the silt and clay in all the sites from 2003 to 2008.

Benthos and associated fauna

The monitoring of the artificial reef stations from 2002 to 2008 showed that the artificial reef is efficient in attracting and aggregating biological resources (Figure 2). Among the macrobenthic community, bivalves were the dominant category in the baseline survey. The monitoring reveals an increase in the percentage of gastropods and bivalves, confirming the increase in the benthic population. Gastropods were the dominant contributor followed by bivalves For the echinoderms, scaphopods, polychaetes and crustaceans, the percentage was below 5 % at all stations, but showed an increase over time when compared to the baseline data. This again suggests that due to the presence of the artificial reef sites, more encrusting forms and their associate dwellers became established.

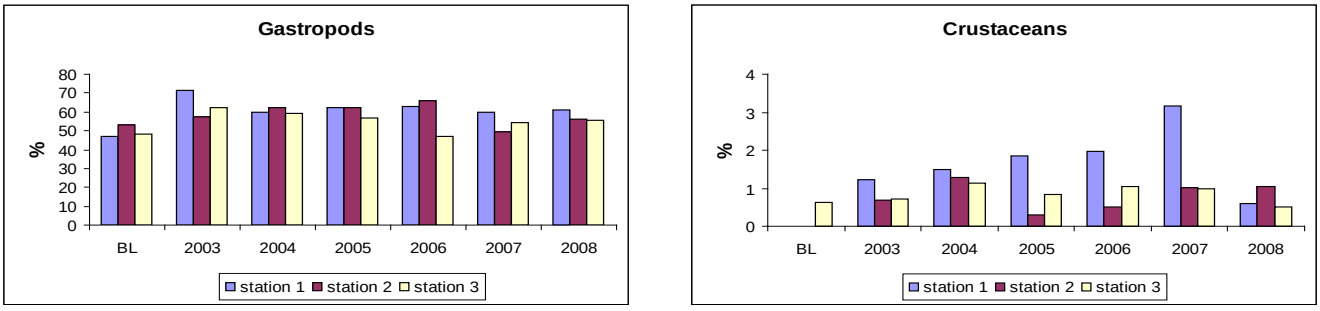


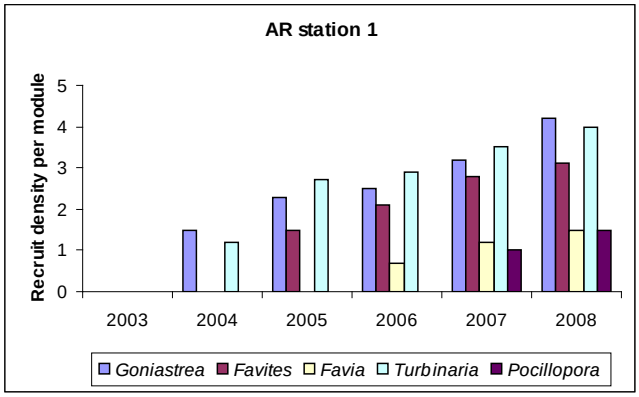
Figure 2: ***Development of numbers (percentages of total number benthos) for two groups of benthic fauna*** *(Gastropod shells are mostly spirally coiled snails and Crustaceans includes animals as crabs, lobsters, shrimps, krill and barnacles) in the three artificial reef stations from 2003-2008, compared with baseline (BL) surveys*

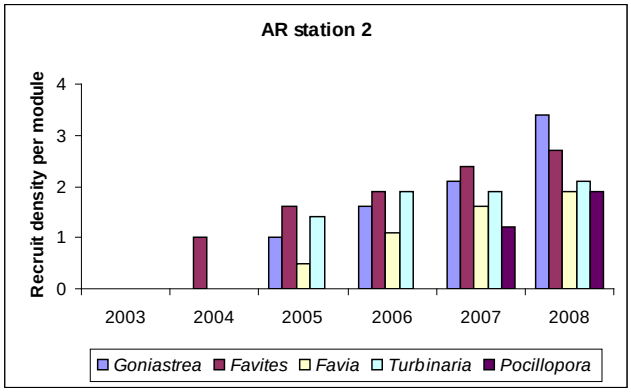
Epifauna

The epifauna began developing on the modules from the 5th day. After two weeks, the cover was around 15 %. The total cover further increased to 40 - 50 % after 8 weeks and 65 - 70 % after 20 weeks. Barnacles (main macrofoulers) in all three stations dominated the cover and gorgonians (sea fans) were observed in small numbers in the 3rd station after six months of the deployment of the modules. Since there is not much predation by carnivorous gastropods or other predators, they thrive well along with hydroids and ascidians.

Coral recruitment

The coral recruitment pattern on the modules was studied from 2003 (Figure 3a). There was high coral recruitment density on the artificial reef modules from 2003 to 2008 as the modules acted as perfect substrate. The observed coral genera were, *Goniastrea*, *Favites*, *Favia*, *Turbinaria* and *Pocillopora*. Most of the recruits on the modules were massive coral species (Figure 3b).





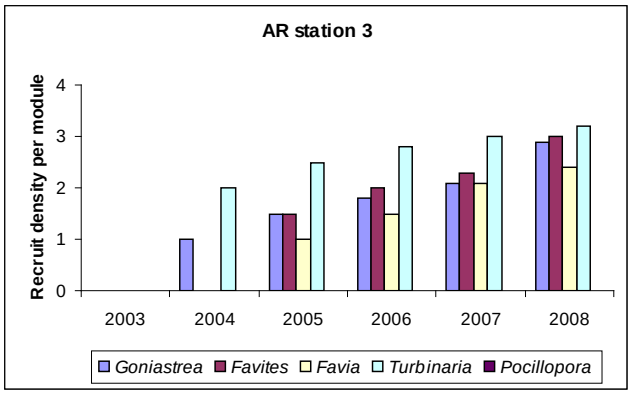


Figure 3a: ***Development of coral recruitment on the modules*** *in the three artificial reef stations from 2003-2008*

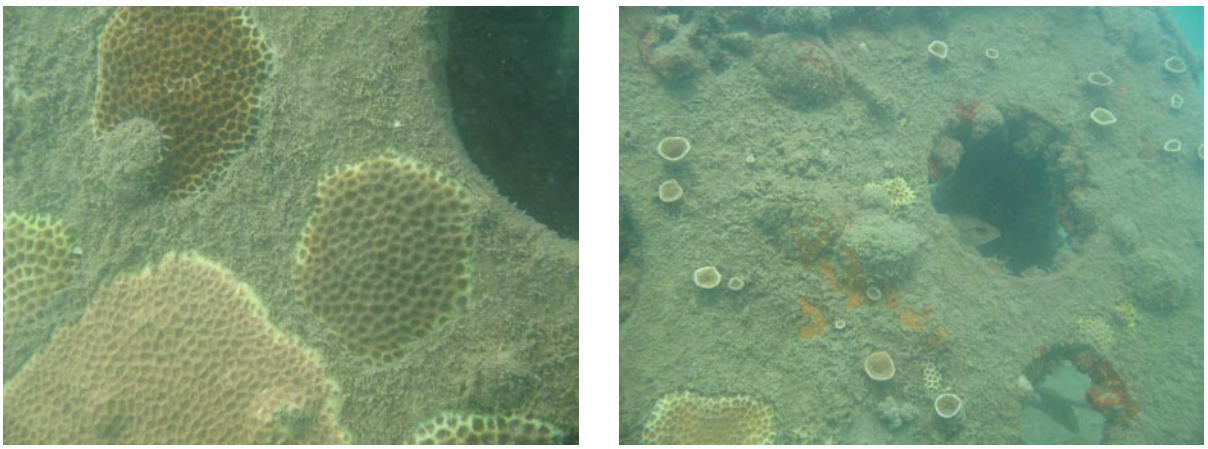


Figure 3b: ***Massive (left) and table (right) coral recruitment*** *on the artificial reef modules, in 2008. (photo: SDMRI)*

Fin fishes

The visual survey in the artificial reef area confirmed the aggregation of large number of fishes and invertebrates on and near the reef over time. Shortly after the deployment of the modules, *Lutjanus* species were observed aggregating around the structures. Initially there were only 2 or 3 individuals, but this gradually increased confirming the attraction of the fishes towards the artificial reef.

***Lethrinus sp**. in one of the Artificial Reef sites, Tuticorin coast. (source – SDMRI)*

During the entire program, 42 species of fishes involving 27 families of 7 orders were observed from 2002 to 2008. Among these 42 species, 10 appeared during most of the months. Due to the habitat preference, food availability and the depth, some species of fish prefer certain areas. Shoaling fishes like snapper and bream seem to swim around the artificial reef site, while solitary fishes like sea perch, grouper and puffer seem to dwell in the crevices of the *artificial reef* modules.

CatchPper Unit effort (CPUE)

There was no baseline data for catch per unit effort. Data were recorded only after the deployment of the artificial reef modules. A gradual and significant increase in the catch per unit effort data in fin fishes, crustaceans, echinoderms and molluscs was observed in all the three stations from 2003-2008 (Figure 4).

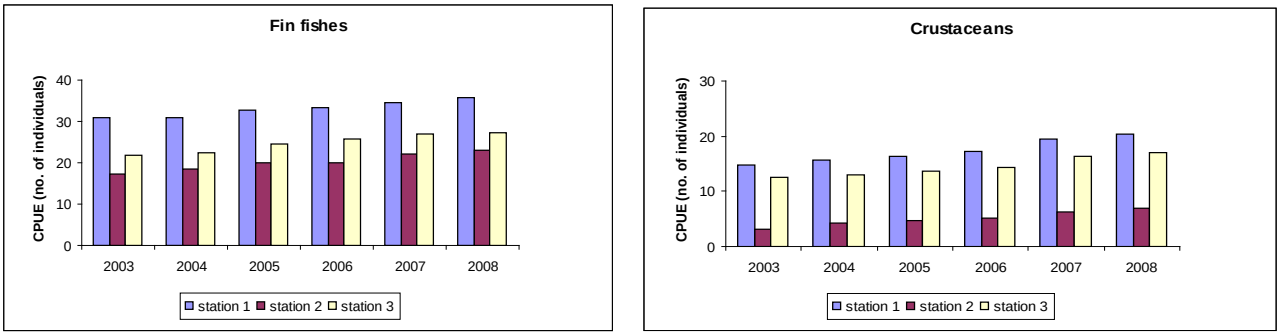


*Figure 4: **Development of CPUE for fish and crustaceans**, the two most important groups for the fishermen, from the artificial reef area (2003-2008)*

The most common fin fish species caught were *Psammoperca waigensis, Lethrinus nebulosus, Lutjanus russelli, Lutjanus lunulatus, Scarus ghobban, Triacanthus* sp., *Terapon jaruba,* and *Siganus canaliculatus*; Crustaceans such as *Portunus pelagicus, Portunus sanginolentus* and *Thalamita cernata;* echinoderms such as *Pentasceraster affinis* and *Diadema savingnyi; and* molluscs such as *Lambis lambis, Harpulina lapponica* and *Dolebella auricularia.* The cuttlefish *Sepia*

pharaonis was found to be spawning on the modules, evident by the presence of egg capsules on the ropes connecting the modules.
In a study of artificial reefs at the west coast of India (Kerala), the catches near artificial reef sites, included trigger fishes, snappers, thread fin breams and lizard fishes all classified as resident fishes at the artificial reef site (Collins *et al*., 1995).
Many studies have referred to high fish density, rapid colonisation and high catch rates in areas where artificial reefs have been deployed (Bohnsack and Sutherland, 1985).

Gut content analysis

Gut content analysis of the fish caught in the nets showed that *Lutjanus* sp., groupers, *Psammoperca waigensis* and *Plotosus* sp. mainly eat crabs. *Thalamita* sp. occurs in all the *artificial reef* stations. Among the fishes, snappers *Lutjanus russelli, L. lunulatus*, sea bass *Psammoperca waigensis,* groupers *Epinephelus coicoides* and *Cephalopholis formosa* were observed throughout the study period. Their gut content analysis (*Lutjanus russelli, L. lunulatus* and *Psammoperca waigensis*) also supports the fact that they are the residential fishes of the artificial reef area. The fishes along with their gut content analysis are classified according to their residential status based on their association with the reef (D'cruz and Vivekanandan, 1995).

Daily Landing Data

The statistical analysis of the catches recorded in the daily landings shows significant differences between fishing gear types. The two target fishing villages operate different types of gear for fishing. The landings of the two villages also vary because of the mode of fishing. There is increase in the landing of fin fishes, shellfishes and cephalopods, particularly in Tharuvaikulam, near Tuticorin (Figure 5). The influence of varying way of fishing especially near the Vellapatti landing affected its fish landings.
The artificial reef modules are one of the reasons for the increase of landings in the two villages. In addition, the decrease in nearshore destructive fishing activities, such as shore seine and push net operation in and around the artificial reef, helped. The modules also increased the awareness among the local fisher community of the importance of artificial reefs and the long term negative effects of destructive fishing.

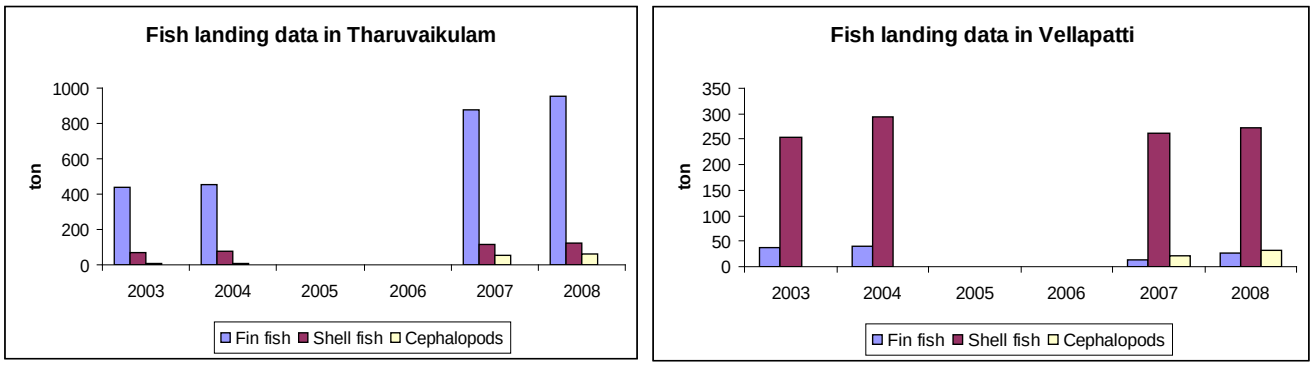


Figure 5: ***Landings of fish in the two target villages*** *(in 2005 and 2006 landings were not monitored).*

The amount of data on the landings is considerable, covering landings per species for fin fishes and shellfishes independently for the 2 target villages. The data are available as tables at request to the authors of this paper.

4. Conclusions

Literature shows that artificial habitats are designed for a variety of biological functions, but they primarily serve social functions by providing services or resources to different user groups. The success of the artificial reef programme is reflected by the enhancement of coastal fishery stocks, coral recruitment and the formation of new food chains. This ultimately helps enhance the socio-economic status of the poor traditional fishermen - who mainly depend on the fishery resources near the reef areas - through increased fishery production.

The fishermen and their families in the target villages were informed about species diversity and density in the artificial reefs stations through the awareness programmes. They were impressed with the fishery production in the artificial reefs area. The target villagers of Tharuvaikulam and Vellapatti have requested the deployment of additional artificial reefs around the Islands of Tuticorin region in order to increase the fishery production. This would enable them to obtain catches more easily and help avoid inshore trawling.

Eco-tourism opportunities are clearly present in the Tuticorin coastal area, however not experimented with, so far. There are indications that eco-tourism will play a greater role in this area in the near future. In that case, artificial reefs could play a major role in attracting diving tourists, which in turn would help to support the livelihood of the local fisher folk and strengthen conservation initiatives.

5. References

- **Bohnsack, J. A. and D. L. Sutherland, 1985**: *Artificial Reef research: a review with recommendations for future priorities;* Bull. Mar. Sci. 37: 11 – 39.
- **Chin, G. D. and R. Simmons, 1994**: *Valuating artificial reefs at Parteau Cove Provincial Park*; Bull. Mar. Sci. 55: 1332.
- **Collins, K., A. Jensen, P. Robert, and J.B. Rajan, 1995**: *Artisanal artificial reefs in Kerala*, *S. India*; in: ECOSET 95'. International Conference on Ecological System enhancement Technology for Aquatic Environments, The Sixth Internat.Conference on Aquatic Habitat Enhancement, Tokyo, Japan: 703 – 707.
- **D'Cruz, T. and V. Vivekanandan, 1995**: *Impact of artificial fish habitat on artisanal fishing communities in Kerala, India;* in: ECOSET 95' Internat. Conference on Ecological System enhancement Technology for Aquatic Environments, The Sixth Intern.Conference on Aquatic Habitat Enhancement, Tokyo, : 720 – 726.
- **Lazarus, S., 1995:** *Artificial fish habitats in traditional fisheries of southwest coast of India*; in: ECOSET 95' International Conference on Ecological System enhancement Technology for Aquatic Environments, The Sixth International Conference on Aquatic Habitat Enhancement, Tokyo, Japan: 732 – 737.
- **Patterson Edward, J.K., G. Mathews, Jamil Patterson, R. Ramkumar, Dan Wilhelmsson, Jerker Tamelander & Olof Linden, 2008:** *Status of Coral Reefs of the Gulf of Mannar, Southeastern Indi;* in Obura, D.O., Tamlander, J., & Linden, O. (eds), 2008: Ten years after bleaching – facing the consequences of climate change inj the Indian Ocean; CORDIO Status Report 2008. Coastal Oceans Research and Development in the Indian Ocean/Sida-S.A.R.E.C., Mombasa

Website:

- **SDMRI: Suganthi Devadason Marine Research Institute – Tuticorin:** www.sdmri.in/