Indian J. Fish., *60(1)* : 1-8, 2013

Economic performance of artificial reefs deployed along Tamil Nadu coast, South India

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ABSTRACT

The economics of fishery from artificial reef (AR) and non-artificial reef (NAR) sites by gillnet and hooks & line was studied during 2007-08 from 11 fishing villages in 6 coastal districts of Tamil Nadu. The Tamil Nadu State Fisheries Department fabricated and deployed the reefs under the technical guidance of the Central Marine Fisheries Research Institute (CMFRI). Based on species composition in the catch, the annual gross income was estimated by multiplying each species/group catch with the average landing centre price of the respective species/group. After deducting recurring expenditures on fishing operation, maintenance, interest on capital/investment on reef, crew wages, depreciation on craft, gear and reefs, from the gross income, the average net income of gillnet and hooks & line per unit operation from AR site were ₹1252 and ₹4650, respectively; and from NAR site was ₹449 and ₹1919, respectively. On an average, the AR site offered economic benefit which was higher by ₹1705.9 per unit compared to NAR site. Hooks & line units performed better than the gillnet units in both the sites. The payback period towards repayment of AR establishment cost was only 0.21 year. In view of better economic viability and short payback period, deployment of artificial reef is recommended in the near shore waters with proper planning.

Keywords: Artificial reef (AR) site, Catch per unit effort (CPUE), Economic benefit, Non-artificial reef (NAR) site, Payback period, Value per unit effort (VPUE)

Introduction

Increase in the number and efficiency of fishing craft and gear has led to enhanced pressure on fishery resources along the Indian coast (Devaraj and Vivekanandan, 1999). Along the Tamil Nadu coast, destruction of a large number of juveniles and several other human induced interventions have impacted many fish stocks, raising the issue of sustainability (Sathiadas *et al.,* 2012). It is emphasised here that, inshore areas (particularly < 10 m depth) harbours seed resources of valuable species like yellowfin tuna, seerfish, pomfrets, mackerel *etc*. It has been realised that fishery resources need to be enhanced for sustaining the sector. One of the options for reconstruction of coastal ecosystems, strengthening biodiversity and enhancement of fishery resources is deployment of artificial reefs in nearshore waters (Adams *et al*., 2011). Artificial reefs (ARs) are also used in fisheries to create fishing opportunities, reduce user conflicts, save time and fuel, reduce fishing effort, make locating fish more predictable, increase public access and safety by deployment in nearshore sites and increase fish abundance at deployment sites by attracting dispersed fishes and producing new fish biomass (Stone, 1985; National Academy Press, 1988; Bohnsack, 1989). In addition to the biological benefits that may accrue from artificial reefs, reefs are deployed to provide benefits to fishermen. Milon *et al.* (2000) suggest that a reef that is not useful to people is not a successful reef. Considering this, assessments of the economic benefits accruing from artificial reefs to user communities are necessary. Such information provides an insight into the degree to which the public benefit is being served by reef deployment and the economic consequences associated with reef use (Adams *et al*., 2011).

Sporadic information is available on the experiences and benefits of artificial reefs deployed along the Indian coast (Bergstrom, 1983; D'Cruz, 1995; Philipose *et al*., 1995). By deploying structures in the coastal waters south off Chennai, Vivekanandan *et al.* (2006) demonstrated the potential role of artificial reefs in resource enhancement and economic benefits. They showed that the catches from artificial reefs comprised of high quality fishes, enabling fishermen realise better economic returns per unit effort than the returns from non-reef areas. The performance of AR was evaluated by them in a limited area by monitoring the catches for a short period. To examine the overall economic consequences of the artificial reef programme undertaken by the Department of Fisheries, Government of Tamil Nadu in technical association with Central Marine

Fisheries Research Institute (CMFRI), we monitored the performance of the artificial reefs from construction, deployment and performance in terms of volume and value of fish catches were monitored for a period of two years, under the present study. As ensuring cost efficiency is vital to maintain a sustainable reef programme, this paper focuses on comparison of cost-benefit of fishing between artificial reef and non-artificial areas.

Materials and methods

Department of Fisheries, Government of Tamil Nadu, constructed and deployed artificial reefs along Tamil Nadu coast, and conducted post-deployment monitoring with technical support from Madras Research Centre of the Central Marine Fisheries Research Institute during 2007 and 2008. The ARs were deployed in the following 11 sites in six districts: (i) Tuticorin district - off Vellapatti and Vembar; (ii) Ramanathapuram district - off Villundi and Thiruppalakudi; (iii) Pudukottai district - off Gopalanpattinam and Kodimunai; (iv) Thanjavur district - off Vallavanpattinam, Eripurakkarai and Kollukkadu; (v) Nagapattinam district - off Thanrangambadi and (vi) Cuddalore district - off Thalanguda (Fig. 1). The geo-coordinates (latitude and longitude) of the sites selected for deployment of artificial reefs, depth, distance from the shore and the period of deployment are given in Table 1. Three types of concrete structures (Fig. 2), *viz.*, i. ring module, ii. reef module, and iii. grouper module, each with 70 units with a volume of 446.25 m^3 were deployed in each site, spread in an area of 1000 m^2. The substratum provided by a single ring module was 10.2 m^2, the reef module 13.5 m^2 and the grouper module 16.04 m^2.

The total substratum (which includes the height and surface area of the modules) provided by the 210 units was 2781.8 m^2. The cost for fabrication and deployment of

Fig. 1. Map showing the 11 sites where artificial reefs were deployed during the study

210 units in each site was 11,50,000. After deployment, the maturation of the artificial reef structures was observed to be six months from the time of deployment. Once the artificial reefs were ready for the commencement of fishing after the maturation period, commercial fishing by gillnet as well as hooks & lines undertaken around the reefs (AR sites) by the 11 villages was monitored for two years during 2007 and 2008. For comparison, fishing by the two gear types from the non-artificial reef sites (NAR) in the

Table 1. Details on the longitude, latitude and depth of the sites selected for the deployment of artificial reefs in the near-shore waters of the selected villages along the Tamil Nadu coast.

District	Village	Latitude	Longitude	Depth (m)	Distance from shore	Month of deployment
Tuticorin	Vellapatti	78° 17' 47.6"E	08° 51' 25.2"N	8.5	6 km	Nov. 2006
	Vembar	78° 25' 21.7"E	09° 01' 04.8"N	9.0	7 km	Nov. 2006
Ramanathapuram	Villundi	79° 21' 25.3"E	09° 20' 17.9"N	8.0	4 km	April 2007
	Thirupalakkudi	79° 00' 05.5"E	09° 31' 24.0"N	7.8	6 km	April 2007
Pudukottai	Gopalapattinam	79° 14' 35.1"E	09° 52' 46.5"N	8.5	6 km	April 2007
	Kodimunai	79° 23' 05.0"E	09° 57' 13.5"N	8.5	9 km	April 2007
Thanjavur	Vallavanpattinam	79° 19' 28.4"E	10° 08' 22.0"N	8.5	5 km	April 2007
	Kollukadu	79° 20' 34.0"E	10° 11' 34.6"N	7.5	6 km	April 2007
Nagapattinam	Eripurakkarai	79° 23' 45.9"E	10° 14' 22.4"N	6.5	6 km	April 2007
	Tharangambadi	79° 54' 02.7"E	11° 00' 38.4"N	18.0	3 km	April 2007
Cuddalore	Thalankuda	79° 49' 35.9"E	11° 45' 48.7"N	16.0	3 km	April 2007

(a)
Diameter of each ring - 0.90 m
Height of the ring - 0.6 m
Weight of one module - 0.65 t
No. of modules in a cluster - 70

(b)
Height x Breadth x Length -1.5 m
Weight of one module - 0.75 t
No. of module in a cluster - 70

(c)
Height x Breadth x Length - 1.5 m
Weight of one module - 0.95 t
Diameter of inner pipes 0.30 m
No. of module in a cluster - 70

Fig. 2. Three types of artificial modules used in the study (a) Ornamental fish module (b) Reef fish module (c) Grouper module

same villages was also monitored. Fishing effort, catch and catch composition from gillnet and hooks & line fisheries (the major gears operated in AR sites), which were landed at the 11 villages from AR and NAR sites were gathered from Fishery Resources Assessment Division, CMFRI. One fishing operation, from the time the boat departed from and returned to the landing centre is termed as one fishing unit. The source location of catch was ascertained from the fishermen at the time of landing the catches. Fish samples were analysed to estimate species composition in the catches. The cost of fishing operations and price of landed fish from AR and non-AR sites were collected randomly during the two year period at the 11 sites. The revenue realised from the annual catch by a gear type was estimated by multiplying the catch of each species/group with the prevailing price of the respective species/group at the landing centre and then by adding up the price of all the species/group for the year (Kasim, 2009). Since the price depends on the type, size and freshness of fish, the average price has been taken for estimation of total value of the catches.

The economic costs, activities and benefits derived from artificial reef projects can be measured and evaluated by following cost effectiveness analysis. This method determines to what extent the estimated cost of deployment was realised in the actual reef deployment process (Adams *et al*., 2011). With limited funds for reef development, ensuring that, cost efficiency is maintained is vital to a sustainable reef programme. Cost effectiveness analysis will help to ensure that reef programmes are completed within the optimum cost. In the present study, cost effectiveness analysis was carried out inorder to evaluate the artificial reef programme.

Results and discussion

Commercial fishing around the AR sites was carried out using gillnet and hooks & line from motorised craft with outboard engine (overall length: 7-10 m; engine horsepower: 7-9). The location of the artificial reefs from the shore varied between 1 and 5 km and was accessed by the fishing vessels by sail if the wind was favourable, or by motor in the absence of wind. Fishing was conducted, on an average, for about 15 and 9 h in a day by gillnet and hooks & line units, respectively and for about 250 days in a year.

Catch per unit effort (CPUE) and Value per unit effort (VPUE)

The areas considered for deployment of ARs were actively exploited fishing grounds. During 2007 and 2008, on an average 35,188 and 1,32,608 units of gillnet and hooks & line units were operated annually in the AR and NAR sites respectively, off the 11 villages (Table 2). The corresponding fishing hours (gear soaking time) was 0.5 and 1.3 million h. The annual catch by the two gear types was 6,305 t, valued at 3627.9 lakhs at the landing centre price level. Nearly 21% of boat units from the 11 villages fished in the AR sites, realising 23.9% of the total catch, and 20.8% of the total value. Among the two gear types, gillnets contributed 77.1% to the total catch and 78.0% to the total value from the two sites. In the AR sites,

Table 2. Profile of gillnet and hooks & line fisheries in the 11 villages (the values are estimated annual average for the years 2007-08)

Parameters	Gillnet		Hooks & line	
	AR sites	NAR sites	AR sites	NAR sites
No. of units	31477	120783	3711	11825
Fishing hours (10^3)	469.2	1192.1	33.5	91.5

gillnets contributed 81.3% to the total catch, and 70.9% to the total value. Thus gillnet was the predominant gear in the AR as well as NAR sites.

Fishing effort expended in the AR sites by each of the 11 villages varied widely. The annual average number of gillnet units ranged from 980 (Villundi) to 5862 (Eripurakkarai); and the 321 hooks & line units from 321 (Vembar) to 1437 (Gopalanpattinam). Considering this, the catch per unit effort (CPUE) and value per unit effort (VPUE) in the AR and NAR sites were determined for each fishing village for the years 2007 and 2008. The CPUE and VPUE also showed wide differences between the villages (Table 3). On an average, the CPUE of gillnetters was higher (39.1 kg) and the VPUE was substantially higher (5608) in the AR sites compared to the NAR sites

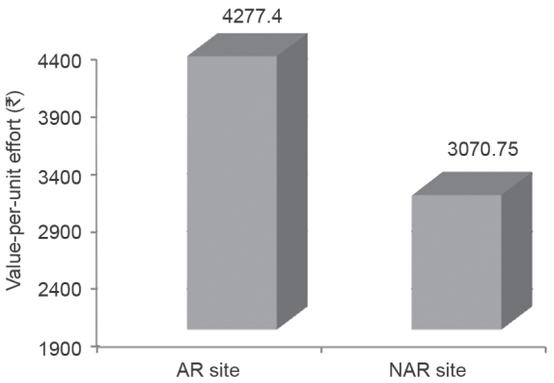

Fig. 4. Value per unit effort of catch from gillnet and hooks & line units

Table 3. Catch-per-unit effort (CPUE, kg) and Value-per-unit effort (VPUE, ₹) recorded in the 11 villages during 2007 and 2008

Fishing village	Gillnet - CPUE (kg)		Gillnet - VPUE (₹)		Hook & line CPUE (kg)		Hook & line VPUE (₹)	
	AR sites	NAR sites	AR sites	NA sites	AR sites	NAR sites	AR sites	NAR sites
Vellapatti	28.5	16.6	1713	1501				
Vembar	30.4	30.6	1447	1283	587.4	533.9	70123	42050
Villundi	44.5	31.9	1568	930		Hooks & line not operated		
Thiruppalakudi	90.1	21.3	3598	971		Hooks & line not operated		
Gopalanpattinam		Gillnet not operated			11.7	24.4	301	596
Kodimunai	29.8	26.1	1747	2121		Hooks & line not operated		
Vallavanpattinam	23.0	20.3	1506	1668		Hooks & line not operated		
Kollukadu	31.3	26.1	1472	2226		Hooks & line not operated		
Eriputakkarai	44.1	47.8	3028	3284		Hooks & line not operated		
Tharangamabdi	30.6	41.7	1030	1355	35.7	76.0	915	1709
Thalanguda		Gillnet not operated			45.4	139.8	1853	4454
Average	39.1	29.2	1901.0	1704.3	61.8	70.4	6653.8	4437.2

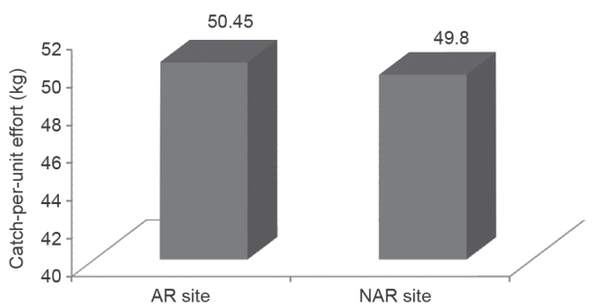

Fig. 3. Catch per unit effort from gillnet and hooks & line units

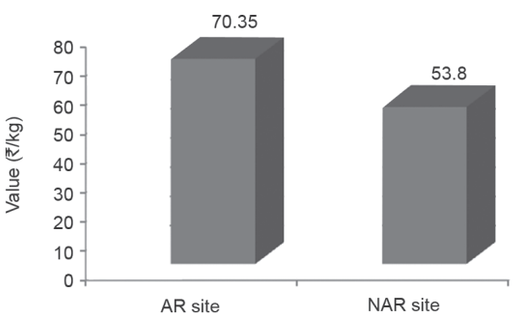

Fig. 5. Value per kg of fish from gillnet and hooks & line units

(30.1 kg and 4083). Pooled data from gillnets and hooks & line showed that CPUE (Fig. 3), VPUE (Fig. 4) and value of per kg fish (Fig. 5) were higher in the AR sites compared to those of NAR sites.

Catch composition

The combined catch from gillnets and hooks & line units consisted of 91 species from AR sites, and 101 species from NAR sites. The fishing effort in AR sites

Table 4. Ten dominant species/groups (by value) caught in gillnets and hooks & line units

AR site	Value (₹ in lakhs)	NAR site	Value (₹ in lakhs)
Scomberomorus commerson	46.3	*Portunus pelagicus*	109.6
Portunus sanguinolentus	16.8	*Scomberomorus commerson*	86.4
Sphyraena barracuda	4.9	*Penaeus semisulcatus*	28.5
Chirocentrus dorab	3.7	*Sphyraena barracuda*	20.8
Psammoperca waigaiensis	3.3	*Stolephorus indicus*	20.1
Pampus argenteus	2.7	*Metapenaeus dobsoni*	15.1
Arius spp.	2.5	*Arius* spp.	13.4
Portunus pelagicus	2.3	*Lethrinus* spp.	13.2
Caranx spp.	2.3	*Fenneropenaeus indicus*	13.1
Fenneropenaeus indicus	1.8	*Metapenaeus stridulans*	12.0

(35,188 fishing units) was only about 26.5% of the effort in NAR sites (1,32,608 units), but the species richness in the catches from the AR sites was only marginally lesser than that of the NAR sites. This indicates aggregation of several species in the AR sites. Seerfish, portunid crabs and barracuda were the major groups caught from the AR sites, yielding high returns (Table 4).

Economic performance of ARs

The economic performance of gillnet and hooks & line units at the AR and NAR sites was assessed by comparing the net income of these units after deducting operational and other related expenditures from the gross revenue derived from the sale of fish catch in a year. As the AR sites offered a limited area as fishing ground, only 3 fishers were engaged in fishing per unit operation with small boats (overall length: 7 m). The NAR fishing ground is extensive and hence, 5 fishers were engaged per unit operation in comparatively larger boats (OAL: 10 m). All the AR sites were very close to the coast and the fishers could access these grounds with low fuel expenditure whenever they used motorised boats. Otherwise, they used either sails when the wind was favourable or oars for propulsion. Consequently the operational and other expenditure per unit was higher for the gillnet units of NAR sites than the units which operated in AR sites. Higher gross income and lower operational expenditure have resulted in a higher net income for the gillnet units of AR sites than those of NAR sites (Table 5).

As in the case of gillnet units, higher gross income and lower operational expenditure were evident in the AR sites from hooks & line units also (Table 6). The catch and revenue realised by hooks & line units were higher than the gillnet units in both AR and NAR sites.

Economic benefit

Artificial reefs were established in 11 sites at a total cost of ₹1,26,50,000 at the rate of ₹11,50,000 per site. The accrued interest (12%) on establishment cost and depreciation (5%) of artificial reefs was ₹21,50,500. The depreciation and interest per unit was ₹61.1. There was no maintenance cost for the reefs. After deducting the eligible costs from the revenue realised per unit of gillnet and hooks & line separately, the net revenue per unit of gillnet and hooks & line was ₹1190.9 and ₹4588.0,

Table 5. Economic performance of a single gillnet unit based on the operation per day by 14 units in AR sites and 54 units in NAR sites in 9 villages.

Recurring expenditure	AR site		NAR site		Total (₹)
	Rate	Total (₹)		Rate	
Wages for 3 fishers	₹ 200 per day	600	5 fishers	₹ 200 per day	1000
Fuel	1 liter	50		6 liters	300
Depreciation to boat and net	10% on cost	60		10% on cost	60
Miscellaneous, Insurance *etc.*	Approximate	10	Insurance *etc.*		20
Total expenditure per unit		720	Total expenditure per unit 1380		
Revenue from fish catch					
Gross revenue per unit	62073130/31477	1972	220869347/120783		1829
Net revenue per unit	1972-720	1252	1829-1380		449
Total net revenue	31477 units[b] @ ₹ 1252	39409204	120783 units[b] @449		54231567

[a]from Table 2; [b]from Table 1

Table 6. Economic performance of a single hooks & line unit based on the operation per day by 4 units in AR sites and 12 units in NAR sites in 4 villages.

Recurring expenditure	AR site		NAR site		
	Rate	Total (₹)	Rate	Total (₹)	
Wages for 3 fishers	₹ 200 per day	600	4 fishers	₹ 200 per day	800
Fuel	1 liter	50		6 liters	300
Cost of bait		1500			1500
Depreciation to boat and net	10% on cost	50		10% on cost	60
Miscellaneous, Insurance *etc.*	Approximately	10	Insurance *etc.*		20
Total expenditure per unit		2210	Total Expenditure per unit		2680
Revenue from fish catch					
Gross revenue per unit	25456885/3711	6860	54385822/11825		4599
Net revenue per unit	6860-2210	4650	4599-2680		1919
Total net revenue	31477 units[b] @ ₹ 1252	17256150	11825 units[b] @ ₹ 1919		22692175

[a]from Table 2; [b]from Table 1

Table 7. Estimation of economic benefit by comparing the net income from fishing by two gear types in AR and NAR sites

Recurring expenditure	AR site		NAR site	
	Rate (₹)	Total (₹)	Rate	Total (₹)
Investment cost				
Cost of AR structure	11,50,000	1,26,50,000		Nil
Interest on investment	12%	15,18,000		Nil
Depreciation	5%	6,32,500		Nil
Total depreciation + interest		21,50,500		
Revenue				
R1 GN net revenue per unit		1252		54231567
R2 H&L revenue per unit		4650		22692175
R3 Depreciation+Interest per unit	I4/35188	61.1		76923742
R4 GN net revenue (R1-R3)		1190.9		0
R5 H&L net revenue (R2-R3)		4588.9	GN+H&L expenditure/unit	2030
R6 GN + H&L net income per unit		2889.9	GN+H&L revenue/unit	3214
R7 Economic benefit ₹ per unit	R6-1184	1705.9	GN+H&L net income/unit	1184
Payback period (years)	Cost/Net income	I1/R7*35188	0.21 year	

respectively (Table 7). The average net income for the two gear types was ₹2889.9 and the additional benefit of operating in the AR sites was ₹1705.9 per unit.

Payback period

The payback period was worked out by dividing the total cost for the installation of artificial reefs at 11 sites by the total economic benefits by both the gear types from AR site *i.e., Payback period: 126,50,000 / 600,27,209=0.21 year.* The payback period is estimated to be a mere 0.21 year as shown above (Table 7). As the payback period is short, fishers who intend to avail loan for the installation of artificial reefs can easily return the loan.

Discussion

Hooks & line units have performed better than gillnet units in both the AR and NAR sites. Narayanakumar *et al.* (2009) also reported that the cost and earnings of single day operations by hooks & line was better than the gillnet units. Since the operating cost of the fishing units in the AR sites in this study is much lower owing to less fuel and labour involved, as compared to that of the NAR sites, the net income is higher from AR sites.

The assessment of fisheries service provided by an artificial reef at Chinnandikuppam, 20 km south of Chennai by Vivekanandan *et al*. (2006) revealed that in 16 months, the fishermen expended 3843.7 h of hooks & line fishing in the AR ground and landed 6404 kg. The catch index was 14.2 kg m^{-3} and the total income was 2.74 lakhs. Comparatively, in the present study a single hooks & line unit fished for 2821 h in 16 months, and produced 23,812.5 kg, which yielded an income of 21.4 lakhs. This shows that the catch is 3.7 times more and the income is 7.82 times higher than that reported by Vivekanandan *et al*. (2006). This may be owing to better performance of the concrete reef structures with large surface area (2781.8 m^2) employed in the present study, which might

have lead to higher biological production and better fish catch. As in the present study, Vivekanandan *et al*. (2006) also observed that the hooks & line operation in the AR sites (71.3 kg h^{-1}) was more remunerative than the gillnet operation (52.5 kg h^{-1}) in the NAR site due to aggregation of high quality fish such as snappers, emperors and carangids in the AR site. Better catch in the AR sites in this study is attributed to the operation of gillnets along with hooks & line, which is supported by the observation by Vivekanandan *et al.* (2006) that, "had gillnet, trap and pot been operated in the AR ground, it is possible that several other groups would have been caught and the catch and income would have been better".

The payback period at Chinnandikuppam works out to 1.22 years (Vivekanandan *et al.,* 2006). Owing to better performance of the ARs in this study, the payback period is less than a year *i.e.*, 0.21 year. Countries like Philippines, Japan and Korea, where millions of cubic meters of ARs have been deployed, the catch is reported to vary between 5 and 50 kg m^{-3} (Rong-Quen Tan *et al.,* 2003). Valiathura along the Trivandrum coast in Kerala, where a number of artificial fish habitats (ARs) were deployed, also showed that the contribution by ARs in terms of value to the total fish production of the village was higher by 6.9%, than the quantity (2.8%)(D'Cruz, 1995). Devaraj (1997) suggested that the ARs should be deployed rationally, in well-planned, selected sites. This is proved to be true from the results of the present study also, where the site selection was done through appropriate underwater survey employing SCUBA diving, and deployment of AR modules was done with proper planning.

Limitations and benefits

It is often criticised that the artificial reefs aggregate a wide variety of fishes at one place and are harvested indiscriminately which may lead to overfishing in a short duration of time. The fishing in the reef areas under this project was customised to avoid overfishing by the fishers by an institution building process in which a reef monitoring committee was formed to regulate fishing in the reef area. There is also a general view that the sea is used as a dumping yard for scrap materials in the name of reefs. But in the present programme, the reef structures have been designed according to the behaviour of different species and further the structures used were well designed concrete blocks with more surface area to encourage various fouling organisms to settle and colonise, leading to an increase in biodiversity and biomass in the area.

The benefits derved are that the artificial reefs increase the biodiversity and biomass leading to enhancement of the ecosystem. Deployment of artificial reefs are better way of ecosystem based fisheries management and they also help to protect the nursery grounds, and thereby enhances recruitment in a sustainable manner. Artificial reef areas can also act as marine protected areas. Fish are available at all the time near the shore. The voyage for fishing is very short leading to saving of fuel, labour, time and expenditure. The fish catch is comparatively fresh, of high quality and of better size resulting in better income and economic benefits. The social benefits are that the fishers are empowered and get organised into an institution to manage fishing activities and post-harvest interventions. There is a social binding among the fishers in reef usage, which reduces the conflict. Moreover, the artificial reefs prevent trawling in a limited area and help the benthic fauna and flora to revive and flourish which in turn enhances the biomass.

Acknowledgements

The authors sincerely thank the Commissioner of Fisheries, Joint Directors and other Staff of the Tamil Nadu Fisheries Department for sanctioning the consultancy project, as well as for the assistance rendered in fabrication and deployment of the artificial reefs and also during the study on impact of the reefs deployed, on the socio-economics of the coastal fishery and fishers. We also acknowledge the support rendered by the fishermen leaders, fishers and others who worked hard with us, during the study.

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Date of Receipt : 10.11.2012
Date of Acceptance : 15.12.2012