Indian J. Fish., **53**(1) : 67-75, Jan.-Mar., 2006

Service provided by artificial reef off Chennai: a case study

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ABSTRACT

The fisheries service provided by an artificial reef (AR) with a pile size of 450 m^3 deployed at 20 m depth off Chinnandikuppam, 20 km south of Chennai was assessed. In 16 months, the fishermen expended 3843.7 hours 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 Rs. 2,74,000. Compared with the income per hour of operation of gillnet fishing in the non-AR grounds (Rs. 52.5 kg/h), the income was 36% higher from hooks & line fishing in the AR ground (Rs. 71.3 kg/h). This was possible due to aggregation of high quality fish such as the snappers, emperor and carangids in the AR. Biological investigations on three resident species in the AR show that juvenile fish colonise in the initial months after deployment, grow to a larger size and spawn in the AR, indicating the service provided by the AR for enhancement of resident fish stocks.

Introduction

Artificial reef (AR) has been recognized as one of the tools to aggregate fish and to improve the income of artisanal fishermen (Bergstrom, 1983; Philipose *et al*., 1995; Devaraj and Vivekanandan, 1999). In recent years, ARs deployed by fishing communities, research institutions and maritime state governments along the southwest and southeast coasts of India have gained popularity (Philipose, 2004). Observations on fisheries around these structures indicate that the ARs facilitate the artisanal fishermen who use hooks & line to harvest good catches without spending much scouting time (D'Cruz, 1995). However, there are apprehensions among fishermen who use mechanized craft and other gears such as gillnets, bagnets, boatseine and shoreseines due to the damage the ARs may cause to their craft and gear. The government agencies are also concerned about the indiscriminate deployment of ARs in the coastal waters.

In spite of the popularity and controversy, the ARs have generated in recent years, the service provided by the ARs has not been adequately assessed so far. There is no proper monitoring of the catch, catch per unit effort, catch composition and income from the AR grounds and comparison of the same with non-AR grounds. Moreover, earlier studies do not prove whether the ARs merely aggregate fish, or help developing an ecosystem by providing food, shelter and breeding ground for fish, and increase the productivity of the coastal waters. To find provisional answers to the prevailing ambiguities on the values of the ARs to the fishermen and the coastal ecosystem, reef structures were deployed on a modest scale in the coastal waters near Chennai. The catch and

income from the ARs and the biological characteristics of the dominant fish in the catch were monitored.

Materials and methods

Three types of ARs, *viz*., one high density polyethylene (HDPE) hut-shaped structure, 50 ferrocement modules and 100 concrete rings were deployed in January, 2003 on the seafloor at 20 m depth, 2 km off Chinnandikuppam, which is located 20 km south of Chennai. The HDPE structure was a multisided frame (length: 6 m; height: 6 m) made up of HDPE pipes, which was sealed at both ends by extrusion welding and joined together. Fish attractants such as netlon cones (netlon attached to cone-shaped frames), old automobile tyres and plastic strips of different colours were attached to the structure. Anchors were attached to the four corners. The ferrocement triangular module was of equal size on all the sides (length/height: 1.5 m; width: 0.7 m), and hence each module settles in a stable, identical position on the seafloor. The concrete ring (diameter: 0.6 m; height: 0.5 m) is a popular AR structure used by the fishermen. The purpose of deployment of different types of structures was to remove the possible bias in fish aggregation that may arise if any one type of structure had been deployed. The total cost of fabrication of all the structures was Rs 2,50,000 and the total cost was granted by the ICAR under the AP Cess Fund.

Prior to deployment, all the structures were piled on the beach and the pile size was estimated as 450 m^3. The structures were taken to the site in catamarans and deployed on the seafloor by slowly lowering each structure using nylon ropes. The structures were deployed very close to each other and care was taken not to disperse them.

The number of active fishermen in Chinnandikuppam was 55. There were 40 catamarans (including seven catamarans with outboard motor), 37 gillnet units and 15 hooks & line units. The AR was made the property of the entire fishing community in the village. The fishermen accessed the AR on a self-regulated, rotational basis and used hooks & line. Fishing in the AR ground was in addition to regular fishing in non-AR grounds by using drift gillnet.

To monitor the fishing effort, catch and income from the AR and non-AR grounds, observations were made twice a week at the time of landing between 0600 and 1500 hrs during April, 2003 – July, 2004. The fishing effort was estimated in terms of (i) number of units (refers to the number of fishing voyages), (ii) number of fishermen, (iii) actual fishing hours and (iv) total effort (includes the time taken to reach the fishing ground and back). The catch was assessed by weighing the landings. The catch on the days of observation was weighted for the month by enquiring the fishermen on the number of fishing days. Fish samples were collected regularly from the catch from the AR ground and brought to the laboratory for analysis. Measurements of the total length and weight, and analysis of the sex ratio, stomach condition and major food items in the stomach of the dominant species, viz., the bigeye snapper *Lutjanus lineolatus*, the pinjalo snapper *Pinjalo pinjalo* and the djedabba trevalle *Alepes djedabba* were made. Maturity condition of the female was identified into six stages and further categorized into immature/maturing (stages 1 and 2), mature (stages 3 and 4) and ripe (stages 5 and 6) ovaries.

Results

Fishing effort

After the deployment in January, 2003, the fishermen did not conduct fishing in the AR ground for three months, which would have allowed the AR to mature by the settlement of algae and microorganisms and colonization of small fish. Fishing started in April, 2003 and intensified in June, 2003 (five months after deployment) (Table 1). During April 2003 – July 2004, a total manpower of 846 was engaged in AR fishing from 638 hooks & line operations, expending a total effort of 3,843.7 hours.

TABLE 1. *Effort, CPUE and income from the AR ground*

Month	Units	Fishermen	Fishing duration(h)	Total effort (t)	Catch (kg)	Catch/total effort (kg/h)	Income (Rs)
April, 2003	6	10	23.4	30.9	19.3	0.62	476
May	15	24	61.5	79.5	92.5	1.16	1600
June	43	60	217.3	262.3	653.5	2.49	21463
July	41	55	184.0	234.0	651.6	2.78	24108
August	20	34	83.0	109.0	183.0	1.68	6160
September	33	48	164.4	210.6	339.0	1.61	14138
October	50	72	215.2	280.2	387.1	1.38	15379
November	56	66	255.0	322.2	382.7	1.19	17437
December	36	54	111.0	161.4	268.7	1.66	12361
January, 2004	34	52	125.2	169.4	338.0	2.00	13020
February	36	72	131.4	185.4	432.0	2.33	11070
March	40	45	219.0	279.0	459.9	1.65	24041
April	45	50	142.0	198.3	212.8	1.07	9156
May	76	75	354.0	506.0	727.3	1.44	35039
June	64	60	494.0	577.2	852.0	1.48	46720
July	43	69	188.3	238.3	404.6	1.70	21834
Total	638	846	2968.7	3843.7	6404.0	1.67	274000

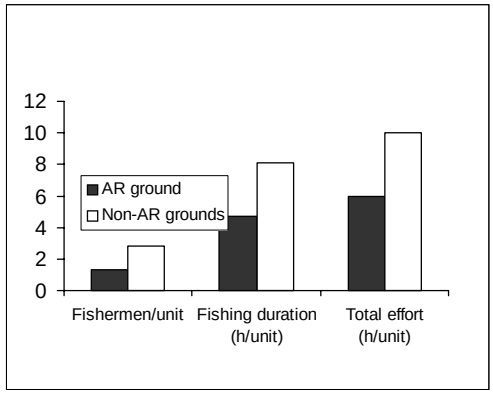

Fig. 1. Comparison of fishing effort in the AR and non-AR grounds

On an average, each unit engaged 1.3 fishermen (Fig. 1), expended 6.0 h total effort, of which 4.7 h was spent in fishing and 1.3 h in travel.

In the non-AR grounds, the total manpower was 5930 in 2,108 gillnet operations, and the total effort was 21,048 h (Table 2). On an average, each unit engaged 2.8 fishermen (Fig. 1), expended 10.0 h total effort, of which 8.1 h was spent in fishing and 1.9 h in travel. Compared to the AR ground, the effort was 3.3, 7.0, 5.7 and 5.5 times higher in

TABLE 2. *Effort, CPUE and income from non-AR grounds*

Month	Units	Fishermen	Fishing duration(h)	Total effort (t)	Catch (kg)	Catch/total effort (kg/h)	Income (Rs)
April, 2003	150	325	1205.0	1497.0	1942.4	1.30	51931
May	110	304	974.3	1214.3	1205.2	0.99	35601
June	129	335	1076.4	1374.4	3537.0	2.57	73485
July	160	398	1478.1	1866.1	3541.4	1.90	69272
August	204	576	1594.3	1880.3	3405.2	1.81	79484
September	92	252	481.5	711.5	1805.1	2.54	79471
October	141	422	1000.1	1204.6	1647.3	1.37	37810
November	186	496	1652.0	2061.2	3347.2	1.62	80036
December	78	210	581.1	682.5	1456.5	2.13	33030
January, 2004	72	216	598.0	742.0	678.7	0.91	22702
February	32	171	408.0	493.0	9349.9	18.97	265087
March	148	441	893.1	1266.1	3026.3	2.39	82091
April	95	275	574.3	799.3	1737.5	2.17	34055
May	195	585	1797.3	2031.3	2818.3	1.39	60007
June	162	504	1656.3	1873.3	2248.2	1.20	48246
July	154	420	1012.2	1351.2	2072.0	1.53	53760
Total	2108	5930	16982.0	21048.1	43818.2	2.08	1106066

the non-AR grounds in terms of number of units, number of fishermen, fishing hours and total effort, respectively.

Of the total number of units (2746) and manpower (6776 fishermen) employed during the 16 months' observation period, 23.2% of units and 12.5% of manpower were deployed for AR fishing. The effort spent per unit operation in the non-AR grounds was considerably higher than that in the AR grounds due to the following reasons: (i) Gillnet operation requires more manpower. (ii) Gillnet fishing requires more net soaking time compared to hooking, and hence, the fishing hour per unit was about 70% higher in non-AR grounds. (iii) Since the boats venturing into non-AR grounds have to scout for fish shoal, the total effort per unit in the non-AR grounds was 66% higher than that in the AR-grounds.

Catch and CPUE

The catch and CPUE, which were low until May, 2003, considerably increased with the advancing age of the AR. Very high catch was observed in May, 2004 (727.3 kg) and June, 2004 (852.0 kg; Table 1) when the age of the AR was 16 and 17 months, respectively. During the period under observation, nearly 50% of the total catch was obtained when the AR was 13 to 18 months old. It is expected that the catch may remain high for a few more months before the structures gradually get dispersed or sunken due to current action and siltation.

Generally, the catch and CPUE in the AR ground were high in those months when the catch and CPUE in the non-AR grounds were also high. For instance, the catch and CPUE were high in both the grounds in June and July,

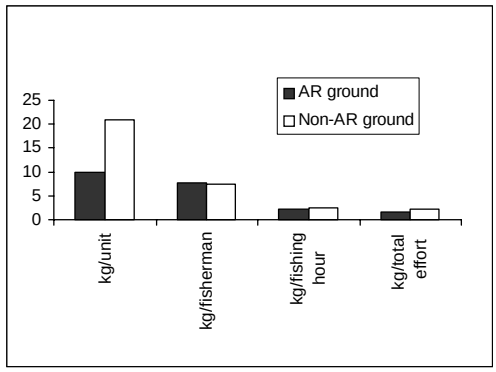

Fig. 2. Comparison of CPUE in AR and non-AR grounds

2003 (Tables 1 and 2). In the non-AR grounds, the catch and CPUE were substantially high in February, 2004 due to incursion of a huge shoal of the whitebait *Stolephorus indicus* and the Indian mackerel *Rastrelliger kanagurta* into the gillnet fishery.

The total catch from both the grounds was 50222.2 kg, and the contribution of the AR to the total catch was 12.8%. Whereas the CPUE in terms of unit effort was higher in the non-AR grounds (20.8 kg/unit) than that in the AR ground (10.0 kg/unit) the CPUE in terms of other effort parameters, viz., number of fishermen, fishing duration and total effort was almost equal between AR and non-AR grounds (Fig. 2). However, it may be mentioned here that the CPUE from non-AR grounds was obtained from several gears whereas it was from hooks & line alone from the AR ground.

Catch composition

Analysis of catch composition indicates the types of fishes that aggregate in the AR. The catch consisted of 19 species of finfishes. The dominant groups were snappers (42.5%), emperor (23.3%) and carangids (22.9%) in addition to several other groups. The number of months of occurrence of each species indicates whether the species is a resident or a visitor to the AR (Rong-Quen Jan *et al*., 2003). Residents are characterized by an almost continuous, and visitors by sporadic occurrence. By considering those species with more than 10 months of continuous occurrence as residents, it may be concluded that five species, *viz*., *Lethrinus nebulosus*, *Lutjanus lineolatus*, *Pinjalo pinjalo*, *Alepes djeddaba* and *A. melanoptera* are the residents.

The catch from non-AR grounds consisted of clupeids (29.9%), crabs (27.4%) and Indian mackerel (15.6%) in addition to several other groups. The catch consisted of 30 species of finfishes and shellfishes. The large difference between the catch composition of the AR and non-AR grounds was because of the different types of gears used. The hooks & line used in the AR ground targeted demersal groups whereas the gillnet used in the non-AR grounds targeted small pelagics.

Income

The catch from the AR fetched Rs 2,74,000 in 16 months (Table 1). The income was maximum in May and June, 2004 (age of AR: 16 to 17 months) when the number of units operated was high.

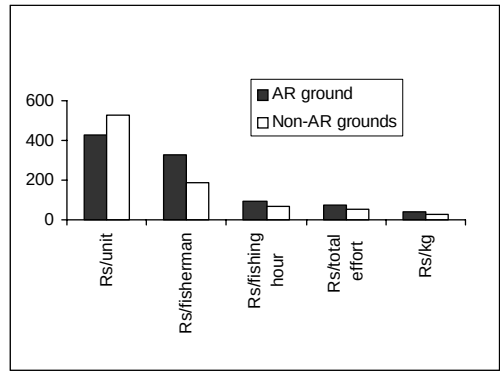

Fig. 3. Comparison of income from AR and non-AR grounds

The AR contributed only 12.8% to the total catch, but 20.0% to the total income. This was possible because of contribution of large quantities of high quality residents such as *Lethrinus nebulosus* (Rs 60/kg) and *Pinjalo pinjalo* (Rs 80/kg), which were not caught from the non-AR grounds. The average value of the catch from the AR ground (Rs 42.8/kg) was 70% higher than that from non-AR grounds (Rs 25.2/kg) (Fig. 3). The income for a fisherman and for one hour of fishing in the AR ground was higher by 74% and 42%, respectively than fishing in non-AR grounds.

Biological characteristics

During the observation period, the total length of *L. lineolatus* (n = 1,450), *P. pinjalo* (n = 1023) and *A. djedabba* (n = 1874) ranged from 85 to 190 mm, 195 to 385 mm and 85 to 265 mm, respectively in the sample from AR landings. The mean length of *L. lineolatus* progressed from 122 mm when the age of the AR was 7 months to 179 mm when it was 14 months old, but declined to 112 mm at 16 months (Fig. 4). Female dominated the catch in all the months and the M : F ratio was 1 : 4.8. The maturity condition of the female *L. lineolatus* also progressed with the age of the AR; 72.6% of the individuals were in immature/maturing condition in the 7th month of AR, 100% of the individuals were in mature condition in the 8th to 10th months and 52.4% of the individuals were in ripe condition in the 15th month. However, immature/ maturing individuals were dominant again in the 16th to 18th months (Table 3). This observation indicates that the fish have made the AR as a habitat, and grown, reproduced and get recruited to the fishery. Stomach condition analysis revealed that the stomach of 61.8% of the individuals was empty (Table 4). Of the

TABLE 3. *Progression of ovarian maturity in relation to the age of AR*

Age of AR	*Lutjanus lineolatus*			*Pinjalo pinjalo*			*Alepes djedabba*		
(month)	Immature	Mature	Ripe	Immature	Mature	Ripe	Immature	Mature	Ripe
3							100.0		
4							100.0		
5							100.0		
6							100.0		
7	72.4	27.6					100.0		
8		100.0		100.0			100.0		
9		100.0		100.0			100.0		
10		100.0			100.0		100.0		
11	34.9	65.1			100.0		100.0		
12	24.3	75.7			83.4	16.6		100.0	
13		54.3	45.7					100.0	
14		52.4	47.6			100.0		39.2	60.8
15		47.6	52.4			100.0	100.0		
16	100.0			89.1	10.9		100.0		
17	61.9	38.1		43.2	56.8		73.4	36.6	
18	53.6	46.4		47.4	52.6		35.5	64.5	

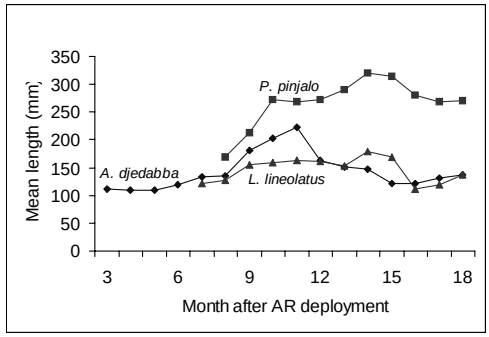

Fig. 4. Mean length in the catch from AR ground

276 stomachs analysed, fish, shrimps and crabs were found in 163, 91 and 62 stomachs, respectively.

The mean length of *P. pinjalo* progressed from 170 mm when the age of the AR was 8 months to 320 mm when it was 14 months old, but declined to 270 mm at 18 months. Female dominated the catch in all the months and the M : F ratio was 1 : 3.5. The maturity condition of the female progressed from 100% immature ovary in the 8th and 9th months to 100% ripe ovary in the 14th and 15th months. The stomach of 55.2% of the individuals was empty; of the 230 stomachs with food remains, fish, shrimps and crabs were found in 132, 118 and 79 stomachs, respectively.

The mean length of *A. djedabba* increased from 110 mm when the age of the AR was 3 months to 223 mm when it was 11 months old, but decreased to 121 mm at 16 months. The M : F ratio was 1 : 1.4. The maturity condition of the female progressed from 100% immature ovary during 3rd to 11th month of the AR to 60.8% ripe ovary in the 14th month; immature/maturing individuals were dominant again in 15th to 17th months. The stomach of 67.8% of the individuals was empty; of the 319 stomachs with food remains, fish, shrimps and crabs were found in 107, 98 and 139 stomachs, respectively.

Discussion

The fishing effort in the AR ground off Chinnandikuppam contributed 15.4% to the total effort (which includes the fishing effort in the non-AR grounds), 12.9 % to the catch and 20.0% to the total income. Whereas the catch rate (kg/h) was higher in the non-AR grounds and the catch per fisherman was almost equal in the AR and non-AR grounds, the actual gain from the AR ground was 36% higher income realized per hour of operation. The fishermen realized Rs 71.3/h from the AR ground, but only Rs 52.5 kg/h from the non-AR grounds. This was possible because of aggregation of high quality fishes such as the snappers, emperor and carangids in the AR ground. The average value of the catch from the AR ground (Rs 42.5/kg) was 67% higher than that of the catch from the non-AR grounds (Rs. 25.4/kg). If operated from non-AR grounds too, the hooks & line fishery, which targets larger quality fish, is expected return better revenue than the small-meshed gillnet fishery, which targets bulk catch of small pelagics. However, the fish scouting duration in hooks & line fishery in non-AR grounds is generally very long. And the fishermen of Chinnandikuppam did not venture into hooks & line fishing in non-AR grounds after deployment of the AR. An analysis of the catches off Valiathura (Trivandrum coast, Kerala) where a number of ARs has been deployed revealed that the ARs contributed a significant share of 6.9% to the total fish production of the village in terms of value, but only 2.8% in terms of quantity (D'Cruz, 1995).

The catch composition from the AR and non-AR grounds was different. This may be due to any of the following two

TABLE 4. *Stomach condition and major food item of fish in AR ground*

Stomach condition/ food item	*L. lineolatus*	*P. pinjalo*	*A. djedabba*
	Stomach condition		
Sample	1450	1023	1874
Empty (%)	61.8	55.2	67.8
Half full (%)	24.4	31.9	30.3
Full (%)	13.8	12.9	1.9
	Occurrence of food (Number of stomach)		
Sample	276	230	319
Fish	163	132	107
Shrimps	91	118	98
Crabs	62	79	139
Others	43	9	41

reasons: (i) only selected species aggregate around the AR; or (ii) the types of gear operated were different. The second reason seems a possibility since the food of the resident fish consisted of groups such as the shrimps and crabs, which were not found in the catch from the AR ground. The catch index from the AR was 14.2 kg/m^3. In countries such as the Philippines, Japan and Korea where millions of cubic meter of ARs have been deployed, the catch is estimated to range from 5 to 50 kg/ m^3 (Rong-Quen Jan *et al*., 2003). 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 higher.

Biological characteristics of selected groups of residents collected from the AR ground indicate that juvenile fish colonise in the initial months after deployment, grow to a larger size and spawn in the AR. This study indicates that fish, especially the residents use the AR as a habitat, thereby help increase the productivity, rather than merely aggregating around the structures. However, more studies by undertaking SCUBA diving and underwater photography are needed to confirm the service provided by the AR for resource enhancement.

The AR was deployed at a cost of Rs 2,50,000 and the fishermen realized Rs 2,74,000 in 16 months' fishing. When the study was completed, fishing was being carried out with full intensity. The structures may last for another 20 months, and may get dispersed or sunken thereafter. By that time, the AR would have returned a good income to the fishermen. Larger pile size is likely to fetch higher income (Rong-Quen Jan *et al*., 2003). However, ARs should be deployed in well-planned, selected sites, and not irrationally (Devaraj, 1997).

Acknowledgements

The authors thank the Director, CMFRI, Cochin for encouragement, and Dr. H. Mohamad Kasim, Scientist-in-Charge and Shri M.M. Meiyappan, Principal Scientist, Madras Research Centre of CMFRI for support. The financial assistance by the Indian Council of Agricultural Research, New Delhi under the AP Cess Fund is gratefully acknowledged.

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Date of Receipt : 15-1-2005
Date of Acceptance : 22-11-2005