International Journal of Agricultural Sciences ISSN: 2167-0447 Vol. 5 (4), pp. 685-692, June, 2015. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Colonization of fish through artificial reefs in the Persian Gulf (Bandar Lengeh-Iran): Reef designs and seasonal changes of fish abundance

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Accepted 6 May, 2015

Artificial reefs are used as a management tool to compensate for overfishing and anthropogenic degradation. In the present study, to find the best artificial structure for enhancing of fish yields, the values of total fish catch and its seasonal changes were investigated in different forms of artificial structures placed in costal waters of Persian Gulf (Bandar-e-Lengeh-Iran). For this purpose, eight treatments including different forms of artificial reefs, reef ball (RB), fish house (FH), non-designed materials (ND), RB+FH, RB+ND, FH+ND and RB+ND+FH and one control group (C) were established. At each site, the fish sampling were carried out every three months for one year. According to data, total fish catch was higher significantly in RB+ND+FH treatment than in other experimental reef structures. As well as, the total fish yields in spring season were significantly higher than in other seasons. The catch composition data showed that *Epinephelus coioides* with 65% allocates the main quota of total catch on experimental artificial structures. In conclusion, the results indicated that artificial structures especially a complex of RB+ND+FH are more suitable for enhancing of fish catch successes in inshore waters of Bandar Lengeh.

Key words: Artificial reefs, reef ball, Persian Gulf.

INTRODUCTION

Artificial reefs are man-made or natural habitats placed in selected areas of the marine environment to provide or improve sea bottom and thereby increase the productivity and harvest ability of certain fish valuable to man. Most exploitable fishes inhabit the continental shelf, but much of this area is consisted of unproductive sand or mud bottom. Although, coral reefs and rocky habitats are desirable sites for fish assemblage, but are found only in limited areas along most coasts. On the other hand, such suitable sites are in danger of destruction due to the some causes such as physical and chemical destructions arising from industrial activities, untreated sewage of nearby cities and factories, oil and gas contamination from refineries, passing vessels and oil rigs. Therefore artificial reefs have potentials as a positive management tool that can be used to allow the damaged natural site to recover, and to develop quality of sea bottoms for local fishing. Generally, artificial reefs have several advantages including: providing of shelter for fish and other sea organisms, attraction of organisms which are vital sources of food for different marine species and thereby increasing of wild fish population (Matthews, 1985; Ambrose and Swarbrick, 1989; Bayle-Sempere et al., 1994; Baine 2001; Lance et al., 2005).

The use of artificial reefs to increase fish harvests or for aquaculture also has a long history. Historically Iranian fishermen have used sunken artificial materials such as blocks of stones, palm trunks and broken clay pots to improve fishery (Rostamian, 1998). Anglers realized through experimentation that the sunken materials cause increasing of fish catches.

Several studies showed that different forms of artificial reefs provide species-specific habitat for colonization of some fishes by change of environmental factors such as light, crevice, water flow, turbulence patterns, sedimentary regimes, temperature. These ecological changes can influence on marine communities (benthos, plankton, nekton or other) (Bohnsack et al., 1991; Kim et

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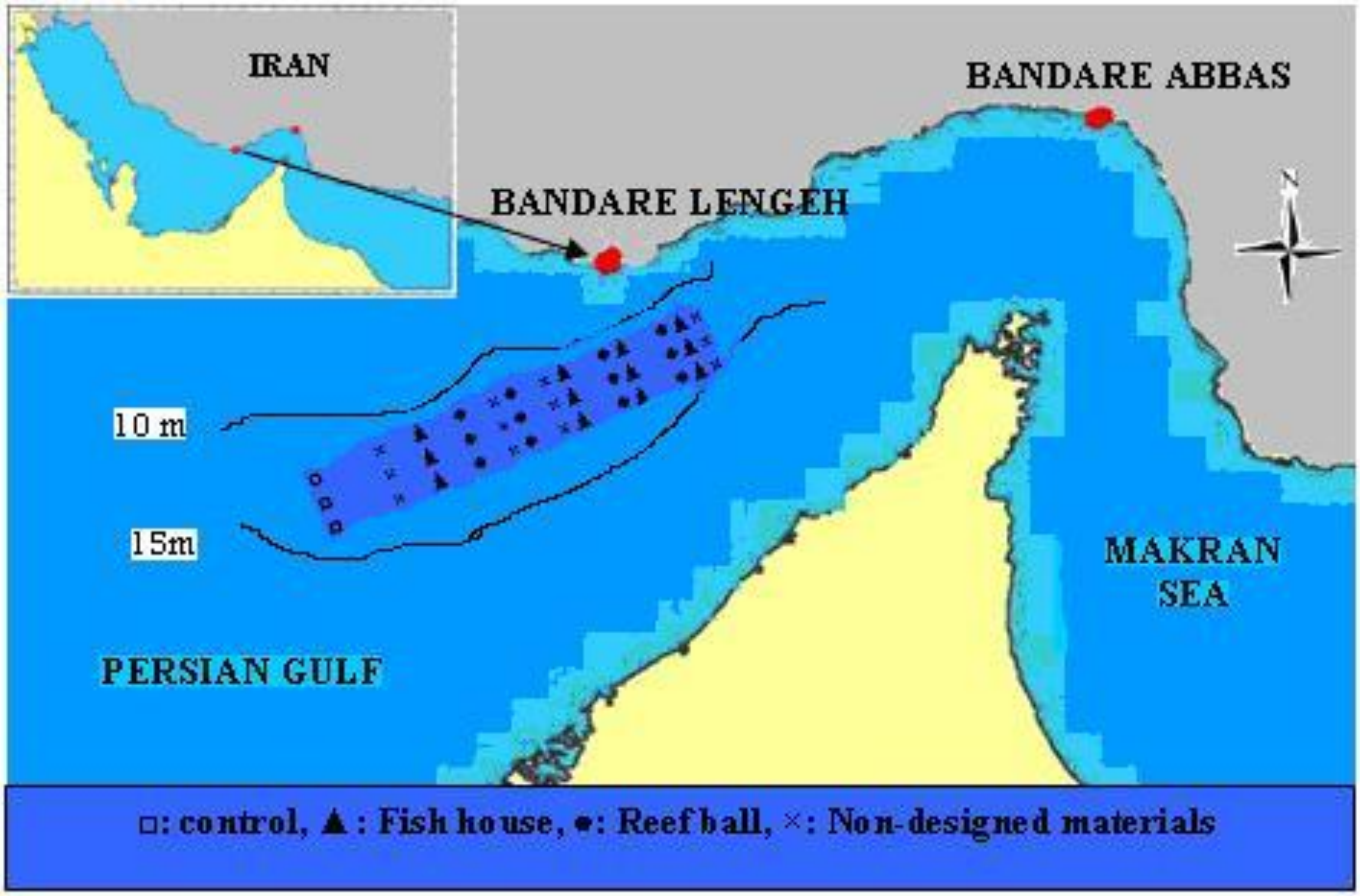

Figure 1. Study area and location of the experiment sites in the Persian Gulf (Bandar Lengeh-Iran).

al., 1994). The artificial reefs are now employed in over 40 countries (Baine, 2001) especially Japan, USA, Malaysia, Philippines, Australia, Taiwan, Italy, France and Spain in order to the increasing of catches in local fishing grounds using simple, readily available materials like rocks, trees, bamboo, scrap tires and etc. In this study, the different forms of artificial reefs were applied in order to the examination of their efficiency on total fish catch in the coastal waters of the Bandar-e-Lengeh. It is obvious that such development could be really life-enhancing for coastal peoples that their life is strongly dependent on sea resources.

MATERIALS AND METHODS

Study area, artificial reefs and fish sampling

The studied area was Bandar-e-Lengeh, located in latitude 26° 29 774′ N and longitudes 54° 45 055′ E, north of the Persian Gulf, Hormozgan Province offshore. The site was selected on hard sea bottom (Figure 1). The locations of sites for the artificial reefs establishments were determined through preliminary survey with GPS and buoys. Three forms of artificial reefs including reef ball (RB) (1.2 m high, 1.5 m wide and about 1 to 1.5 tons weight) (Figure 2a), fish house (FH) (1.5 m high, 1.4 m wide and 1 to 1.5 tons weight) (Figure 2b) and non-designed materials (ND) were used. Reefs in each form were similar in terms of size and weigh. Non-designed materials were the used materials, e.g. broken concrete, columns, old concrete pipes and bridges.

Samplings were done in every three months once during a period of one year (2005) by trap nets (a combination of three trap nets for each reef structure as follow: large trap net (diameter: 120 cm; mesh size: 5 cm); medium trap net (diameter: 90 cm; mesh size: 4 cm) and small trap net (diameter: 70 cm; mesh size: 3 cm. In each visit, the trap nets were placed in every sampled site by skilled experts and divers and then abounded for a period of 5 to 7 days. The catch per reef site was collected after this period. The fishes in the different reefs were grouped into families and species and then their number and total weight (kg) were recorded.

Experiment design and statistical analysis

A research layout was designed for this experiment comprising seven treatments and a control with three replicates for each of them (Figure 1). The treatments were RB, FH, ND, RB+FH, RB+ND, FH+ND and RB+ND+FH. The distance between artificial reefs treatments was 300 m and replicates were 100m (Walker et al., 2002; Miguel and Carlos, 1998), occupying an area of 36 ha approximately, with depths ranging from 10 to 15 m (Figure 1). In

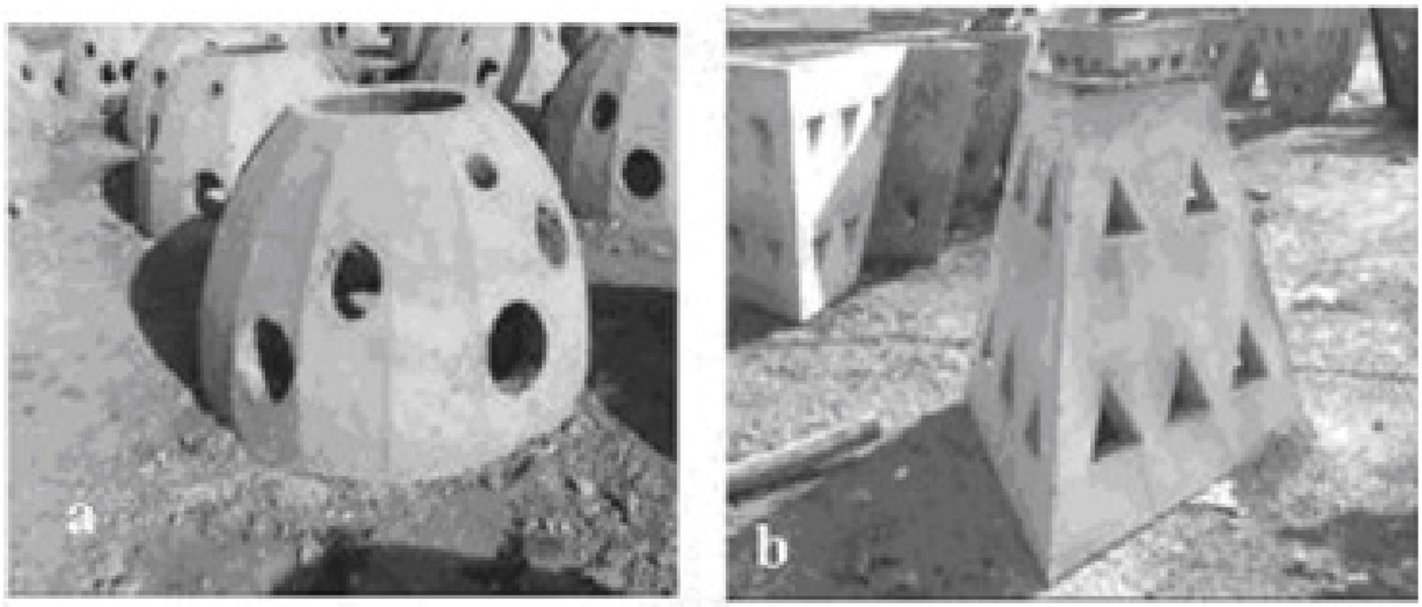

Figure 2. Artificial structures used for experiment: (a) Reef ball (RB); (b) Fish house (FH).

each site (replicate), 4×4=16 pieces of artificial reefs was placed in a square shape of arrangement with 10 ×10 m dimension. Natural reefs (NR: places with hard sea bottoms) were considered as control sites (C). The SPSS software was used for data analysis. Catch data were normal according to Kolmogorov Smirnov test. One-way analysis of variance (ANOVA) was employed to compare the means of catch per unit effort (CPUE) between experimental groups (treatments and control).

RESULTS

Throughout experiment, 18 commercial fish species belonging to 10 families were identified in catch composition (Tables 1 to 3). In this regard, *Epinephelus coioides* (Serranidae) with 65% of catch composition had most quotas (Figures 3 and 4).

The total fish catch was higher in RB+FH+ND and FH+ ND reefs than other treatments and control sites (Figure 5). The least quota of fish catch was yielded in RB. The mean of CPUE was significantly higher in RB+FH+ND reefs than RB+ND and ND (Figure 6). Also, the total fish catch fluctuated in different periods of sampling, which was higher in spring and fall than in other seasons (Figure 7). The minimum level of fish catch was found in winter (Figure 7).

DISCUSSION

In marine environment, the natural reefs serve as habitats for many marine organisms especially fish species. During past decades, coral reefs and other critical fish habitats have been under severe negative impacts such as dredging, landfill operations, oil pollution events, bleaching events and other anthropogenic manipulations. Thus, during recent years, numerous attempts have been initiated in order to recover these habitats in several marine regions of the world. Currently, artificial reefs are used as a management tool to compensate for overfishing and anthropogenic degradation (Grove, 1982; Chou et al., 1992; Pratt, 1994; Bohnsack et al., 1997; Chou, 1997). These man-made structures provide new habitats for juveniles and adults, and contribute to protecting resources and subsequently enhancing of fishing yields (Bohnsack, 1989; Chou, 1997; Grossman et al., 1997).

The Persian Golf is one of the oil rich regions of the world. Therefore, the danger of oil pollution is possible for natural reefs. During present study, aquatic organisms including fish and sessile organisms were aggregated gradually in location of examined artificial reefs (Author personal observations). The appearance of many species at the examined reef structures may be a result of habitat loss on the Bandare-Lengeh. In agreement with our observations, Bailey-Brock (1989) stated the importance of the relationship between the sessile organisms found on artificial reefs and the appearance of fish species feeding on them. In this study, effects of several types of artificial reefs were investigated on seasonal fishing yields. The results showed that compositions of RB+FH+ND and FH+ND were more effective on total fish catch than other treatments. On the other hand, in the spring and fall seasons, the higher values of fish catch were yielded.

Several studies showed that effectiveness of artificial reefs in increasing productivity depends on the design of

Table 1. The abundance and total fish catch for each species over the course of experiment. Reef ball (RB), fish house (FH), non-designed structures (ND) and control (C). Seasons with no catch for all reef forms were not presented in table.

Species	Experimental groups							
Epinephelus coioides (Serranidae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH +ND	C
Spring	(n=4, W=2211)	(n=2, W=823)	(n=2, W=1746)	(n=14, W=11463)	(n=2, W=1027)	(n=12, W=7886)	(n=1, W=1010)	(n=9, W=14202)
Summer	(n=1, W=392)	---	---	(n=3, W=2883)	(n=1, W=1249)	(n=4, W=2120)	(n=4, W=6405)	---
Fall	(n=3, W=2335)	(n=3, W=1788)	(n=3, W=5683)	---	(n=3, W=4529)	(n=8, W=13314)	(n=11, W=13882)	---
Winter	(n=1, W=330)	(n=1, W=1395)	---	(n=1, W=511)	(n=1, W=558)	(n=4, W=2202)	(n=2, W=2958)	---
Scarus persicus (Scaridae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
Spring	(n=2,W=1818)	(n=1, W=1482)	---	(n=1, W=531)	---	---	(n=2, W=602)	---
Fall	---	---	---	---	---	(n=3, W=2631)	(n=1, W=572)	---
Acanthopagrus bifasciatus (Sparidae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
Spring	---	---	---	---	---	(n=1,W=411)	---	---
Lutjanus johni (Lutjanidae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
Spring	---	---	---	(n=1, W=1110)	---	---	---	---
Scarus ghobban (Scaridae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
Fall	---	---	---	---	---	(n=1, W=411)	---	---
Pomacanthus maculosus (Pomacanthidae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
Spring	(n=1,W=367)	(n=13,W=7829)	---	---	(n=1,W=463)	---	(n=3, W=645)	---
Summer	---	---	---	---	---	(n=1, W=392	---	---

a reef structure, in particular whether it meets the specific habitat requirements of individual target species and age groups (Scarratt, 1973; Spanier, 1991; Fabi 1996; Jensen and Collins, 1996). Nevertheless, certain fish species and reef populations have been shown to prefer less complex structures (klima and Wickham, 1971; Risk, 1972; Sale and Douglas, 1984). Studies in Korean waters, for example, have identified dice shaped reef units as being preferred by rockfish, turtle shaped reef units being dominated by demersal fish, while tube shaped structures exhibit intermediate characteristics (Lee and Kang, 1994). For finfish, cylinders with holes along the sides and hollow 'jumbo' structures have been shown to consistently support the highest species diversity, probably due to the hiding spaces, hollow interior spaces, shadow against light, high surface area and protuberances characteristic of these designs (Kuwantani, 1980; Kim et al., 1994; Marinaro 1995).

Size, relief, surface area, complexity and location were all demonstrated to be important factors influencing the success of an artificial reef as an attractor of targeted species and as a means to enhance the fish community (Bohnsack et al., 1991; Kim et al., 1994). The structural complexity also influences community diversity by providing numerous shelters with different habitat characteristics (light, crevice, water flow, turbulence patterns, sedimentary regimes, temperature, etc).

In the present study, the total fish catch at RB+FH+ND was higher than on the natural sites and other artificial reefs which can probably be attributed to its unique spatial complexity. Such

Table 2. The abundance and total fish catch for each species over the course of experiment. Reef ball (RB), Fish house (FH), Non-designed structures (ND) and Control (C). Seasons with no catch for all reef forms were not presented in table.

Species				**Experimental groups**				
Acanthopagrus latus (Sparidae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
Spring	---	---	---	(n=1, W=221)	---	---	---	---
Summer	---	---	(n=2,W=760)	---	---	---	---	---
Fall	---	---	(n=2,W=460)	---	---	---	---	---
Siganus javus (Siganidae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
Spring	---	(n=12, W=2749)	---	---	---	---	(n=19, W=3872)	---
Winter	---	---	---	(n=1, W=210)	---	---	---	---
Pinjalo pinjalo (Lutjanidae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
Spring	---	---	---	---	---	---	(n=6, W=796)	(n=1, W=339)
Summer	(n=11, W=1519)	(n=1, W=102)	(n=3, W=447)	---	(n=12, W=1798)	---	(n=4, W=623)	(n=4, W=575)
Plectorhinchus pictus (Haemulidae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
Fall	---	---	(n=4,W=2439)	---	---	---	---	---
Alepes djedaba (Carangidae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
Summer	---	(n=10, W=720)	(n=1, W=61)	---	---	---	(n=3, W=283)	(n=3, W=277)
Plectorhinchus shtaf (Haemulidae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
Fall	---	---	---	(n=1,W=380)	---	---	(n=2,W=835)	---
Lutjanus russelli (Lutjanidae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
Spring	---	---	---	---	(n=1,W=178)	(n=1,W=142)	---	---

structure (RB+FH+ND) can therefore serve as a model for further construction of artificial structures designed to rehabilitate areas where natural reefs have been damaged. According to catch data, *E. coioides* (65%) was most observed fish species inhabiting on experimental artificial structures during experiment which this may be due to its marked preference for inhabitation on rocky and reef bottoms in sea. Thus, the high affinity of this fish to natural reefs and rocky bottoms makes it more vulnerable to habitat destruction than other fish species. Walker et al. (2002) mentioned that total abundance and richness of fishes fluctuated with different time in year.

It is likely that spring season has been the best period because of its optimum condition for blooms of phytoplankton and zooplankton (Kamali, 2005) that are very important as fish food in sea waters (Seaman, 2000) including the Persian Gulf. Therefore, the increased fish catch in spring could be attributed to the probable blooms of phytoplankton and zooplankton.

Conclusion

The results showed that composition of RB+FH+ND reefs could be the best choice for artificial reef development in the north Persian

Table 3. The abundance and total fish catch for each species over the course of experiment. Reef ball (RB), Fish house (FH), Non-designed structures (ND) and Control (C). Seasons with no catch for all reef forms were not presented in table.

Species	**Experimental groups**							
Heniochus acuminatus (Chaetodontidae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
summer	(n=1, W=85)	---	---	---	---	---	---	---
Winter	---	---	---	(n=5,W=706)	---	---	---	---
Letrinus nebulosus (Serranidae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
spring	---	---	---	---	(n=2, W=379)	---	---	---
summer	---	---	(n=1,W=290)	---	---	---	---	---
Fall	---	(n=1,W=1300)	---	(n=2,W=550)	---	---	---	---
Lutjanus malabarieus (Lutjanidae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
Spring	---	---	---	---	---	---	---	(n=1,W=300)
Summer	---	---	(n=1,W=290)	---	---	---	---	---
Fall	---	---	---	---	---	---	---	(n=2,W=568)
Cephalopholis hemistiktos (Serranidae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
Fall	---	---	---	---	---	---	(n=1, W=490)	---
Diagrama pictum (Haemulidae)	RB	FH	ND	RB+FH	RB+ND	FH+ND	RB+FH+ND	C
Spring	---	(n=16, W=6360)	---	---	---	---	---	---
Summer	---	---	(n=2,W=492)	---	---	---	---	---
Fall	(n=1,W=210)	---	(n=2,W=318)	---	---	---	---	---
Winter	---	(n=1,W=250)	---	---	(n=1,W=1379)	---	(n=1,W=1227)	---

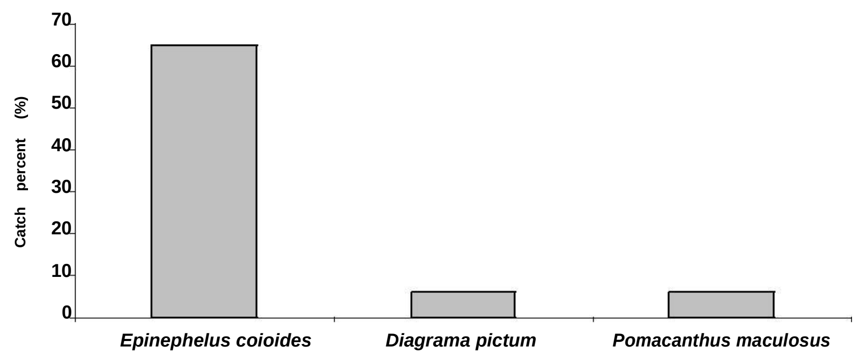

Figure 3. Fish catch composition over the course experiment: species with.

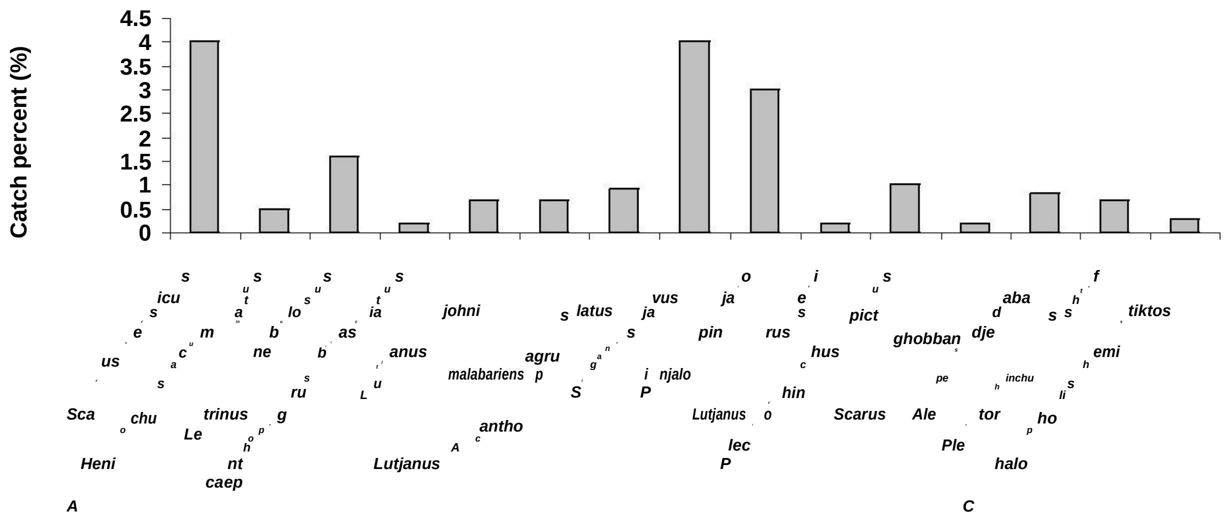

Figure 4. Fish catch composition over the course experiment.

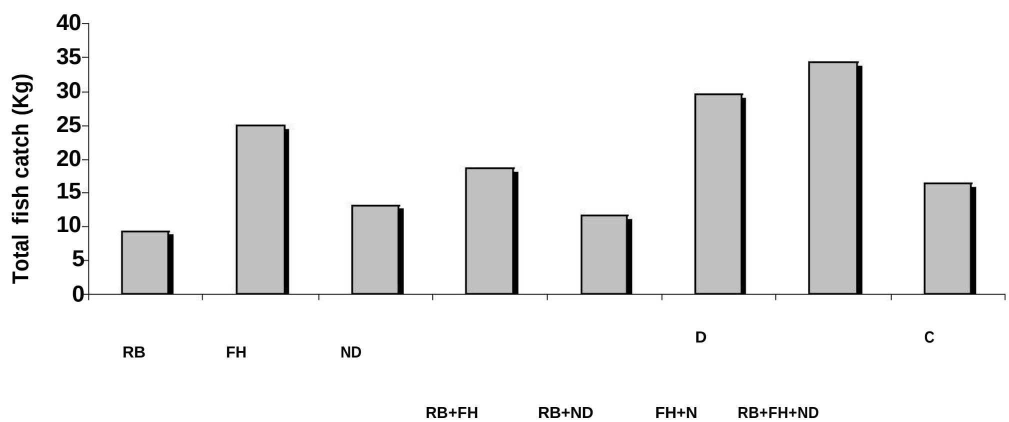

Figure 5. Total fish catch (Kg) in different forms of artificial reefs and in the control over the course of experiment.

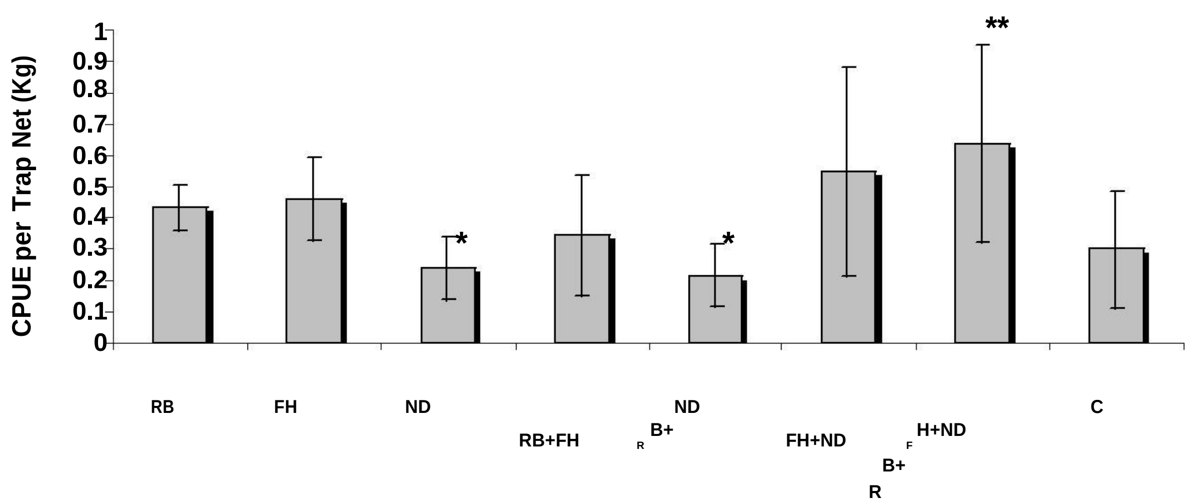

Figure 6. Values of Catch Per Unit Effort (CPUE) for different forms of artificial reefs and in the control over the course of experiment. The values with the different symbols letter in figure are significantly different (P<0.05).

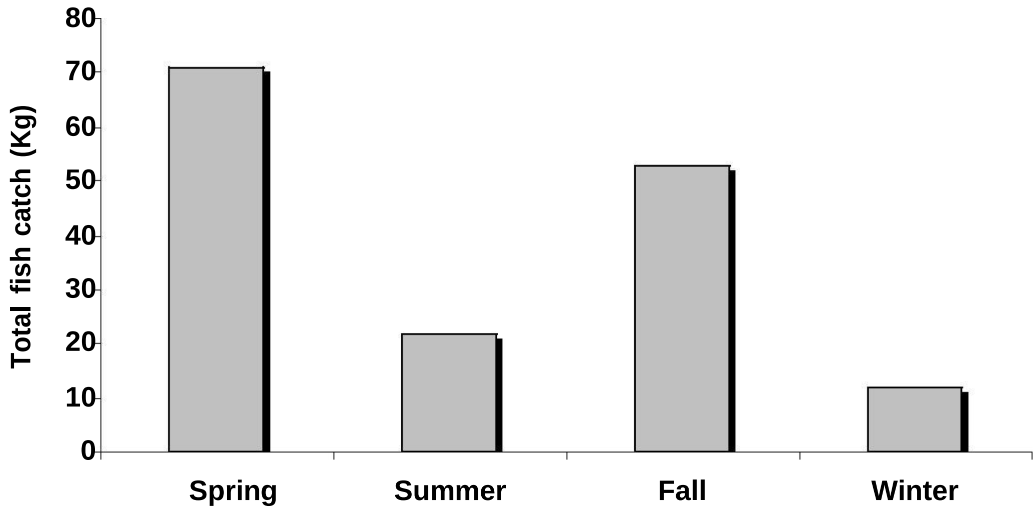

Figure 7. Total fish catch (Kg) for each season over the course of experiment.

Gulf coastal region. Also, the main captured species are common components in reef fish communities (that is, *Serranidae*, *Haemulidae* and *Pomacanthidae*). These three fish species more captured are important to regional fisher as well as to touristic diving activities near reefs, which could improve the people income in that area.

REFERENCES

Ambrose RF, Swarhrick SL (1989). Comparison of fish assemblages on artificial and natural reefs off the coast of southern California. Bull. Mar. Sci., 44: 718-733.

Bailey-Brock JH (1989). Fouling community development on an artificial reef in Hawaiian waters. Bull. Mar. Sci., 44: 580-591.

Baine M (2001). Artificial reefs: A review of their design, application, management and performance. Ocean Coast. Manage., 44: 241-259.

Bayle-Sempere JT, Ramos-Espla AA, Garcia Charton JA (1994). Intraannual variability of an artificial reef fish assemblage in the marine reserve of Tabarca (Alicante. Spain, SW Mediterranean). Bull. Mar. Sci., 55: 824-835.

Bohnsack JA (1989). Are high densities of fishes at artificial reefs the result of habitat limitation or behavioral preference? Bull. Mar. Sci., 44: 631-645.

Bohnsack JA, Ecklund AM, Szmant AM (1997). Artificial reef research: Is there more than the attraction-production issue? Fisheries, 22: 14-16. Bohnsack JA, Johnson DL, Ambrose RF (1991). Ecology of artificial reef habitats and fishes. In: Seaman W and Sprague LM Eds Artificial Habitats for Marine and Freshwater Fisheries. Academic Press, New York, pp. 61-107.

Chou LM (1997). Artificial reefs of southeast Asia: do they enhance or degrade the marine environment? Environ. Monit. Assess., 44: 45-52.

Chou LM, Lim GSY, Leng CB (1992). Fish communities in natural reef and artificial habitats in the coastal waters of Brunei, Darussalam.pp. ICLARM Conference. Proc, Darussalam, Brunei, 34: 75-90.

Fabi G (1996). Molluscan aquaculture on reefs. Paper presented at the European Artificial Reef Research Network (EARRN) Conference, Ancona, Italy, pp. 26-30.

Grossman GD, Jones GP, Seaman Jr. WJ (1997). Do artificial reefs increase regional fish production? A review of existing data. Fisheries, 22: 17-23.

Grove RS (1982). Artificial reefs as a resource management option for siting coastal power stations in southern California. Mar. Fish. Rev., 44: 24-27.

Jensen AC, Collins KJ (1996). The use of artificial reefs in crustacean fisheries enhancement. Paper presented at the European Artificial Reef Research Network (EARRN) Conference, Ancona, Italy, pp. 26-30.

Kamali E (2005). Ecological Study in coastal area of Bandar-e-Lengeh, Final report, Institute of Fisheries Research for Persian Golf and Oman Sea.

Kim CG, Lee JW, Park JS (1994). Artificial reef designs for Korean coastal waters. Bull. Mar. Sci., 55: 858-866.

Klima EF, Wickham DA (1971). Attraction of coastal pelagic fishes with artificial structures. Trans. Am. Fish. Soc., 100: 86-99.

Kuwantani Y (1980). Theory and Practice in Artificial Fishing Reefs. vol. II. Japan Fishery Resources Conservation Association, pp. 17-22.

Lance KB, Jordan David S, Gilliam R, Spieler E (2005). Reef fish assemblage structure affected by small-scale spacing and size variations of artificial patch reefs. J. Exp. Mar. Biol. Ecol., 326: 170-186.

Lee JW, Kang YS (1994). Variations of fish community and fish density on artificial reefs. Bull. Kor. Fish. Soc., 27: 535-548.

Marinaro JY (1995). Artificial reefs in the French Mediterranean: A critical assessment of previous experiments and a proposition in favour of a new reef planning policy. Biol. Mar. Medit., 2: 65-76.

Matthews KR (1985). Species similarity and movement of fishes on natural and artificial reefs in Monterey Bay, California. Bull. Mar. Sci., 37: 252-270.Miguel NS, Carlos CM (1998). Comparison of the catch and fishing yield from an artificial reef system and neighboring areas off Faro (Algarve, south Portugal). Fish. Res., 39: 55-65.

Pratt JR (1994). Artificial habitats and ecosystem restoration: Managing for the future. Bull. Mar. Sci., 55: 268-275.

Risk MJ (1972). Fish diversity on a coral reef in the Virgin Islands. Atoll Res. Bull., 153: 1-6.

Rostamian H (1998). Investigation of the practicality of artificial reefs in the Persian Gulf. Iranian Fisheries Research Organization Press, p. 79.

Sale PF, Douglas W (1984). Temporal variability in the community structure of fish on coral patch reefs and the relation of community structure to reef structure. Ecol., 65: 409-422.

Scarratt DJ (1973). Lobster populations on a man made rocky reef. ICES CM K, p. 47.

Seaman W Jr. (2000). Artificial reef evaluation with application to natural marine habitats. Academic press, New York, USA., pp. 179-270.

Spanier E (1991). Artificial reefs to insure protection of the adult Mediterranean slipper lobster, Scyllurides lutus (Latreille, 1803). In: Boudouresque CF., Avon, M., Gravez, V., Eds Les Especes Marines a Proteger en Mediterranee. GIS Posidonie, France, pp. 179-185.

Walker BK, Henderson B, Spieler RE (2002). Fish assemblages associated with artificial reefs of concrete aggregates or quarry stone offshore Miami Beach, Florida, USA. Aquat. Living Resour., 15: 95-105.