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The Effectiveness Of Concrete Artificial Reefs OfPulauPayar, Kedah

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Abstract: *Artificial reefs (ARs) have been established in Malaysian fisheries waters since 1975 using various materials such as discarded tyres, derelict and confiscated fishing vessel, reinforced concrete, polyvinyl chloride (PVC), fiberglass reinforce concrete (FRC), fiberglass, ceramic, combination of several materials (reef balls) as well as abandon oil platform. PulauPayar's ARs project started in October 1975 shortly after the first ARs built in Malaysia at the PulauTelur, Kedah. For a long time, it never been assessed for its effectiveness as habitats providing shelter and food for the fishes. This study applied the observation methods to enumerate species and individual number of the fishes and adopting Margalef's index (R1) and Menhinick's index (R2) to measure species richness and Shannon-Weiner and Simpson indices for biodiversity measures. Several natural coral reefs surveyed by other researchers were selected for comparison purposes. It is found that that theShannon-Weiner's diversity indices of the ARs are lower that the surveyed natural reefs but Simpson's index of the ARs compared to natural reefs of PulauPayar itself indicates positive result. An important finding is the failure of the ARs to attract the coral fishes to dwell around and within its vicinity though the presence of commercial species may balance its weaknesses.*

Keywords**:** *artificial reefs****,*** *biodiversity, coral fishes, effectiveness, PulauPayar.*

I. Introduction

PulauPayar along with other nearby smaller islands was gazetted as Marine Parks under the Marine Parks Malaysia Order 1989 [1]. The Order was enacted following the stipulated provisions under the Fisheries Act 1985, Part 41 through Part 45 [2]. Some studies had shown that the diversity of most corals in Malaysia (PulauPayar included) was declining [3], [4] and facing environmental threats [5] thus prompting the government to establish the Fisheries Prohibited Areas (FPA) [1] and later gazetted towards more organized and stringent Marine Parks regime. At the beginning, besides creating the marine parks, more conservation efforts were concentrated on the rehabilitation of coral reef ecosystem, through the construction of artificialreef throughout the country [6].Artificial reefs (ARs) have been established in Malaysian fisheries waters since 1975 using various materials such as discarded tyres, derelict and confiscated fishing vessel, reinforced concrete, Polyvinyl Chloride (PVC), fiberglass reinforce concrete (FRC), fiberglass, ceramic, combination of several materials (reef balls) as well as abandon oil platform [7].PulauPayar's ARs project started in October 1975 shortly after the first ARs built in Malaysia at the PulauTelur, Kedah [8].

Common fish found in PulauPayar reefs as recorded by De Silva and Ridzwan [9] were barracuda (*Sphyraena sp*.), groupers (*Epinephelus sp*. and *Promicrops sp*.), rabbit fish (*Siganusoramin*), fusiliers (*Caesiochrysozonus* and C. *erythrogaster*), sergeant-majors (*Abudefdufsaxatilis*) and snappers (*Lutjanuslineolatus*). Reference [10] recorded 23 families with total number of 7,029 individual; the highest abundance compared to other sites located around Langkawi Island (PulauSingaBesar, TelukDatai and PulauRebakBesar). Recent study by [11] found that the abundance of some major species such as snapper (131.08 individuals per 500 m^3) being the most abundant food fish, with lower populations of grouper (2.83 per 500 m^3) and parrot fish (2.08 per 500 m^3).Study of the effectiveness of the ARs of PulauPayar had been carried out by [12] at locations of 06.06^0 N and 100.04°E where sunken boats, tyres and concrete reefs were placed in the early 1970's. Three genera of groupers (*Epinephalus sp*., *Cephalopholis sp*. and *Anypherodon sp*.) were recorded and found to be abundant in all three types of reef (the number observed was more than six fishes per 10 m^2) and they concluded that the artificial reef program by DOF was successful in increasing the number of fishes around the reefs.

The use of diversity indices to compare the health between coral reefs or other ecosystems is a common practice among researchers [13], [14] and [15]. In this study, the health of the coral reefs corresponds to fishes' diversity values although there are researchers adopting other ecosystem's components such as water quality, microbial diversity and benthic cover in their evaluation of reef's health [16]. A diverse ecosystem is more preferable and important [17], [18] and [19] therefore, it is used as indicator for the effectiveness of the ARs in

this study.Studies on the PulauPayar's biodiversity by [20], [21] and[22] on Bidong's reefs provides a good benchmark for the health of the ecosystem. Essentially, the use of density measure, normally in term of number per unit area [23]or sometime in volume [24] is another good indicator for effective reef assessment.

The objective of this study is to assess the effectiveness of the concrete ARs [25] at PulauPayarin improving fish diversity, by methods of species and behavioural identification, enumerating fish number at genera level and comparing diversity measures with other healthy coral reef areas.

II. Materials And Method

PulauPayar is located approximately 20nm south-east of Langkawi Island, 15 nm west of Kuala Kedah on the Peninsular mainland (Look Fig. 1). The length of the island is about 1.75 km and the breadth on average is 500 m with total area of 31 ha [1] making it the largest island among the other islands which are closer to it; namely, thePulauSegantang, PulauKaca and PulauLembu. Five locations were chosen as study sites mainly based on the known areas where ARs were constructed10 -15 years ago by the DOF. They were at Lat. 06° 03'35.9" N Long. 100° 02'27.5" NE, Lat. 06° 03'36.6" N Long. 100° 02'28.2" NE, Lat. 06° 03' 36.6" N Long. 100° 02' 26.4" NE, Lat. 06° 03' 37.2" N Long. 100° 02' 28.2" NE and Lat. 06° 03' 35.9" N Long. 100° 02' 26.4" NE. All ARs were located on the east side of the PulauPayar (Look Fig. 2). All ARs under study were made of concrete (Look Photo 1 through Photo 4).

Figure 1: Map showing the location of PulauPayar, Kedah.

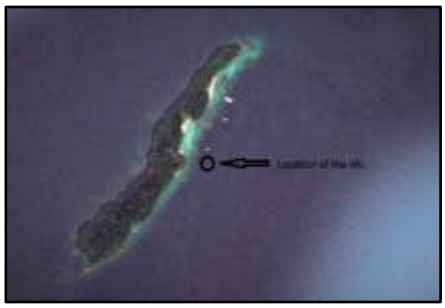

Figure 2: Location of the ARs

Photo 1: Concrete AR

Photo 2 : Concrete AR

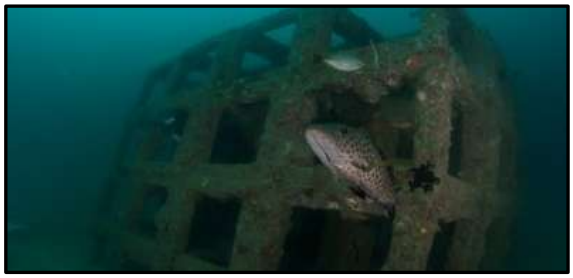

Photo 3: Concrete AR

Photo 4 : Concrete AR

The study on coral fishes adapted the direct observation method [26], [27] which is non-extractive [28], non-destructive [29] and non-manipulative [30] methods by SCUBA [31]. Species identification referred to [32],[33] and [34]. Cryptic species were ignored due to the difficulty in identifying them and their insignificance to the larger masses of fishes under study [35].A diver-researcher observed and recorded his findings on water-proof paper placed on a slate. Other apparatus used were under-water camera, echo-sounder, measuring tape, rope and torch-light. Each dive usually took about 45-55 minutes at depth between 15-24 m. At the end of the task, prior to surfacing, the diver performed safety stop [36] for three minutes at depth of six meters for the

purpose of nitrogen elimination to avoid decompression sickness [37]. A total of 15 day-time divesand two night-timeswere made between November 2014 and February 2015.

Biodiversity or diversity study was restricted to the ARseach enclosed within the cylinder of five meters radiusand five meters high measured using the measuring tape and a 10 m rope rested across the AR served as a transect line. The volume of the cylinder was calculated to be 392 m^3. Before each dive, a location was chosen randomly using the random numbers generator following Stat Trek [38]. The diver-researcher then swam above the transect-line at the height of five meters and counted the fishes on the left and right sides of the line [27].Data needed for diversity index measurement such as number of species and individuals were recorded along other parameters such as depth, time and temperature. The visibility was between 1.2 m and 3.0 m. Diversity indices were measured as follow;

(i) Richness indices

Margalef's index (R_1) and Menhinick's index (R_2) are simple measure of species richness and are expressed as;

$$R_1 = \frac{(S-1)}{\ln N} \text{ and} R_2 = \frac{S}{\sqrt{N}}$$

where S is the number of species and N the number of individuals.

(ii) Diversity indices

The density indices used in this study were the Shannon-Weiner and Simpson indices. Shannon-Weiner's diversity index of function H^1, also referred as the Shannon-Weaver assumes that all species are represented in the sample and are randomly sampled [39]. The function is defined as:

$$H^1 = - \sum_{i=1}^{S_{obs}} p_i \log_e p$$

Where, $p_i$is the proportion of individuals in the *i*th species; $S_{obs}$is the actual number of species observed and $\log_e$ is the natural logarithm. Values of H^1 for real communities typically fall between 1.5 and 3.5. The Shannon evenness is given by $J = H^1/\ln S$, where S is the number of species and ln is the natural logarithm.

Following [40], Simpson's index (D) gives the probability of any two individuals drawn at random from an infinitely large community belonging to different species as:

$$D = \sum p_i^2$$

Where*p* = the proportion of individuals in the *i*th species. In order to calculate the index, the form appropriate to a finite community is used:

$$D = \sum \left(\frac{n_i(n_i-1)}{N(N-1)} \right)$$

Wheren_i = the number of individuals in the *i*th species and N = the total number of individuals. As D increases, diversity decreases and Simpson's index is therefore usually expressed as 1 - D or 1/D.Another method of estimating number of the reef fishes is by using the Coral Fish Diversity Index (CFDI) as devised by [41]. It is a convenient method for assessing and comparing overall reef fish diversity. It sums up the inventory of six key families: Chaetodontidae, Pomacanthidae, Pomacentridae, Labridae, Scaridae, and Acanthuridae. Since PulauPayar falls under the category of areas with surrounding seas encompassing less than 2,000 km^2 , the formula used will be; Estimated number of reef fishes= 3.39 X CFDI – 20.595 .

III. Results And Discussion

In this study, the effectiveness of ARs is assessed by the density or abundance of the fishes existedat the time of observation within the stipulated surrounding area, in this case within the 392 m^3sphere. It summarizes, the higher the density of fishes measured, the more effective it is. Observation showed that fishes get attracted to ARs due to availability of food and shelter [42], [43]. Fish behaviour within the vicinity of the ARs was thus characterized following Nakamura [44], where he observed thatthe affinity of some fishes towards the ARs structures can be characterized as (a) benthic dwellers in physical contact with it, (b) linked to it visually only, and (c) at some distance to it.From Nakamura[44], fish characteristics in this study are rephrased and described as follows; (a) resident fishes are fishes that are benthic, stay within the ARs most of the time during the observation period, (b) visitorfishes are fishes in contact with the ARs and seen nibbling the surface probably searching for suitable food attached to the surfaces of ARs, they were seen leaving the ARs

and went for another places, and (c) hovering fishes or visitor fishes but not in contact with the ARs and usually came in school.Fish abundance could be sightedclearly during the daytime dives especially in the early morning to midday but at night only resident fishes were detectable. For this reason, only data collected during the day-time (morning to midday) are considered to represent the fish population. This is in agreement with Brock [45] who suggested that comparisons between fish communities based on visual census data should be restricted to the diurnally exposed species only. It was observed that groupers, sweetlips andmangrove snapper, resided within the ARsbutswam away from it when searching for food or being disturbed by the presence of the diver. They were the residents of the ARs however not seen feeding during the observation. Groupers had demonstrated the territorial characteristic seen chasing other fishes coming nearer to its resting area. Fishes such as puffer fish (*Arothronstellatus*), fusilier (*Ceasiocuning*), wrasse (*Thalassomalunare*), anglefish(*Pomacanthusannularis*), yellow back fusilier (*Caesioxanthonota*) were merely visitors obviously looking for food attached to the ARs. Most of the time, they were seen nibbling on the structures and left .Another group of fishes is visitor type but not in contact with the ARsandsearching for food, probably the planktons, close to it. The fishes were spadefish(*Plataxsp*), batfishes, andbig eye snapper (*Lutjanuslutjanus*). The last group of fishes were the hovering type for example big eye trevally (*Caranxsexfasciatus*) which came in school and seen swimming against the lee wave. Some of the fishes photographed during the observation are shown in Photo 5 through Photo12 below. A total of 25 species were identified during the 36 dives (See Table 1).

Photo 5: Resident fish (*Epinephalus sp*.)

Photo 6: Resident fish (*Plectorhincus gibbosus*)

Photo 7 : Resident fish (Lutjanus argentimaculatus)

Photo 8 : Resident fish (*Pomacanthus annularis*)

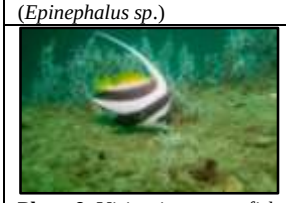

Photo 9: Visitor in-contact fish (*Heniochus acuminatus*)

Photo 10: Visitor in-contact fish (*Scarus ghobban*)

Photo 11: Visitor not in-contact (Caesio caerulaurea)

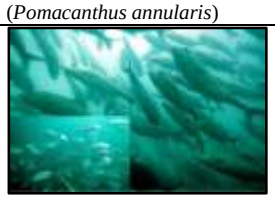

Photo 12: hovering fishes (*Caranx sexfasciatus*)

Table 1: Fish observed in vicinity of the ARs (local name/English name)

No.		
1.	*Abalistes stellaris* (Ikan Jebong / Trigger fish)	Visiting in contact – nibbling on the AR probably nesting nearby on the sand substrate
2.	*Anyperodon leucogrammicus* (Kerapu Batik / Slender grouper)	Resident – but very elusive – burst awa upon noticing divers
3.	*Apogon sp*. (Seriding / Cardinal fish)	Visiting in contact – sheltering in the shad of artificial reef – feeding on plankton
4.	*Arothron stellatus* (Buntal - Pasir Bintang / Star Puffer)	Visiting not in contact – not bothered b presence of divers
5.	*Caesio sp*. (Ikan Delah/ Fusilier)	Visiting not in contact – feeding o plankton
6.	*Caesio xanthonota* (Ikan Delah atas Kuning / Yellowback fusiliers)	Visiting not in contact – feeding o plankton
7.	Caesio cuning (Ikan Delah Pinang / Fusilier)	Visiting not in contact – feeding o plankton
8.	*Carangoides fulvoguttatus* - (Ikan Demudok Bintik Kuning / Yellow dotted trevally)	Hovering – feeding
9.	*Caranx sexfasciatus* (Kerepoh / Big eye trevally)	Hovering – feeding
10.	*Cephalopholis formosa* (Kerapu Garis Biru / Blue lined Coral Cod)	Visiting in contact – often found hiding i artificial reef
11.	*Chromis sp*. (Gombing / Damsels)	Visiting in contact – feeding – nibbling o AR surfaces
12.	*Epinephelus sp*. (Kerapu / Grouper)	Resident - elusive
13.	*Epinephelus coiodes* (Kerapu Bintik / Orange Spotted grouper)	Resident – elusive - ambush attack feedin type
14.	*Heniochus acuminatus* (Gayam Panji / Longfin bannerfish)	Visiting in contact – feeding by nibbling o AR surface
15.	*Lutjanus argentimaculatus* (Ikan Jenahak/ Mangrove Gray Snapper)	Resident – elusive – ambush attack feedin type - predator
16.	*Lutjanus lutjanus* (Ikan Kunyit / Big eye snapper)	Visiting in contact – swimming in and ou of AR and feeding
17.	*Platax teira* (Tudung Periok / Spadefish)	Visiting not in contact
18.	*Plectorhinchus gibbosus* (Kaci Hitam / Gibbus sweetlips)	Resident
19.	*Pomacanthus annularis* (Ikan Taring Pelanduk / Blue Ring Anglefish)	Resident – feeding by nibbling and breakin up oysters on the AR surface
20.	*Pterocaesio chrysozona* (Ikan Delah Karang / Goldband Fusiler)	Visiting not in contact – feeding o plankton
21.	*Scolopsis sp*. (Ikan Pasir Pasir / Monocle bream)	Visiting not in contact – feeding on bentho
22.	*Scomberoides tala* (Ikan Talang Talang/ Queenfish)	Hovering – fast swimming – feeding o small fishes
23.	*Siganus javus* (Dengkis/ Rabbit Fish)	Visiting in contact – feeding by nibbling o AR surfaces
24.	*Thalassoma lunare* (Ketarap/ Moon Wrasse)	Visiting in contact – feeding by nibbling o AR surfaces
25.	*Zanclus cornutus* (Ikan Layang Layang/ Moorish idol)	Visiting in contact – feeding by nibbling o AR surfaces

In term of diversity, the effectiveness of ARs is discerned by comparing the diversities of other well-known, established and healthy coral reef areas. Table 2 shows species and individuals number enumerated during the seventeen (17) dives between the months of December 2014 and April 2015.However, only day-time dives were considered valid as dives no. 2,4,8,12 and 15 were carried out in the afternoon while dives no. 16 and 17 were at night and before sunrise respectively. The values of the richness and diversity indices of the ARs compared with the indices of natural coral reefs measured by other researchers are shown in Table 3. In general, diversity of the ARs of PulauPayar is lesser than the natural reefs of selected locations. In term of Margalef'srichness (R_1), it is only 13.7% of the maximum richness of the natural reefs of PulauPayar surveyed by MCRCP in 2005 and 14.7% of PulauBidong surveyed in 2014. However, the Shannon-Weiner index (H^1) of the ARs is 87.8% of the diversity of Andavadoaka, Madagascar's reefs although other reefs it ranges from 56.2% to 67.2%. With respect to Simpson's index (D), the performance of the ARs is shown excellent as it is 88% of the diversity of the PulauPayar natural reefs as surveyed by MCRCP. Density of the fishes is calculated to be from 0.04 fish m^3 to 5.6 fishes m^3 for the 10 dives or the mean of 1.51 fish m^3. This is much better assessment of density as the survey done by MCRCP only gives the density of 0.09 fish m^3.

Table 2: Number of species and individuals enumerated during the daytime dives

	Species	DIVE 1	DIVE 2	DIVE 3	DIVE 4	DIVE 5	DIVE 6	DIVE 7	DIVE 8	DIVE 9	DIVE 10	DIVE 11	DIVE 12	DIVE 13	DIVE 14	DIVE 15	DIVE 16	DIVE 17
1	***Abalistes stellaris***					1												
2	***Anyperodon leucogrammicus***						1	2			1							
3	***Apogon sp.***						5											
4	***Arothron stellatus***																	
5	***Caesio sp.***	500	20	20			30				50		50	100	10	15	50	
6	***Caesio xanthonota***											500						
7	***Caesio cuning***							50				50						7
8	***Carangoides fulvoguttatus***			200					50			100		1				
9	***Caranx sexfasciatus***							500		50	500	1000	100		500			
10	***Cephalopholis formosa***						1	2	1									
11	***Chromis sp.***			30		8			20	50	50					1	50	
12	***Epinephelus sp.***																	
13	***Epinephelus coiodes***		1			1			1	1		1						
14	***Heniochus acuminatus***	8	4	2	2		3	10	3	28	20	10	4		4		4	4
15	***Lutjanus argentimaculatus***		1	1			1	1		3	2	3	3					
16	***Lutjanus lutjanus***	500					100			15		500					500	100
17	***Platax teira***				1							10						
18	***Plectorhinchus gibbosus***	7	6	2	2	3	2	2	4	8	2	2	1		2		1	1
19	***Pomacanthus annularis***	2	2		1		2		2	2	2	2	6			2		2
20	***Pterocaesio chrysozona***																	
21	***Scolopsis sp.***					3												
22	***Scomberoides tala***			1							2							
23	***Siganus javus***			20				100	6			10		200	10			4
24	***Thalassoma lunare***	2	1	1				1				4	4		1			
25	***Zanclus cornutus***				2								5					
	Number of Individuals	1019	35	277	8	16	145	668	87	157	629	2192	173	301	527	18	605	118
	Number of Species	6	7	9	5	5	9	9	8	8	9	13	8	3	6	3	5	6
	R1	0.72	X	1.42	X	1.44	1.61	1.23	X	1.38	1.24	1.56	X	0.35	0.8	X	X	X
	R2	0.190	X	0.540	X	1.250	0.750	0.350	X	0.640	0.360	0.280	X	0.170	0.260	X	X	X
	H'	0.8	X	1	X	1.32	1	0.83	X	1.58	0.78	1.37	X	0.66	0.27	X	X	X
	Eveness=H/Hmax	0.44	X	0.45	X	0.82	0.45	0.38	X	0.76	0.35	0.53	X	0.6	0.15	X	X	X
	D	0.52	X	0.46	X	0.68	0.48	0.41	X	0.76	0.35	0.69	X	0.45	0.1	X	X	X
	Density (no. of fishes /392 cu.m)	2.6	X	0.71	X	0.04	0.37	1.7	X	0.4	1.6	5.6	X	0.77	1.34	X	X	X

Table 3: Comparison of diversity values between previous study of natural coral reefs and this study

	ARs of Pulau Payar (2015) by this study	Barrier reef of Andavadoaka, Madagascar [46] (2005)	Coral reefs of Bidong Island, Trengganu, Malaysia [22] (2014)	Reefs of PulauPayar [20] (2006)
R_1	0.35-1.61	-	7.42-11.73	-
R_2	0.17-1.25	-	-	-
H^I	0.27-1.58	1.8	2.72-2.81	0.97-2.35
D	0.1-0.76	-	-	-

	Malaysia coral reef conservation project (MCRCP): PulauPayar [21] (2005)
R_1	7.74-10.94
R_2	-
H^I	2.15-2.43
D	0.81-0.86

In this study, the attempt to assess reef fishes using CFDIhad failed as the number of species that falls under the common six key families: Chaetodontidae, Pomacanthidae, Pomacentridae, Labridae, Scaridae, and Acanthuridae was considered insignificant. Only two individuals of *Pomacanthusannularis*of family Pomacanthidae and two individuals of *Thalassomalunare*of family Labridae were observed near the ARs. This clearly indicates that the ARs had failed to attract coral fishes to dwell within and around its vicinity.

IV. Conclusion

This study has shown that over long period of time, the fish resources in term of diversity of the ARs have not been able to match the natural coral reefs. However, to some extent, the ARs are able to create habitats that are suitable to certain species and managed to offer shelter and feeding areas for the fishes. Comparing the diversities of other natural reefs provides a general idea of the effectiveness of the ARs which may assist researchers to improve the ARs in term of structure design, location and materials used. Failure of the ARs to attract coral reef fishes may indicate the weakness in flora and fauna development of the ARs which offer an area of study to accelerate their growth. On the other hand, the presence of commercial species is a positive indicator of the success of the ARs as this will motivate the government and researchers to continue with the ARs project around the country.

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