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Distribution and Diversity of Corals on Artificial Reefs at Pasir Akar and Teluk Kalong, Redang Island, Malaysia

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Abstract: Present study was conducted to determine the propagation and biodiversity of corals on artificial reefs at Teluk Kalong and Pasir Akar, Malaysia to check the feasibility of artificial reef to rehabilitate natural reef ecosystems and to provide artificial habitat for marine organisms. Two types of artificial reef deployed in these areas were Dome Reef and EnviroReef which were developed by the Dorken Company. Based on the results obtained, coral distribution was higher at Pasir Akar compared to Teluk Kalong. The Shannon diversity index (H') and evenness index ($E_{H'}$) of coral at Teluk Kalong were 0.6425 and 0.1766, respectively while the Shannon diversity index (H') and Pielou evenness index ($E_{H'}$) of coral at Pasir Akar were 1.7410 and 0.3247, respectively. Overall, 2 species were found and identified at Teluk Kalong and 10 species were at Pasir Akar with *Seriatopora hystrix* as the dominant species at both the stations. Coral distribution was higher on Dome Reef compared to EnviroReef. The diversity index (H') and Pielou evenness index ($E_{H'}$) of EnviroReef were 0.5359 and 0.1284 respectively while it was 2.2192 and 0.4274, respectively in Dome Reef. A total of 3 and 9 species were found and identified from the EnviroReef and Dome Reef, respectively with *Seriatopora hystrix* being the dominant in both the reef structures. We conclude that both artificial reefs structures were suitable as habitat for coral propagation.

Key words: Artificial reefs, dome reef, enviroreef, Pasir Akar, Teluk Kalong, coral propagation

INTRODUCTION

Corals are marine organisms from the class Anthozoa and exist as small sea anemone-like polyps, typically in colonies of many identical individuals. The group includes the important reef builders that are found in tropical oceans, which secrete calcium carbonate to form a hard skeleton (Darwin, 1889). The development of these structures is aided by algae that are symbiotic with reef-building corals, known as zooxanthellae. The reef is topographically complex and because of that, thousands of species of fish and invertebrates live in association with reefs, which are by far the richest marine habitats (Holing, 1990).

In recent days, coral reefs are under threat from the climate change and ocean acidification. However, human activities may represent the greatest threat to coral reefs. Pollution especially agricultural runoff, over-fishing, blast fishing and the digging of canals threaten reefs by reducing the water quality. Experts have found a new way to save and to restore the population of coral reef by creating high-quality artificial habitat for marine organisms and helps jump-start the establishment of coral community (Goreau and Hilbertz, 2005). The solution is to develop artificial reefs made from certain substances such as concrete and ceramic.

An Artificial Reef (AR) is a structure that is deliberately or accidentally introduced to the seabed and is performing the function of attracting marine life. The creation of manmade structures to enhance marine resources is the basis of a specialized branch of marine technology known as 'artificial reef development' and is widely considered as a tool for protecting the natural ecosystem and enhancing fisheries production. An AR provides shelter from predation and surfaces for larvae to settle on; the organisms that are attracted create new food sources and attract other species, thus a matured AR site (3-5 years) may also play a role in increasing biodiversity in and around the AR site (Goldberg, 1973). Coastal communities in some countries have traditionally used ARs to increase their catches. They are now established with the involvement of governments, the private sector

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and NGOs for various reasons, using a diverse range of materials from disused oilrigs, ships, vehicles and railway tracks, to purpose made concrete blocks and bamboo structures. AR construction has different purposes in different countries, for example, in the United States ARs are constructed mainly to improve recreational fisheries; in Japan, to benefit commercial fisheries; and in some European countries, to control inshore trawling and to increase fish production for rural fishing communities (Wilkinson, 2008).

Artificial reefs have potentials as a positive management tool that can be used to allow the stressed natural site to recover and to develop a new habitat on the seafloor for reef creatures like corals, fishes and other marine invertebrates. One of the high priorities of marine organisms is a safe sanctuary and artificial reef offers many hiding places from the surroundings and once corals are present its even better (Clark and Edwards, 1999). Hard coral is the core of a coral reefs ecosystem; therefore a restoration structure has to promote coral growth in an area where it would otherwise not occur (Clark and Edwards, 1999).

Upon considering the importance of artificial coral reef ecosystem, present study was conducted to determine the propagation and biodiversity of corals on artificial reefs at Teluk Kalong and Pasir Akar, Malaysia.

MATERIALS AND METHODS

Study area: This study was carried out at Redang Island which is located 45 km off the coast of Kuala Terengganu, Malaysia. Two locations were chosen as the study area since the artificial reefs were deployed there (Fig. 1). The first location is Pasir Akar (Lat: 5.75°, Long: 103°) which is situated approximately 3 km off from the jetty and submerged at 15 m of depth. In this area, around 15 units of Dome Reefs and 70 units of EnviroReefs were deployed. The second location was Teluk Kalong (Lat: 5.7666667°, Long: 103.0166667°) which was about 1 km off from the jetty. The water was shallower with mean depth of about 5 m. In this area, a total of 15 units of Dome Reefs, 56 units of EnviroReefs and 10 units of Cheese Reefs were deployed.

These artificial reefs were developed by the Dorken Company. Dome Reef was built mainly from concrete. It has holes that not only go into the module but also between the walls. The large open area in the center was designed to provide fish shelter. EnviroReef was made from ceramic with selective mixture of oxide minerals which naturally occurred in the environment. It was built to mimic branching corals which increases it stability (Fig. 2a, b).

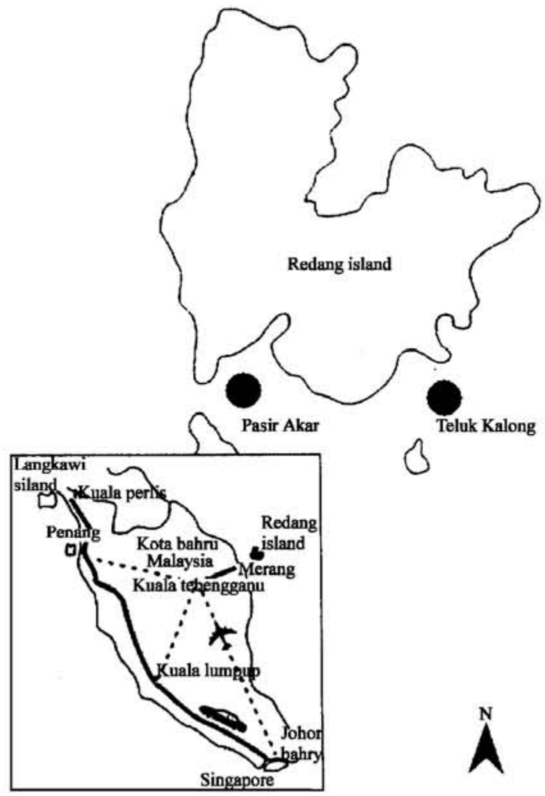

Fig. 1: Location of the study area

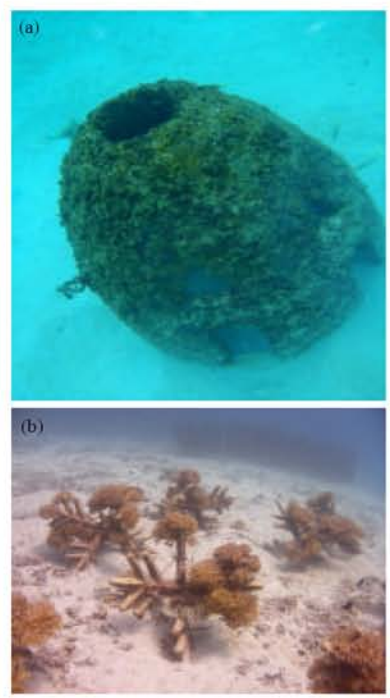

Fig. 2: (a) Dome Reef structure and (b) EnviroReef structure were deployed at the sampling stations

The sampling was carried out at two different stations during a sunny day (between 9 am to 3 pm). This period received optimum sunlight and provided the best visibility to identify the corals, capture pictures and record data. Ambient environmental parameters such as temperature, conductivity, total suspended solid, salinity, dissolved oxygen, pH and turbidity of the study area were measured using a multiprobe parameter. The sampling process was carried out by capturing photo and video recording using underwater camera. Underwater slate was used to record data such as characteristic (e.g., shape, colour, size etc.) and identified using standard reference (Humann and De Loach, 2002). These data were obtained after several diving at the sampling sites during 2009. Collected data were analyzed using Shannon Wiever Diversity Index and Pielou Evenness Index.

RESULTS

Coral distribution on artificial reefs at Teluk Kalong and Pasir Akar: Based on the observations, coral distribution on artificial reefs at Teluk Kalong was relatively low (Table 1). In the EnviroReefs structure, *Seriatopora hystrix* was the only coral growth observed. 40% of the reefs surface was occupied by *Seriatopora hystrix* on the dome reefs structure, followed with *Macrodactyla doreensis*. Pasir Akar had recruited greater abundance and diversity of corals compared to Teluk Kalong (Table 2). In this area, 3 species were identified on EnviroReefs structure. However, *Seriatopora hystrix* was still the dominant species with other coral species such as *Favia stelligera* and *Platygyra sinensis* were growing on certain part of the branching structures. Interestingly, on the dome reefs 8 species were identified with *Oulophyllia crispa* being the most abundant coral.

Index analysis: In general, the diversity index of both locations was relatively low. The Shannon diversity index of corals at Teluk Kalong and Pasir Akar was 0.6425 and 1.7410, respectively. The Pielou Evenness Index of Teluk Kalong and Pasir Akar was 0.1766 and 0.3247, respectively.

Diversity of corals on different reef structure: The Shannon diversity index of corals on EnviroReefs and dome reef structures were 0.5359 and 2.2192, respectively while the evenness index showed the value of 0.1284 and 0.4247, respectively (Table 3). Overall, the diversity index showed that the diversity of corals on dome reefs was higher than the EnviroReefs structure.

Table 1: The abundance and diversity of corals samples at Teluk Kalong

	Number of corals observed					
	1st sampling		2nd sampling			
Species	Enviro	Dome	Enviro	Dome	Total quantity	H'
Seriatopora hystrix	5	7	5	8	25	0.2755
Macrodactyla doreensis	-	5	-	8	13	0.3670
Total		38				H'= 0.6425
						$E_{H'}$ = 0.1766

Table 2: The abundance and diversity of corals samples at Pasir Akar

	Number of corals observed					
	1st sampling		2nd sampling			
Species	Enviro	Dome	Enviro	Dome	Total quantity	H'
Striatopora hystix	22	10	23	15	70	0.3657
Favia stelligera	2	-	3	-	5	0.0176
Platygyra sinensis	3	-	2	-	5	0.0176
Oulophyllia crispa	-	15	-	19	34	0.2929
Favites sp.	-	13	-	15	28	0.2668
Alveopora sp.(crispy)	-	12	-	12	24	0.2460
Acropora formosa	-	5	-	6	11	0.1530
Plerogyra sinuosa	-	3	-	2	5	0.0176
Monstastrea curta	-	10	-	13	23	0.2404
Alveopora sp.	-	4	-	4	8	0.1234
Total		213				H'= 1.7410
						$E_{H'}$ = 0.3247

Table 3: Species diversity and evenness index of corals observed on selected artificial reef structures

Artificial reef structure	Species	quantity	H'
Enviroreef structure	*Seriatopora hystrix*	55	0.1413
	Favia stelligera	5	0.1973
	Platygyra sinensis	5	0.1973
	Total	65	H' = 0.5359
	$E_{H'}$ = 0.1284		
Dome reef structure	*Seriatopora hystrix*	40	0.3305
	Macrodactyla doreensis	13	0.1860
	Oulophyllia crispa	34	0.3107
	Favites sp.	28	0.2850
	Alveopora sp. (crispy)	24	0.2642
	Acropora formosa	11	0.3517
	Plerogyra sinuosa	5	0.0973
	Monstastrea curta	23	0.2585
	Alveopora sp.	8	0.1353
	Total	186	H' = 2.2192
			$E_{H'}$ = 0.4247

DISCUSSION

Coral distribution on artificial reefs: The low abundance and diversity of corals on artificial reefs at Teluk Kalong might be due to the fact that the area had no natural coral reefs which could propagate the coral larval to initiate the restoration process. The location itself was situated only 1km away from the jetty where it was exposed to the daily movement of tourist boats and fishing ships. As a result, water turbidity of this area might act as a limiting factor on the coral propagation. These factors made the establishment of coral community in that area becomes a time-consuming process. Existing natural coral reef ecosystem would provide the home to various coral species that ultimately result in coral larvae to spread along the surrounding environment at Pasir Akar. Moreover, it is also a protected area where human influence is strictly restricted. Therefore the natural habitat is conserved with suitable water quality. This condition provides a suitable environment that promotes a better growth of coral colonies in this area.

Corals diversity and distribution on dome reefs were higher than on EnviroReefs structure. This might be due to the structure of EnviroReefs which has branching-like arrangement which is more suitable in recruiting branching coral such as *Seriatopora hystrix*. It was also observed that dome reef provided a more stable medium for the recruitment of slow-growing corals such as *Oulophyllia crispa*. Most of them grew on the wall of the dome reefs which provided a large amount of surface area for the attachment.

The installation of artificial reefs was expected to foster the creation of new suitable and stable surfaces in order to assist coral recruitment (Abelson, 2006; Walsh, 1985). Artificial reefs at Teluk Kalong and Pasir Akar were designed to restore natural coral reefs community. Both EnviroReefs and dome reefs were designed to mimic the natural reefs in order to meet the ecological needs of corals and fishes in this area.

EnviroReefs were designed with a structure similar to the branching corals. Small reef fish inhabits in EnviroReefs installations naturally keep algal and soft coral overgrowth under control, creating favorable conditions for rapid coral colonization. The modules in these Reefs have features to help facilitate the successful settlement of microscopic coral larvae, including fluted surfaces to generate turbulence and a microporous surface texture for improved coral adhesion. In addition, when installed in large, close-packed arrays of modules, the turbulence generated by the module branches slows water flow over the site, stabilizing sediment and creating conditions conducive for fish nursery area (Philipose, 1996).

Dome reefs had been engineered to withstand against sea forces (chemical and physical) and shaped with ecological uses. Ecologically, dome reefs were built to optimize protective void spaces for fishes and include features such as rough surface textures to enhance coral settlement. Holes were designed to create whirlpools that help bring nutrients to corals and animals living on the dome reefs surface. Therefore, dome reefs were an excellent shelter and feeding area of fishes and other coral related organisms (Han *et al*., 1994; McGurrin *et al*., 1989).

CONCLUSION

In conclusion, diversity indices showed that Pasir Akar had better coral establishment when compared with Teluk Kalong. It was also clear that dome reefs were better in promoting the propagation of coral communities in this area. However, when comparing the two types of artificial reef structures in term of ecological role in restoring the coral reefs ecosystem it was proven that both were efficient in providing a medium for coral establishment as well as other coral associated organisms.

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