PURPOSED PLANNED ARTIFICIAL REEF AS TOOL TO AID RE-ESTABLISHMENT OF NEW MARINE HABITAT IN PULAU TIOMAN

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Studies and monitoring were conducted between 2007 and 2010 to determine the effectiveness of concrete artificial reef blocks developed by NAHRIM called the WABCORE as potential tool to aid establishment of new marine ecosystem. The WABCORE blocks are first deployed and submerged in Panuba Bay, Tioman Island, Pahang in September 2006. Preliminary positioning survey was conducted using side scan imaging to locate and identified each of deployed WABCORE blocks. In-situ quantitative survey of subtidal epibiota assemblages including sessile invertebrates and other live forms found on the WABCORE blocks were evaluated using quadrat technique whereas coral reef fishes and invertebrates were assessed by non-destructive visual census. Total coverage for sessile marine organisms recorded an average of 17.02% between April 2008 and May 2010, with the highest being 29% in August 2008. A total of 46 hard corals were discovered around the AR site. A total of 7 genera were determined for soft corals whereas 3 genera were recorded for gorgonians. As for coral reef fishes, 33 types of fishes from 33 families were recorded. Marine water quality around the artificial reef site was assessed with *in-situ* method using multiparameter water quality sondes. It was observed that the mean dissolved oxygen saturation for April 2008 to May 2010 was more than 80% saturation which falls in Class 1 of Malaysia Marine Water Quality Criteria and Standard (MWQCS) established by the Department of Environment (DOE) for preservation, marine protected areas and marine park. pH was normal ranging from 7.66 – 8.58 whereas salinity was recorded at an average value of 32.19 PSU, which is neither hypersaline nor hyposaline. Low turbidity ranging from 0.00 – 9.42 NTU, was detected from April 2008 to May 2010. Temperature recorded was within range of 28 - 29°C between April 2008 and August 2009 except for May 2010 that depicted a value of 31.69 °C due to the regional sea surface temperature (SST) rise and caused mass coral bleaching in Malaysia. Although the total coverage for sessile marine organisms is still low, mainly to surrounding anthropogenic factors, the overall result showed that WABCORE deployed at Panuba Bay, Tioman Island exhibit the potential of establishing new habitat for corals and other sessile organisms.

Keywords : Artificial reef, marine sessile epibiota assemblage, corals, coral reef fishes, invertebrates, marine water quality

Introduction

Coral reefs are among the most valuable ecosystem on earth (Constaza et al, 1997), resembling tropical rainforests as coral reefs thrive under nutrient-poor condition, yet support rich communities through incredibly efficient recycling processes and exhibits high levels of species diversity with highest levels of total productivity on earth (Bryant et al, 1998).

However, a report by the World Resources Institute suggested that as many as 56% of the world's reefs are currently threatened. There are already 24% of the world's reefs that have been severely damaged or destroyed. Many reefs have been monitored and show a steady decline in live coral cover over the last 15 years. Some scientists reckon that by 2020 up to 70 percent might be permanently lost. Coral reefs worldwide are being continuously disturbed by natural and man-made stresses that severely deteriorate their condition (Wilkinson, 2000). Concern over the decline of natural coral reefs and loss of reef ecosystems around the world has prompted the establishment of artificial reefs to counterbalance these losses. Artificial reef (AR) has been suggested as a potential tool for reef restoration and rehabilitation (Clark & Edwards, 1999; Spieler, Gilliam, & Sherman, 2001). Artificial reef is a man-made submerged structure placed on the substratum (seabed) deliberately, to mimic some characteristics of a natural reef. Man-made structures such as piers, offshore oil platforms, sunken ships, and other large concrete and metal objects submerged in the marine environment eventually become incrusted with marine organisms through natural processes. They serve many of the same functions as naturally occurring "hard" substrates.

Man-induced damages to existing reefs e.g ship anchoring, dredging operations, pollution, and water quality degradation. Increased demands on reef areas for eco-tourism and recreation activities, including fishing, snorkeling, SCUBA diving, and recently proposed artificial reefs for surfing. Artificial reef provide areas for these activities, and relieve the stresses associated with high demand on natural reef areas. Another purpose for artificial reefs is using them as submerged breakwaters for shoreline stabilization. Breakwaters can reduce wave energy, providing protection for eroding beach areas. Therefore, it requires designs that will withstand the tremendous wave forces imposed by waves breaking directly on and over the submerged breakwaters.

The WABCORE (Figure 1), a composite system of concrete units developed by NAHRIM provides an alternative to the use of imported and costly artificial reefs. Concrete was chosen as it consists of cementing material, comprised primarily of calcium carbonate, which is the substance of coral reefs. Besides, concrete is extremely compatible with marine environment, highly durable, stable and readily available. The flexibility to cast concrete into a great variety of forms makes the material ideal for developing prefabricated WABCORE units. Furthermore, concrete provides excellent surfaces and habitat for the settlement and growth of encrusting or fouling organisms, which in turn provide forage and refuge for other invertebrates and fish.

Figure 1: WABCORE artificial reef being deployed for the first time in Panuba Bay, Tioman Island

Whilst possessing a simple Omega shaped design, the WABCORE unit's construction is not complex and the configurations may comprise between a single and more layers of WABCORE units. WABCORE was designed to be able to increase the effective overall reef sizes with its interlocking and stacking action, thus combining functionalities with flexibilities. A preliminary survey data collection was conducted to locate suitable site before the actual deployment to increase the chances of survival and coral growing on the artificial reefs. The first WABCORE structures in the form of stacking artificial reefs were deployed near Panuba Bay, Tioman Island in September 2005. The initial objectives of the reefs deployment was for the WABCORE to function as coral hosts and act as a protected habitat for its surrounding marine life. For this deployment, the WABCORE was constructed using Grade 25 concrete with 10mm reinforcement. The WABCORE is currently being tested in laboratory to function as coastal protection structure.

Objectives

The main objectives of this study are:

i. To determine exact positioning of the WABCORE;
ii. To determine the Marine Sessile Epibiota Assemblages on WABCORE;
iii. To determine the Coral Reef Fishes Assemblages on WABCORE;
iv. To determine the Invertebrates Assemblages on WABCORE.

Materials and methods

Study site

The positioning survey of the WABCORE blocks was conducted in 2007 at the waters of Panuba Bay, Tioman Island, Pahang where the WABCORE blocks were first deployed. The studies were conducted around the latitude and longitude of 2˚50.994'N and 104˚9.197'E respectively as shown in Figure 2.

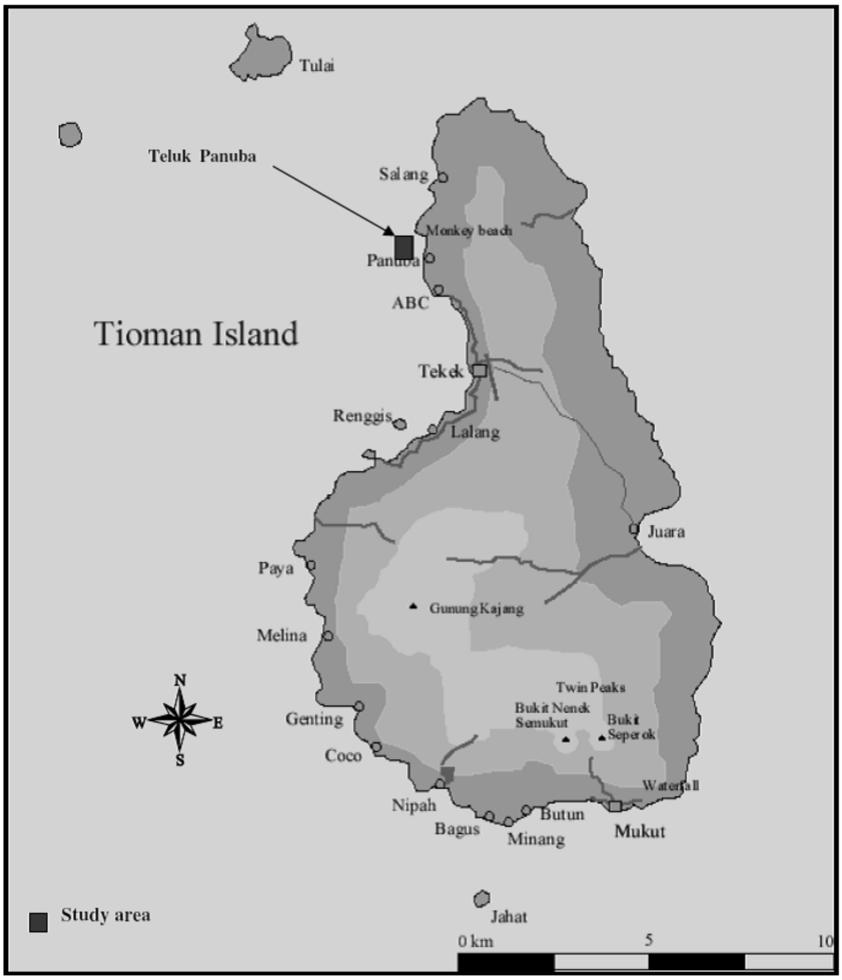

Figure 2: The location of WABCORE study site

Conducting a proper positioning survey is important as several organizations have raised concerns over the intentions of artificial reef used in various locations. Generally, the main concern is artificial reefs construction should not be used as ‘alternative’ for offshore dumping. Therefore, careful planning should go into placing artificial reef structures so as not to present navigational hazards, interfere with naturally occurring marine habitats, or block normal current flows and circulation of waters, especially in shallow bays.

Data collection

A positioning survey was conducted in November 2007 using Side Scan Sonar method. Detailed studies were carried out between 2008 and 2010 to determine the coverage of marine epibiota assemblage on the artificial reef clusters.

Marine Sessile Epibiota Assemblages

In-situ quantitative survey of subtidal epibiota assemblages including sessile invertebrates (hard corals, soft corals and sponges) and other live forms found on the artificial reef blocks were evaluated using quadrat technique (English *et al.*, 1997; Murray & Nature, 2001). Random quadrats of 0.5m x 0.5m (0.25m^2) made of polyvinyl chloride (PVC) pipe were fixed permanently for future monitoring and references. Polyvinyl chloride (PVC) pipe was used as material for these quadrats due to its durability. Each of the artificial reef blocks had three permanent quadrats placed randomly. All the quadrat markers were hammered into the substratum to ensure that they were secured. Recruitment, coverage and colony of each type of epibiota were recorded during April and August (post and pre monsoon season) between 2008 and 2010 with photographs taken at right angles to the reef substratum to indicate recruitment into the quadrat area and changes in the community pattern of the macrobenthos within the quadrat. A total of five (5) census or data collection was conducted starting April 2008 until May 2010.

Quadrat is chosen in this study because it provides a simple, repeatable non-destructive method, which is also suitable for a whole series of statistical tests; this makes it ideal for use in a long-term monitoring strategy. Quadrats are very versatile in terms of shape and size, and can be easily tailored to provide the best application for a whole range of different community types. Coverage (%) of the marine epibiota was calculated. Figure 3 shows some of the quadrats installed on WABCORE block clusters.

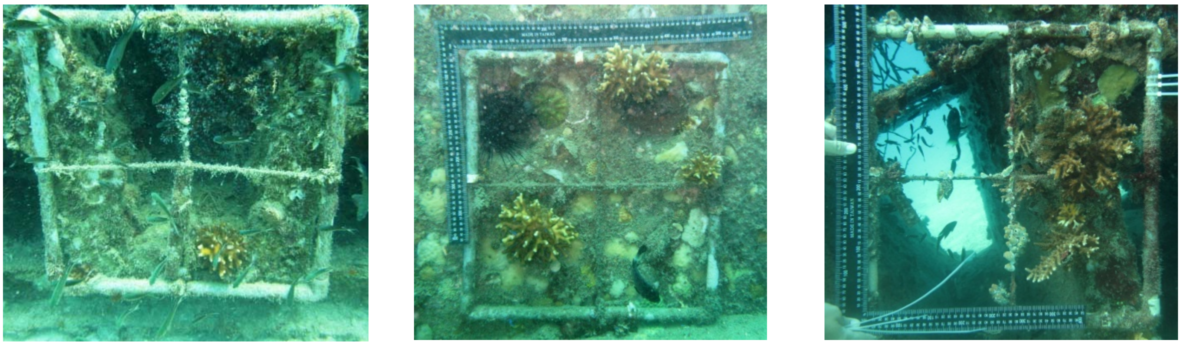

Figure 3: PVC quadrats installed on WABCORE artificial reefs

Coral Reef Fishes Assemblages

Coral reef fish populations were assessed by non-destructive visual census method using SCUBA during daytime. No specimens were taken for identification. Underwater photographs were taken for identification and future references. The method is useful to estimate relative abundance and is based on the assumption that the probability of encountering a species increases with its abundance.

Invertebrates Assemblages

Invertebrates were assessed by non-destructive visual census method using SCUBA during daytime around the artificial reefs. No specimens were taken for identification. Underwater photographs were taken for identification and future references.

Marine Water Quality Monitoring

Marine water quality at the artificial reef site was assessed with in-situ method at the Latitude of 2.85° and Longitude of 104.1532°. Water depth was around 4 – 6m. *In-situ* data of marine water quality at mid-depth consisted of pH, Dissolved Oxygen (DO), salinity, temperature, turbidity and total dissolved solids were measured using YSI Multiparameter Water Quality Sondes Model 6600 V2 twice a year during artificial reef monitoring from year 2008 to year 2010. The marine water quality data were then compared with the Malaysia Marine Water Quality Criteria and Standard (DOE, 2010)

Results and Discussion

WABCORE positioning survey provided side scan image of these 14 WABCORE blocks with exact position of longitude and latitude together with the dimensions and water depth in less time consuming approach. The position and location of the tagged artificial reef blocks deployed is shown in Figure 4 and Figure 5. The exact position of each WABCORE blocks was recorded in Latitude and Longitude using the Universal Transverse Mercator (UTM) projection, Zone 48N in WGS-84 datum. It was observed that WABCORE blocks were scattered at the seabed of Panuba Bay, approximately 200 m off the Panuba Bay beach, covering an area of 1,116m^2 at depths ranging from 4 m – 12 m (Mean sea level, MSL).

The WABCORE blocks identified were basically comprised of two types of single units with a height of 0.5 m and 0.8 m respectively, being stacked into single, double, triple and quadruple layers. 14 blocks of WABCORE from single unit to different stacking configurations were identified and tagged manually by divers from A1 to A15 with A6, a natural patch reef near the WABCORE blocks, act as control.

Figure 4: Side Scan Imaging showing the position and location of WABCORE blocks

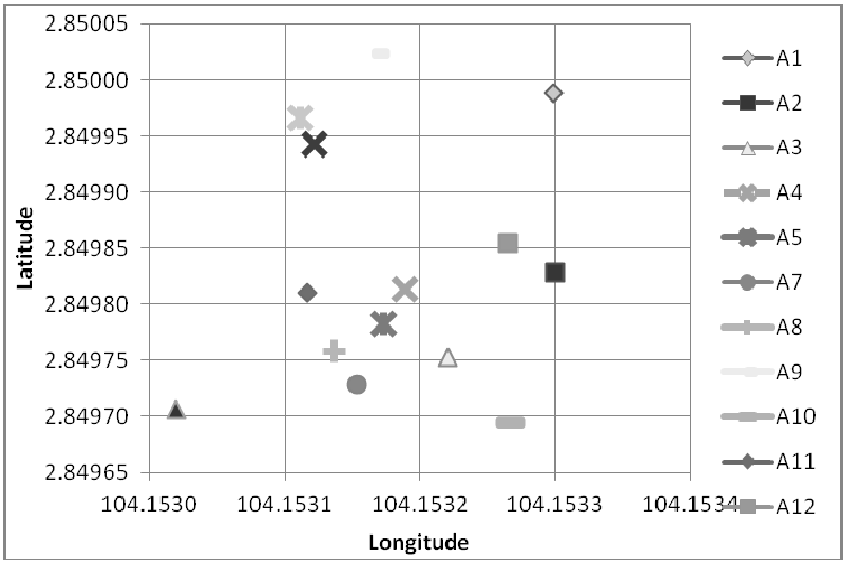

Figure 5: The layout location of each WABCORE blocks

For marine sessile epibiota assemblages, a total of 42 permanent quadrats were placed randomly onto the 14 artificial reef clusters with three quadrats on each block, occupying a total area of 10.50 m^2 (1.05 x 10^5 cm^2) where each quadrat had an area of 0.25 m^2. The coverage (%) of marine epibiota recorded using the quadrat method between 2008 and 2010 is as shown in Figure 6.

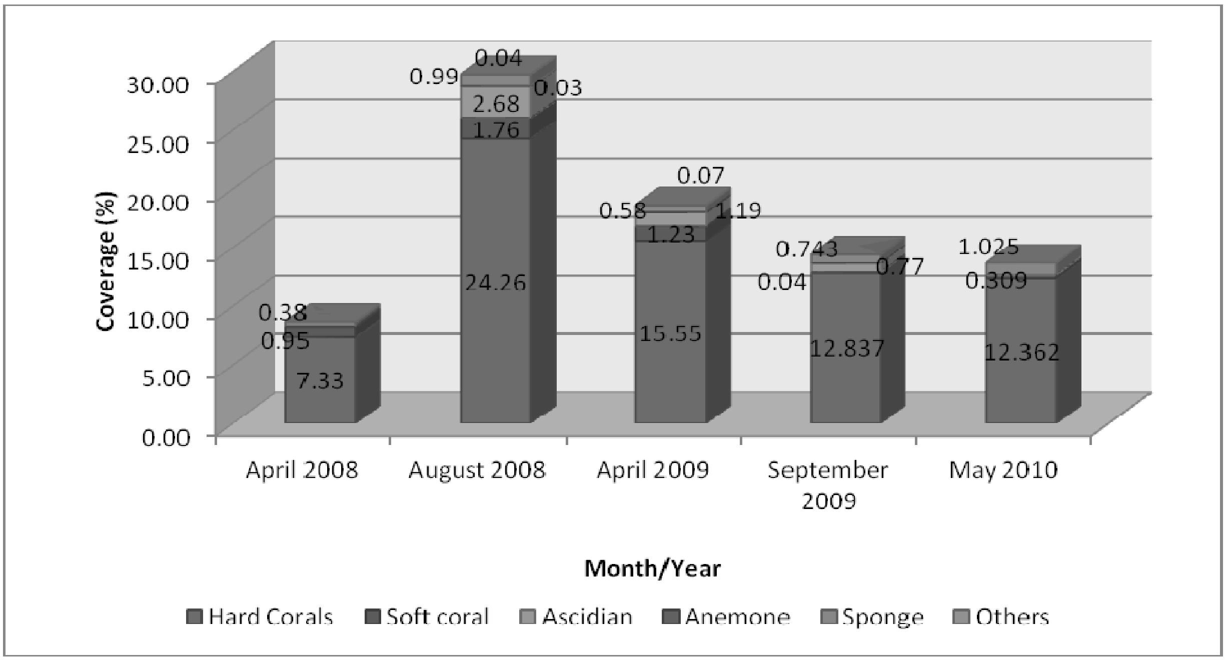

Figure 6: Total coverage (%) of marine epibiota from April 2008 to May 2010

From Figure 6, it was observed that hard corals dominated the total marine epibiota coverage where hard coral had the total coverage of 7.33%, 24.26%, 15.55%, 12.84%, 12.36% for April 2008, August 2008, April 2009, September 2009 and May 2010, respectively. The minor marine epibiota found on the WABCORE were soft corals, ascidians, sponges and anemone.

It was also observed that total hard corals coverage increased from April 2008 to August 2008 but decreased gradually from April 2009 to May 2010. Hard corals within the quadrats were observed to be bleached and died as shown in Figure 7. This phenomenon might be caused by anthropogenic activities, sedimentation or high turbidity around the WABCORE area due to active diving activities stirring up the sediment at the seabed, attack of Crown-of-Thorn star fish as well as the increase of water temperature that caused coral bleaching. Coral bleaching was detected in Tioman Island starting April 2010 and the temperature recorded during low tide on 11-12 May 2010 was approximately 30^{o}C. Observation on August 2010 revealed that most of the corals bleached and died during the sea temperature rise period. Some of the bleached or dead corals are as shown in Figure 7. However, it is anticipated that these dead corals would be the base for the colonisation of other coral species in the future.

)Crown-of-Thorn (COT) detected feeding on the ›rals within the quadrat.

›)Coral bleached and died between May and ugust 2010

Figure 7(a) & 7(b): The condition of corals within the quadrats

It was observed that the marine epibiota covered a total area of 8.66% from the total area of the artificial reefs on April 2008 and increased to 29.75% on August 2008 where August 2008 depicted the highest coverage among all the studies conducted. The total marine epibiota coverage (%) decreased gradually starting April 2009 to May 2010 from 18.62%, 14.39% and 13.70%, respectively. This phenomenon might be due to factors such as stress from human activities including diving activities at the artificial reefs site where observation during the census depicted that some corals in the quadrats were destroyed, fishing nets were found trapping on the artificial reef blocks, fishing traps were deployed around the artificial reefs site as well as the mooring of boats utilising the artificial reef blocks as anchors for the boats as shown in Figure 8.

)Coral debris (Photo taken on 12 May 2010).

)Ray fish trapped in the fishing net (Photo taken ı 11 May 2010).

)One of the fishing trap found at the /ABCORE site (Photo taken on 11 May 2010).

l)The collapse of artificial reef block A1 due to equent anchoring of boats and the ropes tied to the /ABCORE were connected to boats on the water ırface (Photo taken on 11 May 2010).

Figure 8 (a)-(d): Anthropogenic activities affecting the study at the WABCORE site

Non-destructive census conducted between 2007 and 2010 showed the coral reef fishes showed an increase in fish species as shown in Figure 9. It was observed that the initial study during September 2007 recorded 20 species of coral reef fishes. The species then increased to 29 species, 45 species, 55 species, 62 species and 66 species for April 2008, August 2008, April 2009, September 2009 and May 2010 respectively. This condition revealed that the WABCORE was favourable and suitable as habitat for coral reef fishes as the total species was increasing.

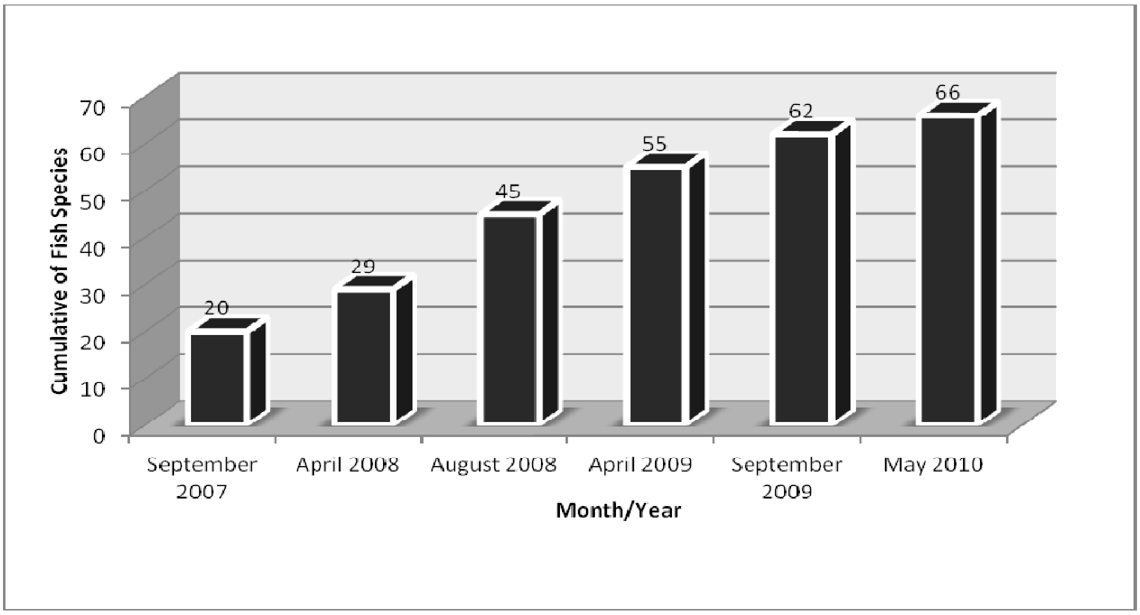

Figure 9: Cumulative coral reef fishes species recorded from September 2007 to May 2010

Figure 10 shows the cumulative invertebrates recorded. It was observed that the invertebrates recorded during September 2007 was 15 species and increased to 17 and 18 species during April 2008 and August 2008, respectively. In April 2009, the total species of invertebrates increased to 31 species and then increased to 36 and 38 species on September 2009 and May 2010 respectively. This shows that WABCORE is suitable to serve as new habitat for invertebrates and has the potential to mimic natural reefs in the future.

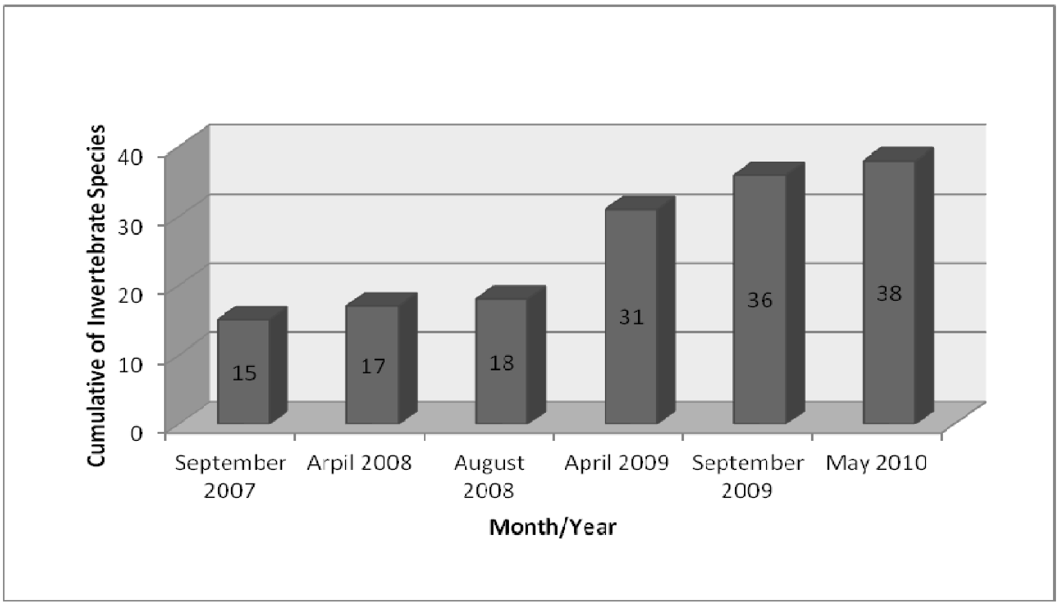

Figure 10: Cumulative invertebrates recorded between September 2007 and May 2010

In order to monitor the condition of the artificial reef environment, *in-situ* water quality data were measured from April 2008 to May 2012 for five times simultaneously with the artificial reef monitoring programmes. Data was collected for three days and mean data was calculated. The *in-situ* marine water quality data at the artificial reef site is shown in **Table 1**.

Table 1: Marine Water Quality at WABCORE artificial reef site, Tioman Island.

Month/ Year	Temperature (°C)	pH	Salinity (ppt)	[DS (g/l)	SpCond (mS/cm)	)O (mg/l)	DO (%)	Turbidity (NTU)
pril 2008	29.78	8.58	34.32	26.84	53.07	4.10	62.5	1.83
ugust 2008	28.53	8.22	33.69	33.42	54.89	6.05	93.97	9.42
pril 2009	29.62	8.44	30.84	30.29	47.16	6.93	110.03	4.55
ugust 2009	29.54	7.66	32.92	32.1	50.13	3.73	55.99	0.00
ay 2010	31.69	8.17	29.17	29.48	45.36	6.49	103.6	0.00
[ean	**29.83**	**8.214**	**32.19**	**30.43**	**50.12**	**5.46**	**85.22**	**3.16**

It was observed that temperature was almost the same from April 2008 to August 2009 (below 30 ℃) except for May 2010 which recorded a temperature of 31.69 ℃. This was due to the short term sea surface temperature (SST) rise during year 2010 that caused mass coral bleaching in Malaysia and the global. The elevated sea temperature of 1 – 2°C within 5 – 10 weeks will induce coral bleaching. Photosynthesis in zooxanthellae would be impaired at temperature above 30°C and could lead to the activation of the disassociation of coral/ algal symbiosis, causing coral bleaching (Buchheim, 1998).

pH was normal, ranging from a value of pH 7.66 – 8.58. Salinity depicted an average value of 32.19 PSU, which is normal for coastal waters, not hypersaline or hyposaline. Low turbidity ranging from 0.00 – 9.42 NTU, was detected from April 2008 to May 2010. However, the dissolved oxygen (DO) from April 2008 to May 2010 depicted inconsistency of complying with the Malaysia Marine Water Quality Criteria and Standard (MWQCS) Class 1 standard for preservation, marine protected areas and marine park which should have the value of more than 80% saturation. It was observed that DO saturation for April 2008 was measured at 62.5% whereas DO saturation for August 2009 was recorded at 55.99% only. In overall, the mean DO saturation was still within the range of MWQCS Class 1 standard by recording more than 80% DO.

Although the marine water quality around the artificial reef site was in good condition, precautionary approach should be taken to avoid the deterioration of the marine environment. Other parameter like total suspended solid (TSS) should be monitored as the increase of TSS would reduce the light penetration into the water. Insufficient light would disrupt the process of photosynthesis process of endosymbiotic algae (zooxanthellae), leading to coral bleaching and coral death.

Conclusion

Studies and monitoring conducted between 2007 and 2010 showed that WABCORE depicted high efficiency in the establishment of new marine ecosystem and habitat for corals, sessile benthos, coral reef fishes and invertebrates. WABCORE was effective in providing protection and shelter for octocorals, coral reef fishes and invertebrates as well as serving as breeding ground for some of the marine organisms recorded including fishes, nudibranchs and sea shells. Besides, WABCORE also serves as the host for corals growth as it's surfaces are occupied with various hard corals and soft corals.

Additionally, WABCORE have also depicted a positive and encouraging potential in the conservation of natural marine resources as the artificial reefs site has various population of corals, ascidian, anemone, coral reef fishes and invertebrates. A total of 46 hard corals were discovered (Debelius, 2004 & Ho, 1992) around the artificial reefs site with 23 identified to species level whereas 23 hard corals were determined to genus level. A total of 7 genera consisted of *Sarcophyton*, *Dendronephthya*, *Carijoa*, *Umbellulifera*, *Leptophyton*, *Lobophytum* and *Sinularia* were determined for soft corals (Fabricius & Alderslade, 2001) whereas 3 genera of *Acabaria*, *Annella* and

Acanthogorgia were determined for gorgonians. As for coral reef fishes, 33 types of fishes from 33 families were determined (Lieske & Meyers, 2001). From these 33 families, 66 species of fishes were identified. As for invertebrates, 10 types of invertebrates consisted of feather stars, sea stars, sea cucumbers, nudibranchs, cephalopods, sea urchin, sea shells, jellyfish, marine worms, and crustaceans were recorded (De Bruyne, 2003)

Although the total coverage for sessile marine organisms is still low (average of 17.02% between April 2008 and May 2010), due mainly to surrounding anthropogenic factors, the overall result recorded showed that WABCORE deployed at Panuba Bay, Tioman Island exhibit the potential of establishing new habitat for corals and other sessile organisms such as anemone, ascidians, sponges and marine plants. In conclusion, WABCORE developed and deployed by NAHRIM at Panuba Bay have attracted various types and species of corals, coral reef fishes and invertebrates and could play an essential role to aid in the establishment of new marine ecosystem.

Recommendations

Artificial reefs have to be deployed at the depth which will not obstruct shipping traffic, yet accessible by scuba diving or snorkelling, sufficient light penetration for optimum coral growth and the photosynthesis process by zooxanthellae coral larvae. Besides, artificial reefs have to be deployed at the seabed with less anthropogenic activities like resorts which might affect the water quality due to discharge from these resorts. Information on coral cover over the long-term is not sufficient to determine whether a reef is healthy. A healthy reef must have young recruits, and monitoring coral recruitment is important to identify coral reef areas that function as a source or sink of larvae. Such information can determine recovery potential of a reef after disturbance. Exisiting or future artificial reef programs should continue to share their experiences (successes and failures) with other reef programs nation-wide.

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