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Macrofouling Development on Artificial Structure at Karambunai Bay, Sabah Malaysia

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Abstract. This study investigates macrofouling development on PVC panels deployed in Karambunai, Sabah. The experimental setup includes two sets of connected PVC pipes, framed in a triangular shape, attached to concrete blocks deployed on the seafloor and kept afloat vertically underwater. The first set (upper) of frame positioned 2 m below the surface whereas the second set (bottom) attached 8 m below it. A total of 36 PVC plates measuring 20 cm x 27 cm were tied on each three sides of the two sets of frames. To investigate monthly macrofouling development, three panels were taken from each side of the two frames. This experiment lasted 180 days, starting from end of April to October 2017. As a result, a total of ten different species were identified growing on the front side and the back side of the plates at 2 m and 8 m. The total biomass of macrofouling assemblages at 2 m and 8 m had a significant ($P<0.05$) positive correlation (0.89), suggesting that there was no significant difference of total biomass between two different depths. For macrofouling community, diversity indices showed similar values for both sides of the plates at 2 m and 8 m, indicating that depth and plate orientation had no influence on the distribution pattern of macrofouling growth.

1. Introduction

Macrofouling, one of two types of biofouling, can be described as growth of organisms on a man-made artificial structure that cause destructive impacts and it can affect human interest in many ways depending on the organism's stage of development, species type, geographical location and the type of structure they occupy [1][2]. In the maritime industries, biofouling is one of the major factors that can affect the operation, maintenance and quality of performance of devices and structures. It is reported that biofouling cost the maritime industry a loss of more than US $6.5 billion mainly from higher fuel consumption due to increased drag and frictional resistance during ship movement, and regular maintenance involving cleaning and painting of ships [3][4]. The list of affected structures has lengthened in the past few eras from the increase use of marine environment that includes seawater piping systems, industrial intakes, oil rigs, moored oceanographic instruments and facilities associated with aquaculture operation [1]. Other than that, biofouling also caused the introduction of new species, which can have serious ecological impacts to the composition of native species of the surrounding water bodies [5].

Sabah is one of many states in Malaysia where development of various facilities is rapid along the coastal areas and it is expected that macrofouling may become a problem. However, present information pertaining to macrofouling in Sabah is still lacking and thus requires more study to generate information for better management and mitigation measures of macrofouling. The present study investigated macrofouling on an artificial structure deployed in the shallow waters of

Karambunai Bay, Sabah. We determined the development rates of macrofouling and causal species, in relation to submersion time and depth.

2. Materials and Methods

As described in Affandy *et al*. [6], the experiment was carried out for 180 days starting from end of April 2017 to early of October 2017 at Karambunai Bay situated in the west coast of Sabah, Malaysia. The sea bed is sandy with soft substrata and at the time of study, a few artificial reefs made up of car tyres were found within the study site. Two sets of interconnected artificial structure were deployed at 2 meter (2 m) and 8 meter (8 m) (N 06.13645' E 116.11670') (**Figure 1**) and each of the structure were made of PVC pipes that had three frames combined together, forming a triangle. Each frame had 13 PVC plates, with each plate measuring 20 cm x 27 cm, attached to it (**Figure 2**). Prior to the deployment of the artificial structure, each PVC plate was weighed. PVC was chosen for this experiment because it is non-corrosive and more durable in the marine environment compared to other types of material [6].

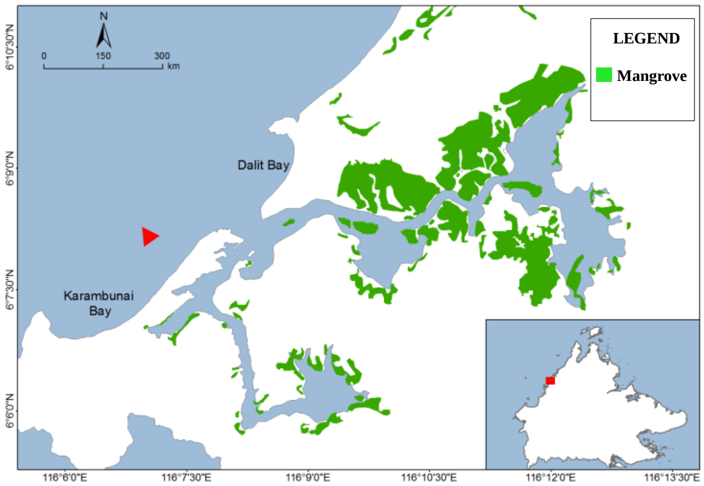

Figure 1. Location where the artificial structure was deployed (marked in red) in Karambunai Bay, Sabah.

Thereafter, 6 plates (3 plates from the 2 m and another 3 from 8 m) were collected at 30 days interval (depending on weather conditions) and stored in zip lock bags for further analysis. At the laboratory, each plate was cleaned under a running tap water and shook, to ensure mobile organisms fall into the basin. Total wet biomass (wet weight in gram), of sessile and mobile macrofouling were then determined for each plate. For the biomass of sessile macrofouling, it is the difference between the weight of each plate after submersion and the weight recorded prior to submersion whereas the biomass of mobile macrofouling refers to the weight of fauna collected in the basin. Both sides of the plates (front side refers to the side that was facing the net current while the back side refers to side that was shielded from the net current) were photographed to record the presence of sessile macrofouling. Grid lines were added on the photographed plate through image processing software, ImageJ. Using the grid lines generated the sessile macrofouling organisms were subsequently identified and enumerated through percentage cover (%) of each species present on the PVC plates. However, percentage cover data of each species was not reported in this paper. Macrofouling species on PVC plates was then identified to the lowest possible taxa following various references (Bryozoan [8]; Macroalgae, seaweed, hydroids and cyanobacteria [9][10][11][12]; Bivalves [8]; Fish [12];

Crustaceans [13][14]; Polychaetes [15]) and were verified using World Register of Marine Species (WoRMS) (http://www.marinespecies.org/).

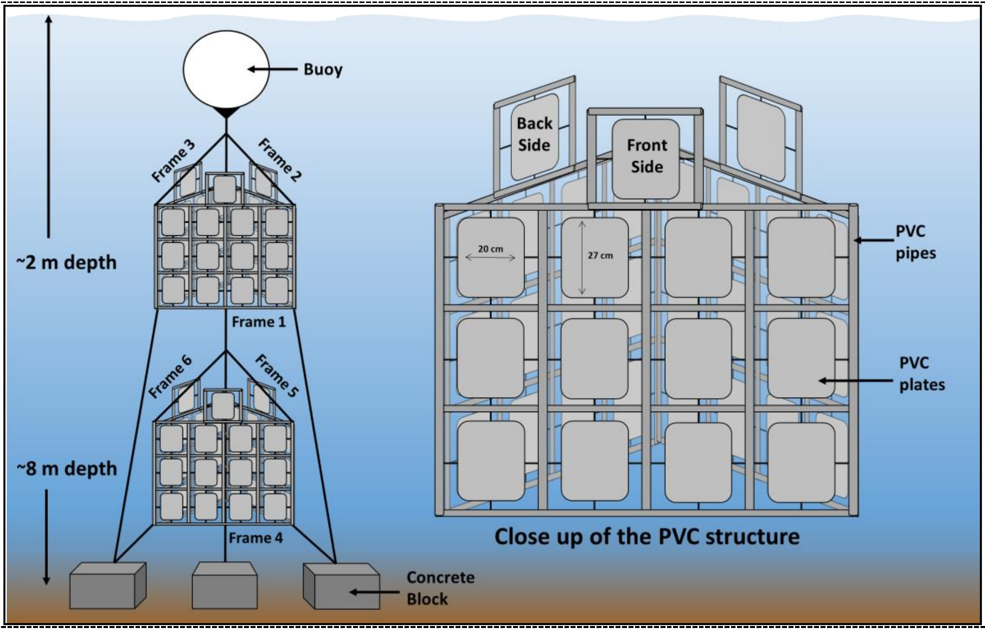

Figure 2. Experiment setup made mainly out of PVC materials. Three frames (1,2,3 and 4,5,6) were tied together, forming a triangle with each frame had 13 PVC attached to it.

Computed biomass data of both sessile and mobile macrofouling were subjected to logarithmic transformation (log x + 1) to achieve normality and homogeneity of variance before statistical analysis. Two-ways ANOVA was used to investigate the possible effect of submersion time (30, 60, 90, 120, 150 and 180) and depth (2 m and 8 m) on the biomass of sessile and mobile macrofouling.

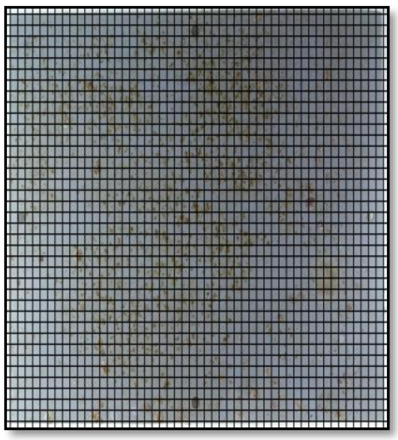

Figure 3. An example of a plate with grid lines added using ImageJ software.

3. Results and Discussion

Table 1. Presence and absence data of sessile and mobile species that appeared on PVC plates collected from frame 1, 2, 3 at 2 m depth and 4, 5, 6 at 8 m depth at Karambunai Bay at intervals over a total of 180 days. Note: (+), (+f) and (+b) indicate the presence of one taxon at both side, front side and back side of the plates, respectively.

Taxa/Species	**Frame 1,2 & 3**						**Frame 4,5 & 6**					
	30	**60**	**90**	**120**	**150**	**180**	**30**	**60**	**90**	**120**	**150**	**180**
Phylum Annelida												
Polychaeta												
Perinereis sp.		+	+	+	+	+	+	+f	+	+	+	+
Phylum Arthropoda												
Maxillopoda												
Amphibalanus sp.	+	+	+	+	+	+	+	+	+	+	+	+
Capitulum sp.			+f									
Malacostraca												
Etisus sp.		+	+	+	+	+		+	+	+	+	+
Phycnogonida												
Nymphon sp.	+	+	+f				+	+	+f			
Phylum Bryozoa												
Gymnolaemata												
Acanthodesia sp.	+b	+		+	+	+f	+	+		+f	+	+
Phylum Cnidaria												
Hydrozoa												
Eudendrium sp.			+f	+	+	+	+b		+	+	+	+
Phylum Chordata												
Actinopterygii												
Blenniidae		+	+	+	+	+		+	+	+	+	+
Phylum Cyanophyta												
Cyanophyceae												
Lyngbya sp.	+	+	+				+	+	+			
Phylum Mollusca												
Bivalvia												
Isognomon sp. 1		+f	+	+b	+	+		+	+	+b	+	+
Isognomon sp. 2			+	+	+	+		+	+	+f	+	+
Phylum Rhodophyta												
Florideophyceae												
Chondria sp.			+						+			
Gracilaria sp.		+f	+					+				
Species Richness (D)	**4**	**9**	**12**	**8**	**8**	**8**	**6**	**10**	**10**	**8**	**8**	**8**

As shown in **Table 1**, 9 sessile species were found growing on both sides of the plates at 2 m and 8 m depths namely *Lyngbya* sp., *Acanthodesia* sp., *Amphibalanus* sp., *Isognomon* sp. 1, *Isognomon* sp. 2, *Gracilaria* sp., *Chondria* sp., *Eudendrium* sp., *Capitulum* sp. and 4 mobile species namely *Etisus* sp., *Nymphon* sp., *Perinereis* sp. and fish larvae of Family Blenniidae [7]. The number of species found in this study was less compared to the study by Ong and Tan [16], where 27 species which comprises of a variety of soft corals, sponges, hydroids and macroalgae were found. The dissimilarity in the results could be attributed to the difference in submersion time and the number of sampling location. As for total average biomass (**Figure 4**), there was a noticeable difference between the average biomass of macrofouling at 8 m (0.25 kg ± 0.003 kg) and at 2 m (0.07 kg ± 0.00 kg) after 90 days. This could probably be due to the high settlement of barnacles on the plates at 8 m compared to at 2 m. According to previous study [17], settlement of barnacle can boost recruitment of fucoid algae by reducing desiccation stress cause by incoming currents or herbivore pressure presented by other types of algae. Other than that, barnacle and mussels, particularly zebra mussels can helped improve water clarity and prominently impact phosphorus content on water [18][19][20][21].

Table 2. Two-way ANOVA of sessile species with submersion time and depth. Note: (*) indicate significant value of relationship (P<0.05).

	df	Sum Sq	Mean Sq	F-value	Pr(>F)
Time	5	0.454	0.091	22.626	$2.3e^{-8}$*
Depth	1	0.023	0.023	5.613	0.03*
Time:Depth	5	0.008	0.002	0.376	0.86
Residuals	24	0.096	0.004		

Table 3. Two-way ANOVA of mobile species with submersion time and depth. Note: (*) indicate significant value of relationship (P<0.05).

	df	Sum Sq	Mean Sq	F-value	Pr(>F)
Time	5	690.89	138.179	1.892	0.13
Depth	1	312.82	312.82	4.284	0.05*
Time:Depth	5	89.79	17.96	0.246	0.94
Residuals	24	0.096	0.004		

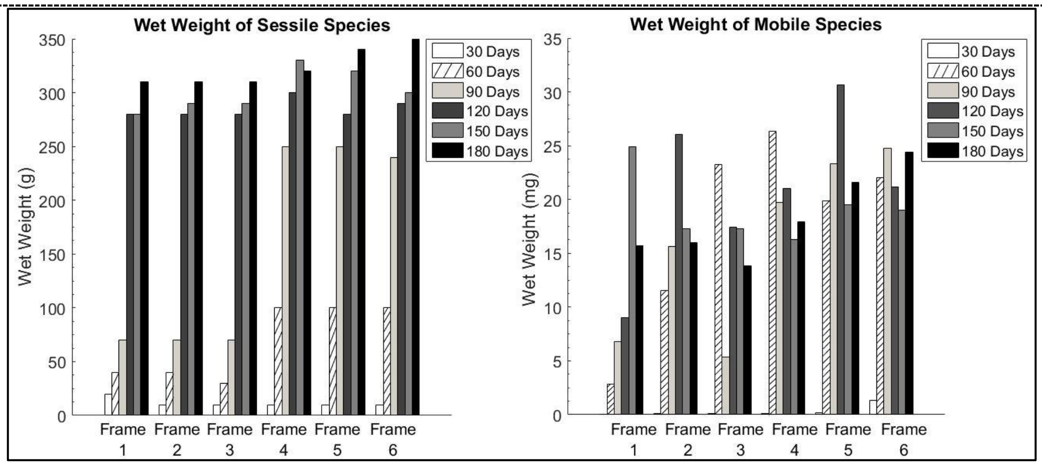

Figure 4. Macrofouling biomass of frame 1, 2 and 3 at 2 m and 4, 5 and 6 at 8 m of sessile (in kg) and mobile species (in mg) throughout 180 days of experiment.

There was a statistically significant interaction between the effect of submersion time and depth on the wet weight of sessile species (P<0.05). Development rates of macrofouling biomass was higher at 8 m depth during the first 90 days, as the total biomass of plates from frame 4, 5, and 6 were approximately 0.35 kg, which was about 2 times higher compared to frame 1, 2 and 3 (at 2 m depth), which has a wet weight of no more than 0.10 kg. This could probably be due to high settlement of barnacles at 8 m compared to at 2 m. The difference in the wet weight of PVC plates throughout 90 days of experimentation could be due to stronger current at 2 m due to wave action near the surface. According to Wethey [22], the settlement of macrofouling species has been found to strongly correlate with the characteristics of boundary-layer flow (shear stress) under the motion of current and wave. Lower shear stress would increase the chances of settlement as firm adhesion to the plate surface would be more successful compared to higher shearing stress. Towards the end of the experiment, the difference was reduced as both depth strata attained similar amount of biomass. This is because the plates at 2m depth caught up in terms of number of individual.

As for the mobile species, a distinct increase in biomass after 30 days at all frames was observed. Possible reason is that there was less settlement of sessile organism on the plates prior to Day 30 which is a food source for these mobile organisms. An increase in sessile organisms therefore led to an increase in mobile organisms. Statistical analysis using two-way ANOVA showed that depth had significant interaction with the wet weight of mobile species ($P<0.05$). These findings were similar to Rico *et al.* [23] where they found that depth plays a major role in structuring the fouling community, as macroalgae were dominant on the plate attached near the surface, while invertebrates were more common at the bottom.

4. Conclusion

Holistically, there were 13 different fouling species (sessile and mobile) found at all frames on both sides of the PVC plates at 2 m and 8 m. Based on two-way ANOVA, there was a significant interaction on wet weight of sessile species on submersion time and depth. However, for mobile species, the wet weight only had a significant interaction with depth.

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