STATUS OF CORAL REEFS AND SEDIMENTATION AT KOTA KINABALU: A PRELIMINARY STUDY AT GAYA BAY AND SEPANGAR BAY

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ABSTRACT. *Sedimentation is considered as one of the major factors that cause degradation of coral reefs in coastal areas. This study examined the effect of sedimentation on coral reefs at Gaya Island (Gaya Bay), Sepangar Island and UMS jetty (*Sepangar *Bay). At each location, two depths were surveyed, between 3m - 5m and between 7m -10m. The status of coral reefs was surveyed by using Line Intercept Transect, Fish Visual Census and Invertebrate Belt Survey. Two 20m line transects were laid at each depth. Sedimentation rates were measured by placing sediment traps at areas where the reef was surveyed. The sediment traps were collected once a month and further laboratory analysis was undertaken to determine the sedimentation rate, calcium carbonate content, organic matter content and sediment composition. Coral reef surveys conducted at all the sites showed that three sites were in fair condition (25-50% hard coral cover) while the other three sites were in good condition (50-75% hard coral cover). The low levels or absence of indicator species suggest overexploitation of the invertebrates and fishes on the reef. The mean sedimentation rate measured at the UMS jetty was higher than Gaya Island and* Sepangar *Island (126.25 ± 86.58 mg/cm2/day, 3.15 ± 1.75 mg/cm2day and 7.62 ± 6.9 mg/cm2/day, respectively). Results suggested that more detailed studies and continuous monitoring are required to investigate the effects of sedimentation on status of coral reefs.*

KEYWORDS. *Coral reefs, sedimentation, Gaya Bay,* Sepangar *Bay*

INTRODUCTION

Malaysia has a vast area of highly diversified coral reefs of approximately 4,000 km^2, of which more than 75% of these reefs situated in Sabah (Burke *et al.*, 2002). Coral reefs are ecosystems with high productivity and are very important in supporting coastal fisheries primarily by providing nursery grounds to many juvenile fishes. In addition, reefs also act as buffer zones that protect the coastal area from erosion by reducing the wave energy to the shore. Furthermore, this fascinating ecosystem offers immense recreational opportunities that attract tourists. Lastly, scientific findings have proven that reef communities hold many medicinal values (Sammarco, 1996).

Corals require a specific combination of environmental conditions to survive. Typically, corals thrive in clear waters, as the symbiotic algae (zooxanthellae) that corals depend on need sufficient sunlight to actively carryout photosynthesis (Gleason, 1998).

Warm water (23-25°C) (Nybakken and Bertness, 2005) with low nutrient (Leão & Kikuchi, 2005), normal salinity (32-35 ppt) (Nybakken and Bertness, 2005) and is free from pollution is essential for coral growth (Brodie *et al.*, 2001). Firm substrate is also a requisite for coral recruitment. Due to these limitations, coral reefs are depth limited and are typically found in shallow areas in tropical regions (Nybakken and Bertness, 2005).

Increasing levels of human activity along coastal areas have put pressure on these conditions and threaten the health and viability of coral reefs. Disposal of waste such as sewage, pesticides, heavy metals (Bastidas *et al.*, 1999), rubbish and other by-products of human activities in coastal areas cause many problems for the coral reef ecosystem (Leão and Kikuchi, 2005; Thomsen and McGlathery, 2006). One of the visible consequences of human activities for the coastal waters is sediment pollution (McClanahan and Obura, 1997).

The existence of substances such as sediment in the water column can decrease light penetration and therefore deprive corals of zooxanthellae (Nybakken and Bertness, 2005). This is one of many causes of coral bleaching. Sediments that settle on corals can choke the polyps and cause the symbiotic zooxanthellae to be expelled from corals or die. The increase in sedimentation can deteriorate the health of reefs and cause adverse effects on the whole ecosystem in terms of coral biodiversity (Edinger *et al.*, 1998). Reefs with good health are usually reflected in the high number and diversity of species of live corals, fishes, invertebrates and other biota living within the area (Subade, 2007).

In the present study, we examined the general status of the coral reefs (which includes indicator fishes, invertebrates and other benthic life) at three sites around Kota Kinabalu that are exposed to different scales of sedimentation.

MATERIALS AND METHODS

Study site

The study was conducted at selected sites at Gaya Island (Police Beach, Gaya Bay), Sepangar Island and Universiti Malaysia Sabah (UMS) jetty (Sepangar Bay) (Figure 1). Police Beach at Gaya Island is part of the Tunku Abdul Rahman Marine Park, Kota Kinabalu.

Police Beach (06º 01.891' N, 116 º 01.657' E) is reserved and managed as a marine park since 1974 by Sabah Parks. No human activities are allowed in this area except for scientific research conducted with permit. The coral reefs at Police Bay are protected by laws and regulations from destructive fishing methods and land-based developments. Sepangar Island (06 º 03.615' N and 116 º 04.001' E) was chosen as a study site as it is situated away from human populations. The UMS jetty is located in front of the UMS boathouse (06 º 02.435' N, 116 º 06.564' E), in between the Menggatal and Inanam rivers.

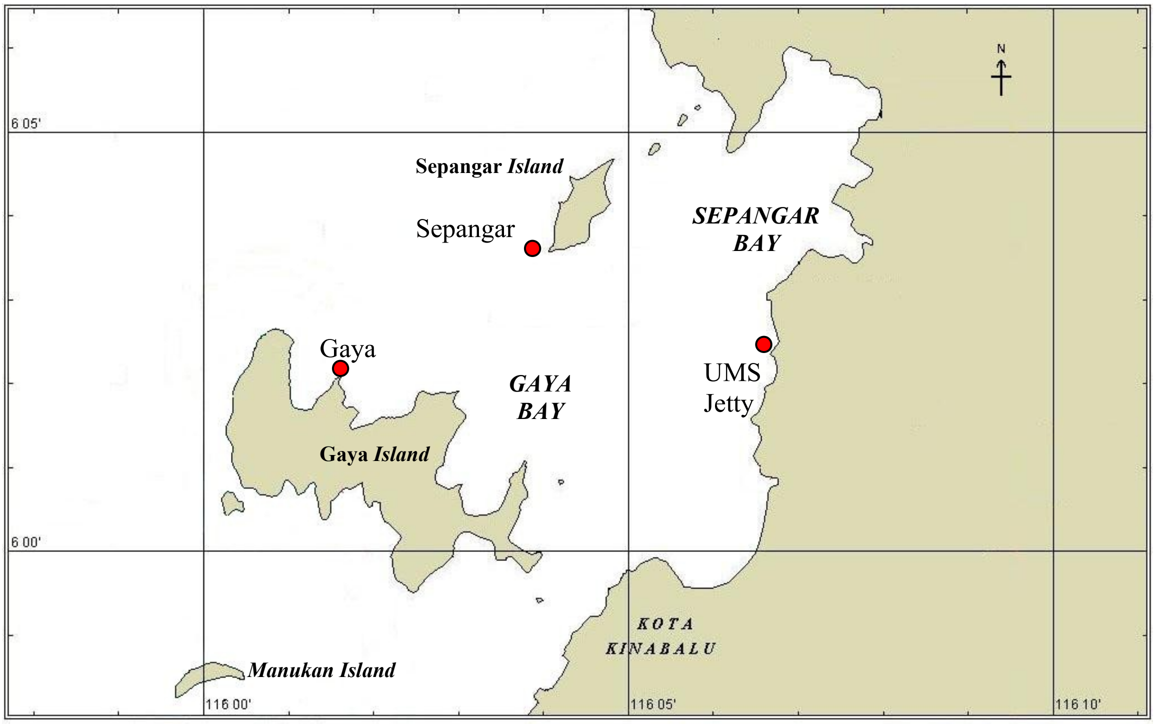

Figure 1. Location of the study sites at Gaya Bay and Sepangar Bay

Data collection and analysis

The status of the coral reef was determined by using the Reef Check monitoring protocol (Hodgson *et al.*, 2004) with minor modifications to suit the reef environment. Reef Check includes the Fish Belt Transect and Invertebrate Transect while the benthic survey was carried out using the Line Intercept Transect (LIT) method (English *et al.*, 1997). Indicator species of fish and invertebrates were recorded in order to get a picture of the general condition of the reef. The surveys were carried out along two 20m transect lines at depths of between 3m - 5m and 7m - 10m, which were laid parallel to the shore.

Sediment deposits in the study sites were sampled using sediment traps, which contained three bottles that remained upright with fixed position underwater (English *et al.*, 1997). Each sediment trap was covered with an iron-mesh netting (mesh size of 1 mm) and secured by rubber bands. The netting was used to prevent fishes, crustaceans or molluscs from entering and re-suspending the sediment collected in the bottles. At each site, two sets of traps were installed at the depths of 5 m and 10 m. The samples were collected and replaced each month for three months (October – December 2005). Approximately 500 ml of water samples were also collected from each site at both depths using a water sampler each time the sediment traps were collected.

Sedimentation rates (mg/cm^2/day) were determined by dividing the dry weight (in mg) with the area of the sediment trap aperture width (in cm^2) over the duration (in days) the sediment trap was placed underwater. Then the particle size and organic content of sediment deposits were estimated for each site by using sieving and BOT method respectively.

RESULTS

Reef fish indicators

Several fish indicator species were recorded at the transects of the study site (Table 1). The butterflyfish is an indicator of good live coral cover and was observed at each site on the shallow transect. The snapper, sweetlips and grouper are species with high commercial value. Hence, they are commonly overfished from the reef and make good indicators of overfishing. Sweetlips were only sighted at Gaya along the shallow transect, however, snappers were not seen at any sites. Groupers were the most abundant fish indicator and were found at almost every site. The parrotfish are good indicators of algae coverage and were mostly found at Sepangar, which also is the site with the highest number of fishes when compared to the other sites.

Table 1. Fish indicators that were recorded at the study sites

Depth	Location	Butterflyfish	Snapper	Sweetlips	Grouper	Parrotfish	Total
3m - 5m	Gaya	4	-	3	2	2	11
	Sepangar	2	6	-	6	3	17
	UMS	2	4	-	-	1	7
7m - 10m	Gaya	2	-	-	1	-	3
	Sepangar	5	-	-	12	14	31
	UMS	-	12	-	3	-	15
	Total	**15**	**22**	**3**	**24**	**20**	**84**

Reef invertebrate indicators

The invertebrate indicators that were recorded at the study sites along the transects are given in Table 2. The giant clams and edible sea cucumber have high economic value and are good indicators of overharvesting. Giant clams were only recorded at Gaya while sea cucumbers were found at almost every site except at Gaya (7m-10m). The long-spined sea urchins are indicators of algal abundance and are harvested by the local communities for food. The urchins were the most abundant invertebrate indicator, but were only recorded at the shallow transects of every site. The Crown-of-thorns starfish (COT) are usually found at areas with good live coral cover. In this study, they were only found at Sepangar.

Table 2. Invertebrate indicators that were recorded at the study sites

Depth	Location	Giant Clam	Long-spined Black Sea Urchin	Edible Sea Cucumber	Crown-of-thorns Starfish	Total
3m - 5m	Gaya	3	4	2	-	9
	Sepangar	-	6	4	3	13
	UMS	-	9	4	-	13
7m - 10m	Gaya	2	-	-	-	2
	Sepangar	-	-	3	2	5
	UMS	-	-	1	-	1
	Total	**5**	**19**	**14**	**5**	**43**

Benthic components of the bottom substrate

The benthic components were categorised into five major components, abiotic components, dead corals, hard corals, other fauna and algae (Figure 2). The hard corals were divided into *Acropora* and non-*Acropora* corals following the AIMS GCRMN method (English *et al.*, 1997). UMS jetty had the highest percentage of abiotic component (55.95%) followed by Sepangar (41.55%) and Gaya (32.50%). However, UMS jetty had the lowest percentage of hard coral cover (30.05%), when compared to Sepangar (36.40%) and Gaya (44.88%). All three sites of coral cover fell under the 'fair' category, a designation developed at the Third Asean-Australia Symposium on Living Coastal Resources (Chou *et al.*, 1994). Massive type of coral was the most dominant hard coral category at Gaya and Sepangar, while mushroom corals were most dominant at UMS jetty (Table 3). Sepangar recorded a noticeably higher percentage of algae (18.05%).

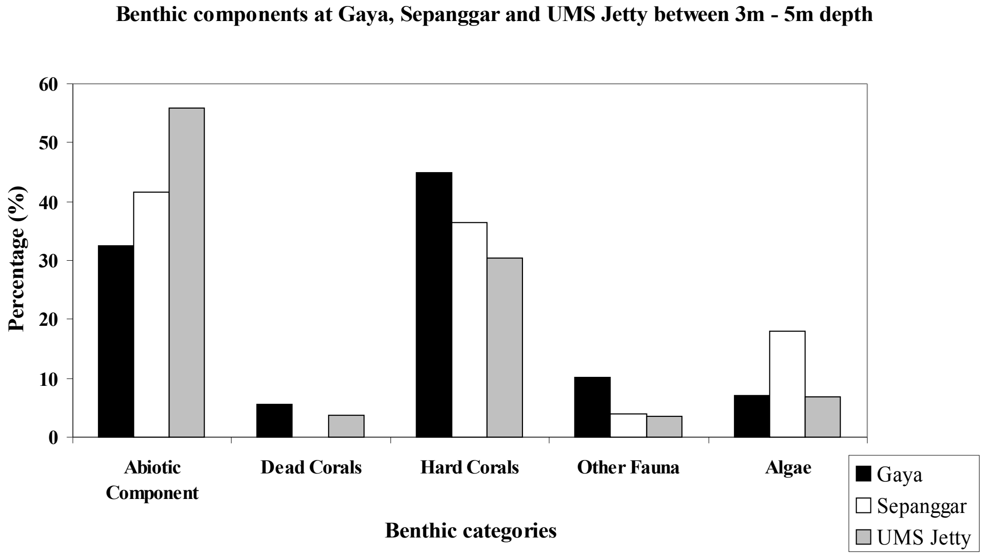

Figure 2. Benthic components of the bottom substrate at Gaya, Sepangar and UMS Jetty between 3m – 5m depth

Table 3. Percentage of hard coral categories at Gaya, Sepangar and UMS Jetty between 3m – 5m depth

Hard Coral Category	**Percentage of Benthic Cover**		
	Gaya	**Sepangar**	**UMS Jetty**
Acropora Branching	4.13	6.75	2.75
Acropora Encrusting	-	-	-
Acropora Submassive	1.25	1.25	-
Acropora Tabular	2.25	3.50	-
Coral Branching	4.00	1.25	-
Coral Encrusting	4.38	5.25	3.65
Coral Foliose	5.25	4.50	4.25
Coral Massive	14.63	7.25	6.00
Coral Submassive	4.50	1.25	4.00
Mushroom Coral	4.50	5.40	9.40
Total	44.88	36.40	30.05

Similar to the shallow transect, the deeper transect at UMS jetty recorded the highest percentage of abiotic components (50.25%) and lowest percentage of hard corals (33.95%). The percentage of hard coral cover ranged from ‘good’ at Gaya (59.38%) and Sepangar (60.10%) to ‘fair’ at UMS jetty (Figure 3, Table 4). The hard coral category that was most dominant at all sites was ‘coral massive’. The algal percentage at these depths ranged from 2.75% to 4.40%.

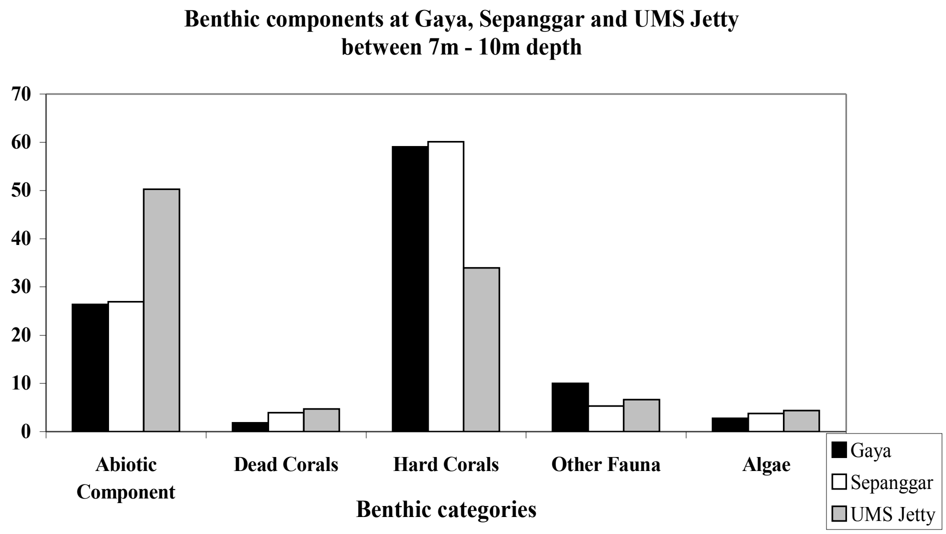

Figure 3. Benthic components of the bottom substrate at Gaya, Sepangar and UMS Jetty between 7m – 10m depth

Table 4: Percentage of hard coral categories at Gaya, Sepangar and UMS Jetty between 7m – 10m depth

Hard Coral Category	**Percentage of Benthic Cover**		
	Gaya	**Sepangar**	**UMS Jetty**
Acropora Branching	3.75	6.08	4.00
Acropora Encrusting	-	-	-
Acropora Submassive	0.50	-	-
Acropora Tabular	5.25	3.23	-
Coral Branching	3.75	3.18	1.50
Coral Encrusting	6.75	7.35	5.15
Coral Foliose	12.00	9.60	1.25
Coral Massive	13.50	16.90	12.00
Coral Submassive	5.13	6.45	3.35
Mushroom Coral	8.75	7.33	6.70
Total	59.38	60.10	33.95

Sediment

The sedimentation rate was highest at UMS jetty for both shallow and deep transects (96.34 ± 11.5791 and 156.15 ± 12.7052, respectively). The rate was very much lower at Sepangar (5.76 ± 1.3119 and 8.15 ± 2.1047 at the shallow and deep transect, respectively) and Gaya (2.80 ± 0.3715 and 3.50 ± 0.4455 at the shallow and deep transect, respectively).

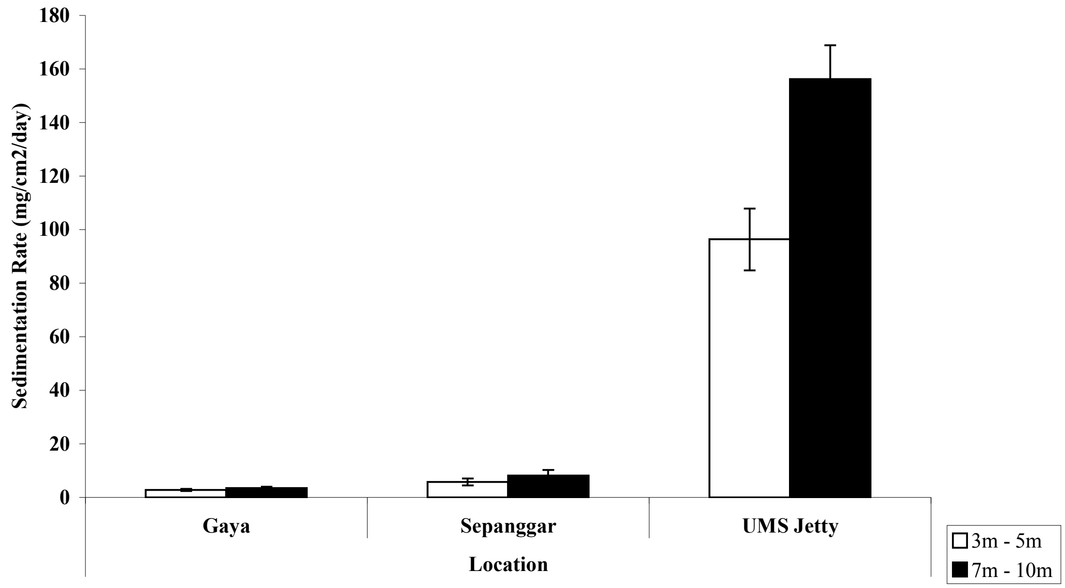

Figure 4. Sedimentation rate at Gaya, Sepangar and UMS jetty at the shallow and deep transect.

The mean calcium carbonate and organic matter content was highest at Sepangar (ranged between 23.82 ± 4.6765 and 26.02 ± 5.3271, 7.04 ± 2.6348 and 2.60 ± 0.8116, respectively) (Figure 5).

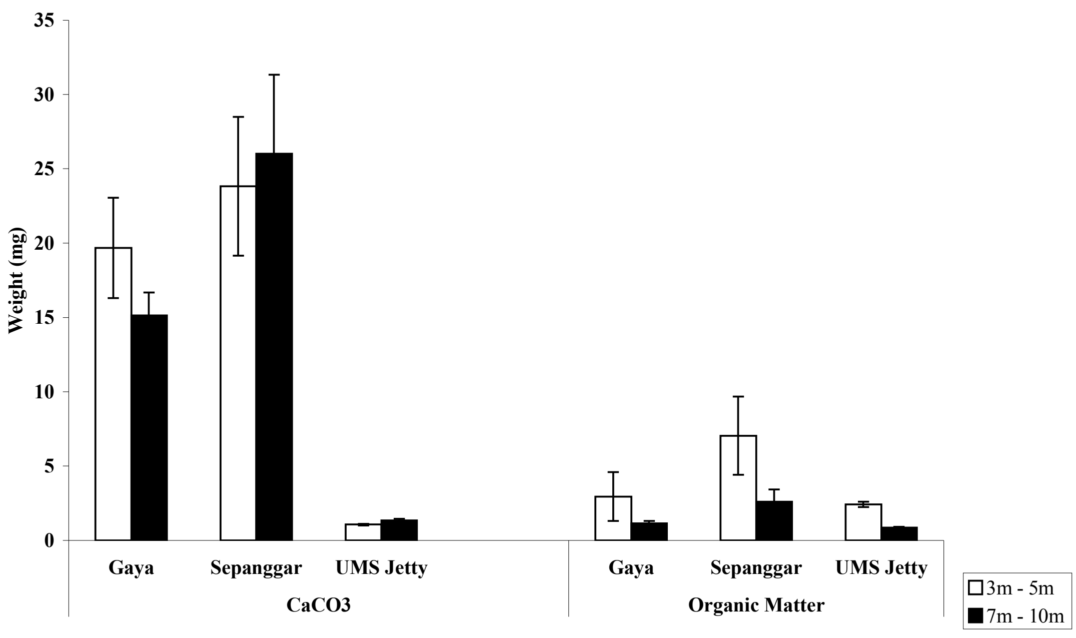

Figure 5. Organic matter and calcium carbonate content at Gaya, Sepangar and UMS jetty at the shallow and deep transects.

Sand content was highest at all the three sites with UMS jetty having 64.52%, Sepangar with 50.95% and Gaya with 46.47%. Organic matter content was lowest especially at UMS jetty, with 1.64%, followed by Gaya (2.05%) and Sepangar (5.3%).

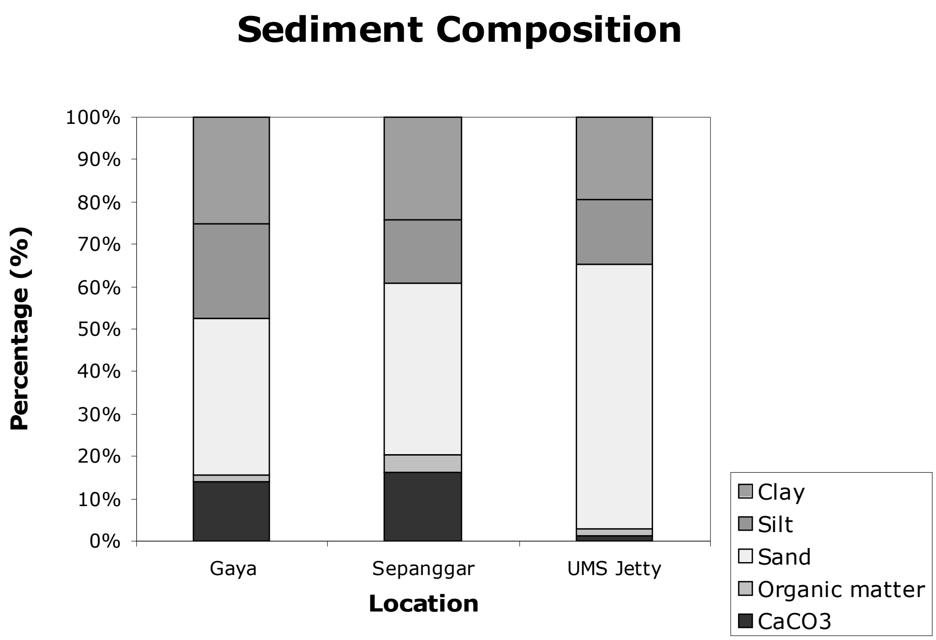

Figure 6. Composition of the sediment sampled from Gaya, Sepangar and UMS jetty using sediment traps.

Data for the mean shallow and deep transect were combined and the mean values for sedimentation rate, calcium carbonate and organic mater content are given by sites in Table 5. ANOVA test revealed that there is a significant difference in means between the sedimentation rate, calcium carbonate and organic matter among the three sites. However the normality assumption was not fulfilled; therefore the nonparametric Kruskal-Wallis test was applied (Table 6) to compare the findings with ANOVA to ensure that the difference is significant and not coincidental. The analysis determined that there was a significant difference in the sedimentation rate (χ^2=71.28, p<0.001), calcium carbonate content (χ^2=70.08, p<0.001), and organic matter content (χ^2=12.76, p=0.002), among the sites.

Table 5. Mean sedimentation rate, calcium carbonate content and organic matter content at Gaya, Sepangar and UMS jetty.

Location		Mean	Std. Error
Gaya	Sedimentation Rate	3.1463	0.29195
	$CaCO_3$	17.4006	1.8718
	Organic Matter	2.0456	0.8285
Sepanggar	Sedimentation Rate	7.6220	1.3753
	$CaCO_3$	20.2648	3.2596
	Organic Matter	5.3000	1.7183
UMS Jetty	Sedimentation Rate	126.2493	14.4307
	$CaCO_3$	1.2003	6.181 E-02
	Organic Matter	1.6408	0.1621

Organic Matter

	LOCATION	N	Subset for alpha = 0.5	
			1	2
Tukey HSD	UMS Jetty	36	1.6408	
	Gaya	36	2.04560	2.0456
	Sepanggar	33		5.3000
	Sig.		0.961	0.082
Duncan	UMS Jetty	36	1.6408	
	Gaya	36	2.04560	
	Sepanggar	33		5.3000
	Sig.		0.788	1.000

	χ^2	p
Sedimentation Rate	71.28	$p<0.001$
$CaCO_3$	70.079	$p<0.001$
Organic Matter	12.762	$p=0.002$

Table 6. Non parametric test for comparing means (Kruskal-Wallis test)

The multiple comparison test was carried out using post-hoc analysis in ANOVA. The Tukey HSD and Duncan tests showed that the sedimentation rate at UMS jetty was significantly higher than the other sites (Table 7). The tests also showed that the calcium carbonate content at UMS jetty was significantly lower than the other sites (Table 8). The Duncan test conducted on the organic matter content data indicated that Sepangar had a significantly higher content when compared to the other sites (Table 9).

Table 7. Tukey HSD and Duncan tests for sedimentation rate

Sedimentation Rate

	LOCATION	N	Subset for alpha = 0.5	
			1	2
Tukey HSD	Gaya	36	3.14633	
	Sepanggar	33	7.62200	
	UMS Jetty	36		126.24931
	Sig.		0.928	1.000
Duncan	Gaya	36	3.14633	
	Sepanggar	33	7.62200	
	UMS Jetty	36		126.24931
	Sig.		0.714	1.000

Table 8. Tukey HSD and Duncan tests for calcium carbonate

Calcium Carbonate

	LOCATION	N	Subset for alpha = 0.5	
			1	2
Tukey HSD	UMS Jetty	36	1.2003	
	Gaya	36		17.4006
	Sepanggar	33		20.2648
	Sig.		1.000	0.599
Duncan	UMS Jetty	36	1.2003	
	Gaya	36		17.4006
	Sepanggar	33		20.2648
	Sig.		1.000	0.336

Table 9. Tukey HSD and Duncan tests for organic matter

Organic Matter

	LOCATION	N	Subset for alpha = 0.5	
			1	2
Tukey HSD	UMS Jetty	36	1.6408	
	Gaya	36	2.04560	2.0456
	Sepanggar	33		5.3000
	Sig.		0.961	0.082
Duncan	UMS Jetty	36	1.6408	
	Gaya	36	2.04560	
	Sepanggar	33		5.3000
	Sig.		0.788	1.000

DISCUSSION

A total of 84 individual fish indicators were recorded at the study site. Snappers and groupers were rarely recorded along the transects. According to Hodgon and Lieber (2002), the low number of snappers and groupers show that target fishing and overfishing occur in the area. However, the behaviour of the fish could also explain their absence on the reef, for example groupers that tend to hide under rocks or crevices during the day. The effects of overfishing can also be seen in the low abundance of parrotfish, angelfish, surgeonfish and scavengers (McClanahan *et al.,* 1999). However, the absence of fishes on the transects could also be due to the disturbances caused when deploying the transect tape (Hodgson *et al.*, 2004).

Based on most reef surveys in Sabah, overfishing can be caused by destructive fishing methods such as dynamite and cyanide fishing (Oakley *et al.*, 1999). This results in severe damage to corals and can lead to changes in fish population by decreasing the number of individuals and causing changes in size structure. The low percentage of hard coral cover (as low as 30.05%) also reflects the absence in the number of fishes because they provide shelter and food source to the fishes.

Butterflyfishes are usually found on reefs with good coral cover. Its presence is considered to be a sign that the reef is in good health. However there is no correlation between coral cover and abundance of butterflyfish, as not all butterflyfish feed on coral polyps (Allen *et al.*, 1998). Therefore, the low abundance of butterflyfish does not necessarily mean that the reefs are degraded.

Apart from the fish indicator species, damselfishes were also noted during the surveys as they were found in large schools around the transects (30 to 50 individuals). The abundance of damselfishes denotes that the reefs are structurally complex as they depend on these coral structures for refuge and as nursery grounds (Allen, 1996). Other distinct fishes that were sighted during the surveys are species of wrasse and Scorpionfish. The general diversity and abundance of fishes on a reef give a good indication of reef health (Koh *et al.*, 2002).

The low numbers of sea urchin in the study area can be attributed to the low abundance or low availability of their food (Castro and Huber, 2003). Sea urchins are important grazers, scrapping algae off the bottom substrate on reefs (McClanahan *et al.*, 1996). The sea urchin also feeds on live coral, but they use an optimal foraging strategy choosing fleshy algae over coral (Carpenter, 1981). They were recorded only at the shallow transect, where the percentage of algal coverage was higher, as there is more light for photosynthesis. Koh *et al.* (2002) discovered from their surveys that sea urchin abundance was adversely correlated to snappers and breams. This was also reported in previous sea urchin reduction studies but the reason has yet to be determined (McClanahan *et al.,* 1996).

Sea cucumbers are targeted for commercial purposes. The scarcity of sea cucumbers at the sites suggests that the invertebrates have been removed from the reef. This is also common in other area such as Pulau Banggi, where the absence of sea cucumbers were a sign of overexploitation (Koh, *et al.*, 2002; Lee and Chou, 2003).

The low number of COT starfish at the study sites indicated that they are currently not a threat to the reefs around the area at the time of the survey. According to Harding *et al.* (2001) low numbers of COTs are found when the live hard coral cover in the area is on the whole low. Interestingly, the COTs were only found at Sepangar. This could be attributed to the presence of more branching coral types at this site, especially the *Acropora*, which are the preferred diet by the COTs (De'ath and Moran, 1998).

Giant clams were also scarce and only recorded at Gaya. Giant clams are harvested for their meat and their shells are sold in local markets. Evidence suggests that the giant clams have been completed fished out from the reefs of Sepangar and UMS jetty by the local communities that reside nearby. However, Gaya is protected by the park status. Consistent with the findings of Harborne *et al.* (2000), higher densities of giant clams and sea cucumbers were recorded in three marine parks on the east coast of Peninsula Malaysia, compared to the Banggi Island region, which is not protected as a marine park.

Generally, the hard coral cover at all three sites were in fair or good condition (30.05% - 60.1%) based on the categories developed by the ASEAN-Australia Living Coastal Resources project (Chou *et al.*, 1994). A total of ten hard coral categories (by lifeform) were recorded. The different lifeforms will provide further information about the reef condition and even suggest factors that are influencing it.

Several surveys were carried out at various sites of Pulau Banggi, Kudat, which yielded coral cover percentages of 10.6% - 71.3% (Koh *et al.*, 2002), 19.38% - 64.38% (Lee and Chou, 2003) and 6.56% - 78.13% (Isa Tanzil and Chou, 2004). This shows that the reefs at Gaya, Sepangar and UMS jetty are comparable to other reefs in Sabah. In a study at Port Dickson, the percentage of live coral cover ranged from 5 – 17% with dominant coral growth form of the sub-massive type, followed by massive, foliose and encrusting (Lee, 2005).

Our findings showed that coral cover for the coral massive category recorded the highest percentage of all benthic categories for all three sites and both depths, except at the UMS jetty shallow transect (which had mushroom coral with most coverage). This is because they are able to withstand wave action (Allen, 1996) better than the other growth forms. The presence of slow-growing massive corals is indicative of reef stability; the more large colonies, the longer the period that the reef is free of destruction (Sorokin, 1993).

Mushroom coral also recorded one of the highest percentages of coverage. They are also able to withstand wave action and move about using their tentacles. Mushroom corals can turn the right way up when they are knocked over by wave action or strong currents (Castro and Huber, 2003).

Acroporas were hardly found at UMS jetty, and only branching *Acropora* was noted. High *Acropora* coverage suggests that the reef is exposed to high energy and strong wave action (Sorokin, 1993). They are sensitive to sediments and have limited abilities in trapping and removing sediments from their surfaces. Sediments decrease light penetration and clogs coral polyps.

Abiotic components along the transect consisted of rock, silt, rubble and sand. At UMS jetty, the abiotic component comprised of more than 50% of the transect length at both depths, of which 40% comprised of sand.

The sedimentation rate at UMS jetty is extremely high (126.25 $mg/cm^2/day$) and exceeded the maximum sedimentation rate for the survival of corals, which is $10 mg/cm^2/day$ (Rogers, 1990). Sedimentation rates of more than $100 mg/cm^2/day$ at coral reef areas are considered heavy sedimentation (Philipp and Fabricius, 2003). This affects coral community structure by reducing coral species richness and live coral cover as well as damaging coral colonies by killing the exposed coral tissues (Brown *et al.*, 1990; Rogers, 1990; Riegl and Branch, 1995). High sedimentation also reduces photosynthetic yield in corals (Philipp and Fabricius, 2003), which leads to the loss of zooxanthellae and causes reduced coral calcification (Bak, 1978). Both Gaya and Sepangar sites recorded significantly lower sedimentation rates compared to UMS Jetty with values lower than the suggested $10 mg/cm^2/day$ for coral survival. However continuous sedimentation even if the rate is low, can also affect the health and survival of corals (Fabricius, 2005).

Minton *et al.* (2006) suggested that non-$CaCO_3$ materials in marine sediments can be used as a measure of terrestrial inputs on coral reefs where marine sediments are almost exclusively composed of $CaCO_3$. Based on the Tukey HSD test (Table 8), the $CaCO_3$ content in sediment samples collected from UMS Jetty were significantly lower than both Gaya and Sepangar. The percentage of $CaCO_3$ content in samples collected from all sites were low and ranged from 1.2% –20.26%, suggesting that most of the sediments from all sites were from terrestrial runoff.

Particulate organic matter has been found to be a great contributor to nutrient availability in many coastal regions, because a majority of nutrients are discharged to the marine environment in particulate form (Furnas, 2003). The increase in nutrients and organic matter onto reefs can lead to increase of algae abundance (Schaffelke, 1999) and further cause eutrophication that will retard coral growth (Fabricius, 2005). The Tukey HSD test showed that organic matter content in sediment samples collected from Sepangar were significantly higher relative to UMS Jetty but not with Gaya (Table 9). Sediment samples collected from Sepangar were in close proximity to local communities, hence domestic wastes that enter into the coastal waters may be the contributor to the high amount of organic matter into the reef, which was shown by the higher algae coverage.

Sediment collected from UMS Jetty consisted of more sand fraction particles than those collected from Gaya and Sepangar (Figure 5). The percentage of sand in the sediment at UMS Jetty was relatively higher compared to the other sites because it was near a sandy beach whereas Gaya (Police Beach) was a combination of sandy and rocky shore, and Sepangar is at a reef slope. Other land-based developments along the coast near UMS might have contributed towards the amount of sand particles in the area.

However, the amount and duration of sedimentation alone does not appear to be the main factor causing coral damage, the sediment type plays a major factor as well (Fabricius, 2005). Other studies have indicated that coral tissue damage under a layer of sediment increases with increasing organic content and bacterial activity, and with decreasing grain sizes (Hodgson, 1990; Weber *et al.*, 2004). Although both Gaya and Sepangar recorded lower percentages of sand fraction particles compared to UMS Jetty, they contained higher percentages of finer sediment particles of silt and clay. Continuous sedimentation of finer particles, although at a low rate have more severe effects to corals compared to larger particles such as sand (Fabricius, 2005).

Although hydrodynamics were not part of this study, previous studies have shown that sediment run-off from land due to land-based developments can also be influenced by coastal hydrodynamics in terms of wave (Hewitt *et al.*, 2003) and currents (de Mahiques *et al.*, 2004) as well as occurrence of catastrophic events (Hindson and Andrade, 1999). Locally generated wind waves are also an important mechanism of sediment resuspension especially at wind-exposed areas (French *et al.*, 2000).

CONCLUSION

Coral reef surveys conducted at all the sites showed that the sites were either in fair or good condition. The low levels or absence of indicator invertebrate and fish species suggest that overexploitation occur on the reef. The mean sedimentation rate measured at the UMS jetty exceeded the maximum sedimentation rate for the survival of corals. This rate is also higher than the sedimentation rate of Gaya Island and Sepangar Island. The results from this research denote that future investigations of the effects of sedimentation on coral reefs need to be carried out, as this is a preliminary study. Point sources of sedimentation and water parameters such as the level of nutrients and hydrodynamic studies should also be taken into account in future studies.

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