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Diversity patterns of Scleractinian corals at Kota Kinabalu, Malaysia, in relation to exposure and depth

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Abstract. A large part of the fringing and patch reefs of Kota Kinabalu is situated along the coastline of Sabah and around the islands of the Tunku Abdul Rahman Park (TARP). The park is composed of five islands and together with the surrounding sea it covers an area of ca. 50 km^2. Several studies have been carried out in the 1970s and 1980s to determine the status of the park's hard coral fauna, which serves as baseline information. The present study builds on previous ones by determining the species richness patterns of scleractinian coral families Fungiidae, Agariciidae, and Euphylliidae observed at 28 reef sites within and outside the TARP boundary. Three additional sites were surveyed for mushroom coral species. The species diversity from this study is higher than those previously recorded. Based on the coral species composition for each site, results from multivariate analyses suggest two distinct groups of sites that reflect a difference in reef exposure, where the highest species numbers were observed at the exposed and deeper reefs. Findings of this study can provide a basis for future comparisons in order to detect changes in the coral communities around Kota Kinabalu and can be applied to developing conservation priorities for the park.

Key words. Scleractinia, Agariciidae, Euphylliidae, Fungiidae, species richness, exposure, bathymetry

INTRODUCTION

The coral reefs of Kota Kinabalu are part of a larger reef system along Borneo's west coast extending from Sulaman Bay in the north to Dinawan Island in the south with fringing reefs of approximately 54 km in length. (Mathias & Langham, 1978). Previous studies have documented the condition of Kota Kinabalu's coral reefs, mainly referring to their coral cover (Lulofs, 1973; Lulofs et al., 1974; Wood, 1977, 1979; Mathias & Langham, 1978; Nyanti & Johnston, 1992; Pilcher & Cabanban, 2000), whereas only a few mentioned the coral fauna composition (Marsh, 1992; Nyanti & Johnston, 1992). Other references are listed in some of these studies, but most of these consist of unpublished reports and student dissertations that are difficult to access and not available for use as baseline.

One of the first documented studies on corals of Kota Kinabalu was about the use of corals as a limestone resource for construction purposes (Fitch, 1950). By 1962, the main building materials produced in Sabah consisted of sand, stone, clay and coral. According to the Geological Survey Department (1963) the production of corals then was 44,000 m^3 with the approximate value of US$78,400.00. Approximately 450 tons of corals could be mined in a single day, which is estimated to be the equivalent of between 64 and 90 coral boulders. This report gave the first account of the condition of some Kota Kinabalu reefs, while specific aspects of reef damage were discussed in a subsequent report (Lulofs et al., 1974).

Very little literature appears to be available on the scleractinian coral diversity of Kota Kinabalu. Older studies reported on coral diversity to genus level only (Wood, 1979; Nyanti, 1984). During surveys carried out between 1984 and 1986, a total of 56 genera and 148 species of hard corals was recorded in the Tunku Abdul Rahman Park (TARP) of Kota Kinabalu (Nyanti & Johnston, 1992). Marsh (1992) reported 53 genera and 131 species of hard corals from a survey of 10 days within the park area. A compilation of the coral species resulting from these reports comprised of 74 genera and 207 species of hard corals (Marine Research Unit of Sabah Parks, 2005). However, 124 species among these were listed as "sp." and because they were based on different sources, it is difficult to verify the identity of these species. In addition, these sources did not include species descriptions or illustrations of the specimens. Furthermore, the identifications were made using various references following different coral species concepts. In studies concerning the offshore Mengalum Island, Wood (1979) found 28 genera, while Lee (1994) reported 64 genera of hard corals. These few studies have not presented a very clear coral diversity pattern of the Kota Kinabalu reefs.

Reefs in TARP that were surveyed every three to four years since 1987 showed a decline in live coral cover since 1994 (Woodman & Wilson, 1994). However, the coral species diversity remained constant on most reefs (Mitchell, 1999). On Manukan Island, there was a significant decrease in diversity and loss in coral cover between 1987 and 1999.

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There were changes in the coral fauna composition at generic level with increased abundance of *Acropora*, *Pocillopora*, and *Seriatopora*, which are fast-growers. In turn, *Fungia* and *Porites* decreased in abundance. These changes were brought upon after a tropical storm in 1996 (Mitchell, 1999).

A combination of anthropogenic impacts and natural events has affected the coral reefs in the vicinity of Kota Kinabalu. Reefs have been damaged by blast fishing (Lulofs, 1973; Lulofs et al., 1974; Wood, 1977, 1979; Mathias & Langham, 1978), and to some extent by commercial collection of reef fauna for the aquarium and curio trade (Wood, 1977, 1979; Phillips, 1979). In 2002, a total of 13 blasts were recorded from nearby Sapangar Island (Woodman et al., 2004). Based on reef surveys conducted by Reef Check Malaysia in early 2010, a high cover of rubble was still evident on the reef of Malohom Bay (Gaya Island) resulting from previous blast fishing activities. Sedimentation has been inferred from land clearing in parts of Sapangar and Gaya bays (Mathias & Langham, 1978). Wood (1979) observed intact but dead coral covered with either algae or silt. Reef conditions were better in shallow parts than on deeper slopes with horizontal visibility generally less than 7 m and considered sedimentation as a contributory factor in causing mortalities. A preliminary study on the sedimentation rates of the reefs in Gaya and Sapangar islands showed that the rates were < 10 mg cm^{-1} d^{-1} (Waheed et al., 2007) and within the acceptable threshold for coral reefs (Rogers, 1990; Erftemeijer et al., 2012). However, the sedimentation rates were between 96–156 mg cm^{-1} d^{-1} on the reefs along the coastline near Sapangar Bay (Waheed et al., 2007).

Although Sabah lies outside the typhoon zone, severe storms have affected the shallow reefs in Kota Kinabalu. Stormy weather in Jan.1976 devastated the reef flat on the patch reefs off Gaya Island (Wood, 1977, 1979). Tropical storm Greg, which occurred in December 1996, caused severe damage to the reefs on the windward sides of Manukan, Sapi, Gaya, and Sulug islands (Pilcher & Cabanban, 2000). An outbreak of 'red tide' caused by phytoplankton blooms is known to have occurred off the west coast of Sabah in 1976 (Roy, 1977). Since this incident, red tide or harmful algal blooms (HABs) have occurred periodically and is a recurring problem in the west coast of Sabah, particularly in the coastal waters of Kota Kinabalu (Usup et al., 1989; Anton et al., 2008; Adam et al., 2011). Low densities of Crown-of-thorns starfish *Acanthaster planci* (Linnaeus, 1758) have been reported from Sapangar Island (Lulofs, 1973) and the west coast islands (Wood, 1977, 1979), but a significant outbreak was noted on Merangis reef of Gaya Island in 1991 and 1994 resulting in significant losses of branching corals such as *Acropora* spp. (Pilcher & Cabanban, 2000).

The widespread coral bleaching event of 1997–1998 also affected the nearshore reefs of Kota Kinabalu (Wilkinson, 1998). About 30–40% of the coral cover at Gaya Island adjacent to the Tunku Abdul Rahman Park was reported to show bleaching in May 1998 when the water temperature peaked at 32°C. Within the park boundary, minor bleaching occurred only in Mamutik Island (Wilkinson, 1998; Pilcher & Cabanban, 2000). Another mass bleaching event occurred in 2010, when bleaching on the reefs of Sabah in general was rated as medium (25–50%) and extended down to 20–25 m depth (Tun et al., 2010). In 2012, the reefs of Kota Kinabalu had high bleaching rates (46–90 % of the coral cover), which affected the hard corals, soft corals, and their associated fauna (Aw & Muhammad Ali, 2012).

With the exception of coral mining, risks that stem from threats mentioned above still exist for the reefs of Kota Kinabalu. Much of what is known on the coral reefs of this area is entirely attributed to the few previous studies that reported on the general reef status and diversity. The present study aims to explore the coral fauna of the reefs, in particular its species diversity pattern across the coastal zone. The findings could add to the current knowledge of the area and perhaps be compared with what is known about the reefs to detect if there have been changes in the coral reef communities over time.

MATERIAL AND METHODS

Research area. Research was carried out on the west coast of Sabah, specifically in Kota Kinabalu, which includes seven islands: Suluq, Mamutik, Manukan, Sapi, Gaya, Sapangar and Udar Besar islands from Tanjung Aru to Sapangar Bay of the Kota Kinabalu coastline (Fig. 1). A large part of this area is within the Tunku Abdul Rahman Park (TARP).

TARP was established in 1974 and comprised of a large part of Gaya Island and the whole of Sapi Island, covering an area of 36.4 km^2. The inclusion of Manukan, Mamutik, and Sulug islands in 1979 expanded the park area to 49.3 km^2 (Spait, 2001). The eastern part of Gaya Island that faces Kota Kinabalu has been excluded (Wood, 1979). The villages here comprise of houses on stilts all along the beach that extend out to the sea. Currently there are three resorts within the park area and one just outside its boundary. The number of visitors to TARP increased from approximately 136,000 in 1998 to nearly 300,000 in 2009 (Sabah Parks Visitor Statistics). TARP is managed by Sabah Parks and the administrative centre is based on Manukan Island. Situated to the north of TARP are the islands Sapangar [variations in spelling = Sepangar, Sepanggar], Udar Besar, Udar Kecil and Peduk off Sapangar Bay. These islands are not tourist destinations. Similar to Gaya Island, the eastern shore of Sapangar Island is lined with houses on stilts. There is a road connecting Udar Kecil to the mainland, which is now part of the Sepanggar Naval Base. Udar Besar and Peduk islands are uninhabited.

Coral reefs fringe along most parts of these islands, and some parts of the coastline. Generally, the reefs in the north and west of the islands are often exposed to waves and sea swells, and hence characterised by predominantly rocky substratum and boulders interspersed with patches of rubble and coarse sand (Wood, 1979). Reefs in the south and east of the islands that are facing the mainland are described to have sheltered conditions, where white-sandy beaches are found. Around Gaya Island, reefs have developed along the headland of both the north and south coast, but Wood (1979) remarked that the fauna here was different in some aspects. The condition of the reefs are varied, but the most extensive reef lies along the southern end of Sulug Island, which is rather exposed to strong currents. There are several patch reefs [= platform reefs; see Wood, 1979] within the research area. Edgell Patches lie 1.6 km to the west of Sapi Island, just outside the park boundary. These reefs rise to about 12–13 m below the surface, and are rather flat with dense coral cover. The reef slopes down to 20 m and flattens out gradually before sloping down again. On the second tier of the reef flat, large barrel sponges *Xestospongia* sp. and whip corals have been encountered, indicating the possible occurrence of strong currents.

Rivers in the vicinity of Kota Kinabalu are the Menggatal River that flows into Sapangar Bay and Inanam River that flows into Gaya Bay. The river systems in Sabah transport sediment to the coast during and after periods of rainfall. The sediment plume can reach between 5–10 km from the coastline to the South China Sea depending on the sediment load and water discharge, and areas with high sediment concentrations had either no coral reefs or only poor quality reefs (Jakobsen et al., 2007). The sediment plume from the Inanam River has been thought to be one of the main factors contributing to the degradation of reefs in the vicinity of Gaya Bay (Shoreline Management in the ICZM Context in Sabah, 1999).

The northeast monsoon occurs from October to March and peaks in December to January while the southwest monsoon is from May to September and peaks in July to August (Wyrtki, 1961), but yearly variations occur. The calmest conditions on the west coast reefs are from February to May (Wood, 1979) although the area between the islands and the mainland is relatively sheltered year-round. Based

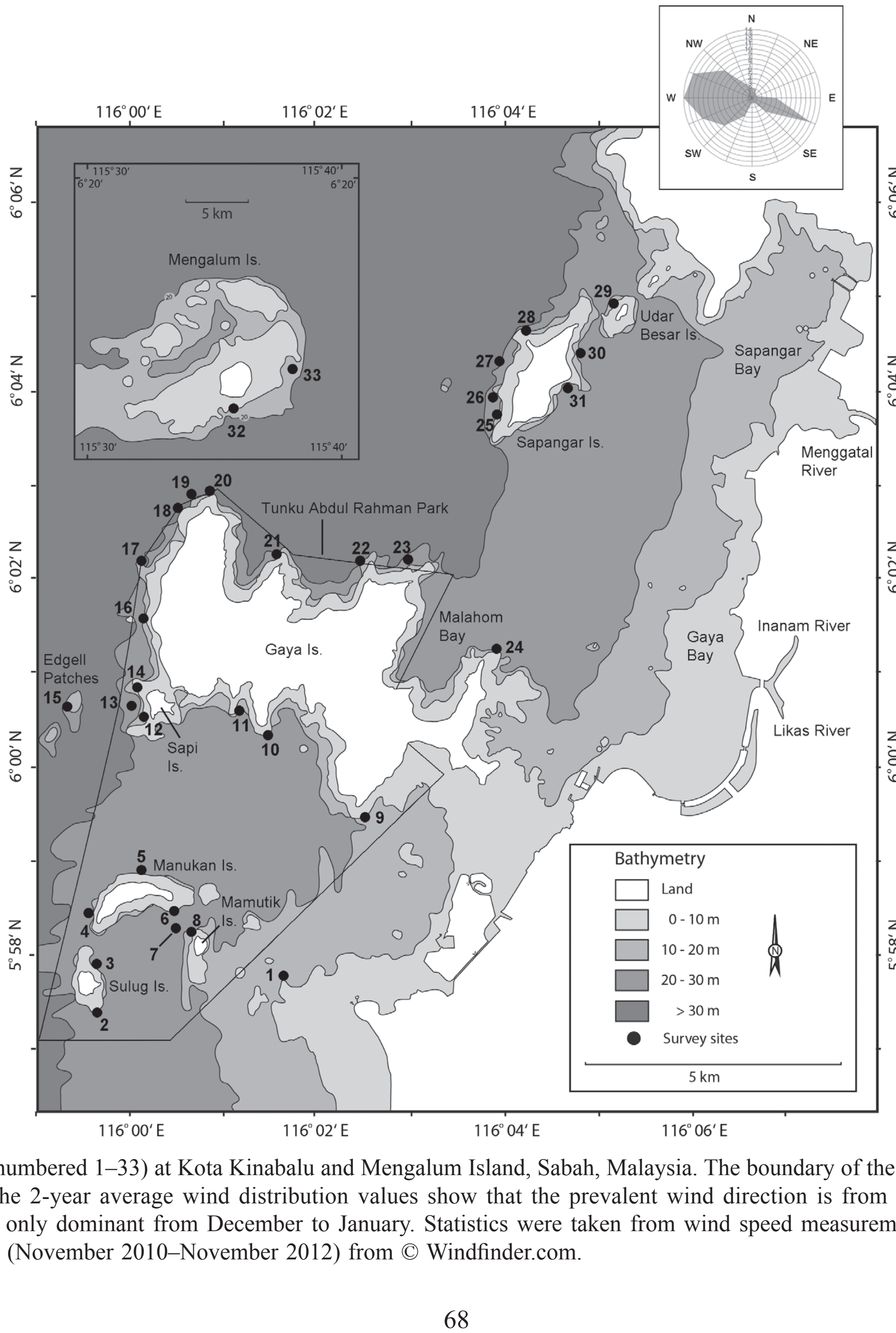

Fig 1. Survey sites (numbered 1–33) at Kota Kinabalu and Mengalum Island, Sabah, Malaysia. The boundary of the Tunku Abdul Rahman Park is indicated. The 2-year average wind distribution values show that the prevalent wind direction is from the west. Winds from the east-southeast is only dominant from December to January. Statistics were taken from wind speed measurements at Kota Kinabalu International Airport (November 2010–November 2012) from © Windfinder.com.

Table 1. Locality data of the survey sites in Kota Kinabalu and Mengalum Island. Five sites (8, 12, 14, 32, and 33) were not included in the multivariate analyses as data were not collected for all three coral families. Exposure: exposed or sheltered in relation to the predominant wind from the west. Depth (maximum) of seafloor: shallow (≤ 30 m) or deep (≥30 m).

No.	Site	Latitude (N)	Longitude (E)	Exposure	Depth
1	Tanjung Aru reef	05°57'33.9"	116°01'44.6"	Sheltered	Shallow
2	S Sulug	05°57'23.3"	115°59'37.9"	Exposed	Shallow
3	N Sulug	05°57'47.5"	115°59'38.9"	Sheltered	Shallow
4	E Manukan Is.	05°58'26.4"	115°59'30.7"	Exposed	Shallow
5	N Manukan Is.	05°58'46.1"	116°00'10.6"	Exposed	Shallow
6	SE Manukan Is.	05°58'21.5"	116°00'32.3"	Sheltered	Shallow
7	NW Mamutik Is. 1	05°58'09.5"	116°00'34.1"	Sheltered	Shallow
8	NW Mamutik Is. 2	05°58'07.0"	116°00'45.0"	Sheltered	Shallow
9	SE Gaya Is., Tg. Wokong	05°59'25.6"	116°02'26.5"	Exposed	Shallow
10	S Gaya Is.	06°00'16.2"	116°01'29.1"	Exposed	Shallow
11	S Gaya Is., Batu Point	06°00'34.2"	116°01'11.6"	Exposed	Shallow
12	SW Sapi Is.	06°00'26.0"	116°00'13.0"	Exposed	Deep
13	W Sapi Is.	06°00'35.3"	116°00'01.3"	Exposed	Deep
14	NW Sapi Is.	06°00'45.0"	116°00'07.0"	Exposed	Deep
15	Edgell Patches	06°00'38.7"	115°59'22.2"	Exposed	Deep
16	W Gaya Is. 1	06°01'23.5"	116°00'14.9"	Exposed	Deep
17	W Gaya Is. 2	06°01'57.5"	116°00'16.1"	Exposed	Deep
18	NW Gaya Is., Tg. Bulijong 2	06°02'34.7"	116°00'32.8"	Exposed	Deep
19	NW Gaya Is., Tg. Bulijong 1	06°02'44.6"	116°00'40.5"	Exposed	Deep
20	NW Gaya Is., Tg. Bulijong 3	06°02'38.4"	116°00'52.9"	Exposed	Deep
21	N Gaya Is., Tg. Merangis	06°02'07.9"	116°01'29.2"	Sheltered	Deep
22	NE Gaya Is., Tg. Tavajun 2	06°01'58.8"	116°02'33.7"	Exposed	Deep
23	NE Gaya Is., Tg. Tavajun 1	06°01'55.9"	116°02'54.4"	Exposed	Deep
24	NE Gaya Is., Tg. Logong	06°01'05.7"	116°03'52.8"	Sheltered	Shallow
25	SW Sapangar 1	06°03'42.8"	116°04'03.5"	Exposed	Deep
26	SW Sapangar 2	06°03'50.1"	116°03'54.1"	Exposed	Deep
27	W Sapangar	06°04'11.3"	116°03'58.1"	Exposed	Deep
28	NW Sapangar	06°04'30.0"	116°04'18.2"	Exposed	Deep
29	Udar Besar Is.	06°04'49.1"	116°05'12.8"	Exposed	Shallow
30	NE Sapangar	06°04'26.0"	116°04'47.4"	Sheltered	Shallow
31	E Sapangar	06°03'58.5"	116°04'42.5"	Sheltered	Shallow
32	SW Mengalum Is.	06°11'10.4"	115°35'23.9"	Sheltered	Shallow
33	NE Mengalum Is.	06°12'42.1"	115°37'24.1"	Sheltered	Shallow

on the average wind distribution values throughout the year, the prevalent wind direction is from the west (Fig. 1). From December to January, the wind from the east-southeast is rather dominant as well. During this period of the year, the water temperature is cooler. At the time of the survey high concentrations of slow-swimming salps (Thaliacea: Salpida: Salpidae) were observed in the water column and over the reefs, which were preyed on by mushroom corals (Hoeksema & Waheed, 2012).

Field sampling. The survey was conducted between 16 and 28 July 2011 on 28 reef sites of Kota Kinabalu, Sabah (5°57'–6°5'N, 115°59'–116°5'E). Mushroom corals (Fungiidae) were previously monitored at three additional localities in July 2005. The reefs were surveyed from the reef base no deeper than 30 m to the reef flat, varying from sheltered to exposed conditions that were within 10 km from the coastline (Table 1, Fig. 1). Two additional sites were surveyed in Mengalum Island, situated approximately 56 km northwest of Kota Kinabalu, near the edge of the continental shelf. Both sites were not included in the data analysis because reef conditions appeared to differ from those more nearshore and weather conditions did not allow additional sampling, which would have given a better representation. Site selection was based on Malaysia Nautical Charts MAL 8608 and MAL 864 and Google Earth imagery.

Species incidence data were recorded at each site for the coral families Fungiidae, Agariciidae, and Euphylliidae as proxy for all reef-dwelling Scleractinia by employing the roving diver technique (Schmitt et al., 2002). These coral families are found in various reef habitats and have a wide geographical distribution. A similar study was done in Semporna, Sabah (Waheed & Hoeksema, 2013), and comparisons on the coral composition and species richness patterns of these families can be made. Coral specimens were identified following the species concepts from taxonomic revisions and coral fauna descriptions: Veron & Pichon (1980); Dinesen (1980); Hoeksema (1989); Veron (2000); and Ditlev (2003). The classification of the Fungiidae was adapted according to a recent phylogenetic construction of this family (Gittenberger et al., 2011), whereas for consistency in the comparisons, two recently added species (Benzoni et al., 2012) were not included in the survey. Photographs of each species were taken and specimens were collected when in situ identification was not possible. These specimens were deposited in the Borneo Marine Research Institute reference collection in Universiti Malaysia Sabah (UMS) in Kota Kinabalu. Specimens of the target coral families already in the Sabah Parks reference collection at TARP, Manukan Island were examined and re-indentified.

Data analysis. Species of coral families Fungiidae, Agariciidae, and Euphylliidae were listed and compared to previous studies undertaken in the same area. Species richness estimators were calculated using EstimateS 8.20 (Colwell, 2009) to show the rate at which additional species were found in the course of consecutive dives, which indicates the expected total species richness in an area (Magurran, 2004). For the coral families Agariciidae and Euphylliidae, data were collected at 28 sites and for the Fungiidae at 31 sites.

Multivariate analyses of the coral species composition were carried out for 28 sites (where data were collected for all families) using PRIMER (Plymouth Routines in Multivariate Ecological Research) version 6 (Clarke & Warwick, 2001; Clarke & Gorley, 2006). Based on the Bray-Curtis resemblance matrix, sites that were most similar to each other were represented in a group-averaged hierarchical clustering dendrogram. The sites were also visualised in multidimensional scaling (MDS) plots, whereby the distance between each site represents their similarity or dissimilarity. Similarity profiles (SIMPROF) were derived from the dendrogram and contours were applied to the MDS plots to highlight the significant groupings of the sites, which were then plotted on the map to discern species richness patterns. The analysis of similarities (ANOSIM) was used to test for significant differences among the a priori groups classified by reef habitats influenced by exposure to wind-generated waves and depth. Sites that were exposed to the predominant wind from the west were labeled as exposed (20 sites), while sites at the leeward side of islands were labeled as sheltered (8 sites). Sites in the west and north of Gaya Island and west of Sapangar Island, where the seafloor extends beyond 30 m were considered deep (14 sites), while the rest of the sites that flattened out at around 20 m depth were considered shallow (14 sites, see Table 1).

RESULTS

The biodiversity survey of Kota Kinabalu reefs resulted in records of 35 species of Fungiidae from 31 sites, and 26 species of Agariciidae and 11 species of Euphylliidae from 28 sites (Table 2, Appendix 1). In comparison to the species list that was compiled by Sabah Parks (Marine Research Unit of Sabah Parks, 2005), 17 Fungiidae, 13 Agariciidae, and 3 Euphylliidae in our survey represent new records for Kota Kinabalu. The two dives at Mengalum Island added two additional species to the list: *Pavona* sp. (Agariciidae) and *Plerogyra simplex* (Euphylliidae). Both were encountered only once and not found at any of the surveyed sites within Kota Kinabalu reefs. The total number of coral species per site ranged from 29 (site 1) to 55 (site 15) (see Fig. 1). Nineteen sites (68%) had a total of ≥40 species, while five out of these 19 sites had ≥50 species. Some coral species were common and recorded for every site, while a few others were rare and found at only a few sites (Table 3).

The species accumulation curves showed that the expected number of species (ICE, Chao 2) for Fungiidae is close to the observed number, and that with additional sampling, two more species are to be expected (Fig. 2a). For the families Agariciidae and Euphylliidae, the curves showed that the expected richness is identical to the observed, therefore more sampling is not expected to result in higher numbers (Figs. 2b, c).

The dendrogram derived from the cluster analysis comprised of three groups of sites and three singletons based on the SIMPROF test, which suggests that separations based on species richness were driven by either reef exposure or bathymetry. At 82% similarity the dendrogram and MDS plots showed two main groups that are represented by reefs exposed to- and sheltered from the predominant wind directions from the west, and a smaller group of two sites with relatively sheltered reefs (Figs. 3a, b). The exposed reefs, especially at Gaya and Sapangar islands, also extend to greater depths than the other reef sites (see Fig. 4). Based on the a priori groupings however, the ANOSIM test did not suggest a significant difference in coral species composition based on exposure to wind (ANOSIM Global $R = 0.399$, $p = 0.1$) and depth (Global $R = 0.311$, $p = 0.1$). There was also no significant difference in composition structure among the a priori groups using the two-way crossed ANOSIM test. This is most likely because the species composition of the reefs are about 80 % similar. Nevertheless, it was clear that sites with the highest coral species diversity ($n \geq 50$) were exposed with reef slopes extending to depths of at least 30 m (Fig. 4).

DISCUSSION

Historical records. Only few studies on the reefs of Kota Kinabalu have been published despite their close proximity to the city's main jetty. Findings of other research may be present in the form of grey literature that has not been made available through online resources and therefore cannot easily be found. When comparing the present coral species list to those of previous studies and specimens in reference collections, it is difficult to draw conclusions as those earlier studies reported coral taxa mostly at genus level. However, the species listed by Sabah Parks were also found in the present study, except for the mushroom coral *Cycloseris* cf. *vaughani*. This species was reported in the checklist by Nyanti & Johnston (1992), but no description, illustrations or locality data were given, therefore it is difficult to verify the former presence of this species. Since this species is usually found on offshore reefs and at greater depths (Hoeksema, 2012a, b), locality data in the earlier records could have supported the earlier identification. From the present study, 33 species are new records for Kota Kinabalu. This updated species list could serve as a baseline for future studies on the coral fauna of Kota Kinabalu.

Most of the coral specimens deposited in the Sabah Parks reference collection were free-living mushroom corals (Fungiidae) and staghorn corals (*Acropora* spp.). Fungiidae and Acroporidae are two iconic and commonly occurring coral taxa that can easily be found and sampled. Both taxa can cover large areas and may occur in dense multi-species aggregations or in monospecific stands (Wallace, 1999; Hoeksema, 2004, 2012a; Hoeksema & Gittenberger, 2010; Hoeksema & Matthews, 2011; Hoeksema & Benzoni, 2013). Based on this reference collection, it appears that only common and shallow-living species were targeted and therefore these collections were not representative enough for comparison with the present data. Although reference material in museum collections can serve as baselines for studies of coral communities over time (e.g., Hoeksema & Koh, 2009; Van der Meij et al., 2010; Hoeksema et al., 2011; Van der Meij & Visser, 2011; Hoeksema & Wirtz, 2013), this is only useful if the collections are extensive and sufficiently representative of the area by also including uncommon species.

Species occurrences. When comparing the coral species of the three target families between Kota Kinabalu and Semporna in the southeast coast of Sabah, the latter recorded 18 species more: nine fungiids (35 vs. 44), five agariciids (28 vs. 33), and four euphylliids (11 vs. 15). Some of these additional species are endemic to northeast Borneo such as

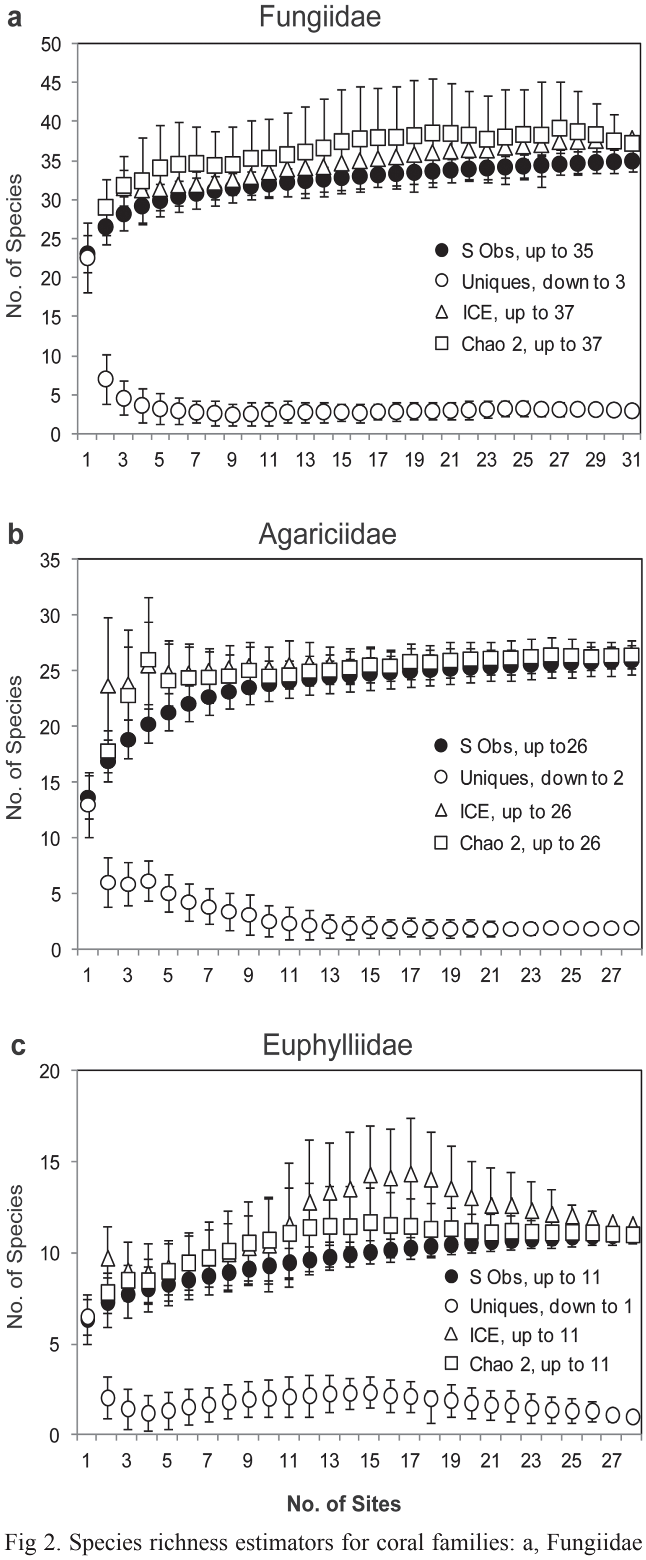

Fig 2. Species richness estimators for coral families: a, Fungiidae (n=35); b, Agariciidae (n=26); and c, Euphylliidae (n=11) observed at Kota Kinabalu. The curves indicate that the occurrence of two additional species is possible for the Fungiidae, but no extra species are expected for the Agariciidae and Euphylliidae.

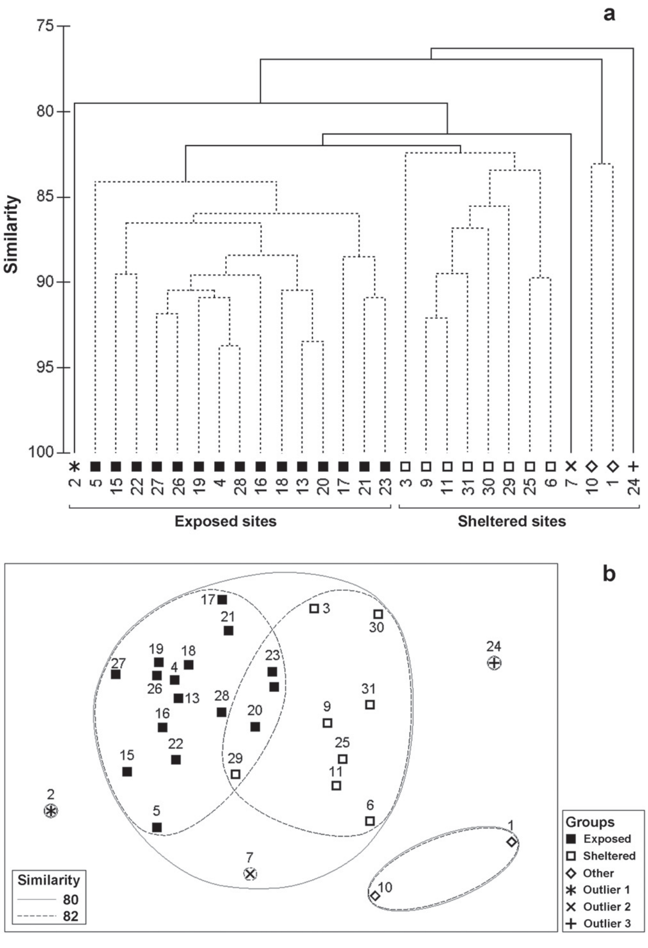

Fig. 3. a, Dendrogram; and b, multidimensional scaling (MDS) plots with significant clusters of 28 sites at Kota Kinabalu based on the Bray-Curtis resemblance matrix of coral species composition (presence/absence) of the families Fungiidae, Agariciidae, and Euphylliidae. The solid and open symbols represent exposed and sheltered reef sites, respectively.

Table 2. Coral species of the families Fungiidae, Agariciidae, and Euphylliidae recorded from the Tunku Abdul Rahman Park and nearby islands in Kota Kinabalu during present and previous studies (Marine Research Unit of Sabah Parks, 2005) and Sabah Parks reference collections. Six additional species from Nyanti & Johnston (1992) are each marked with an asterisk (*). All identifications have been updated to current revisions and descriptions.

	Sabah Parks List	Sabah Parks Reference Collection	Present Study
Fungiidae			
Ctenactis albitentaculata Hoeksema, 1989			×
Ctenactis crassa (Dana, 1846)			×
Ctenactis echinata (Pallas, 1766)	×	×	×
Ctenactis sp.	×		
Cycloseris costulata (Ortmann, 1889)		×	×
Cycloseris cyclolites (Lamarck, 1815)	*		×
Cycloseris fragilis (Alcock, 1893)			×
Cycloseris mokai (Hoeksema, 1989)			×
Cycloseris sinensis Milne Edwards and Haime, 1851			×
Cycloseris somervillei (Gardiner, 1909)			×
Cycloseris tenuis (Dana, 1846)			×
Cycloseris cf. *vaughani* (Boschma, 1923)	*		
Cycloseris sp. 1			×
Cycloseris spp.	×		
Danafungia horrida (Dana, 1846)		×	×
Danafungia scruposa (Klunzinger, 1879)		×	×
Fungia fungites (Linnaeus, 1758)		×	×
Fungia spp.	×		
Halomitra pileus (Linnaeus, 1758)	×		×
Halomitra sp.	×		
Heliofungia actiniformis (Quoy and Gaimard, 1833)	×		×
Heliofungia sp.	×		
Herpolitha limax (Esper, 1797)	×	×	×
Herpolitha sp.	×		
Lithophyllon concinna (Verrill, 1864)	*		×
Lithophyllon repanda (Dana, 1846)		×	×
Lithophyllon scabra (Döderlein, 1901)			×
Lithophyllon spinifer (Claereboudt and Hoeksema, 1987)			×
Lithophyllon undulatum Rehberg, 1892	×		×
Lithophyllon sp.	×		
Lobactis scutaria (Lamarck, 1801)	*		×
Pleuractis granulosa (Klunzinger, 1879)			×
Pleuractis gravis (Nemenzo, 1955)			×
Pleuractis moluccensis (Van der Horst, 1919)			×
Pleuractis paumotensis (Stutchbury, 1833)		×	×
Pleuractis taiwanesis Hoeksema and Dai, 1991			×
Podabacia crustacea (Pallas, 1766)	×		×
Podabacia motuporensis Veron, 1990			×
Podabacia sinai Veron, 2002			×
Podabacia sp.	×		
Polyphyllia talpina (Lamarck, 1801)	×		×
Polyphyllia sp.	×		
Sandalolitha dentata Quelch, 1884			×
Sandalolitha robusta (Quelch, 1886)	×	×	×
Sandalolitha sp.	×		
Zoopilus echinatus Dana, 1846		×	×
Zoopilus sp.	×		
Agariciidae			
Coeloseris mayeri Vaughan, 1918	×		×
Coeloseris sp.	×		
Gardineroseris planulata (Dana, 1846)	×		×
Gardineroseris sp.	×		
Leptoseris explanata Yabe and Sugiyama, 1941	×		
Leptoseris foliosa Dinesen, 1980			×
Leptoseris fragilis Milne Edwards and Haime, 1849			×
Leptoseris gardineri Van der Horst, 1921			×
Leptoseris glabra Dinesen, 1980			×

Table 2. Cont'd.

	Sabah Parks List	Sabah Parks Reference Collection	Present Study
Leptoseris hawaiiensis Vaughan, 1907			×
Leptoseris incrustans (Quelch, 1886)			×
Leptoseris mycetoseroides Wells, 1954	×		×
Leptoseris papyracea (Dana, 1846)		×	
Leptoseris scabra Vaughan 1907	×		×
Leptoseris cf. *solida*			×
Leptoseris tubulifera Vaughan 1907			×
Leptoseris yabei (Pillai and Scheer, 1976)	×		×
Leptoseris sp. 1	×		
Leptoseris spp.	×		
Pachyseris gemmae Nemenzo, 1955			×
Pachyseris rugosa (Lamarck, 1801)	×		×
Pachyseris speciosa (Dana, 1846)	×	×	×
Pachyseris sp.	×		
Pavona cactus (Forskål, 1775)	×		×
Pavona clavus (Dana, 1846)	×		×
Pavona decussata (Dana, 1846)	×	×	×
Pavona explanulata (Lamarck, 1816)	×		×
Pavona frondifera (Lamarck, 1816)	*		×
Pavona maldivensis (Gardiner, 1905)			×
Pavona minuta Wells, 1954			×
Pavona varians Verrill, 1864	×		×
Pavona venosa (Ehrenberg, 1834)			×
Pavona sp.	×		
Euphylliidae			
Catalaphyllia jardinei (Saville-Kent, 1893)	*		×
Euphyllia ancora Veron and Pichon, 1980	×		×
Euphyllia cristata Chevalier, 1971			×
Euphyllia divisa Veron and Pichon, 1980	×		×
Euphyllia glabrescens (Chamisso and Eysenhardt, 1821)	×		×
Euphyllia paraancora Veron, 1990			×
Euphyllia paradivisa Veron, 1990			×
Euphyllia yaeyamaensis (Shirai, 1980)			×
Euphyllia sp.	×		
Physogyra lichtensteini (Milne Edwards and Haime, 1851)	×		×
Physogyra sp.	×		
Plerogyra multilobata Ditlev, 2003		×	
Plerogyra sinuosa (Dana, 1846)	×		×
Plerogyra sp. 1	×		

Lithophyllon ranjithi, *Plerogyra diabolotus*, and *P. cauliformis* (Waheed & Hoeksema, 2013), while others have a limited distribution range, such as *Halomitra clavator* (Hoeksema & Gittenberger, 2010). The total of 35 species of mushroom corals that was found in Kota Kinabalu is considered diverse and comparable to other areas that have been studied within the Coral Triangle (Hoeksema, 2007, 2012a, b; Waheed & Hoeksema, 2013). Mushroom coral species preferring offshore conditions were rare on the Kota Kinabalu reefs (as listed in Table 3 and includes *Lithophyllon spinifer* and *Podabacia sinai*). *Cycloseris boschmai*, a relatively small species (Hoeksema, 2014), was only encountered once (site 12) and has also been found in Semporna and Kudat (Waheed & Hoeksema, 2013, Waheed et al., subm.).

Agariciid corals that were considered rare in Kota Kinabalu were also uncommon in Semporna, such as *Pavona minuta*. An unusual *Leptoseris* specimen was encountered during the present study. It has irregular mounds (proximal cushions) protruding from its surface that is characteristic of *Leptoseris solida* (Quelch, 1886), but with several column-forms that are unlike *L. solida*'s. Its other characters closely resemble those of *L. solida*. As such, this specimen has been labeled *Leptoseris* cf. *solida* until further examination suggests differently. In a short note on the corals from the west coast of Sabah, *Leptoseris solida* was reported to be uncommon, usually found at reef edges and has a twisted and contorted growth form (Phillips, 1979). The depicted specimen looked very much like some *Leptoseris tubulifera* specimens that were encountered during the present survey, which had larger corallites and coarser septocostae than the species' type specimen (Vaughan, 1907). The colony was also larger and generally more contorted than the typical *Leptoseris tubulifera* growth form. This variation could be related to a different locality or habitat type, as was observed for specimens of *Leptoseris hawaiiensis* and *L. scabra* from Semporna (Waheed & Hoeksema, 2013).

The euphylliid coral *Plerogyra multilobata* Ditlev, 2003 has previously only been recorded from Semporna and Darvel Bay (Waheed & Hoeksema, 2013) and Kudat-Banggi, Sabah (Waheed & Hoeksema, subm.). This species was described solely by macro-morphological characters and is distinguishable from *P. diabolotus* only by its polyp structure (Ditlev, 2003). The taxonomy of the Euphylliidae requires revision as molecular analyses have suggested that this family is polyphyletic (Fukami et al., 2008; Kitahara et al., 2010). The genera *Plerogyra*, *Physogyra*, and *Nemenzophyllia* have close affinities with *Blastomussa*, which was originally classified with the family Mussidae (Huang, 2012; Benzoni et al., in press). Their present inclusion in the Euphylliidae is based on the current classification by Veron (2000), which is based on the macro-morphology of the polyps and the coral skeletons. *Plerogyra* species described by Ditlev (2003) needs to be investigated further with the help of molecular methods to determine their taxonomic position.

The common occurring coral species of Kota Kinabalu are also similar with those in the other regions of Sabah as well as other areas within the Coral Triangle. The mushroom corals *Danafungia scruposa*, *Fungia fungites*, *Herpolitha limax*, *Lithophyllon repanda*, *Pleuractis granulosa*, and *P. paumotensis* were common in Semporna and Kudat. *Fungia fungites*, *L. repanda*, and *P. paumotensis* were also common in northwest Java, Berau, Raja Ampat, Ternate, and Makassar, Indonesia, while the other species mentioned above were considered dominant reef-dwelling species (Hoeksema, 1991, 2008, 2010, 2012a; Hoeksema et al., 2004). These species have a widespread distribution and are found on many Indo-West Pacific reef habitats. Agariciid and euphylliid corals have not been as well studied as the fungiid corals, but in comparison with the other reefs of Sabah, it was found that common species include the euphylliid coral *Plerogyra sinuosa*, and the agariciid corals *Pavona varians* and *Pachyseris speciosa* (Waheed & Hoeksema, 2013, Waheed et al., subm.). Although these agariciid corals were not encountered at all survey sites in Kota Kinabalu, they were common on the reefs.

Due to weather constraints during the fieldwork, only two dives were made at Mengalum Island. Coral cover was rather poor, especially at site 32, which was close to the island. The reef was shallow (<10 m) and patchy along a gradually declining sandy slope. However, it was here that specimens of *Pavona* sp. and *Plerogyra simplex* were encountered. The *Pavona* sp. specimen has deep corallites and exsert primary septa. It superficially resembles *Pavona diffluens* (Lamarck, 1816), a species only reported from the Red Sea, the Arabian Sea, and the Persian Gulf (Veron, 2000). Wood (1979) observed that several species of coral and fish that occur around the island were rarely seen on the west coast reefs (including Kota Kinabalu) and presumably reflected the offshore position of the island. She also noted that the slope around the island was gentle and sandy, and while the shallow reefs may be interesting, they are not striking. No account has been made on the bank reefs and shoals that lie closer to the edge of the continental shelf.

Species distributions. The cluster analysis and MDS ordination suggested a difference in coral species composition between the two main groups, which appears to be influenced by the exposed and sheltered conditions of the reefs. This is not supported by ANOSIM, most likely because the species composition of the reefs in the area are about 80% similar, as suggested by the dendrogram and MDS plots. Nevertheless, a difference in species composition was indicated by the SIMPROF test (Fig. 4). The exposed reefs extended down to 30 m depth and had better water clarity as compared to the sheltered reefs that did not exceed 20 m. The third group of the clusters, which comprised of relatively sheltered sites 1 and 10, had the lowest species diversity of all localities (with the exception of the outlier, site 24). In general, localities that were sheltered from the predominant winds and situated closer to the shoreline of the mainland had noticeably lower species diversity. A similar pattern was found for the mushroom coral faunas in the vicinity of river mouths near Madang, Papua New Guinea (Hoeksema, 1993), Berau, East Kalimantan (Hoeksema et al., 2004) and Makassar, South Sulawesi (Hoeksema, 2012a, b). In contrast, highest species diversity of Semporna was found in the sheltered nearshore reefs (Waheed & Hoeksema, 2013). In studies comparing species diversity at a larger scale, high species richness is usually found in areas showing high habitat heterogeneity (Best et al., 1989; Hoeksema & Moka, 1989; Cornell & Karlson, 1996; Karlson, 1999; Karlson & Cornell, 1999; Hoeksema, 2007). By showing gradients in exposure and maximum depth from nearshore to offshore, the habitat diversity of the reefs of Kota Kinabalu may be considered high, although not as much as the reefs of the much larger Semporna, which also include a barrier reef system and lagoonal reefs (Waheed & Hoeksema, 2013).

The reefs of Kota Kinabalu are fringing nearshore reefs predominant along rocky shores, which may lack variation in habitat type, such as those found in the barrier reef system on the Spermonde shelf off Makassar, South Sulawesi (Moll, 1983; Hoeksema, 2012a, b). Such reefs contain sheltered and exposed sites in close proximity to each other at opposed sites of sand cays, and usually show much habitat heterogeneity along depth gradients from extensive shallow reef flats to moderately steep reef slopes and slowly declining sandy reef bases. The coral fauna of Kota Kinabalu included species that are restricted to certain habitat conditions, such as *Zoopilus echinatus*, which is a predominantly offshore species (Hoeksema, 1993, 2012a; Hoeksema et al., 2004). On the other hand, some species were absent when they should be present based on their known distribution ranges (see Veron, 2000), such as the agariciid *Pavona duerdeni* and the euphylliid *Nemenzophyllia turbida*. Both species were found on the reefs of Brunei approximately 150 km southwest of Kota Kinabalu, albeit uncommon (Turak & DeVantier, 2011). In Semporna, *P. duerdeni* was only encountered on exposed reefs while *N. turbida* had a preference for turbid and sheltered conditions. Both sheltered and exposed reef conditions are present in Kota Kinabalu, which implies that there may be other limiting factors at play.

Table 3. Coral species that were the most and least common during the survey (excluding Mengalum Island). A = Agariciidae, E = Euphylliidae, F = Fungiidae.

Coral Species Found at All Sites		Least Common Coral Species (n≤3)	
Danafungia horrida	F	*Cycloseris boschmai*	F
Danafungia scruposa	F	*Cycloseris somervillei*	F
Fungia fungites	F	*Pleuractis taiwanensis*	F
Heliofungia actiniformis	F	*Podabacia motuporensis*	F
Herpolitha limax	F	*Zoopilus echinatus*	F
Lithophyllon concinna	F	*Leptoseris gardineri*	A
Lithophyllon repanda	F	*Leptoseris* cf. *solida*	A
Pleuractis granulosa	F	*Pavona minuta*	A
Pleuractis moluccensis	F	*Euphyllia cristata*	E
Pleuractis paumotensis	F	*Euphyllia paradivisa*	E
Leptoseris glabra	A	*Euphyllia yaeyamaensis*	E
Leptoseris scabra	A	*Plerogyra multilobata*	E
Plerogyra sinuosa	E		

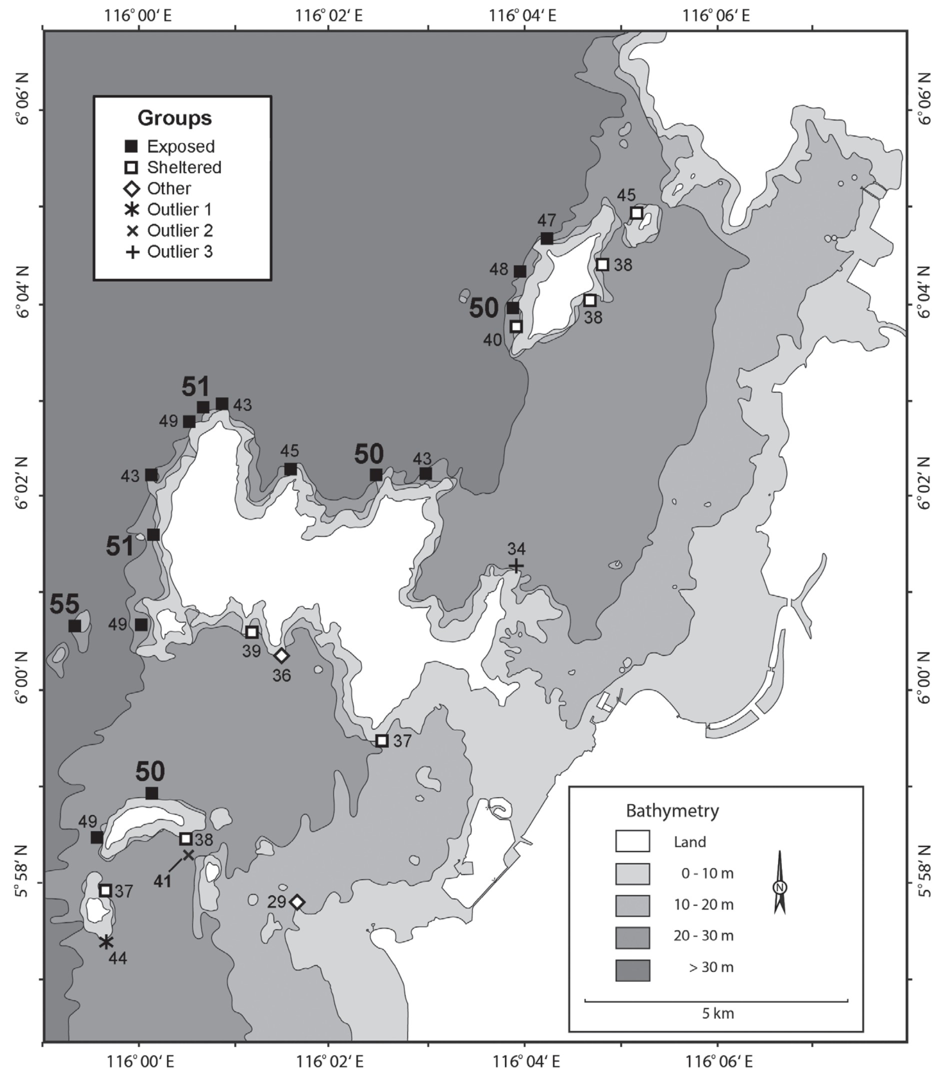

Fig. 4. Species richness patterns derived from the dendrogram and MDS plots in Fig. 3a, b. The numbers represent the combined species diversity of all three coral families Fungiidae, Agariciidae, and Euphylliidae. Sites with the highest species diversity (≥ 50 species) are shown in bold and larger fonts.

Wave action generated by winds can influence the coral composition on the reefs (e.g., Bradbury & Young, 1981; Dollar, 1982; Brown et al., 1983; Moll, 1983; Hoeksema, 2012a), especially on the exposed upper reef slopes, while sediment movement is the controlling factor on the lower slopes and reef base (Sheppard, 1982). Reefs are also known to be limited by depth and light intensity (Chappell, 1980; Done, 1983). Sediment load can affect both mentioned factors by further decreasing light penetration reaching the reef. Wood (1979) stated that reef conditions in the shallower reef zones were generally better than on deeper slopes and suggested sedimentation as the cause, in particular at several sites of Gaya and Sapi islands. Although the point source of sediments has not been determined, anthropogenic activities such as land clearing and reclamation for development, and nutrient enrichment from storm drains in Kota Kinabalu are possibly responsible (Pilcher & Cabanban, 2000). There was no obvious difference in the water clarity ranging from the shallow to the deeper reef zones, but during the survey horizontal visibility was better in the exposed reef (~10 m) compared to the sheltered reef sites (5–7 m). In Jakarta Bay, various species of corals appeared to have disappeared from the reefs when a survey was done in 2005 and compared with scleractinian specimen collections from the 1920s (Van der Meij et al., 2010). Loss of some mushroom coral species from the reefs of Singapore has also been observed when the findings from a survey in 2006 were compared with old museum specimens that were collected since the 1860s (Hoeksema & Koh, 2009). Both studies linked the loss of coral species with increased sediment load in the waters and reefs as a result of development.

The proximity of the TARP coral reefs to Kota Kinabalu makes it a popular tourist destination. In recent years, there has been an increase in the number of visitors to the park, and out of the five marine parks in Sabah, TARP receives the highest number of tourists (Sabah Parks Visitor Statistics). Although the actual impact of tourism has not been measured, it has been suggested that tourist activities have contributed to the pressure on the reefs (Pilcher & Cabanban, 2000). The park would be an ideal area for conducting research on the impacts of tourism, as well as the effects of sedimentation to the coral reef community in Kota Kinabalu (Cabanban & Nais, 2003).

CONCLUSIONS

In summary, the present study gives an account of the coral species richness of the families Fungiidae, Agariciidae, and Euphylliidae, which could serve as a baseline for future studies on the coral reef ecosystem of Kota Kinabalu. These studies can either focus on other coral families, therefore adding more species to the current list, or to revisit the species richness of these three families in order to determine changes in the coral communities. There was a noticeable but statistically insignificant difference in the coral species composition between the sheltered shallow reefs and the exposed deeper reefs, with highest diversity in the latter. Presumably, the sheltered and shallow reefs offer less variety of habitats (shorter depth gradient), and may be influenced by nearshore processes such as sedimentation. Periodic monitoring is recommended in order to detect changes on the reef communities of Kota Kinabalu. For instance, very little is known about the effects of the 2010 coral bleaching event (Tun et al., 2010; Aw & Muhammad Ali, 2012) in comparison to some other areas in Southeast Asia (e.g., Chavanich et al., 2012; Guest et al., 2012; Sutthacheep et al., 2012; Hoeksema et al., 2012, 2013; Yeemin et al., 2013). Although the coral fauna of Kota Kinabalu is less diverse than Semporna, the area is deemed species-rich and from a mushroom coral standpoint, Kota Kinabalu should be considered part of the Coral Triangle (Hoeksema, 2007).

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Appendix 1. Scleractinia species of families Fungiidae, Agariciidae, and Euphylliidae at Kota Kinabalu (Sites 1–31) and Mengalum Island (Sites 32 & 33).

Sampling Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	**Total**
Fungiidae																																		
Ctenactis albitentaculata Hoeksema, 1989	0	1	0	0	0	0	0	1	0	0	0	0	1	0	1	1	1	1	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	11
Ctenactis crassa (Dana, 1846)	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	31
Ctenactis echinata (Pallas, 1766)	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	31
Cycloseris boschmai Hoeksema, 2014	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cycloseris costulata (Ortmann, 1889)	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	30
Cycloseris cyclolites (Lamarck, 1815)	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	0	0	0	0	1	1	1	0	0	0	0	9
Cycloseris fragilis (Alcock, 1893)	0	1	0	1	1	0	1	1	1	1	1	0	1	0	1	1	0	1	0	1	0	1	0	1	1	1	1	1	1	1	1	0	0	22
Cycloseris mokai (Hoeksema, 1989)	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	30
Cycloseris sinensis Milne Edwards and Haime, 1851	0	1	0	1	0	0	1	0	0	0	0	0	1	0	1	1	0	1	1	1	1	0	1	0	1	1	1	1	0	0	0	0	0	15
Cycloseris somervillei (Gardiner, 1909)	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Cycloseris tenuis (Dana, 1846)	0	1	1	1	1	1	0	0	0	0	0	1	0	1	1	0	0	1	1	0	1	0	0	0	0	1	1	1	1	0	1	0	1	17
Danafungia horrida (Dana, 1846)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	32
Danafungia scruposa (Klunzinger, 1879)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	32
Fungia fungites (Linnaeus, 1758)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	33
Halomitra pileus (Linnaeus, 1758)	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	1	0	0	0	1	1	1	0	0	0	1	0	12
Heliofungia actiniformis (Quoy and Gaimard, 1833)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	31
Herpolitha limax (Esper, 1797)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	33
Lithophyllon concinna (Verrill, 1864)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	33
Lithophyllon repanda (Dana, 1846)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	33
Lithophyllon scabra (Döderlein, 1901)	0	0	1	1	1	0	0	0	0	0	0	0	1	0	1	1	1	1	1	0	1	1	1	0	1	1	1	1	0	1	0	1	1	19
Lithophyllon spinifer (Claereboudt and Hoeksema, 1987)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	1	1	0	1	0	1	0	0	7
Lithophyllon undulatum Rehberg, 1892	1	1	1	1	1	1	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	28
Lobactis scutaria (Lamarck, 1801)	0	0	0	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	1	1	21
Pleuractis granulosa (Klunzinger, 1879)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	32
Pleuractis gravis (Nemenzo, 1955)	0	1	1	1	1	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	1	0	23
Pleuractis moluccensis (Van der Horst, 1919)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	33
Pleuractis paumotensis (Stutchbury, 1833)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	33
Pleuractis taiwanensis Hoeksema and Dai, 1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
Podabacia crustacea (Pallas, 1766)	0	0	1	1	1	0	1	0	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1	1	24
Podabacia motuporensis Veron, 1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Podabacia sinai Veron, 2002	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	4
Polyphyllia talpina (Lamarck, 1801)	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	31
Sandalolitha dentata Quelch, 1884	0	1	1	1	1	0	1	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	0	0	21
Sandalolitha robusta (Quelch, 1886)	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	32
Zoopilus echinatus Dana, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Total	13	24	21	28	26	19	22	17	20	16	18	21	26	21	29	26	24	28	29	23	27	25	24	18	21	29	27	27	25	21	21	20	14	

Appendix 1. Cont'd.

Sampling Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	Total
Agariciidae																																		
Coeloseris mayeri Vaughan, 1918	1	1	1	1	1	0	1	–	1	1	1	–	1	–	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1	1	26
Gardineroseris planulata (Dana, 1846)	0	0	0	0	0	0	0	–	0	1	0	–	1	–	1	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1	0	1	0	11
Leptoseris foliosa Dinesen, 1980	0	1	0	0	1	0	0	–	0	0	0	–	1	–	0	1	0	0	0	1	0	1	0	0	0	1	1	0	0	0	0	0	0	8
Leptoseris fragilis Milne Edwards and Haime, 1849	0	1	0	0	1	1	0	–	0	1	0	–	0	–	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	7
Leptoseris gardineri Van der Horst, 1921	0	0	0	0	1	0	0	–	0	0	0	–	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Leptoseris glabra Dinesen, 1980	1	1	1	1	1	1	1	–	1	1	1	–	1	–	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	28
Leptoseris hawaiiensis Vaughan, 1907	0	1	0	0	0	1	0	–	0	0	0	–	0	–	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4
Leptoseris incrustans (Quelch, 1886)	0	0	0	1	1	0	0	–	0	0	0	–	1	–	0	1	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	1	0	9
Leptoseris mycetoseroides Wells, 1954	1	1	0	1	1	1	1	–	1	1	1	–	1	–	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0	26
Leptoseris papyracea (Dana, 1846)	0	1	0	1	0	0	1	–	0	0	0	–	1	–	1	0	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	10
Leptoseris scabra Vaughan, 1907	1	1	1	1	1	1	1	–	1	1	1	–	1	–	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	29
Leptoseris cf. *solida*	0	1	0	0	0	0	0	–	0	0	0	–	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Leptoseris tubulifera Vaughan, 1907	1	1	1	1	1	1	1	–	0	1	1	–	1	–	1	1	0	1	1	1	0	1	0	0	1	1	1	1	1	0	0	0	0	21
Leptoseris yabei (Pillai and Scheer, 1976)	0	0	0	0	1	0	1	–	0	1	0	–	1	–	1	0	0	1	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	10
Pachyseris gemmae Nemenzo, 1955	0	0	0	1	0	0	0	–	1	0	1	–	1	–	0	1	1	0	1	0	1	1	0	0	0	1	1	1	1	1	0	1	1	16
Pachyseris rugosa (Lamarck, 1801)	0	0	0	0	1	0	1	–	0	0	1	–	0	–	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	8
Pachyseris speciosa (Dana, 1846)	1	1	1	1	1	1	1	–	1	1	1	–	1	–	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	29
Pavona cactus (Forskål, 1775)	1	1	1	1	1	1	1	–	1	1	1	–	1	–	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	28
Pavona clavus (Dana, 1846)	0	0	0	0	1	0	0	–	0	1	0	–	0	–	1	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	1	0	8
Pavona decussata (Dana, 1846)	1	1	1	1	1	1	1	–	1	1	1	–	1	–	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	29
Pavona explanulata (Lamarck, 1816)	1	0	1	1	1	1	1	–	1	1	1	–	1	–	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	27
Pavona frondifera (Lamarck, 1816)	0	0	0	0	0	1	1	–	0	0	1	–	0	–	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	6
Pavona maldivensis (Gardiner, 1905)	0	1	1	0	0	0	0	–	0	0	0	–	0	–	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Pavona minuta Wells, 1954	0	0	0	0	1	0	0	–	0	0	0	–	0	–	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2
Pavona varians Verrill, 1864	1	1	1	1	1	1	1	–	1	1	1	–	1	–	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	28
Pavona venosa (Ehrenberg, 1834)	1	1	1	1	1	1	1	–	1	1	1	–	1	–	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	28
Pavona sp.	0	0	0	0	0	0	0	–	0	0	0	–	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Total	11	16	11	14	19	13	15	0	11	15	14	0	17	0	20	18	12	14	15	14	11	18	12	9	11	14	14	13	13	10	10	15	7	

Appendix 1. Cont'd.

Sampling Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	**Total**
Euphylliidae																																		
Catalaphyllia jardinei (Saville-Kent, 1893)	0	0	0	1	0	0	0	–	0	0	1	–	1	–	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	18
Euphyllia ancora Veron and Pichon, 1980	1	1	1	1	1	1	1	–	1	0	1	–	1	–	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	28
Euphyllia cristata Chevalier, 1971	0	0	0	0	0	0	0	–	0	0	0	–	0	–	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	2
Euphyllia divisa Veron and Pichon, 1980	0	1	1	1	1	1	0	–	1	1	1	–	1	–	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	26
Euphyllia glabrescens (Chamisso and Eysenhardt, 1821)	1	1	0	1	1	1	1	–	1	1	1	–	1	–	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	28
Euphyllia paraancora Veron, 1990	1	0	1	1	1	1	1	–	1	1	1	–	1	–	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	27
Euphyllia paradivisa Veron, 1990	0	0	0	0	0	0	0	–	0	0	0	–	0	–	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	3
Euphyllia yaeyamaensis (Shirai, 1980)	0	0	0	1	0	0	0	–	0	0	0	–	0	–	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3
Physogyra lichtensteini (Milne Edwards and Haime, 1851)	1	0	1	0	0	1	0	–	1	1	1	–	0	–	1	1	1	1	1	0	1	1	1	0	1	0	0	1	1	0	0	0	0	17
Plerogyra multilobata Ditlev, 2003	0	0	0	0	0	0	0	–	0	0	0	–	0	–	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Plerogyra simplex Rehberg, 1892	0	0	0	0	0	0	0	–	0	0	0	–	0	–	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Plerogyra sinuosa (Dana, 1846)	1	1	1	1	1	1	1	–	1	1	1	–	1	–	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	29
Total	5	4	5	7	5	6	4	0	6	5	7	0	6	0	6	7	7	7	7	6	7	7	7	7	8	7	7	7	7	7	7	5	0	