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Article

Diversity and Abundance of Scleractinian Corals in the East Coast of Peninsular Malaysia: A Case Study of Redang and Tioman Islands

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Abstract – The species lists of scleractinian hard corals in Peninsular Malaysia have not been updated for 15 years. The present study aimed to determine the diversity and abundance patterns of scleractinian hard corals at twenty eight fringing reef sites along the coast of Redang and Tioman Islands. Visual photograph analyses of the coral video transect method revealed a total of 128 species from 47 genera in Redang and 239 species from 55 genera in Tioman. Following recent taxonomy of scleractinian corals, coral surveys and past studies revealed a total of 166 species from 53 genera in Redang and 350 species from 67 genera in Tioman. Current data at both islands presented a total of 358 species from 69 genera and 15 families of scleractinian corals with an additional 8 new species records for the east coast of Peninsular Malaysia. *Acropora*, *Montipora* and *Porites* were the most dominant genera and were found distributed within the coral assemblages. The reefs around both islands can be categorized under "good" coral conditions with the live corals cover from 40.9% to 73.5%. Overall findings indicated that the less affected reef zones by coastal development and human activities at both islands have established good coral conditions and coral genera diversity.

Keywords – scleractinian coral, coral diversity, coral abundance, marine protected area, Peninsular Malaysia

1. Introduction

Coral reefs comprise the highest levels of marine species diversity around the globe (Bowen et al. 2013). They are vital to the economy, subsistence and cash-crop fisheries of approximately 200 million people in the Coral Triangle (CT) area (Wilkinson 2008). The CT area encompasses the 16 ecoregions of six Asia-Pacific countries from the Philippines, Indonesia, East Malaysia (Sabah region), Timur Leste, Papua New Guinea and the Solomon Islands (Veron et al. 2011). This area has been largely recognized as the global center of coral mega biodiversity regions, which hosts 605 zooxanthellate coral species (Veron et al. 2011).

A recent study showed that 16 reef areas around the South China Sea (SCS) region (including the eastern part of Peninsular Malaysia) host about 571 zooxanthellate coral species (Huang et al. 2015). Based on the species list of hard corals published by Affendi and Rosman (2012), a total of 431 species have been recorded in the eastern part of Peninsular Malaysia. This region also had the highest coral diversity in comparison to the southern part with 245 species and the western part with only 63 species, which is revealed as the lowest coral diversity region in Peninsular Malaysia. The data compiled to date gives a species count of 480 hard corals in Peninsular Malaysia (Affendi and Rosman 2012). This figure represents approximately 80% of the total number of coral species identified by Huang et al. (2015) in the SCS region.

Most islands in Peninsular Malaysia have been protected under jurisdiction of the Department of Marine Park Malaysia (DMPM 2011). Redang and Tioman Islands, located on the east coast of Peninsular Malaysia, are recognized as the most popular Marine Parks that formed the basis for a valuable tourism industry with potential for ecotourism and education-related activities (Hanim et al. 2010). Besides healthy and diverse coral species, good infrastructure and tourism facilities,

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such as roads, an airport, resorts, hotels, restaurants, shops and a golf course have become major attractions for local and international tourists to visit these islands (Shahbudin et al. 2017).

Despite providing direct economic benefits for local communities, unsustainable coastal development activities and dredging impacts from construction of resorts and jetty facilities are among the major threats affecting coral reefs in these islands (Harborne et al. 2000; Maseri 2003). The large number of visiting tourists engaged in uncontrolled tourism activities such as diving, snorkeling and boating has also been correlated with a major decline in the live coral coverage (Badaruddin et al. 2004: Toda et al. 2007; Shahbudin et al. 2017). Furthermore, the natural impact from the bleaching phenomenon recorded in the middle of 2010 was observed to cause bleaching with respect to approximately 50% of the hard coral colonies around Redang and Tioman Islands (Tan and Heron 2011). Hence, the elevated current sea surface temperature (SST) due to global climate change is predicted to increase the number of bleaching events and further promote the emergence of coral diseases along the Malaysian reefs (Miller et al. 2015).

In light of this, management action such as updating a comprehensive inventory of scleractinian corals should be taken to ensure the conservation and sustainability of this ecosystem. The present study is considered important in providing holistic data and information on the current status of coral reefs in Redang and Tioman Islands. The aims of this study are 1) to update the list of scleractinian coral species in Redang and Tioman Islands by combining with previous data from Harborne et al. (2000), Affendi et al. (2005) and Affendi et al. (2007) using the most recent taxonomic classification of scleractinian corals, 2) to determine the generic diversity and abundance patterns of scleractinian corals and 3) to evaluate coral conditions at 28 sampling stations in Redang and Tioman Islands. The outcomes of this study may help the relevant agencies such as the section of Marine Park Malaysia, Department of Fisheries (DOF) and universities in updating hard coral inventories for future systematic conservation plans towards sustainable management of coral reef resources.

2. Materials and Methods

Sampling Area

Surveys were carried out between September 2014 and November 2014 at 28 sampling stations in Redang Island (15 sampling stations) and Tioman Island (13 sampling stations). Redang Island is located approximately 25 km from Merang and Tioman Island, 50 km from Mersing off the east coast of Peninsular Malaysia. The sampling stations were selected based on the information given by tourist operators and local communities about dive sites designated for snorkeling and diving activities around the islands. The sampling stations then were categorized into several sampling zones based on the difference in environmental conditions, coastal developments and human activities that might give a clear comparison regarding the diversity and abundance patterns of scleractinian corals (Fig. 1). All the sampling stations were categorized as fringing reef sites from a maximum depth of 18 m to the shallow reef crest of 3 m.

Corals survey method

The Coral Video Transect (CVT) method adopted by Liew et al. (2012) and optimized by Safuan et al. (2015) was used in this study with some modifications. Four x 30 m transect lines were placed in parallel form for every sampling station with a 3 m interval between each transect. A total of 112 transect lines were used in this study. The images of benthic communities along the transect lines were recorded using an underwater camera (Olympus TG-3 in a ratio of 16:4 and 1980 × 1080 high definition (HD) resolution) protected with a waterproof casing (Olympus PT-053). The height of the camera from the substrates was approximately 50 cm and held at a perpendicular angle to the bottom. The camera was run along the transect lines at a speed of 5 minutes per transect line to get clear and sharp images for coral identification. The additional stilt pictures of close-up coral corallites were captured to aid in the identification process. Scleractinian corals were identified using the books of Corals of the World (Veron 2000). The following update of species list was further standardized with the most recent taxonomic classification of scleractinian corals following the World Register of Marine Species (WoRMS).

Image processing and data analyses

The recorded videos of benthic communities along four x 30 m transect lines for every sampling station were converted to 300 images (approximately 80% of total image extracted). All the images were analyzed using Coral Point Count with Excel extension (CPCe) software version 4.1 developed by Kohler and Gill (2006) with 10 random points per image. Data were summarized into percentage cover of three benthic

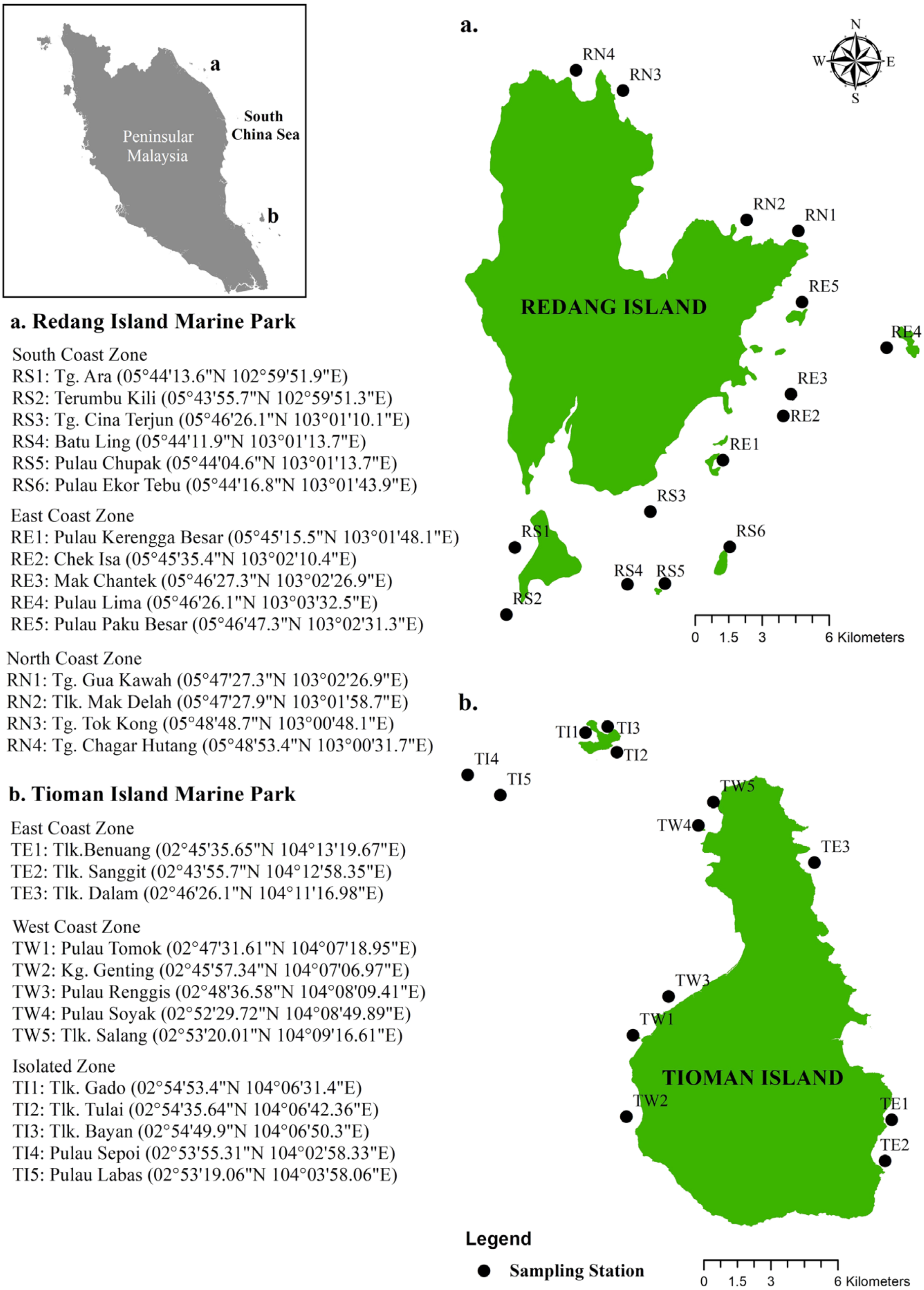

Fig. 1. Location and coordinate position of 28 sampling stations in a) Redang Island Marine Park which were divided into three zones: south coast (RS1, RS2, RS3, RS4, RS5, RS6), east coast (RE1, RE2, RE3, RE4, RE5) and north coast (RN1, RN2, RN3, RN4,) zones. b) Tioman Island Marine Park which were divided into three zones: east coast (TE1, TE2, TE3), west coast (TW1, TW2, TW3, TW4, TW5) and isolated (TI1, TI2, TI3, TI4, TI5) zones

categories: live corals (live hard and soft corals), dead corals (coral rubbles and dead coral with algae) and others (coralline algae, other macroalgae, other invertebrates and abiotic elements). The coral condition was indicated by the percentage of live corals following Gomez et al. (1994) as excellent (100–75% live coral), good (74.9–50% live coral), fair (49.9–25% live coral), and poor (24.9–0% live coral). The abundance of each scleractinian genus was estimated based on a rating scale of one to five crosses (+) adopted by Fabricius and McCorry (2006) as followed: where +: one or few colonies covering < 1% of the corals; ++: uncommon, covering 1–5% of the corals; +++: common, covering 6–10% of the corals; ++++ = abundant, covering 11–20% of the corals; and +++++: dominant, covering > 20% of the corals. In addition, the Shannon diversity index (H') (Shannon and Weaver 1998) and Pielou's evenness index (J') (Pielou 1966) were used to determine the diversity and evenness of coral genera recorded for every sampling station using PAST (Paleontological Statistic) software version 3 (Hammer et al. 2001). The statistical test of Kruskal-Wallis was performed using Minitab 17 software to determine the significant differences ($p < 0.05$) on the mean of H' and J' indices between zones and islands.

3. Results

Checklist of scleractinian coral species

Following recent taxonomy of scleractinian corals, the coral survey recorded 128 species of scleractinian corals in Redang Island and 239 species in Tioman Island (Table 1). A previous study done by Harborne et al. (2000) recorded 135 scleractinian species at 6 reef sites (Tlk. Mat Delah, Chagar Hutang, Pulau Ling, Pulau Lima, Pulau Lang Tengah and Terumbu Kili) in Redang Island. Furthermore, a total of 325 scleractinian species were recorded in Tioman Island from surveys done by Harborne et al. (2000) at 7 reef sites (Batu Malang, Tlk. Juara, Pulau Gut, Pulau Tokong Bahara, Pulau Seri Buat, Tlk. Kadar at Pulau Tulai and Pulau Renggis), Affendi et al. (2005) at Tlk. Tekek and Affendi et al. (2007) at several reef sites from Kg. Paya to Kg. Genting. Therefore with regards to all studies above, present findings recorded a total of 358 species, 69 genera and 15 families (including 8 species and 5 genera of Inceratae sedis) of scleractinian corals in Redang and Tioman Islands. The result also revealed 31 species of new scleractinian coral records for Redang Island and 25 species for Tioman Island that were not documented during earlier studies. Moreover, 8 species are listed as new scleractinian coral records for the east coast of Peninsular Malaysia (Fig. 2).

Diversity and abundance patterns of scleractinian coral genera

A total of 47 genera from 13 families including 2 genera of Incertae sedis were recorded in Redang Island (Table 2). Family Merulinidae was found dominant with an average coverage of 27.0% ± 0.6 followed by Acroporidae, Poritidae and Fungiidae with 23.4% ± 4.4, 15.0% ± 7.0 and 12.6% ± 1.0, respectively. Genus *Acropora* had the highest average coverage with 16.1% followed by *Porites* 14.5%, *Fungia* 10.6%, *Dipsastraea* 7.4%, *Favites* 6.9%, *Pocillopora* 6.8%, *Montipora* 6.4%, *Plerogyra* 5.3% and *Platygyra* 4.5%. Meanwhile, other genera had only < 3% average coverage. Genera *Acropora, Montipora, Pavona, Galaxea, Fungia, Lobophyllia, Dipsastraea, Favites*, *Platygyra*, *Pocillopora, Porites* and *Plerogyra* were found to be well distributed at most of the sampling stations ($n \geq 3$). Among these genera, *Acropora* and *Montipora* were found to be dominant at RE3 and RN1 which are located in the east coast and north coast zones, respectively. Genus *Pocillopora* was found to be dominant at RE5 in the east coast zone. Meanwhile other genera such as *Fungia, Dipsastraea* and *Porites* were found to be dominant at several sampling stations in the north coast zone. Genera *Coscinarea, Cycloseris, Lithophyllon, Polyphyllia, Cynarina, Oxypora, Psammocora* and *Leptastrea* were found to be poorly distributed and least abundant ($n \leq 1$) in Redang Island. *Cynarina* was classified as a rare genus as it can be found at only one sampling station covering only a few colonies in Redang Island and was not found in Tioman Island.

In comparison, Tioman Island had a higher number of scleractinian coral genera compared to Redang Island with a total of 55 genera from 14 families including 4 genera of Incertae sedis being recorded (Table 3). Family Acroporidae was found to be dominant with an average coverage of 34.8% ± 5.1 followed by Merulinidae, Poritidae and Euphylliidae with 23.9% ± 0.5, 13.6% ± 6.3 and 9.2% ± 1.2, respectively. Similarly, genus *Acropora* also had the highest average coverage in Tioman Island with 21.5% followed by *Porites* 13.1%, *Montipora* 12.5%, *Favites* 7.3%, *Galaxea* 5.6%, *Platygyra* 5.0%, *Goniastrea* 3.5%, *Pavona* 3.3% and *Pocillopora* 3.1%. Other genera had only < 3% average coverage (Table 3). Genera *Acropora, Montipora, Pavona, Diploastrea, Galaxea, Fungia*, *Lobophyllia, Astrea, Dipsastraea, Favites, Goniastrea, Platygyra, Pocillopora* and *Porites* were found to be well distributed at

Table 1. Checklist of scleractinian coral species in Redang Island and Tioman Island Marine Parks. The symbol (x) indicates the species occurrence. Species were not reported from previous records are highlighted. Previous records are indicated as follows: a) Harborne et al. (2000), b) Affendi et al. (2005), c) Affendi et al. (2007)

No.	Scleractinian coral species	Redang Island Marine Park	Previous record "a"	Tioman Island Marine Park	Previous records "a, b, c"
	Acroporidae Verrill, 1902				
1	*Acropora abrolhosensis* Veron, 1985				x
2	*Acropora aculeus* (Dana, 1846)			x	x
3	*Acropora anthocersis* (Brook, 1893)			x	x
4	*Acropora appressa* (Ehrenberg, 1834)				x
5	*Acropora aspera* (Dana, 1846)	x	x	x	x
6	*Acropora austera* (Dana, 1846)	x		x	x
7	*Acropora awi* allace & Wolstenholme, 1998				x
8	*Acropora carduus* (Dana, 1846)	x		x	
9	*Acropora cerealis* (Dana, 1846)	x	x	x	x
10	*Acropora clathrata* (Brook, 1891)			x	x
11	*Acropora cytherea* (Dana, 1846)	x	x	x	x
12	*Acropora dendrum* (Bassett-Smith, 1890)				x
13	*Acropora digitifera* (Dana, 1846)	x	x	x	x
14	*Acropora divaricata* (Dana, 1846)	x	x	x	
15	*Acropora donei* Veron & Wallace, 1984			x	x
16	*Acropora elseyi* (Brook, 1892)		x		x
17	*Acropora florida* (Dana, 1846)	x	x	x	x
18	*Acropora gemmifera* (Brook, 1892)	x	x	x	x
19	*Acropora grandis* (Brook, 1892)	x		x	x
20	*Acropora hemprichii* (Ehrenberg, 1834)				x
21	Acropora hoeksemai Wallace, 1997			x	x
22	*Acropora horrida* (Dana, 1846)		x	x	x
23	*Acropora humilis* (Dana, 1846)	x	x	x	x
24	*Acropora hyacinthus* (Dana, 1846)	x	x	x	x
25	Acropora indonesia Wallace, 1997*			x	
26	*Acropora intermedia* (Brook, 1891)	x	x	x	x
27	*Acropora kirstyae* Veron & Wallace, 1984				x
28	*Acropora latistella* (Brook, 1892)	x	x	x	x
29	*Acropora listeri* (Brook, 1893)				x
30	*Acropora loripes* (Brook, 1892)	x	x	x	x
31	*Acropora lutkeni* Crossland, 1952				x
32	*Acropora microclados* (Ehrenberg, 1834)				x
33	*Acropora microphthalma* (Verrill, 1869)	x	x	x	x
34	*Acropora millepora* (Ehrenberg, 1834)			x	x
35	*Acropora monticulosa* (Brüggemman, 1879)			x	x
36	*Acropora muricata* (Linnaeus, 1758)	x	x	x	x
37	*Acropora nana* (Studer, 1878)				x
38	*Acropora nasuta* (Dana, 1846)	x	x	x	x
39	*Acropora papillare* Latypov, 1992				x
40	*Acropora pruinosa* (Brook, 1893)				x
41	*Acropora pulchra* (Brook, 1891)				x
42	*Acropora retusa* (Dana, 1846)				x
43	*Acropora robusta* (Dana, 1846)	x	x	x	x
44	*Acropora samoensis* (Brook, 1891)	x	x	x	x

Table 1. Continued

No.	Scleractinian coral species	Redang Island Marine Park	Previous record "a"	Tioman Island Marine Park	Previous records "a, b, c"
45	*Acropora secale* (Studer, 1878)			x	x
46	*Acropora selago* (Studer, 1878)			x	x
47	*Acropora solitaryensis* Veron & Wallace, 1984		x	x	x
48	*Acropora spicifera* (Dana, 1846)			x	
49	*Acropora subglara* (Brook, 1891)	x			
50	*Acropora tenuis* (Dana, 1846)	x	x	x	x
51	*Acropora valida* (Dana, 1846)				x
52	*Acropora valenciennesi* (Milne Edwards & Haime, 1860)		x	x	x
53	*Acropora vaughani* Wells, 1954				x
54	*Acropora yongei* Veron & Wallace, 1984				x
55	*Alveopora minuta* Veron, 2000				x
56	*Alveopora spongiosa* Dana, 1846			x	x
57	*Anacropora matthai* Pillai, 1973			x	x
58	*Anacropora forbesi* Ridley, 1884			x	
59	*Anacropora reticulata* Veron & Wallace, 1984				x
60	*Astreopora gracilis* Bernard, 1896			x	x
61	*Astreopora listeri* Bernard, 1896				x
62	*Astreopora myriophthalma* (Lamarck, 1816)	x	x	x	x
63	*Astreopora ocellata* Bernard, 1896		x	x	x
64	*Isopora bruggemanni* (Brook, 1893)		x	x	x
65	*Isopora cuneata* (Dana, 1846)			x	
66	*Isopora palifera* (Lamarck, 1816)			x	x
67	*Isopora togianensis* (Wallace, 1997)				x
68	*Montipora aequituberculata* Bernard, 1897	x	x	x	x
69	*Montipora altasepta* Nemenzo, 1967	x	x		x
70	*Montipora cactus* Bernard, 1897			x	
71	*Montipora calcarea* Bernard, 1897				x
72	*Montipora caliculata* (Dana, 1846)				x
73	*Montipora capricornis* Veron, 1985				x
74	*Montipora cebuensis* Nemenzo, 1976			x	
75	*Montipora cocosensis* Vaughan, 1918				x
76	*Montipora confusa* Nemenzo, 1967			x	x
77	*Montipora crassituberculata* Bernard, 1897			x	x
78	*Montipora danae* (Milne Edwards & Haime, 1851)			x	x
79	*Montipora delicatula* Veron, 2000			x	x
80	*Montipora digitata* (Dana, 1846)				x
81	*Montipora effusa* Dana, 1846				x
82	*Montipora efflorescens* Bernard, 1897			x	
83	*Montipora flabellata* Studer, 1901*			x	
84	*Montipora florida* Nemenzo, 1967				x
85	*Montipora foliosa* (Pallas, 1766)		x	x	x
86	*Montipora foveolata* (Dana, 1846)				x
87	*Montipora friabilis* Bernard, 1897			x	x
88	*Montipora gaimardi* Bernard, 1897	x	x		x
89	*Montipora grisea* Bernard, 1897			x	
90	*Montipora hirsuta* Nemenzo, 1967				x

Table 1. Continued

No.	Scleractinian coral species	Redang Island Marine Park	Previous record "a"	Tioman Island Marine Park	Previous records "a, b, c"
91	*Montipora hispida* (Dana, 1846)	x	x	x	x
92	*Montipora informis* Bernard, 1897	x	x	x	x
93	*Montipora malampaya* Nemenzo, 1967		x		x
94	*Montipora meandrina* (Ehrenberg, 1834)				x
95	*Montipora millepora* Crossland, 1952		x	x	x
96	Montipora mollis Bernard, 1897		x		
97	*Montipora monasteriata* (Forskål, 1775)			x	x
98	*Montipora nodosa* (Dana, 1846)				x
99	*Montipora palawanensis* Veron, 2000				x
100	*Montipora peltiformis* Bernard, 1897				x
101	*Montipora spumosa* (Lamarck, 1816)				x
102	*Montipora stellata* Bernard, 1897	x		x	x
103	*Montipora tuberculosa* (Lamarck, 1816)		x	x	x
104	*Montipora turgescens* Bernard, 1897			x	
105	*Montipora turtlensis* Veron & Wallace, 1984			x	
106	*Montipora undata* Bernard, 1897			x	x
107	*Montipora venosa* (Ehrenberg, 1834)			x	x
108	*Montipora verrucolosus* Veron, 2000			x	x
109	*Montipora verrucosa* (Lamarck, 1816)			x	x
110	Montipora vietnamensis Veron, 2000			x	
	Agariciidae Gray, 1847				
111	*Gardineroseris planulata* (Dana, 1846)	x	x	x	x
112	*Leptoseris explanata* Yabe & Sugiyama, 1941	x	x		x
113	*Leptoseris foliosa* Dinesen, 1980				x
114	*Leptoseris gardineri* Van der Horst, 1921				x
115	*Leptoseris hawaiiensis* Vaughan, 1907	x	x		x
116	*Leptoseris mycetoseroides* Wells, 1954	x	x		x
117	*Leptoseris papyracea* (Dana, 1846)				x
118	*Leptoseris scabra* Vaughan, 1907			x	x
119	*Leptoseris tubulifera* Vaughan, 1907				x
120	*Leptoseris yabei* (Pillai & Scheer, 1976)				x
121	Pavona bipartita Nemenzo, 1979		x		x
122	*Pavona cactus* (Forskål, 1775)	x	x	x	x
123	*Pavona clavus* (Dana, 1846)			x	x
124	*Pavona danai* Milne Edwards & Haime, 1860			x	x
125	*Pavona decussata* (Dana, 1846)	x	x	x	x
126	*Pavona duerdeni* Vaughan, 1907				x
127	*Pavona explanulata* (Lamarck, 1816)	x	x	x	x
128	*Pavona frondifera* (Lamarck, 1816)		x	x	x
129	*Pavona gigantean* Verrill, 1869				x
130	*Pavona maldivensis* (Gardiner, 1905)				x
131	*Pavona venosa* (Ehrenberg, 1834)			x	x
132	*Pavona varians* Verrill, 1864	x	x	x	x
	Astrocoeniidae Koby, 1890				
133	*Palauastrea ramosa* Yabe & Sugiyama, 1941				x
134	*Stylocoeniella armata* (Ehrenberg, 1834)				x
135	*Stylocoeniella cocosensis* Veron, 1990			x	x
136	*Stylocoeniella guentheri* Bassett-Smith, 1890			x	x

Table 1. Continued

No.	Scleractinian coral species	Redang Island Marine Park	Previous record "a"	Tioman Island Marine Park	Previous records "a, b, c"
	Coscinaraeidae Benzoni, Arrigoni, Stefani & Stolarski, 2012				
137	*Coscinaraea columna* (Dana, 1846)	x	x	x	x
138	*Coscinaraea exesa* (Dana, 1846)			x	x
139	*Coscinaraea hahazimaensis* Yabe & Sugiyama, 1936				x
	Dendrophylliidae Gray, 1847				
140	*Turbinaria frondens* (Dana, 1846)		x	x	
141	*Turbinaria irregularis* Bernard, 1896				x
142	*Turbinaria mesenterina* (Lamarck, 1816)	x	x	x	x
143	*Turbinaria peltata* (Esper, 1794)	x	x	x	x
144	*Turbinaria reniformis* Bernard, 1896				x
145	*Turbinaria stellulata* (Lamarck, 1816)	x	x	x	x
	Diploastraeidae Chevalier & Beauvais, 1987				
146	*Diploastrea heliopora* (Lamarck, 1816)	x	x	x	x
	Euphylliidae Alloiteau, 1952				
147	*Catalaphyllia jardini* (Saville-Kent, 1893)		x	x	
148	*Euphyllia ancora* Veron & Pichon, 1980	x		x	x
149	*Euphyllia cristata* Chevalier, 1971*	x			
150	*Euphyllia divisa* Veron & Pichon, 1980	x	x	x	x
151	*Euphyllia glabrescens* (Chamisso & Eysenhardt, 1821)	x	x	x	x
152	*Euphyllia paradivisa* Veron, 1990				x
153	*Euphyllia paraglabrescens* Veron, 1990				x
154	*Euphyllia yaeyamensis* (Shirai, 1980)			x	x
155	*Galaxea astreata* (Lamarck, 1816)	x	x	x	x
156	*Galaxea fascicularis* (Linnaeus, 1767)	x	x	x	x
157	*Galaxea horrescens* (Dana, 1846)				x
158	*Pachyseris foliosa* Veron, 1990		x	x	x
159	*Pachyseris gemmae* Nemenzo, 1955			x	x
160	*Pachyseris rugosa* (Lamarck, 1801)	x	x	x	x
161	*Pachyseris speciosa* (Dana, 1846)	x	x	x	x
	Fungiidae Dana, 1846				
162	*Ctenactis albitentaculata* Hoeksema, 1989	x	x	x	x
163	*Ctenactis crassa* (Dana, 1846)	x	x	x	x
164	*Ctenactis echinata* (Pallas, 1766)	x	x	x	x
165	*Cycloseris costulata* (Ortmann, 1889)			x	x
166	*Cycloseris distorta* (Michelin, 1842)				x
167	*Cycloseris fragilis* (Alcock, 1893)	x	x	x	x
168	Cycloseris mokai (Hoeksema, 1989)			x	
169	*Cycloseris somervillei* (Gardiner, 1909)			x	x
170	*Cycloseris tenuis* (Dana, 1846)				x
171	*Cycloseris vaughani* (Boschma, 1923)				x
172	*Danafungia horrida* (Dana, 1846)		x	x	x
173	*Danafungia scruposa* (Klunzinger, 1879)	x	x		x
174	*Fungia fungites* (Linnaeus, 1758)	x	x	x	x
175	*Heliofungia actiniformis* (Quoy & Gaimard, 1833)			x	x
176	*Heliofungia fralinae* (Nemenzo, 1955)				x
177	*Herpolitha limax* (Esper, 1797)	x	x	x	x

Table 1. Continued

No.	Scleractinian coral species	Redang Island Marine Park	Previous record "a"	Tioman Island Marine Park	Previous records "a, b, c"
178	*Lithophyllon concinna* (Verrill, 1864)	x	x	x	x
179	*Lithophyllon repanda* (Dana, 1846)	x	x	x	x
180	*Lithophyllon scabra* (Döderlein, 1901)			x	x
181	*Lithophyllon spinifer* (Claereboudt & Hoeksema, 1987)				x
182	*Lithophyllon undulatum* Rehberg, 1892	x	x	x	x
183	Lobactis scutaria (Lamarck, 1801)				x
184	*Pleuractis granulosa* (Klunzinger, 1879)	x	x	x	x
185	*Pleuractis gravis* (Nemenzo, 1955)	x		x	
186	*Pleuractis moluccensis* (Van der Horst, 1919)		x	x	x
187	*Pleuractis paumotensis* (Stutchbury, 1833)		x	x	x
188	*Podabacia crustacea* (Pallas, 1766)		x	x	x
189	*Podabacia motuporensis* Veron, 1990			x	x
190	*Polyphyllia talpina* (Lamarck, 1801)	x	x	x	x
191	*Sandalolitha dentata* Quelch, 1884			x	x
192	*Sandalolitha robusta* (Quelch, 1886)	x	x	x	x
	Lobophylliidae Dai & Horng, 2009				
193	*Acanthastrea brevis* Milne Edwards and Haime, 1849*			x	
194	*Acanthastrea echinata* (Dana, 1846)			x	
195	*Acanthastrea hemprichi* (Ehrenberg, 1834)	x	x	x	x
196	*Acanthastrea pachysepta* Chevalier, 1975			x	x
197	*Acanthastrea subechinata* Veron, 2000*	x		x	
198	Cynarina lacrymalis (Milne Edwards & Haime, 1849)	x			
199	*Echinophyllia aspera* (Eillis & Solander, 1786)		x	x	x
200	Echinophyllia orpheensis Veron & Pichon, 1980	x	x	x	x
201	*Homophyllia australis* (Milne Edwards & Haime, 1849)		x		x
202	Homophyllia bowerbanki (Milne Edwards, 1857)				
203	*Lobophyllia agaricia* Milne Edwards & Haime, 1849	x	x	x	x
204	*Lobophyllia corymbosa* (Forskål, 1775)			x	x
205	*Lobophyllia diminuta* Veron, 1985				x
206	*Lobophyllia flabelliformis* Veron, 2000	x		x	x
207	*Lobophyllia hassi* Pillai & Scheer, 1976			x	x
208	*Lobophyllia hataii* Yabe, Sugiyama & Eguchi, 1936	x	x	x	x
209	*Lobophyllia hemprichii* (Ehrenberg, 1834)	x	x	x	x
210	*Lobophyllia radians* Milne Edwards & Haime, 1849		x	x	x
211	*Lobophyllia recta* (Dana, 1846)	x	x	x	x
212	*Lobophyllia robusta* Yabe & Sugiyama, 1936	x		x	x
213	*Lobophyllia valenciennesii* Milne Edwards & Haime, 1849	x	x	x	x
214	*Lobophyllia vitiensis* (Brüggemann, 1877)		x	x	x
215	*Micromussa diminuta* Veron, 2000*			x	
216	*Micromussa lordhowensis* Veron and Pichon, 1982			x	x
217	*Micromussa multipunctata* Hodgson, 1985				x
218	*Micromussa regularis* Veron, 2000				x
219	*Oxypora crassispinosa* Nemenzo, 1979			x	x
220	*Oxypora glabra* Nemenzo, 1959				x
221	*Oxypora lacera* (Verrill, 1864)	x	x		x
222	*Australogyra zelli* (Veron, Pichon & Wijsman-Best, 1977)				x

Table 1. Continued

No.	Scleractinian coral species	Redang Island Marine Park	Previous record "a"	Tioman Island Marine Park	Previous records "a, b, c"
	Merulinidae Verrill, 1865				
223	*Astrea annuligera* Milne Edwards & Haime, 1849				x
224	*Astrea curta* Dana, 1846	x		x	x
225	Caulastraea tumida Matthai, 1928	x	x		
226	*Coelastrea aspera* (Verrill, 1866)	x		x	x
227	*Coelastrea palauensis* (Yabe & Sugiyama, 1936)			x	x
228	*Cyphastrea agassizi* (Vaughan, 1907)				x
229	*Cyphastrea chalcidicum* (Forskål, 1775)	x		x	x
230	*Cyphastrea japonica* Yabe & Sugiyama, 1932				x
231	*Cyphastrea microphthalma* (Lamarck, 1816)			x	x
232	*Cyphastrea ocellina* (Dana, 1846)				x
233	*Cyphastrea serailia* (Forskål, 1775)	x		x	x
234	*Dipsastraea albida* (Veron, 2000)				x
235	*Dipsastraea amicorum* (Milne Edwards & Haime, 1849)	x	x	x	x
236	*Dipsastraea camrasensis* (Latypov, 2013)*	x		x	
237	*Dipsastraea faviaformis* Veron, 2000	x			x
238	*Dipsastraea favus* (Forskål, 1775)	x		x	x
239	*Dipsastraea helianthoides* (Wells, 1954)			x	x
240	*Dipsastraea lizardensis* (Veron, Pichon & Wijsman-Best, 1977)	x		x	x
241	*Dipsastraea maritima* (Nemenzo, 1971)		x	x	x
242	*Dipsastraea marshae* (Veron, 2000)				x
243	*Dipsastraea matthaii* (Vaughan, 1918)	x		x	x
244	*Dipsastraea maxima* (Veron, Pichon & Wijsman-Best, 1977)			x	x
245	*Dipsastraea pallida* (Dana, 1846)	x		x	x
246	*Dipsastraea rosaria* (Veron, 2000)			x	x
247	*Dipsastraea rotumana* (Gardiner, 1899)				x
248	*Dipsastraea speciosa* (Dana, 1846)	x		x	x
249	*Dipsastraea truncatus* (Veron, 2000)			x	x
250	*Dipsastraea vietnamensis* (Veron, 2000)			x	x
251	*Dipsastraea veroni* (Moll & Best, 1984)			x	x
252	*Echinopora gemmacea* (Lamarck, 1816)	x	x	x	x
253	*Echinopora horrida* Dana, 1846	x	x	x	x
254	*Echinopora lamellosa* (Esper, 1795)		x	x	x
255	*Echinopora mammiformis* (Nemenzo, 1959)				x
256	*Echinopora pacificus* Veron, 1990	x	x	x	x
257	*Favites abdita* (Ellis & Solander, 1786)	x	x	x	x
258	*Favites acuticollis* (Ortmann, 1889)	x	x	x	x
259	*Favites chinensis* (Verrill, 1866)			x	x
260	*Favites colemani* (Veron, 2000)				x
261	*Favites complanata* (Ehrenberg, 1834)			x	x
262	*Favites flexuosa* (Dana, 1846)			x	x
263	*Favites halicora* (Ehrenberg, 1834)	x	x	x	x
264	*Favites magnistellata* (Chevalier, 1971)		x	x	x
265	*Favites melicerum* (Ehrenberg, 1834)			x	x
266	*Favites micropentagonus* Veron, 2000			x	x
267	*Favites paraflexuosus* Veron, 2000			x	x
268	*Favites pentagona* (Esper, 1794)		x	x	

Table 1. Continued

No.	Scleractinian coral species	Redang Island Marine Park	Previous record "a"	Tioman Island Marine Park	Previous records "a, b, c"
269	*Favites spinosa* (Klunzinger, 1879)				x
270	*Favites stylifera* (Yabe & Sugiyama, 1937)				x
271	*Favites valenciennesi* (Milne Edwards & Haime, 1849)			x	x
272	*Goniastrea edwardsi* Chevalier, 1971	x	x	x	x
273	*Goniastrea favulus* (Dana, 1846)			x	x
274	*Goniastrea minuta* Veron, 2000			x	x
275	*Goniastrea pectinata* (Ehrenberg, 1834)	x	x	x	x
276	*Goniastrea retiformis* (Lamarck, 1816)			x	x
277	*Goniastrea stelligera* (Dana, 1846)		x	x	x
278	*Hydnophora exesa* (Pallas, 1766)	x	x	x	x
279	*Hydnophora grandis* Gardiner, 1904		x	x	x
280	*Hydnophora microconos* (Lamarck, 1816)	x	x	x	x
281	*Hydnophora rigida* (Dana, 1846)	x		x	x
282	*Leptoria phrygia* (Ellis & Solander, 1786)	x	x	x	x
283	*Merulina ampliata* (Ellis & Solander, 1786)	x	x	x	x
284	*Merulina scabricula* Dana, 1846			x	x
285	*Mycedium elephantotus* (Pallas, 1766)				x
286	*Oulophyllia bennettae* (Veron, Pichon & Wijsman-Best, 1977)			x	x
287	*Oulophyllia crispa* (Lamarck, 1816)	x	x	x	x
288	*Paragoniastrea australensis* (Milne Edwards & Haime, 1857)				x
289	*Paragoniastrea russelli* (Wells, 1954)				x
290	*Paramontastrea salebrosa* (Nemenzo, 1959)				x
291	*Pectinia alcicornis* (Saville-Kent, 1871)			x	x
292	*Pectinia lactuca* (Pallas, 1766)	x	x		x
293	*Pectinia maxima* (Moll & Best, 1984)	x	x		x
294	*Pectinia paeonia* (Dana, 1846)	x	x	x	x
295	*Platygyra acuta* Veron, 2000			x	x
296	*Platygyra carnosus* Veron, 2000			x	x
297	*Platygyra crosslandi* Matthai, 1928			x	x
298	*Platygyra daedalea* (Ellis & Solander, 1786)	x	x	x	x
299	*Platygyra lamellina* (Ehrenberg, 1834)	x	x	x	x
300	*Platygyra pini* Chevalier, 1975	x		x	x
301	*Platygyra ryukyuensis* Yabe & Sugiyama, 1936			x	
302	*Platygyra sinensis* (Milne Edwards & Haime, 1849)	x	x	x	x
303	*Platygyra verweyi* Wijsman-Best, 1976	x	x	x	x
304	*Platygyra yaeyamaensis* Eguchi & Shirai, 1977			x	x
305	*Scapophyllia cylindrica* Milne Edwards & Haime, 1849			x	x
306	*Trachyphyllia geoffroyi* (Audouin, 1826)			x	x
	Pocilloporidae Gray, 1842				
307	*Pocillopora acuta* Lamarck, 1816*			x	
308	*Pocillopora damicornis* (Linnaeus, 1758)	x	x	x	x
309	*Pocillopora grandis* Dana, 1846				x
310	*Pocillopora meandrina* Dana, 1846			x	x
311	*Pocillopora verrucosa* (Ellis & Solander, 1786)		x	x	x
312	*Stylophora pistillata* Esper, 1797			x	x
313	*Stylophora subseriata* (Ehrenberg, 1834)	x	x	x	x

Table 1. Continued

No.	Scleractinian coral species	Redang Island Marine Park	Previous record "a"	Tioman Island Marine Park	Previous records "a, b, c"
	Poritidae Gray, 1842				
314	*Goniopora columna* Dana, 1846			x	x
315	*Goniopora djiboutiensis* Vaughan, 1907				x
316	*Goniopora fruticosa* Saville-Kent, 1893				x
317	*Goniopora lobata* Milne Edwards & Haime, 1860			x	x
318	*Goniopora norfolkensis* Veron & Pichon, 1982				x
319	*Goniopora planulata* (Ehrenberg, 1834)				x
320	*Goniopora somaliensis* Vaughan, 1907				x
321	*Goniopora stokesi* Milne Edwards & Haime, 1851				x
322	*Goniopora tenuidens* (Quelch, 1886)				x
323	*Porites annae* Crossland, 1952	x	x	x	x
324	*Porites aranetai* Nemenzo, 1955				x
325	*Porites attenuata* Nemenzo, 1955				x
326	*Porites australiensis* Vaughan, 1918	x		x	x
327	*Porites cocosensis* Wells, 1950				x
328	*Porites cumulatus* Nemenzo, 1955				x
329	*Porites cylindrica* Dana, 1846	x	x	x	x
330	*Porites densa* Vaughan, 1918				x
331	*Porites echinulata* Klunzinger, 1879				x
332	*Porites evermanni* Vaughan, 1907		x	x	x
333	*Porites horizontalata* Hoffmeister, 1925		x	x	x
334	*Porites lichen* Dana, 1846			x	
335	*Porites lobata* Dana, 1846	x		x	x
336	*Porites lutea* Milne Edwards & Haime, 1851	x		x	x
337	*Porites mayeri* Vaughan, 1918				x
338	*Porites monticulosa* Dana, 1846		x	x	x
339	*Porites murrayensis* Vaughan, 1918				x
340	*Porites negrosensis* Veron, 1990				x
341	*Porites nigrescens* Dana, 1846	x		x	x
342	*Porites rus* (Forskål, 1775)	x	x	x	x
343	*Porites solida* (Forskål, 1775)	x		x	x
344	*Stylaraea punctata* (Linnaeus, 1758)				x
	Psammocoridae Chevalier & Beauvais, 1987				
345	*Psammocora contigua* (Esper, 1797)	x	x	x	x
346	*Psammocora digitata* Milne Edwards & Haime, 185	x	x	x	x
347	*Psammocora haimiana* Edwards & Haime, 1851		x	x	x
348	*Psammocora nierstraszi* Van der Horst, 1921				x
349	*Psammocora profundacella* Gardiner, 1898	x	x	x	x
	Siderastreidae Vaughan & Wells, 1943				
350	*Pseudosiderastrea tayami* Yabe & Sugiyama, 1935		x		x
	Scleractinia incertae sedis				
351	*Blastomussa wellsi* Wijsman-Best, 1973		x		x
352	*Leptastrea aequalis* Veron, 2000				x
353	*Leptastrea pruinosa* Crossland, 1952	x	x	x	x
354	*Leptastrea purpurea* (Dana, 1846)	x	x	x	x
355	*Leptastrea transversa* Klunzinger, 1879	x		x	x
356	*Physogyra lichtensteini* (Milne Edwards & Haime, 1851)			x	x
357	*Plerogyra sinuosa* (Dana, 1846)	x	x	x	x
358	*Plesiastrea versipora* (Lamarck, 1816)		x	x	x
	TOTAL SPECIES	128	135	239	325

Note. * New scleractinian species records for the east coast of Peninsular Malaysia

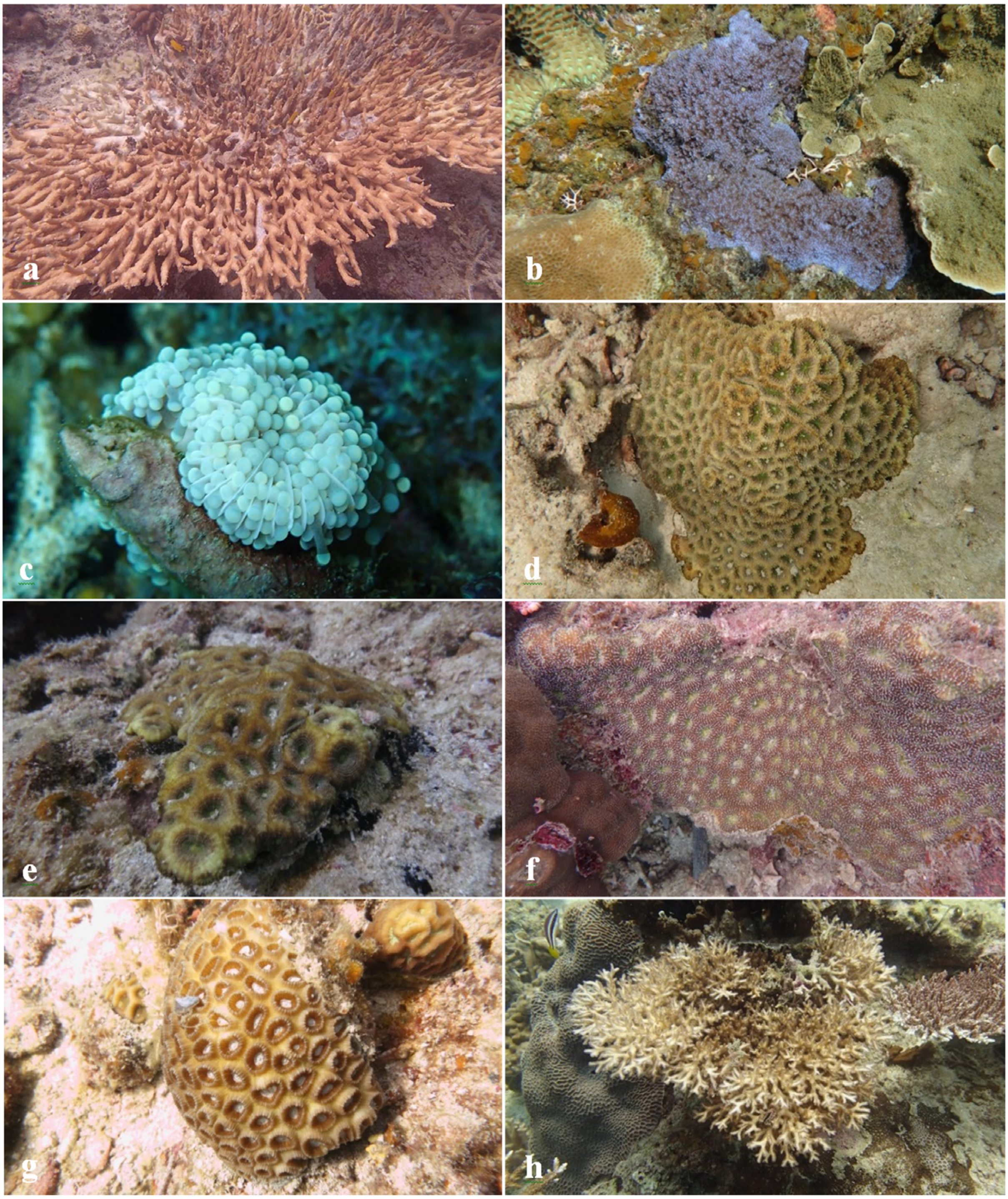

Fig. 2. New scleractinian species records for the east coast of Peninsular Malaysia. a) *Acropora Indonesia,* b) *Montipora flabellate,* c) *Euphyllia cristata,* d) *Acanthastrea brevis,* e) *Acanthastrea subechinata,* f) *Micromussa diminuta,* g) *Dipsastraea camrasensis,* h) *Pocillopora acuta*

most of the sampling stations ($n \geq 3$). Among these genera, *Acropora* was found to be dominant at most of the sampling stations. Genus *Montipora* was found to be dominant at TI2 in the isolated zone. Meanwhile *Porites* was found to be dominant at TW5 in the west coast zones. *Stylocoeniella, Catalaphyllia, Heliofungia, Echinophyllia, Micromussa, Oxypora,*

Table 2. Average coverage (%), diversity and abundance patterns of scleractinian coral genera recorded in Redang Island Marine Park

No	Scleractinian corals	Sampling station															Average coverage (%)
		South Coast Zone						East Coast Zone					North Coast Zone				
		Tg. Ara	Terumbu Kili	Tg. Cina Terjun	Batu Ling	Pulau Chupak	Pulau Ekor Tebu	Pulau Kerengga Besar	Chek Isa	Mak Chantek	Pulau Lima	Pulau Paku Besar	Tg. Gua Kawah	Tlk. Mak Delah	Tg. Tok Kong	Tg. Chagar Hutang	
		RS1	RS2	RS3	RS4	RS5	RS6	RE1	RE2	RE3	RE4	RE5	RN1	RN2	RN3	RN4	
	Acroporidae																23.4 ± 4.4
1	*Acropora*	+++	++	+	++	+	++	+	+++	+++++	+	++	+++++	+	++	++++	16.1
2	*Astreopora*	+	-	+	-	+	-	+	-	-	-	+	+	+	+	-	0.9
3	*Montipora*	+	-	-	+	+	+	+	+++	+++++	+	+	+++++	+	+	+	6.4
	Agariciidae																2.2 ± 0.6
4	*Gardineroseris*	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	0.1
5	*Leptoseris*	-	-	+	+	+	-	+	-	-	-	-	-	-	-	-	0.1
6	*Pavona*	-	+	+	+	+	+	+	+	+	+	-	+	+	+	+	2.0
	Coscinaraeidae																0.0 ± 0.0
7	*Coscinaraea*	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	0.0
	Dendrophylliidae																0.1 ± 0.0
8	*Turbinaria*	-	-	+	-	-	-	-	-	-	-	+	-	-	+	-	0.1
	Diploastraeidae																1.5 ± 0.0
9	*Diploastrea*	-	-	-	-	-	-	+	-	+	+	+	+	+	++	-	1.5
	Euphylliidae																3.8 ± 0.8
10	*Euphyllia*	+	-	-	+	+	+	+	+	+	-	+	-	+	+	-	0.4
11	*Galaxea*	+	-	+	+	+	+	+	+	+	+	+	++	++	++	+	2.9
12	*Pachyseris*	-	-	-	-	+	-	+	+	+	+	+	+	+	+	+	0.5
	Fungiidae																12.6 ± 1.0
13	*Ctenactis*	-	+	-	+	+	-	+	-	+	+	+	+	+	-	+	1.0
14	*Cycloseris*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	0.0
15	*Danafungia*	-	+	-	-	-	-	-	-	-	-	+	-	+	-	-	0.1
16	*Fungia*	+	++++	+	++	++	+	+++	+	++	+++	+	+	+	+	+++++	10.6
17	*Herpolitha*	+	-	-	+	+	-	+	+	+	+	-	-	-	+	+	0.5
18	*Lithophyllon*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	0.0
19	*Pleuractis*	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	0.2
20	*Polyphyllia*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	0.0
21	*Sandalolitha*	-	-	-	-	-	-	+	-	+	+	+	-	+	-	+	0.2
	Lobophylliidae																1.9 ± 0.3
22	*Acanthastrea*	-	-	-	-	+	-	+	-	-	-	-	-	+	+	-	0.2
23	*Cynarina**	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	0.0
24	*Echinophyllia*	+	-	-	+	-	-	+	-	-	-	-	-	-	-	-	0.2
25	*Lobophyllia*	+	-	+	+	+	-	+	+	+	+	+	+	+	+	+	1.5
26	*Oxypora*	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	0.0

Table 2. Continued

No	Scleractinian corals	Sampling station															Average coverage (%)
		South Coast Zone						East Coast Zone					North Coast Zone				
		Tg. Ara	Terumbu Kili	Tg. Cina Terjun	Batu Ling	Pulau Chupak	Pulau Ekor Tebu	Pulau Kerengga Besar	Chek Isa	Mak Chantek	Pulau Lima	Pulau Paku Besar	Tg. Gua Kawah	Tlk. Mak Delah	Tg. Tok Kong	Tg. Chagar Hutang	
		RS1	RS2	RS3	RS4	RS5	RS6	RE1	RE2	RE3	RE4	RE5	RN1	RN2	RN3	RN4	
	Merulinidae																27.0 ± 0.6
27	*Astrea*	+	-	+	-	+	-	+	+	+	+	-	+	++	+	+	1.2
28	*Caulastraea*	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	0.1
29	*Coelastrea*	+	-	-	+	-	-	-	-	-	-	-	+	-	-	-	0.1
30	*Cyphastrea*	-	-	-	+	-	-	+	+	-	-	-	+	+	+	-	0.8
31	*Dipsastraea*	+	+	+	+	+	+	+++	+	+	+	+	++	+++++	+++++	+	7.4
32	*Echinopora*	+	+	-	+	+	-	+	+	-	+	-	+	++	++	+	2.3
33	*Favites*	+	+	+	+	+	+	+	+	+	+	-	+	++	+++	+	6.9
34	*Goniastrea*	-	-	+	-	-	+	+	-	+	+	+	+	++	++	+	2.0
35	*Hydnophora*	-	-	-	-	-	-	+	-	-	-	-	+	+	+	-	0.4
36	*Leptoria*	-	-	-	-	+	-	+	-	-	-	-	+	-	-	-	0.1
37	*Merulina*	+	-	-	-	-	-	+	-	+	-	-	-	+	+	-	0.6
38	*Oulophyllia*	-	-	-	-	-	-	-	-	+	-	-	+	+	+	-	0.2
39	*Pectinia*	-	-	-	+	+	-	+	+	+	-	-	-	+	+	-	0.4
40	*Platygyra*	+	-	+	+	+	+	+	+	+	+	+	++	+++	+++	+	4.5
	Pocilloporidae																7.2 ± 2.2
41	*Pocillopora*	++	++	+	+	+	+	+	-	+	++	+++++	+	+	+	++	6.8
42	*Stylophora*	-	-	-	+	-	-	-	-	-	+	-	-	-	+	-	0.2
	Poritidae																15.0 ± 7.0
43	*Goniopora*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	0.5
44	*Porites*	++	-	+	+	++++	+	++	++	+++	+	++	++++	+++++	+++++	++	14.5
	Psammocoridae																0.0 ± 0.0
45	*Psammocora*	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	0.0
	Scleractinia Incertae sedis																5.3 ± 2.7
46	*Leptastrea*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	0.0
47	*Plerogyra*	+	+	+	++	+++	-	+	++	+	+	+	+	+	++	+	5.3
	Total Genera	19	10	20	22	25	13	32	18	24	21	21	25	29	29	19	

Note. +: one or few colonies covering <1% of the corals; ++: uncommon, covering 1–5% of the corals; +++: common, covering 6–10% of the corals; ++++ = abundant, covering 11–20% of the corals; and +++++: dominant, covering >20% of the corals. *Rare genus

Table 3. Average coverage (%), diversity and abundance patterns of scleractinian coral genera recorded in Tioman Island Marine Park

No	Scleractinian corals	Sampling station													Average coverage (%)
		East Coast Zone			West Coast Zone					Isolated Zone					
		Tlk. Benuang	Tlk. Sanggit	Tlk. Dalam	Pulau Tomok	Kg. Genting	Pulau Renggis	Pulau Soyak	Tlk. Salang	Tlk. Gado	Tlk. Tulai	Tlk. Bayan	Pulau Sepoi	Pulau Labas	
		TE1	TE2	TE3	TW1	TW2	TW3	TW4	TW5	TI1	TI2	TI3	TI4	TI5	
	Acroporidae														34.8 ± 5.1
1	*Acropora*	++	+++++	+++++	+	++	+++++	+++++	++++	++	+++++	++	+++++	+++++	21.5
2	*Astreopora*	+	-	-	-	+	+	+	+	+	-	-	-	+	0.5
3	*Isopora*	+	+	-	-	-	-	-	-	-	+	-	+	+	0.3
4	*Montipora*	+++	++	++	+	++	+	++	+	++++	+++++	+	++++	+++	12.5
	Agariicidae														4.4 ± 0.9
5	*Gardineroseris*	+	+	+	-	-	-	-	+	+	-	+	-	+	0.8
6	*Leptoseris*	-	-	+	-	-	-	+	+	+	-	+	-	-	0.3
7	*Pavona*	+	++++	+	+	+	+	+	+	+	-	+	+	+	3.3
	Astrocoeniidae														0.0 ± 0.0
8	*Stylocoeniella* *	-	-	+	-	-	-	-	-	-	-	-	-	-	0.0
	Coscinaraeidae														0.2 ± 0.0
9	*Coscinaraea*	+	+	-	-	-	-	-	-	-	-	-	-	-	0.2
	Dendrophylliidae														0.3 ± 0.0
10	*Turbinaria*	-	+	-	+	-	-	+	+	-	-	+	-	+	0.3
	Diploastraeidae														1.0 ± 0.0
11	*Diploastrea*	+	+	+	+	+	-	+	+	+	+	+	+	-	1.0
	Euphylliidae														9.2 ± 1.2
12	*Catalaphyllia* *	-	-	-	-	-	+	-	-	-	-	-	-	-	0.0
13	*Euphyllia*	++	+	+	-	-	-	+	+	+	+	++	+	+	2.5
14	*Galaxea*	++	+	++	+	+	+	+	+	++	+	++++	+	+	5.6
15	*Pachyseris*	+	+	+	+	-	-	-	+	-	+	+	-	+	1.1
	F**ungiidae**														3.7 ± 0.3
16	*Ctenactis*	+	-	+	-	+	+	-	-	-	+	-	-	-	0.2
17	*Cycloseris*	-	-	-	-	-	+	-	-	-	-	+	-	-	0.1
18	*Danafungia*	-	-	+	-	-	-	-	-	-	-	+	-	-	0.0
19	*Fungia*	+	+	+	+	+	+	+	+	+	+++	+	+	+	2.6
20	*Heliofungia**	-	-	-	-	-	-	-	-	+	-	-	-	-	0.0
21	*Herpolitha*	-	-	-	+	-	+	+	-	-	-	-	-	-	0.1
22	*Lithophyllon*	+	-	-	+	-	-	-	+	-	-	-	+	-	0.1
23	*Pleuractis*	-	+	-	+	+	-	+	-	-	-	+	-	-	0.2
24	*Podabacia*	-	+	-	-	-	-	-	-	-	-	-	-	-	0.0
25	*Polyphyllia*	-	+	-	-	-	+	-	-	-	-	-	-	-	0.0
26	Sandalolitha	+	+	-	-	+	+	+	+	-	-	+	-	-	0.4

Table 3. Continued

No	Scleractinian corals	Sampling station													Average coverage (%)
		East Coast Zone			West Coast Zone					Isolated Zone					
		Tlk. Benuang	Tlk. Sanggit	Tlk. Dalam	Pulau Tomok	Kg. Genting	Pulau Renggis	Pulau Soyak	Tlk. Salang	Tlk. Gado	Tlk. Tulai	Tlk. Bayan	Pulau Sepoi	Pulau Labas	
		TE1	TE2	TE3	TW1	TW2	TW3	TW4	TW5	TI1	TI2	TI3	TI4	TI5	
	Lobophylliidae														4.0 ± 0.4
27	*Acanthastrea*	+	+	+	-	-	-	+	+	-	+	+	+	-	0.7
28	*Echinophyllia*	-	+	-	-	-	-	-	-	-	-	-	-	-	0.1
29	*Lobophyllia*	+	+	+	+	+	-	+	+	+	+	+	+	+	3.2
30	*Micromussa**	-	+	-	-	-	-	-	-	-	-	-	-	-	0.0
31	*Oxypora*	-	-	-	-	+	-	-	-	-	-	-	-	-	0.0
	Merulinidae														23.9 ± 0.5
32	*Astrea*	+	+	+	+	+	+	+	+	+	-	+	+	+	0.5
33	*Coelastrea*	+	-	+	-	-	-	-	-	-	+	-	+	-	0.0
34	*Cyphastrea*	+	-	+	-	-	-	+	+	+	-	+	-	+	0.9
35	*Dipsastraea*	+	+	++	+	+	+	+	+	+	-	++	-	+	2.9
36	*Echinopora*	++	+++	+	-	+	+	-	+	+	+	-	+	+	2.3
37	*Favites*	++	++	++	+	+	+	+	++	++	+	++++	+	++	7.3
38	*Goniastrea*	+	++	+	-	+	+	++	++	+	+	+	+	+	3.5
39	*Hydnophora*	+	+	+	-	-	+	+	+	+	-	+	-	-	0.4
40	*Leptoria*	-	+	+	-	-	-	+	-	+	-	-	+	+	0.3
41	*Merulina*	+	+	-	+	-	+	+	+	+	-	-	-	+	0.3
42	*Oulophyllia*	-	+	+	-	+	-	+	-	+	-	+	+	+	0.4
43	*Pectinia*	+	-	-	-	+	-	-	-	-	-	-	-	-	0.1
44	*Platygyra*	+	+++	+	+	+	+	++	+	+	+	++	+	++	5.0
45	*Scapophyllia**	-	-	-	-	-	-	-	-	+	-	-	-	-	0.0
46	*Trachyphyllia**	-	+	-	-	-	-	-	-	-	-	-	-	-	0.0
	Pocilloporidae														3.1 ± 1.0
47	*Pocillopora*	+	++	+	-	+	+	+	+	+	+	+	+	+	3.1
48	*Stylophora*	+	-	-	-	-	-	-	-	-	-	-	-	-	0.0
	Poritidae														13.6 ± 6.3
49	*Goniopora*	-	-	-	-	+	+	+	+	+	-	-	-	+	0.5
50	*Porites*	+	+	+	++	+	+++	++++	+++++	++	+	+++	++	++++	13.1
	Psammocoridae														0.5 ± 0.0
51	Psammocora	+	+	-	-	-	-	+	+	-	-	+	-	+	0.5
	Scleractinia Incertae sedis														1.3 ± 0.2
52	*Leptastrea*	-	-	+	-	-	-	-	-	-	-	-	-	+	0.1
53	*Physogyra*	+	-	-	-	-	-	+	-	+	-	+	+	+	0.2
54	*Plerogyra*	+	-	-	+	-	+	+	+	+	-	+	+	+	0.9
55	*Plesiastrea*	-	-	+	-	-	-	-	-	-	-	+	-	+	0.1
	Total Genera	34	34	30	19	23	24	31	30	29	18	31	23	30	

Note. +: one or few colonies covering <1% of the corals; ++: uncommon, covering 1–5% of the corals; +++: common, covering 6–10% of the corals; ++++ = abundant, covering 11–20% of the corals; and +++++: dominant, covering >20% of the corals. *Rare genus

Table 4. Summary of coral coverage (%), coral condition, total genera, Shannon diversity (H') and Pielou's evenness (J') index of corals in Redang Island and Tioman Island Marine Parks

	No	Sampling station	Live corals (%)	Dead corals (%)	Others (%)	Coral condition	Total genera	H'	J'
Redang Island Marine Park	South Coast Zone								
	RS1	Tg. Ara	42.4	43.9	13.7	Fair	19	2.19	0.76
	RS2	Terumbu Kili	55.6	35.4	9	Good	10	1.44	0.66
	RS3	Tg. Cina Terjun	40.9	3.1	56	Fair	20	2.41	0.76
	RS4	Batu Ling	46.5	36.9	16.6	Fair	22	2.55	0.84
	RS5	Pulau Chupak	53.8	32.2	14	Good	25	2.39	0.74
	RS6	Pulau Ekor Tebu	53.7	32.4	13.9	Good	13	1.76	0.71
		Average	48.8 ± 2.6	30.7 ± 5.8	20.5 ± 7.2	Fair	18.7 ± 2.2	2.12 ± 0.2	0.75 ± 0.0
	East Coast Zone								
	RE1	Pulau Kerengga Besar	44.2	31.9	23.9	Fair	32	2.81	0.81
	RE2	Chek Isa	69.0	9.5	21.5	Good	18	2.29	0.79
	RE3	Mak Chantek	48.6	23.9	27.5	Fair	24	2.35	0.74
	RE4	Pulau Lima	53.8	32.2	14	Good	21	2.43	0.78
	RE5	Pulau Paku Besar	28.2	59.4	12.5	Fair	21	1.78	0.60
		Average	48.8 ± 6.6	31.4 ± 8.1	19.9 ± 2.9	Fair	23.4 ± 2.4	2.33 ± 0.2	0.74 ± 0.0
	North Coast Zone								
	RN1	Tg. Gua Kawah	73.5	13.9	12.6	Good	25	2.40	0.74
	RN2	Tlk. Mak Delah	53.2	5.8	41	Good	29	2.58	0.77
	RN3	Tg. Tok Kong	53.8	9.6	36.6	Good	29	2.83	0.83
	RN4	Tg. Chagar Hutang	45.9	42.3	11.8	Fair	19	2.01	0.70
		Average	56.6 ± 5.9	17.9 ± 8.3	25.5 ± 7.7	Good	26.0 ± 2.6	2.46 ± 0.2	0.76 ± 0.0
Tioman Island Marine Park	East Coast Zone								
	TE1	Tlk. Benuang	59.0	29.7	11.3	Good	34	2.95	0.85
	TE2	Tlk. Sanggit	60.3	13.5	26.2	Good	34	2.71	0.78
	TE3	Tlk. Dalam	53.8	19.4	26.8	Good	30	2.56	0.76
		Average	57.7 ± 2.0	20.9 ± 4.7	21.4 ± 5.1	Good	33.3 ± 2.2	2.74 ± 0.1	0.80 ± 0.0
	West Coast Zone								
	TW1	Pulau Tomok	37.6	28.8	33.6	Fair	19	2.46	0.77
	TW2	Kg. Genting	45.1	20.6	34.3	Fair	23	2.33	0.79
	TW3	Pulau Renggis	51.4	21.3	27.3	Good	24	1.95	0.62
	TW4	Pulau Soyak	51.9	36.1	12	Good	31	2.44	0.70
	TW5	Tlk. Salang	52.8	37.8	9.4	Good	30	2.60	0.73
		Average	47.8 ± 2.9	28.9 ± 3.6	23.3 ± 5.3	Fair	26.0 ± 2.3	2.4 ± 0.1	0.72 ± 0.0
	Isolated Zone								
	TI1	Tlk. Gado	51.0	25.0	24	Good	29	2.56	0.76
	TI2	Tlk. Tulai	52.6	21.2	26.2	Good	18	1.66	0.57
	TI3	Tlk. Bayan	47.1	24.4	28.5	Fair	31	2.82	0.81
	TI4	Pulau Sepoi	49.2	20.4	30.4	Fair	23	2.00	0.66
	TI5	Pulau Labas	55.9	24.8	19.3	Good	30	2.60	0.75
		Average	51.2 ± 1.5	23.2 ± 1.0	25.6 ± 1.9	Good	26.0 ± 2.4	2.3 ± 0.2	0.71 ± 0.0
	Total Average of Redang		50.8 ± 2.6	27.5 ± 3.4	21.6 ± 1.0	Good	22.2 ± 1.5	2.28 ± 0.1	0.75 ± 0.0
	Total Average of Tioman		51.4 ± 1.6	24.8 ± 6.8	23.8 ± 1.9	Good	27.7 ± 1.6	2.43 ± 0.1	0.73 ± 0.0

Scapophyllia, Trachyphyllia, and *Stylophora* were found to be poorly distributed and least abundant (n ≤ 1). *Stylocoeniella, Catalaphyllia, Heliofungia, Micromussa, Scapophyllia* and *Trachyphyllia* were classified as rare genera in Tioman Island.

Coral coverage, coral condition and total index of coral genera

Live coral had a higher average coverage in Tioman Island (51.4% ± 1.6) compared to Redang Islands (50.8% ± 2.6). The live coral coverage in the north coast zone of Redang Island was higher compared to the east coast and the south coast zones with 56.6% ± 5.9, 48.8% ± 6.6 and 48.8% ± 2.6, respectively (Table 3). RN1 and RE5 recorded the highest and the lowest coverage of live coral with 73.5% and 28.2%, respectively. Most of the sampling stations in the north coast zone were categorized as being in a "good" coral condition except for RN4. Most of the sampling stations in the south coast and east coast zones were categorized under "fair" coral condition. The average of the total number of coral genera also was higher at the north coast zone (26.0 ± 2.6) compared to the east coast (23.4 ± 2.4) and south coast (18.7 ± 2.2) zones. The north coast zone had the highest H' and J' indices of coral genera with 2.46 ± 0.2 and 0.76 ± 0.0, respectively.

In Tioman Island, the live coral coverage in the east coast zone was higher compared to the isolated zone and west coast zone with 57.7% ± 2.0, 51.2% ± 1.6 and 47.8% ± 2.9, respectively. TE2 and TW1 recorded the highest and the lowest coverage of live coral with 60.3% and 37.6%, respectively. All sampling stations in the east coast zone were categorized under 'good' coral condition, whereas the sampling stations in the west coast and isolated zones were categorized under "good" and "fair" coral condition. The east coast zone also had the highest average of the total number of coral genera (33.3 ± 2.2), H' index (2.74 ± 0.1) and J' index (0.80 ± 0.0). Total average values of H' and J' indices of coral genera differed significantly between zones in Redang and Tioman Islands ($p < 0.05$) but did not differ significantly ($p > 0.05$) between both islands.

4. Discussion

Current status of scleractinian corals

The present data here showed that the scleractinian corals were found to be more diversified in Tioman compared to Redang Islands. A total of 239 species from 55 genera were recorded in Tioman, while only 128 species from 47 genera in Redang Islands. This is consistent with the previous study that reported a higher diversity of hard corals in Tioman (183 species) compared to Redang (149 species) Islands (Harborne et al. 2000). This study also revealed new scleractinian coral records for Redang Island (31 species) and Tioman Island (25 species) that were not reported during earlier studies done by Harborne et al. (2000), Affendi et al. (2005, 2007). Additionally, 8 new scleractinian species were recorded for the east coast of Peninsular Malaysia which supplements and updates the work done by Affendi and Rosman (2012). This provides useful data and information to marine park management personnel on the current status of scleractinian coral diversity at both Marine Parks.

Genera *Acropora*, *Montipora*, and *Porites* are found to be distributed at most of the reef sites in Redang and Tioman Islands. They are also found to be common to dominant at several reef sites in both Marine Parks. This is comparable with previous studies indicated that these coral genera cover the highest percentage and are found to be dominant in Tioman and Sibu Islands on the east coast of Peninsular Malaysia (Toda et al. 2007). Genus *Acropora,* which encompassed 60% coverage of the total Acroporidae family, is recognized to be naturally found distributed in the Indo-Pacific (Wallace 1999). Branching *Acropora* and foliose or encrusting *Montipora* are also known as fast growing species with lateral growth rates of 5–20 cm year per year (Done et al. 1988).They more rapidly expand, compared to slow growing massive *Porites,* with radial growth rates of 1–2 cm year per year (Kenyon et al. 2006; Hennige et al. 2013). However, *Porites* colonies have a stronger skeleton structure to resist high energy forces from waves and current actions compared to the more fragile *Acropora* and *Montipora* colonies (Hong and Sasekumar 1981; Hennige et al. 2013). Hence, it is suggested that the dominance of these coral genera is due to their ability to acquire adaptive capacities to tolerate any environmental conditions such as currents, wave actions and sedimentation loads, as contended by Veron et al. (2011).

Results regarding the abundance patterns of scleractinian coral genera also showed that *Fungia* and *Pocillopora* are found to be common to dominant at several reef sites in both Marine Parks. Genus *Fungia* from the family Fungiidae has been reported to be widely distributed and can be found to be dominant at certain particular reef areas (Veron 1995). Meanwhile, the dominance of *Pocillopora* from the family Pocilloporidae may be due to their reproductive and recruitment strategies, as suggested by Nakamura and Sakai (2010). Brooder spawned colonies of *Pocillopora* species, which fertilize their eggs internally, have higher survival rates due to their fast embryonic development time (Harii and Kayanne 2003). They are able to recruit nearby to their parents and are distributed within the coral assemblages (Nakamura and Sakai 2010). In addition to that, the results also showed that the stress tolerator type of corals such as *Dipsastraea*, *Favites*, *Platygyra*, *Lobophyllia* and *Goniastrea* are found to be distributed in Redang and Tioman Islands. The distributional pattern of these coral genera is related with the ability to tolerate to any fluctuations in current and wave actions due to their massive and sub-massive life forms (Hong and Sasekumar 1981). Furthermore, they are also considered as less susceptible corals to trampling action caused by divers and snorkelers (Ammar and Mahmoud 2006).

Coral reef condition

The conditions of the coral reefs in Redang and Tioman Islands varied between "fair" and "good" with the live corals covering 50.8% and 51.4%, respectively. Overall, this study showed that the reefs around both islands were in "good" coral condition. A previous study also reported that the coral conditions at three reef sites in Tioman Island varied between "fair" and "good" (Toda et al. 2007). A similar finding has also been reported by RCM (2017) which found that the corals in Redang (50.0%) and Tioman (66.4%) Islands were in "good" condition. In making comparisons between zones categorized within reefs around islands, the north coast (56.6%) of Redang and the east coast (57.7%) and isolated (51.2%) zones of Tioman showed "good" average coral condition. Most of the reef sites were also categorized as being in "good" coral condition with the live corals ranging between 53.2–73.5% in Redang and 51.0–60.3% in Tioman Islands. This is likely due to less coastal development for resorts and human settlements established in these zones. Moreover, most reef sites within these zones have very minimum exposure to tourism related activities since they are oriented toward the open sea and are frequently exposed to strong currents and waves.

Meanwhile, the south coast (48.8%) and east coast (48.8%) zones of Redang and the west coast zone (47.8%) of Tioman showed "fair" average coral condition. Unsustainable coastal development is believed to be one of the factors which influenced the resulting "fair" coral condition at some reef sites in both islands. Previous studies indicated that the live corals at several reef sites in the east coast and south coast zones of Redang had declined due to dredging impacts from the construction of submarine water pipelines (Rezai et al. 1999; Maseri 2003). The reef sites near to Kg. Genting (TW2) and Pulau Renggis (TW3) in the west coast zone of Tioman have also been impacted by the rapid construction of resorts and residential sites along the coastal area (Shahbudin et al. 2017). To date, a total of 72 resorts have been developed in Tioman and mostly concentrated along the west coast area (RCM 2017). Rapid and unsustainable coastal development activity may put the tenacity of coral reefs in jeopardy and consequently could lead to coral degradation if reefs are constantly stressed (Jordan et al. 2010).

Furthermore, most of the reef sites in these zones have been a focal point for tourists to venture into water sport activities such as snorkeling, diving and boating. The impacts of these activities can result in the breakage of coral into fragments (Wielgus et al. 2004; Praveena et al. 2012). It has been reported that inexperienced snorkelers and divers are frequently trampling or standing on the corals that this may have led to partial mortality due to the loosening and abrasion of coral fragments (Wielgus et al. 2004; Praveena et al. 2012). These factors, together with boating activities in shallow water areas especially less than 2 m in depth, might increase the re-suspension of bottom sediments. High suspended sediments cause the mortality of live corals due to insufficient penetration of sunlight required for corals to undertake the photosynthesis process (Erftemeijer et al. 2012).

On top of that, the large number of visiting tourists is another main factor that will likely lead to various associated negative impacts on coral conditions in both islands. According to the DMPM (2017), Redang and Tioman are among the most visited islands for both local and foreign tourists. Over three million tourists have visited these islands with an average of almost 200 thousands per year from 2000 to 2017 (DMPM 2017). The excessive number of visiting tourists has contributed to effluent discharges from resorts and chalets surrounding these islands. Nutrient enrichment has been frequently reported in Tioman and Redang Islands due to excess untreated sewage being disposed directly from the hotels and resorts onto the reefs (Hyde et al. 2013). Therefore, a comprehensive framework, good management, and enforcement are required to mitigate these emergent problems. Regulations regarding the carrying capacity of visitors to Marine Park should be implemented and regularly monitoring is required in order to sustain good coral conditions in Redang and Tioman Islands.

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