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Current status of coral reefs in Tioman Island, Peninsular Malaysia

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Abstract: The present study aimed to determine the current status of corals using the coral video transect (CVT) method in the east coast, west coast, and isolated areas of Tioman Island, Peninsular Malaysia. A total of 65 genera from 21 families of corals were identified, from which the scleractinian corals of *Acropora*, *Montipora*, and *Porites* were dominant in the coral assemblages. Nine reef sites were categorised as having 'good' (51.4%–60.3%) coral condition and four reef sites as having 'fair' (37.6%–49.2%) coral condition. This study concluded that the reefs around Tioman Island were in 'good' average coral condition and have high generic diversity with mixed coral morphological structures. The east coast and isolated areas had better live coral cover compared to the west coast area due to less coastal development and human impacts.

Key words: Scleractinian corals, non-scleractinian corals, soft corals, r-K-S ternary diagrams, Tioman Island, Peninsular Malaysia

1. Introduction

Coral reefs are important ecosystems that provide goods and services to marine tropical and subtropical regions (Moberg and Folke, 1999). In Peninsular Malaysia, coral reefs are found in several localities off the west coast, south coast, and east coast of the peninsula (Affendi and Rosman, 2012). The east coast of Peninsular Malaysia has extensive development of coral reefs with a total of 323 scleractinian coral species identified (Harborne et al., 2000). The most recent report on the status of hard coral diversity increased this list to 431 species in this region (Affendi and Rosman, 2012). This figure represents approximately 75% of the total number of 571 coral species identified in the South China Sea (Huang et al., 2015).

Although coral reefs provide various important ecosystem services to human populations, their health status has been declining due to human intervention together with detrimental impacts of climate change and ocean acidification (Wilkinson, 2008; Jordan et al., 2010; Unsworth et al., 2010). Reef Check Malaysia reported that the coral coverage in several reefs of the east coast region was exposed to high rates of sedimentation resulting from construction and land reclamation activities (Reef Check Malaysia, 2008). These pressures affect reef diversity and distribution by reducing light availability. In addition, tourism activities may also be a major impact causing a decrease in live coral coverage (Jonsson, 2003; Toda et al., 2007). Trampling action by inexperienced snorkelers and scuba divers may have a negative impact that can cause partial mortality of corals (Zakai and Chadwic-Furman 2002; Toda et al., 2007). Besides the natural and anthropogenic factors, the lack of a comprehensive database is impeding conservation efforts towards coral reef ecosystems. Therefore, management action based on comprehensive studies of marine biodiversity should be performed to ensure the conservation and sustainability of coral reef ecosystems.

Several studies about coral species diversity were conducted at Tioman Island by Harborne et al. (2000) at seven reef sites, i.e. Batu Malang, Juara Bay, Gut, Tokong Bahara, Seri Buat, Tulai, and Renggis Islands; by Affendi et al. (2007) at several reef sites from Paya to Genting villages; and by Amri et al. (2008) at one reef site in Tekek Bay. The most recent study of generic coral diversity was done by Toda et al. (2007) at three reef sites, i.e. Manggo, Tulai and Renggis Reefs, at this island. It is an important task to keep up-to-date list of corals and perform a continuous evaluation of the status of coral diversity and reef conditions at Tioman Island.

This present study describes the generic diversity and distribution of corals at 13 reef sites in the east coast, west coast, and isolated areas of Tioman Island. The classification of coral morphology class score and the coral condition for each reef site were also determined. Data

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and information related to the current status of coral reefs will help the relevant stakeholders such as the Department of Marine Park Malaysia in updating coral inventories at generic level and providing reliable information to sustainably manage coral reef ecosystems.

2. Materials and methods

2.1. Study area

Tioman Island lies between 02°48′52.1″N and 104°10′29.3″E, 32 km off the east coast of Peninsular Malaysia in the state of Pahang. The land and coastal areas up to 2 nautical miles around the Tioman Island was established in 1994 as a Marine Park under the Fisheries Act (1985) to protect its biodiversity (DMPM, 2011). A total of 13 reef sites were selected surrounding this island as shown in Figure 1. The reef sites were divided into three areas: east coast area (Dalam Bay, Benuang Bay, Benuang), west coast area (Genting Village, Tomok Island, Renggis Island, Soyak Island, Terdau Bay), and isolated area (Gado Bay, Bayan Bay, Tulai Bay, Sepoi Island, Labas Island). These areas were divided based on differences in environmental settings, coastal developments, and human activities that might establish a gradient of human impacts allowing comparisons in diversity and distribution of corals. The isolated area refers to the area located far from Tioman Island, with no coastal development and less impact from tourism activities. All the reef sites around Tioman Island are fringing reef with a depth range from 3 to 16 m.

2.2. Corals survey method

The coral video transect (CVT) method developed by the Australian Institute of Marine Science (AIMS) was adopted in this study (Abdo et al., 2004). Four 30-m transect lines were aligned at each reef site with a 3-m interval between each transect. A total of 52 transect lines were used in this study. An underwater video camera (Olympus underwater camera TG-3 in video resolution 1980 × 1080 HD) protected with a waterproof casing (Olympus PT-053) was used to record the benthic substrate communities along the transect lines with the distance of the camera being approximately 30 to 50 cm from the substrate and held at a perpendicular angle to the bottom. The camera was run along the transect lines at a speed of 6 min per transect line to get clear and sharp images for laboratory analysis. Additional close-up images of corallites were taken to help with the coral identifications.

2.3. Image processing and data analysis

The recorded videos of benthic communities along four 30-m transect lines for each reef site were converted to 300 picture frames. All picture frames with 10 random points per frame were analysed using Coral Point Count with Excel extension (CPCe) software version 4.1 (Kohler and Gill, 2006) to determine the percentage cover of benthic communities. The coral condition was indicated by total percentage of three major benthic categories namely live corals (scleractinian corals, non-scleractinian corals, and soft corals), dead corals (coral rubbles and dead coral with algae), and others (algae, other invertebrates, and abiotic elements). The coral condition was classified based on the percentage cover 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). Numbers of coral genera were directly counted along the transect lines from the video recorded. The abundance of each coral genus for every reef site was determined based on the number of its colony and was categorised as low (≤25 colonies) or high (≥25 colonies). Coral genera were identified following the Indo Pacific Coral Finder Toolkit (Kelley, 2009) supported by Corals of the World (Veron, 2000).

2.4. Coral morphology class score

All reef sites were plotted on the r-K-S ternary diagrams based on the total cover of various coral morphologies in each of the three groups, namely ruderals (r), competitors (K), and stress-tolerators (S), following Edinger and Risk (2000) (Table 1). The coral morphology classes (C's) of 1, 2, 3, and 4 were assigned to each reef site according to its placement on the r-K-S ternary diagrams. Reef dominated by >60% massive, sub-massive, and massive platy corals, categorised as stress-tolerator type of corals (S), were assigned as class 1 (C 1). Reef dominated by >50% branching non-*Acropora* corals, free living *Fungia* corals, and encrusting and foliose corals, categorised as competitor type of corals (K) were assigned as class 2 (C 2). Reef dominated by >50% *Acropora* corals and non-scleractinian corals (*Millepora* and *Heliopora*), categorised as ruderal type of corals (r), were assigned as class 3 (C 3). Mixed coral morphology reefs represented in approximately equal proportions of these ruderal (r), competitor (K), and stress-tolerator (S) type of corals were assigned as class 4 (C 4).

2.5. Multivariate analyses

Cluster analysis was performed to determine the group of similarities between all reef sites based on distance similarity (Johnson and Wichern, 1992). The data were initially normalised using the log (x + 1) transform function and the Euclidean method was used to analyse the cluster variables. The multidimensional (MDS) ordination (Field et al., 1982) was used to illustrate the group of similarities between all reef sites from the data interaction derived from the cluster analysis. Cluster analysis and MDS plots were created using Paleontological Statistic (PAST) software version 3 (Hammer et al., 2001).

3. Results

3.1. Coral diversity and distribution

A total of 65 coral genera from 21 families were recorded in this study. Out of these 65 coral genera, 55 genera

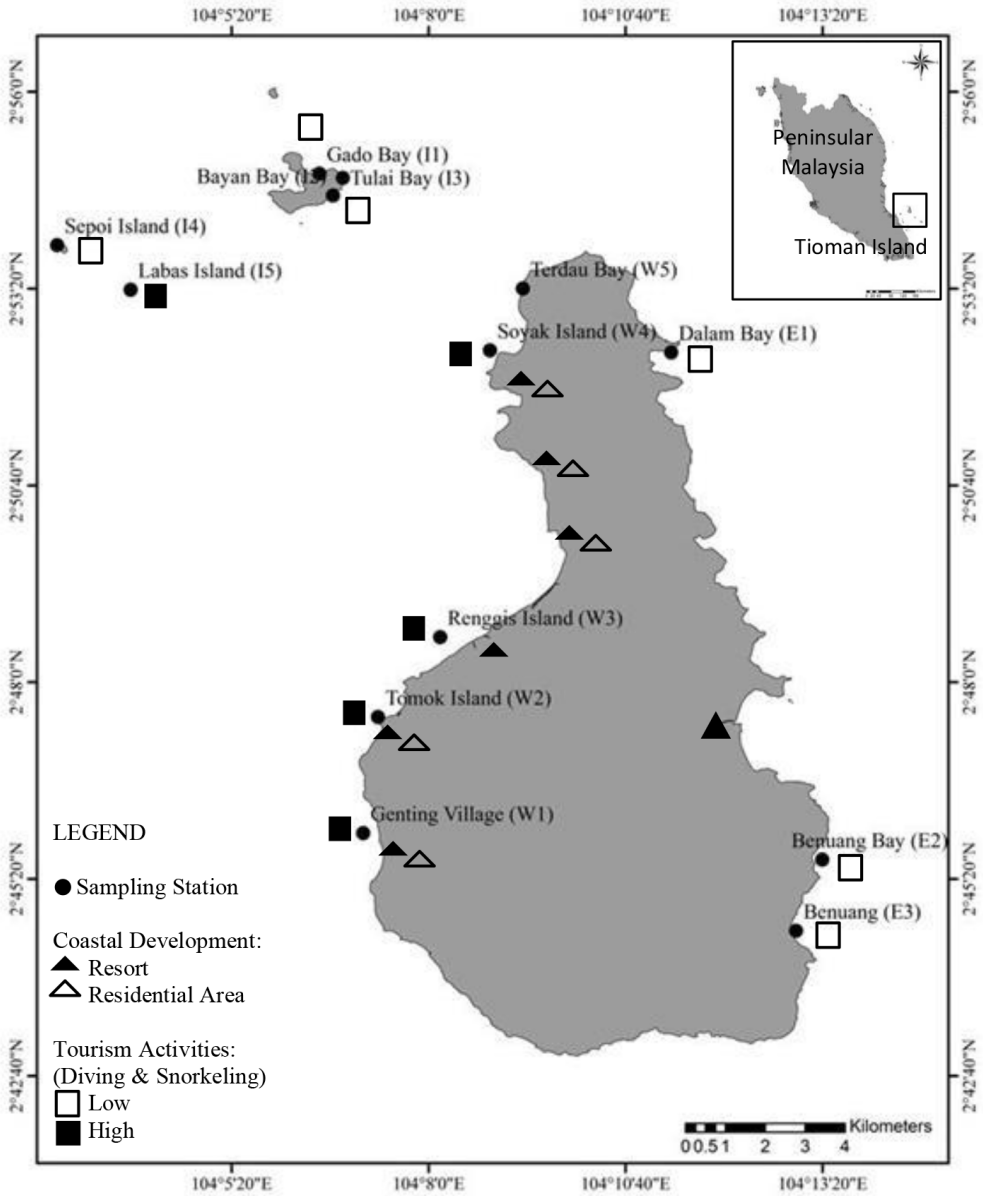


Figure 1. Locations of 13 reef sites at Tioman Island, east coast area: Dalam Bay (E1), Benuang Bay (E2), Benuang (E3); west coast area: Genting Village (W1), Tomok Island (W2), Renggis Island (W3), Soyak Island (W4), Terdau Bay (W5); isolated area: Gado Bay (I1), Bayan Bay (I2), Tulai Bay (I3), Sepoi Island (I4), Labas Island (I5).

corresponded to scleractinian corals, 2 genera were non-scleractinian hard corals (*Millepora* and *Heliopora*), and 8 genera were soft corals (Table 2). Acroporidae was dominant with a cover of 31.4% on average followed by Faviidae, Poritidae, and Alcyoniidae with 21.2%, 11.1%, and 8.9%, respectively. The genus *Acropora* had the highest average coverage at Tioman Island with 19.7%, followed by *Montipora* 11.0%, *Porites* 10.7%, *Sinularia* 6.5%, *Favites* 6.1%, and *Galaxea* 5.0%. Other genera had <5% average coverage. The genera *Acropora*, *Montipora*, *Favia*, *Favites*, *Platygyra*, *Porites*, *Galaxea*, and *Fungia* were found at all reef sites. Among these genera, *Acropora* and *Montipora* were found very well distributed and abundant at all reef sites. The genus *Porites* was found well distributed and abundant in the west coast and isolated areas.

Cluster analysis was done to determine group of similarities between all reef sites based on the number of coral genera found at Tioman Island. The dendrogram and MDS plots revealed two major groups (G I, G II) (Figures 2a and 2b). Benuang, Terdau Bay, Labas Island, Soyak

Table 1. Coral morphology categories used in reef surveys adapted following Edinger and Risk (2000).

Morphology	Code	Description	rKS group
Acropora	AC	*Acropora* branching, bottlebrush, corymbose, digitate, tabular, and submassive	r
Branching coral	CB	Branching non-*Acropora* corals; especially *Porites cylindrica*, some other spp.	K
Encrusting coral	CE	Low relief, often small colonies	K
Massive-platy coral	CMP	Plate-like corals forming large massive colonies, especially *Euphyllia*, *Lobophyllia* spp.	S
Massive coral	CM	Massive or dome-like corals of all sizes.	S
Foliose coral	CF	Foliose, either horizontal or vertical, non-*Acropora*, especially *Montipora*, *Echinopora*	K
Tabular coral (non-*Acropora*)	CTB	Tabular non-*Acropora*, esp. *Montipora*	r
Submassive coral	CSM	Multilobate or "lumpy" corals, sometimes columnar or mixed massive-columnar, especially *Goniopora*, *Galaxea*	S
Mushroom coral	CMR	Free-living fungiid corals	K
Millepora	CME	Various species of *Millepora*. (hydrocoral)	r
Heliopora	CHL	Blue coral (a hydrocoral)	r

Island, Benuang Bay, Gado Bay, Tulai Bay, and Dalam Bay were in group I. Other sampling stations were in group II. Group I consists of a higher number of coral genera that ranged between 32 and 44 genera and most of them were categorised as 'good' coral condition.

3.2. Coral condition and reef classification

Live coral coverage at Tioman Island was 51.4% ± 1.6. The east coast area recorded higher live coral coverage compared to the isolated and west coast areas with 57.7% ± 2.0, 51.2% ± 1.5, and 47.8% ± 2.9, respectively. Nine out of the 13 reef sites were categorised as 'good' coral condition, while Genting Village (W1) and Tomok Island (W2) in the west coast area and Tulai Bay (I3) and Sepoi Island (I4) in the isolated area showed 'fair' coral condition. Dalam Bay (E1), Benuang Bay (E2), and Benuang (E3) in the east coast area showed 'good' coral condition with a higher percentage of live coral coverage compared to the other reef sites. The highest percentage of live coral coverage was recorded at Benuang Island (E3). Soyak Island (W4) and Terdau Bay (W5) in the west coast area recorded a higher percentage of dead corals compared to the other reef sites (Table 3).

Analysis of the r-K-S ternary diagrams showed that most reef sites were grouped in class 4 (C 4) with mixed coral morphological structures. Three reef sites (Tomok Island: W2, Gado Bay: I1 and Tulai Bay: I3) were grouped in class 1 (C 1), of which stress-tolerator corals such as massive corals (*Porites*, *Favia*, *Favites*, *Platygyra*, and *Goniastrea*), sub-massive coral (*Galaxea*), and massive-platy coral (*Euphyllia*) ranged between 61.7% and 77.8%. One reef site (Bayan Bay: N2) located in the isolated area was grouped in class 2 (C 2), of which competitor corals such as non-*Acropora* branching coral (*Pocillopora*), encrusting and foliose coral (*Montipora* and *Pavona*), and mushroom coral (*Fungia*) was 50.1% (Table 4; Figure 3).

4. Discussion

4.1. Coral composition at Tioman Island

In the present study, a total of 57 genera from 17 families of hard corals including scleractinian and non-scleractinian corals were found at Tioman Island. The result was slightly lower than the previous report on the coral reefs of the east coast of Peninsular Malaysia by Harborne et al. (2000). They found a total of 59 genera from 17 families of hard corals at this island. However, it can be postulated that the hard corals were diversified at Tioman Island. The present study also recorded a total of 8 genera from 4 families of soft corals at Tioman Island. Unfortunately, a comparison of diversity for soft coral could not be made due to unavailable data in the previous studies by Harborne et al. (2000), Affendi et al. (2007), Amri et al. (2008), and Toda et al. (2007). Thus, the generic data of soft corals, order Alcyonacea, provide useful information and can be considered the first record on the diversity and distribution of this order at Tioman Island.

The result of coral family analysis showed that Acroporidae (31.4%) had the highest coverage, followed by Faviidae (21.2%) and Poritidae (11.1%). This is consistent

Table 2. Average percentage, diversity, distribution and abundance patterns of coral genera at Tioman Island.

No.	Coral genera	Reef Site													Average (%)
		East coast			West coast					Isolated					
		Dalam Bay	Benuang Bay	Benuang	Genting Village	Tomok Island	Renggis Island	Soyak Island	Terdau Bay	Gado Bay	Bayan Bay	Tulai Bay	Sepoi Island	Labas Island	
		E1	E2	E3	W1	W2	W3	W4	W5	I1	I2	I3	I4	I5	
	SCLERACTINIAN CORAL														
	Acroporidae														31.4
1	*Acropora*	√√	√√	√√	√√	√	√√	√√	√√	√√	√√	√√	√√	√√	19.7
2	*Montipora*	√√	√√	√√	√√	√	√	√√	√	√√	√√	√	√√	√√	11.0
3	*Astreopora*	-	√	-	√	-	√	√	√	√	-	-	-	√	0.5
4	*Isopora*	-	√	√	-	-	-	-	-	-	√	-	√	√	0.3
	Faviidae														21.2
5	*Favia*	√√	√	√	√	√	√	√	√	√	√	√√	√	√	2.5
6	*Favites*	√√	√√	√√	√	√	√	√	√√	√√	√	√√	√	√√	6.1
7	*Barabattoia*	-	-	-	√	-	-	-	√	-	-	-	-	-	0.1
8	*Platygyra*	√	√	√√	√	√	√	√√	√	√	√	√√	√	√√	4.4
9	*Echinopora*	√	√√	√√	√	-	√	-	√	√	√	-	√	√	2.1
10	*Goniastrea*	√	√	√√	√	-	√	√	√√	√	√	√	√	√	3.1
11	*Diploastrea*	√	√	√	√	√	-	√	√	√	√	√	√	-	0.8
12	*Caulastrea*	-	-	-	-	√	-	-	-	-	-	-	-	-	0.0
13	*Montastrea*	√	√	√	√	√	√	√	√	√	-	√	√	√	0.7
14	*Cyphastrea*	√	√	-	-	-	-	√	√	√	-	√	-	√	0.8
15	*Solenastrea*	-	-	-	-	-	-	-	-	-	-	√	-	-	0.0
16	*Oulophyllia*	√	-	√	√	-	-	√	-	√	-	√	√	√	0.3
17	*Plesiastrea*	√	-	-	-	-	-	-	-	-	-	√	-	√	0.1
18	*Leptoria*	√	-	√	-	-	-	√	-	√	-	-	√	√	0.3
19	*Leptastrea*	√	-	-	-	-	-	-	-	-	-	-	-	√	0.1
	Poritidae														11.1
20	*Porites*	√	√	√	√	√√	√√	√√	√√	√√	√	√√	√√	√√	10.7
21	*Goniopora*	-	-	-	√	-	√	√	√	√	-	-	-	√	0.4
	Pocilloporidae														2.9
22	*Pocillopora*	√	√	√√	√	-	√	√	√	√	√	√	√	√	2.8
23	*Stylophora*	-	√	-	-	-	-	-	-	-	-	-	-	-	0.0
24	*Seriatopora*	-	-	-	-	-	-	-	√	-	-	-	-	-	0.0
	Mussidae														3.6
25	*Lobphyllia*	√	√	√	√	√	-	√	√	√	√	√	-	√	1.5
26	*Symphyllia*	√	√	√	√	√	-	√	√	√	√	√	√	√	1.3
27	*Scolymia*	-	-	√	-	-	-	-	√	-	-	√	-	-	0.1
28	*Cynarina*	-	-	-	-	-	-	-	√	-	-	-	-	-	0.0

Table 2. (Continued).

29	*Acanthastrea*	√	√	√	-	-	-	√	√	-	√	√	√	-	0.6
	Oculinidae														5.0
30	*Galaxea*	√√	√√	√	√	√	√	√	√	√√	√	√√	√	√	5.0
	Agariciidae														4.8
31	*Pavona*	√	√	√√	√	√	√	√	√	√	-	√	√	√	2.9
32	*Pachyseris*	√	√	√	-	√	-	-	√	-	√	√	-	√	1.0
33	*Leptoseris*	√	-	-	-	-	-	√	√	√	-	√	-	-	0.2
34	*Gardineroseris*	√	√	√	-	-	-	√	√	-	√	√	√	-	0.7
	Fungiidae														3.1
35	*Cycloseris*	-	-	-	-	-	√	-	-	-	-	√	-	-	0.1
36	*Fungia*	√	√	√	√	√	√	√	√	√	√√	√	√	√	2.4
37	*Herpolitha*	-	-	-	-	√	√	√	-	-	-	-	-	-	0.1
38	*Halomitra*	-	-	-	-	-	-	-	-	-	-	√	-	-	0.0
39	*Sandalolitha*	-	√	√	√	-	√	√	√	-	-	√	-	-	0.4
40	*Ctenactis*	√	√	-	√	-	√	-	-	-	√	-	-	-	0.2
41	*Polyphyllia*	-	-	√	-	-	√	-	-	-	-	-	-	-	0.0
	Pectiniidae														0.1
42	*Pectinia*	-	√	-	√	-	-	-	-	-	-	-	-	-	0.1
43	*Oxypora*	-	-	-	√	-	-	-	-	-	-	-	-	-	0.0
44	*Echinophyllia*	-	-	√	-	-	-	-	-	-	-	-	-	-	0.1
	Dendrophyllidae														0.6
45	*Turbinaria*	-	-	√	-	√	-	√	√	-	-	√	-	√	0.3
46	*Tubastrea*	-	-	-	-	-	-	-	√	-	-	-	-	√	0.3
	Merulinidae														0.7
47	*Merulina*	-	√	√	-	√	√	√	√	√	-	-	-	√	0.3
48	*Hydnophora*	√	√	√	-	-	√	√	√	√	-	√	-	-	0.4
49	*Scapophyllia*	-	-	-	-	-	-	-	-	√	-	-	-	-	0.0
	Euphyllidae														3.0
50	*Plerogyra*	-	√	-	-	√	√	√	√	√	-	√	√	√	0.6
51	*Physogyra*	-	√	-	-	-	-	√	-	√	-	√	√	√	0.2
52	*Euphyllia*	√	√√	√	-	-	-	√	√	√	√	√√	√	√	2.2
	Siderastreidae														0.4
53	*Psammocora*	-	√	√	-	-	-	√	√	-	-	√	-	√	0.4
	Astrocoeniidae														0.0
54	*Stylocoeniella*	√	-	-	-	-	-	-	-	-	-	-	-	-	0.0
	Trachyphyllidae														0.0
55	*Trachyphyllia*	-	-	√	-	-	-	-	-	-	-	-	-	-	0.0
	NON-SCLERACTINIAN CORAL														
	Milleporidae														0.3
56	*Millepora*	-	-	√	-	-	-	√	√	-	-	√	-	-	0.3
	Helioporidae														1.1
57	*Heliopora*	-	-	√	-	-	√	-	√√	-	-	√	-	-	1.1
	SOFT CORAL														
	Nephteidae														1.0

Table 2. (Continued).

58	*Nepthea*	-	√	√	-	√	√	√	√	√	-	-	-	√	0.7
59	*Dendronephthya*	-	-	√	-	-	-	-	√	-	-	-	-	√	0.3
	Alcyoniidae														8.9
60	*Cladiella*	-	-	-	-	-	√	-	-	-	-	-	-	√	0.2
61	*Sinularia*	√√	√√	√√	-	√	-	√	√√	√√	√	√√	√	√	6.5
62	*Lobophytum*	√	√	√√	-	-	-	√	√	√	√	√	-	-	1.2
63	*Sarcophyton*	√	√	-	-	-	-	√	√√	√	-	√	-	√	1.0
	Xeniidae														0.0
64	*Xenia*	-	-	√	-	-	-	-	√	-	-	-	-	-	0.0
	Clavulariidae														0.5
65	*Clavularia*	-	√	√	-	-	-	-	√	-	-	-	√	√	0.5
	Total Genera	32	37	40	24	21	26	36	44	33	20	38	23	38	

*√ = Low abundance (≤25 colonies); √√ = High abundance (≥25 colonies)

with their characteristics, namely that they naturally have the most number of species (Veron, 2000). According to Wallace (1999), Acroporidae comprises the largest number of species and has been dominated by the genus *Acropora* with approximately 60% coverage. Acroporidae, Faviidae, and Poritidae also are commonly found conspicuous and prolific in Indo-pacific reefs (Veron, 1995). In addition, Alcyoniidae (soft corals) was also recorded as among the highest coverage of coral families with 8.9%. This family is known as among the family members that have dominated the Indo-Pacific reefs (Verseveldt, 1980; Malyutin, 1992).

Acropora, *Montipora*, and *Porites* are among the highest coverage of coral genera recorded at Tioman Island. Previous studies also reported that coral communities along the east coast of Peninsular Malaysia including Tioman Island were dominated by the genera *Acropora*, *Porites*, and *Montipora* (Harborne et al., 2000; Toda et al., 2007). This is due to the fact that these coral genera have their own ability to tolerate and survive with the changes in environmental parameters, such as currents, wave actions, and fluctuation of suspended sediment concentrations (Hong and Sasekumar, 1981; Ammar and Mahmoud, 2006; Unsworth et al., 2010).

For instance, *Acropora* and *Montipora* are considered to have fast-growing species that are able to expand more rapidly in certain areas compared to other slow-growing *Porites* species (Rogers, 1990; Karlson and Hurd, 1993; Unsworth et al., 2010). However, slow-growing *Porites* species have greater longevity of their coral skeleton compared to more fragile *Acropora* and *Montipora* species (Hong and Sasekumar, 1981). *Porites* species can also potentially grow faster than *Acropora* species in areas where suspended sediments are high (Ammar and Mahmoud, 2006). *Porites* colonies have the ability to remove sediment accumulated on their surfaces through their own cleaning mechanism, namely mucus secretions or ciliary action (Hong and Sasekumar, 1981). Therefore, it can be assumed that the high distribution and abundance of this genus in the west coast area is caused by its ability to adapt with increased sediment inputs due to environmental factors and anthropogenic impacts.

Data on the distribution of coral genera collected in this study also showed that *Favia*, *Favites*, *Platygyra*, and *Galaxea* were common coral genera found in all reef sites at Tioman Island. Since these genera have mainly colonies with massive and sub-massive forms, they have greater tolerance to environmental changes if compared to non-massive coral colonies (Hong and Sasekumar, 1981). Hong and Sasekumar (1981) reported that these stress tolerator types of coral are able to endure strong current and wave action and as well as high suspended sediment concentrations.

In the family Alcyoniidae, *Sinularia* was commonly found at all the reef sites located in the east coast and isolated areas. Due to directly facing the open sea, these two areas are exposed to strong waves and currents, especially during the northeast monsoon season. Having the structural flexibility to tolerate this type of condition, soft corals are able to thrive on the exposed side of reefs (Hong and Sasekumar, 1981). The other factor that influences the growth of soft corals is the ability to inhibit the growth of their adjacent hard corals by releasing toxins (Maida et al., 1995; Fabricius, 1998). Hence, soft corals are able to grow and compete with hard corals to dominate certain areas of the reefs.

Based on the analysis of r-K-S ternary diagrams, most of the reef sites at Tioman Island were assigned as class 4 (C 4) with mixed coral morphologies. The result indicated that Tioman Island has good habitat complexity and heterogeneity providing the optimum conditions for fish

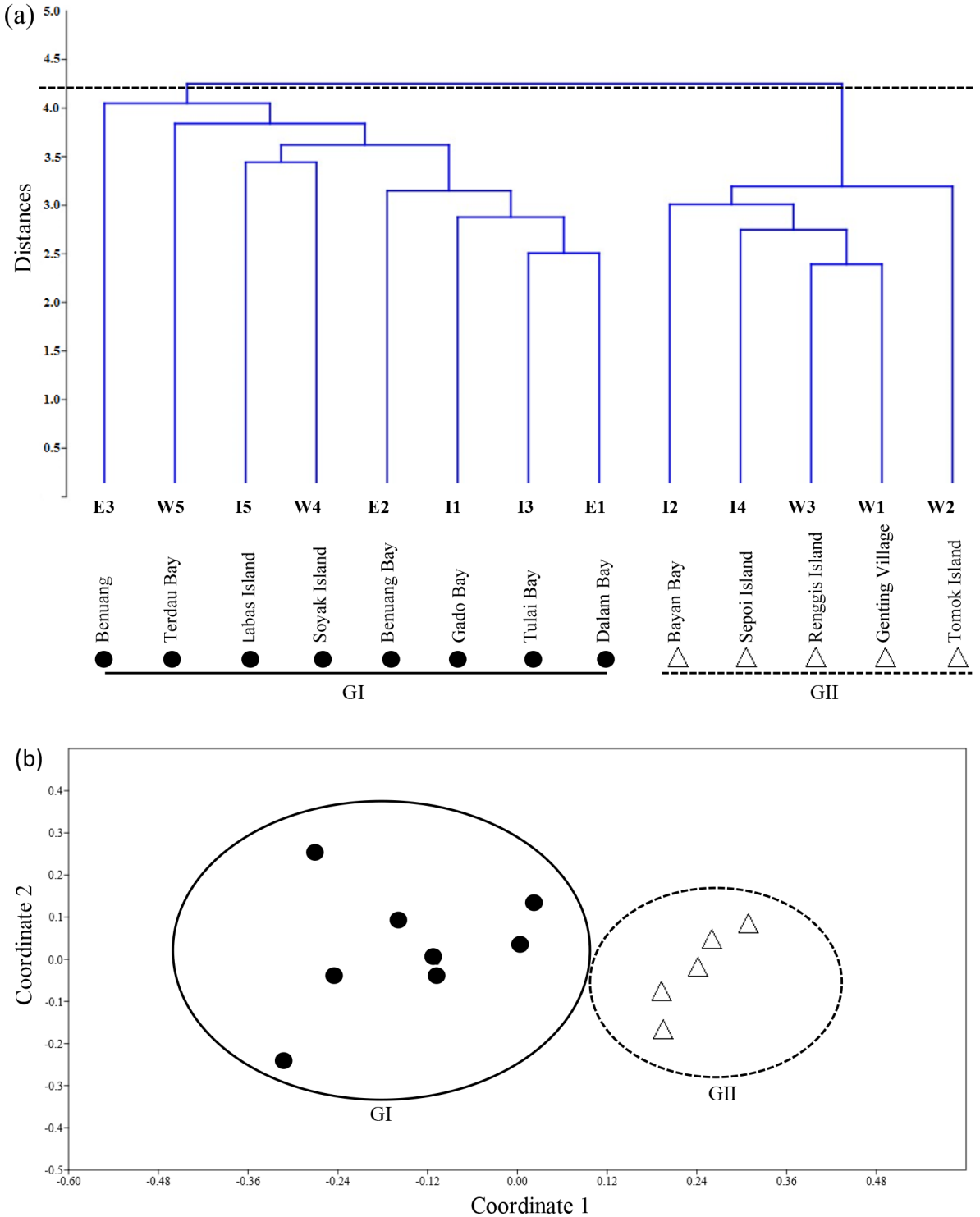


Figure 2. a) Cluster analysis of 13 reef sites based on the number of coral genera found in Tioman Island; b) Ordination of 13 reef sites using multidimensional scaling (MDS) plot based on the significant clusters from a).

and other marine organisms. As supported by previous research, habitat heterogeneity is the most commanding factor that affects the diversity and abundance of fish populations, including commercial fish, by providing many structural habitats for them (McClain and Barry, 2010). Thus, the reef sites around Tioman Island deserve

Table 3. Percentage coverage of live corals, dead corals and coral condition at Tioman Island

Reef Site		Live corals (%)	Dead corals (%)	Others (%)	Coral condition
East coast area					
E1	Dalam Bay	53.8	19.4	26.8	Good
E2	Benuang Bay	59.1	29.7	11.2	Good
E3	Benuang	60.3	13.5	26.2	Good
Average		57.7 ± 2.0	20.9 ± 4.7	21.4 ± 5.1	Good
1. West coast area					
W1	Genting Village	45.1	20.6	34.3	Fair
W2	Tomok Island	37.6	28.8	33.6	Fair
W3	Renggis Island	51.4	21.3	27.3	Good
W4	Soyak Island	51.9	36.1	12.1	Good
W5	Terdau Bay	52.8	37.8	9.4	Good
Average		47.8 ± 2.9	28.9 ± 3.6	23.3 ± 5.3	Fair
2. Isolated area					
I1	Gado Bay	51.0	25.0	23.9	Good
I2	Bayan Bay	52.6	21.2	26.2	Good
I3	Tulai Bay	47.2	24.4	28.4	Fair
I4	Sepoi Island	49.2	20.4	30.4	Fair
I5	Labas Island	55.9	24.8	19.2	Good
Average		51.2 ± 1.5	23.2 ± 1.0	25.7 ± 1.9	Good
Total average		51.4 ± 1.6	24.8 ± 1.9	23.8 ± 2.3	Good

Table 4. Summary of r-K-S percentage and coral morphology class scores at Tioman Island.

Reef site		r%	K%	S%	C no.
East coast area					
E1	Dalam Bay	31.3	14.7	54.0	C 4
E2	Benuang Bay	8.8	37.1	54.1	C 4
E3	Benuang	19.2	43.2	37.6	C 4
1. West coast area					
W1	Genting Village	25.3	40.4	34.3	C 4
W2	Tomok Island	15.0	12.0	73.0	C 1
W3	Renggis Island	43.5	21.2	35.3	C 4
W4	Soyak Island	28.0	21.3	50.7	C 4
W5	Terdau Bay	31.0	11.1	57.9	C 4
2. Isolated area					
I1	Gado Bay	9.6	28.7	61.7	C 1
I2	Bayan Bay	39.3	50.1	10.6	C 2
I3	Tulai Bay	9.4	12.8	77.8	C 1
I4	Sepoi Island	31.1	40.9	28.0	C 4
I5	Labas Island	21.5	28.8	49.7	C 4

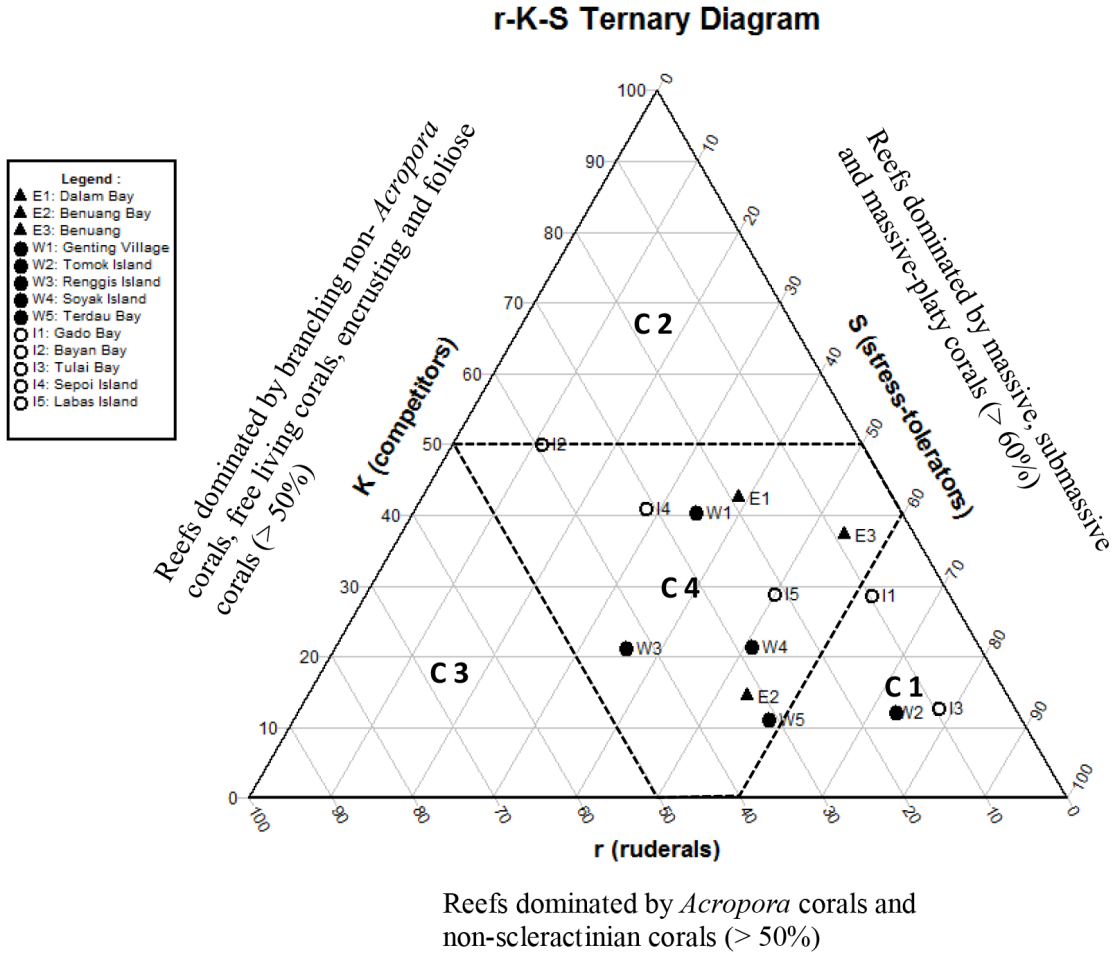


Figure 3. Coral morphology class score for 13 reef sites in Tioman Island. Most of the reef sites were plotted under mixed coral morphologies and received class 4 (C 4). Three reef sites (Tomok Island, Gado Bay, and Tulai Bay) dominated by stress-tolerator corals and received class 1 (C 1). One reef site (Bayan Bay) dominated by competitor corals and received class 2 (C 2).

the highest degree of protection since they can potentially increase the fisheries sector.

4.2. Reef condition at Tioman Island

The coral condition in Tioman Island varied from 'fair' to 'good'. Most of the reef sites with less coastal development and human activity were categorised as 'good' coral condition. Dalam Bay, Benuang Bay, and Benuang, which were located in the east coast area, and Gado Bay, Bayan Bay, and Labas Island, which were located in the isolated area, have shown 'good' coral condition with a high percentage of live coral coverage. The results of cluster analysis and MDS plots also showed that most of the reef sites in these areas consist of a high number of coral genera and are categorised as 'good' coral condition. These areas experience less human activity since they are located far from resorts and residential areas.

Meanwhile, several reef sites located in developed areas and that directly received the impacts from human activities were categorised as 'fair' coral condition. This is supported by the previous study done by Toda et al. (2007) that found the 'fair' coral condition in Genting Village (formerly known as Mango Reef). Genting Village was categorised as a developed area with many resorts and residential sites and has been a focal point for tourists to venture into water sport activities such as snorkelling, diving, and boating. Rapid development of coastal areas and the extensive nature of human activities may represent the greatest threat to corals (Reef Check Malaysia, 2008; Wilkinson, 2008; Unsworth et al., 2010). Scuba divers, snorkelers, and reef walkers could become the major contributors toward coral reef degradation (Zakai and Chadwic-Furman, 2002; Wielgus et al., 2004; Toda et al., 2007; Praveena et al., 2012). These factors, together with boating activities in shallow water areas, might increase the re-suspension of bottom sediment. The high suspended sediment concentrations will reduce the light

intensity required for zooxanthellae algae (*Symbiodinium* sp.) to undergo photosynthesis. Then it will simultaneously inhibit the growth rate of reef-building coral species since they have symbiotic relationship with *Symbiodinium* sp. As a result, some coral species that are unable to tolerate this condition will not survive (Soegiarto, 2000; Chua and Ross, 2002; Toda et al., 2007).

It can be concluded that the intensive coastal development, increasing numbers of tourists, and shortcomings in environmental conservation efforts may lead to the irreversible decline of coral condition and the number of coral genera in this island. As a consequence, significant steps should be taken to conserve and protect the coral reefs. Positive action needs to be implemented to balance the pace of coastal development and number of tourists in order to ensure the sustainability of coral reefs around Tioman Island. Proper guidelines and policies in terms of carrying capacity for snorkelers and divers at particular localities and time should be implemented. If no action is taken, it will inevitably put corals under stress and some of the coral species might vanish in the near future.

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