The biodiversity and conservation status of the marine gastropod (Mollusca; Gastropoda) in Pulau Bidong, Terengganu, Malaysia

Nursalwa Baharuddin, Nur A. Zakaria

School of Marine and Environmental Sciences, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia. Corresponding author: N. Baharuddin, nursalwa@gmail.com

Abstract. Pulau Bidong is known for its history as a Vietnamese refugee settlement during the Vietnam War in the 1970s. By the 1990s, this island was under the jurisdiction of the state government of Terengganu, Peninsular Malaysia. Now, Pulau Bidong is the marine research centre for the Universiti Malaysia Terengganu (UMT MaReSt). It is a low-lying ecosystem harbouring flora and fauna not yet discovered. To date, there is no documented evidence on richness, diversity, and abundance of molluscan fauna found on the island. This study aims to identify diversity, distribution, morphological characteristics, and conservation status following the International Union for Conservation for Nature (IUCN) of marine gastropods. Sampling was done in August 2017 at two selected stations using the Smith-McIntyre grab and dredge. A total of 140 individuals representing three subclasses, 14 families, and 25 species were found. The highest number of individuals collected belonged to *Minolia ceraunia* (Solariellidae), with 27 individuals, followed by *Margistrombus marginatus* (Strombidae), with 20 individuals. Ecological indices, like the Shannon index (*H'*) and Simpson index (*D*), showed that species diversity was 2.67±0.20 and 0.90±0.02, respectively, indicating moderate to high diversity. In addition, Margalef (M_a) and Menhinick (M_e) indices showed high variation scores of 4.61±0.44 and 2.16±0.09, indicating high species richness. Similarly, Evenness (*J'*) and Equitability (E_p) recorded 0.65±0.09 and 0.86±0.04, respectively, showing high homogeneity and distribution pattern of species in relation to other species. All marine gastropods were categorised as 'Not Evaluated' following IUCN. This study provided baseline information for malacology communities and highlighted insufficient information, so a proper assessment of conservation status can occur. Extending the sampling period is recommended, so further surveying and monitoring of other benthic taxa, including algae, crustaceans, molluscs, and polychaetes, can provide a comprehensive study useful for scientists and members, for future follow-up and evaluation programmes.

Key Words: island, species richness, evenness, molluscan, marine gastropod, IUCN.

Introduction. Terengganu is a state situated along the east coast of Peninsular Malaysia possessing the highest number of islands distributed along its shoreline. These seven islands, Pulau Redang, Pulau Kapas, Pulau Perhentian, Pulau Duyong, Pulau Gemia, Pulau Lang Tengah and Pulau Bidong, have become hot spots for tourists for their scenic and natural island ecosystems. Pulau Bidong is known as 'Little Saigon', from its historical use as a Vietnamese refugee settlement during the Vietnam War in the 1970s (Thompson 2010). By the 1990s, this island was under the jurisdiction of the state government of Terengganu. Since then, Pulau Bidong has become the marine research station for the Universiti Malaysia Terengganu (UMT MaReSt), hence areas are restricted for research purposes only, not accessible to the public. It is a low-lying island, composed of six well-vegetated and Dipterocarp forests with rocky and hilly areas (Grismer et al 2014; Adanan et al 2016). This island harbours flora and fauna not yet discovered. Studies on marine biodiversity, including algae (Arumugam 1981; Phang & Wee 1991; Phang et al 2010; Sidik et al 2012), mollusc nudibranch (Alqudah et al 2015), sea urchins (Siti Shazlina et al 2009; Shamsuddin et al 2010), fishes (Liew et al 2006; Matsunuma et al 2011; Abol-Munafi et al 2011; Rumeaida et al 2014; Wan Hussin 2014; Arai et al 2015), scavenging crustaceans (Nakajima et al 2013), marine sponges (Mohamad et al 2009), coral reefs (Mohd et al 1999; Morton & Blackmore 2001; Nakajima et al 2010; Reimer et al 2015;

Boo et al 2017), and blacktip reef sharks (Lorenzo et al 2016) have been conducted in Pulau Bidong. To date, there is no documented evidence on the richness, diversity, and abundance of molluscan fauna found on the island.

Phylum Mollusca is the second largest, after Phylum Arthropoda, consisting of seven classes, including Aplacophora, Scaphopoda, Monoplacophora, Polyplacophora, Cephalopoda, Bivalvia, and Gastropoda (Saxena 2005; Pechenik 2016; Sonak 2017). Gastropoda is one of the largest classes contributing about 80% of the known species and approximately 80,000 to 100,000 described species worldwide (Ponder & Lindberg 2008; Strong et al 2008). They are a zoological group diverse in habitat occupation and living species, successful biologically (Brusca 1980). These organisms are found in ridges, reefs, and great sea depths, and thus are the most widely distributed animals on the planet. The evolutionary success to colonise terrestrial, freshwater, and marine ecosystems (Dayrat et al 2011; Webb 2012) make it uniquely the only class to do so. Gastropods have only one calcareous shell (Dance 1992) varying in size, shape, and colour, becoming its trait characteristics. Their soft body is twisted in this single coiled shelled and divided into four main parts, namely the head, foot, visceral mass, and mantle (Carpenter & Niem 1998). The head protrudes anteriorly from the shell and is equipped with sensory organs including eyes, mouth, and tentacles (Pechenik 2016). The foot is a muscular ventral organ with a flattened base for mobility and possessing operculum acting as a flap or door to close the shell for protection and prevent water loss (Hickman et al 2015). The visceral mass is filled with spire of the shell dorsally, whilst the mantle is a collar-like tegument and secretes the shell (Hickman et al 2015). Despite been known as languid and inactive animals (Oliver 1983), molluscs gastropods play a significant role in the food chain and food webs for communities, including structuring, energy flux of trophic level, and nutrient recycling (Chaloner et al 2009). Their roles are very diverse, including primary consumers (herbivores and detritivores), second-level predators, parasites, and opportunists (Escamilla-Montes et al 2018). Moreover, their social and economic importance, with protein or nutritional values for medicines and commercialisation, have made this phylum among the crucial natural resources harvested by humans (Flores-Garza et al 2012; Escamilla-Montes et al 2018).

Although molluscs are among the highest and largest in distribution and abundance, they have the most severely affected extinction recorded in 2016, in the International Union for Conservation Nature (IUCN) Red Lists third issue, where 297 out of 744 species were listed as extinct (Cowie et al 2017). Most invertebrate taxa are still insubstantial, unknown, and poorly documented (Reid 2000; Diniz-Filho et al 2010). Additionally, most data were based on iconic and well-studied groups like butterflies, dragonflies, certain snail, and reef-building corals (Regnier et al 2015). Hence, this study identifies the diversity, distribution, morphological characteristics, and conservation status of marine gastropods following the IUCN criteria.

Material and Method

Sampling station. This study was conducted at Pulau Bidong, located 35 km northeast of Kuala Terengganu, Terengganu, Peninsular Malaysia (Figure 1). It is situated about eight nautical miles east of Pantai Merang, with an area of 203 hectares. Pulau Bidong is not gazetted as a marine park, unlike other islands around Terengganu. Two sampling stations were selected at the western part of Pulau Bidong: Station 1 (5°36'3.14"N, 103° 2'1.45"E) and Station 2 (5°36'6.30"N, 103°2'5.74"E).

Sampling procedures. Sampling occurred in August 2017 using the UMT Discovery vessel. Gastropod collection used two types of methods, the Smith-McIntyre grab and dredge (Figure 2). The Smith-McIntyre grab (0.05 m^2) was released into the ocean. The grab is a fixed set on a stainless-steel frame hanging from a pair of lowering cables stuck to the bucket arms (Smith & McIntyre 1954). The spring was activated by a trigger mechanism and released when the foot plates touched the base of the ocean floor. The equipment was lifted from the water following protocols. All samples were transferred to an elutriating bin run through moderately flowing seawater. Then, water was flowed onto a 500 μm sieve, chosen following international monitoring of soft sediment communities (Frid 2011). All marine gastropods were sorted by hand or forceps, placed in containers filled with 70% ethanol, and labelled. A dredge was released into the ocean bottom sediment. This dredge dragged along the seafloor. It was lifted through a water column. Marine gastropods trapped in the mesh (mesh size, 20 × 20 mm) were collected, preserved in 70% alcohol, and labelled. Each method was replicated three times. All specimens were brought to the laboratory for further analysis.

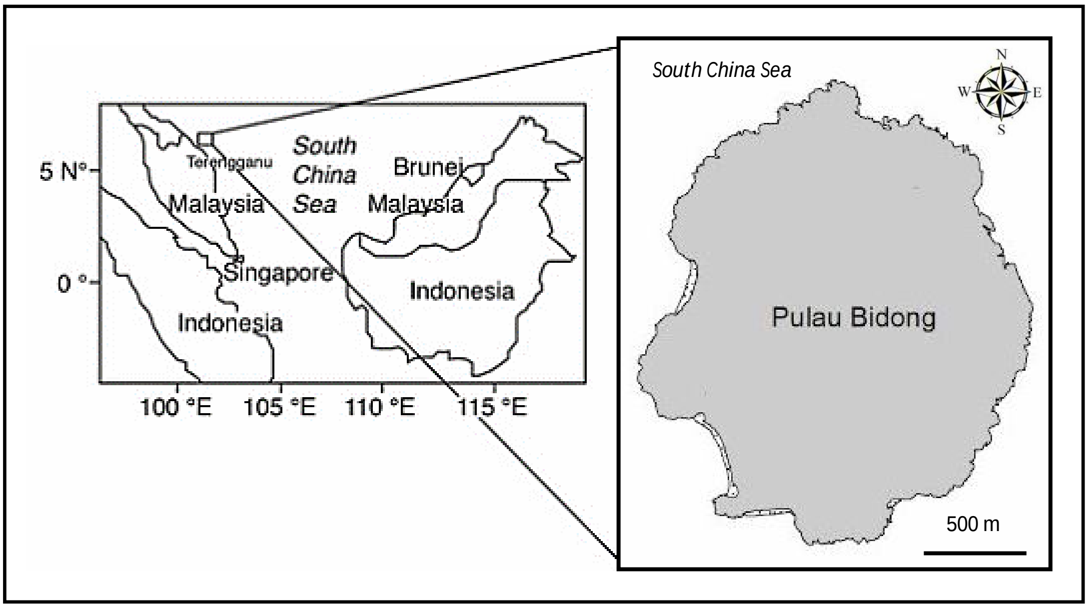

Figure 1. Map of Pulau Bidong located at 35 km northeast of Kuala Terengganu, Terengganu, Peninsular Malaysia.

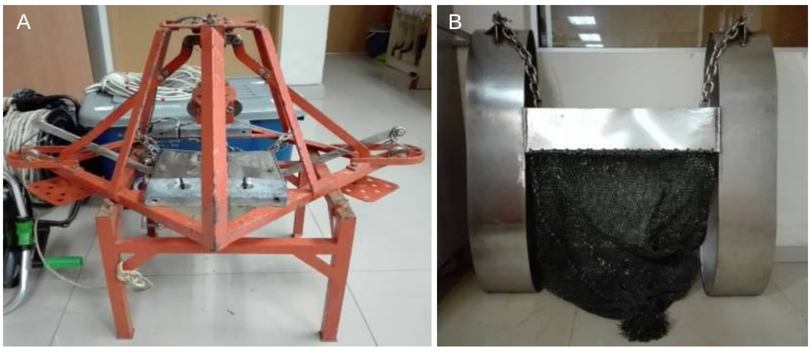

Figure 2. Smith-McIntyre grab (A) and dredge with mesh size of 20 × 20 mm (B) that were used to collect marine gastropods.

Species identification. Marine gastropods were cleaned with a brush and washed with tap water to remove algal film, other encrustations, and debris. Identifications of marine gastropods were based on shell size, colour, pattern, ornamentation, and shape. They were identified to the lowest possible taxonomic levels using the keys of Abbott & Dance (1982), Oliver (1983), Abbott (1991), Dance (1992), Hook (1999), Tan & Chou (2000), Long & Ramli (2010), Baharuddin & Marshall (2014), and Sonak (2017). The validity of species names was reviewed with the World Register of Marine Species (WoRMS) database, www.marinespecies.org. IUCN status for each species was identified with the database of IUCN Red List of Threatened Species, www.iucnredlist.org. Shell morphometrics, including length and width, were measured with digital vernier callipers. For each species, photographs were taken with a Nikon D7000 DSLR camera. All voucher specimens were fixed and preserved in 70% ethanol. All specimens were deposited at the

South China Sea Repository and Reference Centre of the Institute of Oceanography and Environment in Universiti Malaysia Terengganu.

Data analysis. Six ecological indices analysed data, including Shannon (H'), Simpson (D), Margalef (M_a), Menhinick (M_e), Evenness (J'), and Equitability (E_p), using Paleontological Statistic (PAST) software.

Diversity was calculated using Shannon-Wiener index (H'):

$$H' = -\sum_{i=1}^{S} p_i \log p_i$$

In the above, H' is the value of the Shannon-Wiener diversity index, P_i is the proportion of the ith species, $\log_e$ represents the natural logarithm of Pi, and s represents the number of species in the community. The Shannon-Wiener diversity index is classified into three levels: low (H' < 2), moderate (2 < H' < 4), and high (H' > 4) (Odum & Barret 2004).

Simpson's diversity index (D) was calculated as below:

$$D = 1 - \frac{\Sigma n(n-1)}{N(N-1)}$$

In the above, n = the total number of organisms of a specific species, and N = the total number of organisms of all species. When D value reaches 1, it represents infinite diversity, while values reaching 0 represent no diversity.

The richness index was used following Margalef index (M_a) and Menhinick index (M_e), according to Hammer et al (2001), as below:

$$M_a = (s-1)/\ln N$$

$$M_e = s/\sqrt{n}$$

where s equals the number of distinct species represented in the sample and N equals the total number of individual organisms in the sample.

Evenness (J') and Equitability (E_p) indices were used for homogeneity or pattern of species distribution relative to other species (Hammer et al 2001), as below:

$$J' = H'/H' \max$$

$$E_p = H'/\ln (S)$$

where H' = Shannon diversity index and S = number of species. In the above, the value reaching 1 represents complete evenness, whilst values reaching 0 represent no evenness.

Results. A total of three subclasses of marine gastropods (Caenogastropoda, Heterobranchia, and Vetigastropoda) belonging to 14 families and 25 species were found in Pulau Bidong (Figure 3). Family Naticidae and Terebridae represented five species each. In comparison, families like Fasciolariidae, Mitridae, Nassariidae, Olividae, Seraphsidae, Strombidae, Volutidae, Haminoeoidea, Pyramidellidae, and Trochidae only contributed one species each. Sixty three (63) individuals were collected using the dredge, whilst 77 individuals were collected using the Smith-McIntyre grab, for a total of 140 individuals. Eighteen (18) species were found using the dredge and 19 species were found using the Smith-McIntyre grab (Table 1). Among all species, *Minolia ceraunia* (Solariellidae) recorded the highest number of individuals found (27 individuals) followed by *Margistrombus marginatus* (Strombidae) with 20 individuals (Figure 1, Table 1).

Ecological indices like the Shannon diversity index (H') and the Simpson diversity index (D) showed species diversity at 2.67±0.20 and 0.90±0.02, respectively, indicating moderate to high diversity. The Margalef (M_a) and Menhinick (M_e) indices showed high variation scores of 4.61±0.44 and 2.16±0.09 respectively, indicating high species richness. This pattern is like the Evenness (J') and Equitability (E_p), recording 0.65±0.09 and 0.86±0.04, respectively, showing high homogeneity and pattern of species distribution relative to other species (Table 2).

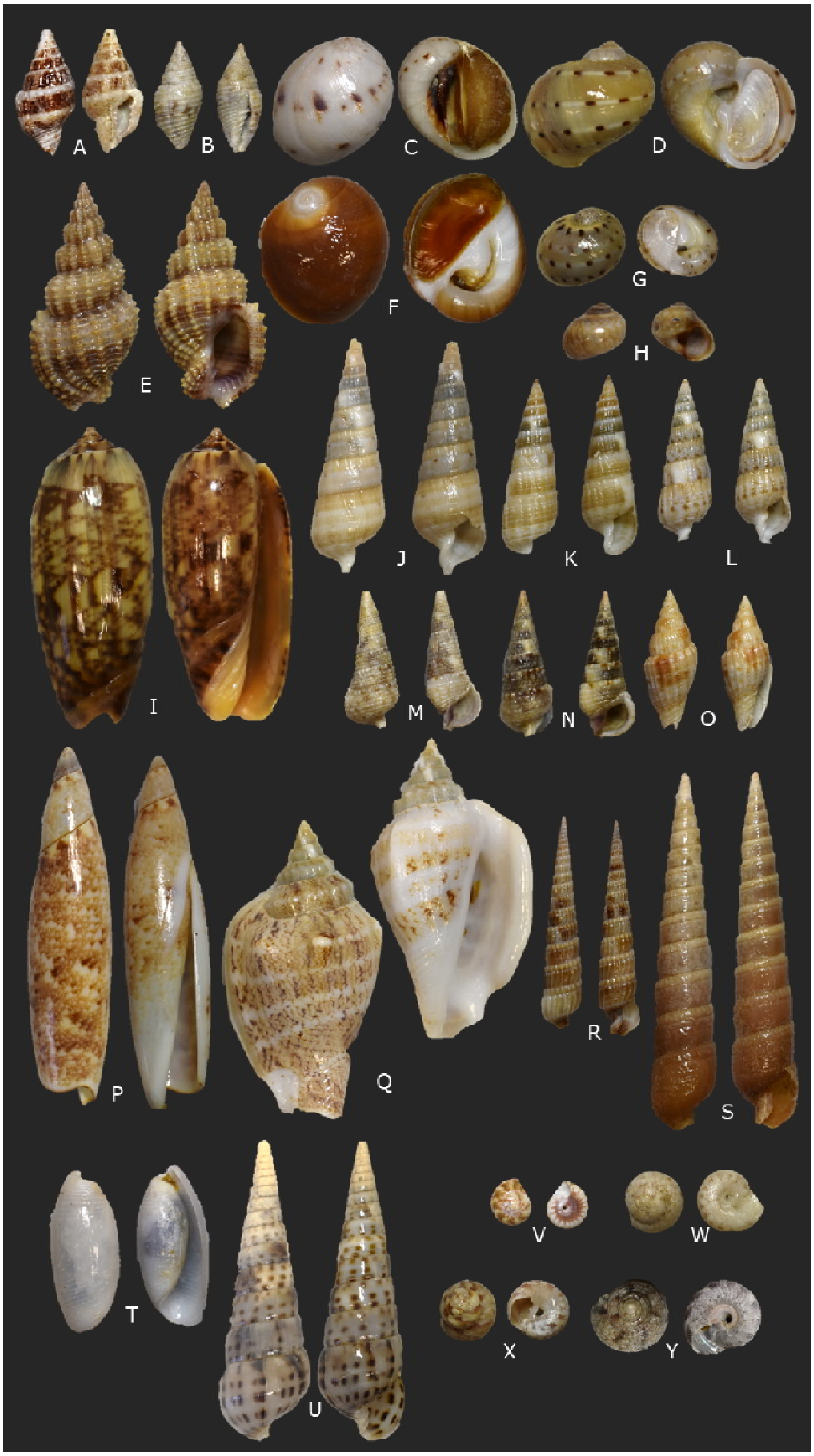

Figure 3. Apertural and abapertural of marine gastropods of Pulau Bidong. A: *Peristernia nassatula* (12), B: *Scabricola incisa* (8), C: *Mammilla syrphetodes* (13), D: *Naticarius alapapilionis* (14), E: *Phos senticosus* (18), F: *Polinices albumen* (18), G: *Tanea tosaensis* (11), H: *Natica menkeana* (6), I: *Miniaceoliva tremulina* (38), J: Species c (36), K: Species d (21), L: Species e (20), M: Species a (14), N: Species b (17), O: *Lyria delessertiana* (16), P: *Terebellum terebellum* (47), Q: *Margistrombus marginatus* (41), R: *Myurella hiscocki* (31), S: *Cinguloterebra anilis* (46), T: *Nipponatys volvulina* (19), U: *Longchaeus acus* (40), V: *Microgaza rotella* (6), W: *Minolia ceraunia* (6), X: *Minolia edithae* (5), and Y: *Monilea belcheri* (8). Number in parenthesis indicates shell length (mm).

Table 1

Marine gastropods according to subclass, family and species with total of individuals (∑ Ind.) according to dredge and Smith-McIntyre grab methods. Grant total of individuals and total species were recorded at Pulau Bidong

Subclass	*Family*	*Species*	*Dredge (∑ Ind.)*	*Grab (∑ Ind.)*
Caenogastropoda	Fasciolariidae	*Peristernia nassatula* (Lamarck, 1822)	0	6
	Mitridae	*Scabricola incisa* (A. Adams & Reeve, 1850)	0	1
	Nassariidae	*Phos senticosus* (Linnaeus, 1758)	4	3
	Naticidae	*Mammilla syrphetodes* Kilburn, 1976	1	1
		Natica menkeana Philippi, 1851	0	2
		Naticarius alapapilionis (Röding, 1798)	2	0
		Polinices albumen (Linnaeus, 1758)	4	0
		Tanea tosaensis (Kuroda, 1961)	1	1
	Olividae	*Miniaceoliva tremulina* (Lamarck, 1811)	8	1
	Cerithiidae	Species a	0	5
		Species b	6	7
	Seraphsidae	*Terebellum terebellum* (Linnaeus, 1758)	5	0
	Strombidae	*Margistrombus marginatus* (Linnaeus, 1758)	16	4
	Terebridae	*Myurella hiscocki* (Sprague, 2004)	1	1
		Cinguloterebra anilis (Röding, 1798)	1	0
		Species c	2	0
		Species d	1	3
		Species e	0	1
	Volutidae	*Lyria delessertiana* (Petit de la Saussaye, 1842)	1	2
Heterobranchia	Haminoeidae	*Nipponatys volvulina* (A. Adams, 1862)	3	2
	Pyramidellidae	*Longchaeus acus* (Gmelin, 1791)	4	1
Vetigastropoda	Solariellidae	*Microgaza rotella* (Dall, 1881)	0	1
		Minolia ceraunia Melvill, 1891	2	25
		Minolia edithae Melvill, 1891	0	10
	Trochidae	*Monilea belcheri* (Philippi, 1849)	1	0
Grand total of individuals			63	77
Total species			18	19

Table 2

Results of ecological indices used to calculate diversity, richness, and evenness of marine gastropods recorded at Pulau Bidong. Mean with standard deviations, S.D.

Ecological indices	*Mean±S.D.*
Shannon Diversity (*H'*)	2.67±0.20
Simpson's Diversity (*D*)	0.90±0.02
Margalef (M_a)	4.61±0.44
Menhinick (M_e)	2.16±0.09
Evenness (*J'*)	0.65±0.09
Equitability (E_p)	0.86±0.04

Terebellum terebellum (Seraphsidae) is the largest, with a shell length of 46.88±5.83 mm, whilst *Microgaza rotella* (Solariellidae) has the shortest shell length, at 2.72 mm. In contrast, *Margistrombus marginatus* (Strombidae) has the widest shell width, at 23.10±5.61 mm, while *Scabricola incisa* (Mitridae) has the narrowest shell width, at 2.93 mm. For aperture length, *Miniaceoliva tremulina* (Olividae) has the longest value, at 33.91±9.21 mm, compared to *Scabricola incisa* (Mitridae) with shortest aperture length, at 1.80 mm. *Margistrombus marginatus* (Strombidae) has the widest aperture at 8.09±2.76 mm, while *Scabricola incisa* (Mitridae) has the narrowest aperture, at 0.48 mm (Table 3).

Table 3

Shell morphometrics (shell length, shell width, aperture length, aperture width) of marine gastropods recorded at Pulau Bidong. Number of individual (n) with mean and standard deviations, S.D.

Species	*Ind.*	*Shell (mm)*		*Aperture (mm)*	
	(n)	*Length±S.D.*	*Width±S.D.*	*Length±S.D.*	*Width±S.D.*
Peristernia nassatula	6	11.64±2.15	4.53±0.93	3.15±1.29	1.07±0.38
Scabricola incisa	1	8.12	2.93	1.80	0.48
Phos senticosus	7	18.41±9.01	8.47±4.01	7.66±4.78	2.66±1.64
Mammilla syrphetodes	2	13.14±7.25	11.39±6.18	9.87±6.60	6.18±4.87
Natica menkeana	2	5.49±1.41	7.04±0.16	3.21±0.23	2.35±0.00
Naticarius alapapilionis	2	13.66±0.81	12.58±0.23	10.89±0.10	5.43±0.35
Polinices albumen	4	18.29±5.06	19.62±7.08	16.11±3.46	5.27±4.35
Tanea tosaensis	2	10.69±3.89	10.25±5.01	7.17±3.75	4.06±2.09
Miniaceoliva tremulina	9	38.08±8.60	17.58±4.96	33.91±9.21	4.14±1.23
Species a	5	14.33±5.51	5.51±2.05	5.60±3.94	1.27±0.60
Species b	13	17.11±4.67	5.86±1.77	3.21±1.40	1.88±0.65
Terebellum terebellum	5	46.88±5.83	11.50±1.10	26.38±3.05	4.14±0.61
Margistrombus marginatus	20	40.81±9.45	23.10±5.61	29.8±7.80	8.09±2.76
Myurella hiscocki	2	30.65±11.43	5.91±1.73	3.41±1.19	1.61±0.21
Cinguloterebra anilis	1	46.32	8.04	5.58	2.37
Species c	2	36.22±4.61	11.07±0.32	6.09±0.83	6.81±2.81
Species d	4	21.41±6.99	7.02±1.63	3.80±0.87	2.40±0.65
Species e	1	20.17	7.36	4.84	2.54
Nipponatys volvulina	5	19.12±4.05	8.69±2.47	14.48±6.85	2.20±1.60
Longchaeus acus	5	40.54±6.51	12.93±2.19	6.97±1.76	4.66±1.24
Microgaza rotella	1	2.72	6.01	1.60	1.77
Minolia ceraunia	27	5.58±1.93	7.39±2.16	3.14±1.04	2.32±0.80
Minolia edithae	10	5.25±1.61	6.53±1.39	2.54±0.91	1.97±0.77
Monilea belcheri	1	8.70	14.86	4.78	4.09

Each species has meristic characteristics useful for identification following key traits. Most marine gastropods of Pulau Bidong possess various shapes, including top, conic, spindle, globose conic, pear, turriculate, ovate, discoid, fusiform, and cylindrical. Descriptions of their shells include spire height, body whorl shape, positioning, patterning, sculpture, and suture colour, as shown in Table 4. All marine gastropods were categorised as 'Not Evaluated' following the International Union for Conservation of Nature (IUCN) (Table 4).

Table 4

Morphological characteristics of marine gastropods and conservation status following International Union for Conservation of Nature (IUCN) for all species found at Pulau Bidong

Species	*Conservation status (IUCN)*	*Characteristics*
Peristernia nassatula	Not evaluated	Moderately thick, elongated and moderately long, spiral folds, pear, brown white
Scabricola incisa	Not evaluated	Moderately thick, spindle, columellar folds inside, shell have stripes, ovate, white grey
Phos senticosus	Not evaluated	Moderately thick, fusiform, polished, glossy, strong ribs at whole shell, pear, brown
Mammilla syrphetodes	Not evaluated	Thin, smooth, glossy, brown on the lip outer, globose conic, white with brown spots
Natica menkeana	Not evaluated	Thin, smooth, glossy, aperture half-moon shape, globose conic, brown golden
Naticarius alapapilionis	Not evaluated	Thin, low spire, deeply impressed suture, aperture lunar-ovate, globose conic, grey with brown spots
Polinices albumen	Not evaluated	Thin, low spire, deep U-shape depression underside, operculum thin horn-like, aperture semilunar, globose conic, orangey brown
Tanea tosaensis	Not evaluated	Thin, low spire, smooth, glossy, aperture lunar-ovate, globose conic, grey with brown spots
Miniaceoliva tremulina	Not evaluated	Thick, spire, smooth, glossy, brown wavy lines, thick callus, aperture elongated, semilunar notch, cylindrical cone, golden brown
Species a	-	Moderately thick, high spire, grunts shell, elongated, cone, creamy with grey
Species b	-	Moderately thick, high spire, grunts shell, elongated, cone, creamy black
Terebellum terebellum	Not evaluated	Moderately thick, short spire, smooth, glossy, aperture narrow, long columellar thick, elongated, golden brownish
Margistrombus marginatus	Not evaluated	Thick, conic, short spire, smooth, pointed apex, aperture elongated, sinuate outer lip, fusiform, yellow brown with white lines
Myurella hiscocki	Not evaluated	Thin, turriculate, long spire, short anterior canal and notch, elongated, white to brownish
Cinguloterebra anilis	Not evaluated	Thin, turriculate, long spire, aperture narrow ovate, short and siphonal canal, elongated, orange brown
Species c	-	Moderately thick, turriculate, high spire, moderately grunts shell, elongated, cone, creamy light brown with grey
Species d	-	Moderately thick, turriculate, high spire, grunts shell, elongated, cone, creamy brown with grey
Species e	-	Moderately thick, turriculate, high spire, grunts shell, elongated with brown spots at body whorl, cone, light brown with grey
Lyria delessertiana	Not evaluated	Thin, moderate spire, protoconchs smooth, elongated fusiform, white orange
Nipponatys volvulina	Not evaluated	Thin, low spire, translucent, aperture narrow posteriorly wider anteriorly, cylindrical, white grey
Longchaeus acus	Not evaluated	Moderately thick, high spire, polish, elongated, white with dark chestnut or chocolate spots
Microgaza rotella	Not evaluated	Thin, solid, low spire, depressed shape or discoid, orange brown pattern on shell, brown red colour under shell with silver sparkling, conical, orange brown
Minolia ceraunia	Not evaluated	Thin, solid, depressed shape or discoid, longitudinal flame marking, aperture ovate-triangular, simple lip, conical, pale orange to white
Minolia edithae	Not evaluated	Thin, solid, aperture ovate-triangular, discoid, simple lip, base almost white, conical, pale orange brown
Monilea belcheri	Not evaluated	Moderately thin, low spire, depressed conidial shape, aperture subhomboidal, top, silver brown

Discussion. The sampling efficiency of methods used in this study clearly proved that both the Smith-McIntyre grab and the dredge have advantages and disadvantages when collecting macrofauna like marine gastropods. For example, most individuals collected by the grab were *Minolia ceraunia* (Solariellidae; Vetigastropoda), with a shell length of 6 mm, compared to *Margistrombus marginatus* (Strombidae; Caenogastropoda), with a shell length of 41 mm, collected using the dredge (Table 3). This shows that the dredge, with a mesh size of 20 × 20 mm, was able to collect larger specimens rather than small- and minute-sized specimens of marine gastropods (Table 1). However, this loss is crucial, because such limitations allowed juvenile or small individuals to pass through the mesh, so the ecosystem was minimally disturbed during the sampling session. A study by Lewis & Stoner (1981) found that on a seagrass bed, small species were abundant, and caution should be observed using mesh larger than 0.5 mm when sampling macrobenthos. The grab is a rectangular box rather than semi-circular cut in the bottom; hence, sampling fauna inhabiting different depths of substrate occurs (Lie 1968). The author added that most community energetics occurred on a layer of substrate efficiently sampled by the grab. Because marine gastropods are mostly benthic organisms, using the grab is practical and efficient for sampling various shell sizes. This study recorded 77 individuals ranging from smaller to larger individuals, 5 to 41 mm in shell length (Tables 1 and 3). Both methods collected between 18 to 19 species (Table 1).

Ecological indices of this study indicate marine gastropods of Pulau Bidong are moderately to highly diverse, and high in species richness and evenness (Table 2). Magurran (2004) proposed that the value for the Shannon diversity index (*H'*) usually falls between 1.5 and 3.5 index, where a value below 1 indicates serious pollution, a value between 1.0-3.0 indicates moderate pollution, and a value exceeding 3.0 show non-polluted (Wilhm & Dorris 1966). Based on this index, Pulau Bidong is categorised as moderately polluted. Its history contributes to this, as it was inhabited by at least 40,000 Vietnam War refugees in 1979 and became the most populated place of a flat area not less than football field-sized (Thompson 2010). However, after almost four decades, Pulau Bidong has slowly restored its ecosystem, especially after been two decades under the jurisdiction of the state of Terengganu and now that it is the UMT marine research station (UMT MaReSt). Studies on marine biodiversity have proven this recovery, including studies on sea urchins, fishes, blacktip reef sharks, and coral reefs, carried out in Pulau Bidong post-Vietnam War.

High species richness and evenness of distribution may be explained through the presence of algal and seaweed in this island, food sources for herbivorous marine gastropods, as stated in studies by Arumugam (1981) and Phang et al (2010). Arumugam (1981) found at least 20 species of algal seaweed comprised of four taxa, including Cyanophyta, Chlorophyta, Phaeophyta, and Rhodophyta, found in different regions of the reef in Pulau Bidong. Phang et al (2010) found at least four families of seaweeds, including Caulerpaceae, Acrochaetiacaea, Peyssonneliaceae, and Dictyoceae, in coral in Pulau Bidong. These marine algae could support marine gastropods like the *Margistrombus marginatus*, from the Strombidae family, known as dog conch gastropod, feeding type herbivore and detritivores (Mutlu 2002; Arularasan et al 2011; Cob et al 2014). This is like Family Solariellidae (*Microgaza rotella*, *Minolia ceraunia*, and *Minolia edithae*), small planispiral coiled snails (usually less than 0.5 cm in diameter) that are often found among algae, under stones, or in plankton (Vermeij 1977).

In this study, at least five species were found from Terebridae. This auger snail is a sand dweller with a distinctive slender tapering shell shape (Olivera et al 2014) (Table 4). Terebrids are vermivorous gastropods feeding on worms; hence, they are only found in sand habitats (Miller 1970). Sandy environments are suitable and support an abundance of infaunal animals, including suspension and detritus feeders like worms. Moreover, terebrids are known as one of the common and abundant molluscans in tropical marine sand communities (Miller 1970). Naticidae also recorded five species and are known carnivorous or predatory gastropods. They drill holes in bivalve shells and extract the meat (Demoran & Gunter 1956). Naticids, commonly known as the moon snail, are globular in shape (Table 4), with a boring mechanism using radula and acid secretions at the margin of the bivalve *Venus striatula*, on the thinnest area, the posterior of the valves (Belding 1930), and random distribution (Hayasaka 1933). Like terebrids, they live on sandy substrate and are distributed in tropical regions (Carter 1968).

Marine gastropods recorded in this study are categorised as 'Not Evaluated' by IUCN. This category means a taxon has not yet been assessed against the criteria (IUCN species survival commission 1994). Worldwide, out of approximately 1.4 million invertebrate species, only 15,911 are described and listed in the IUCN Red List; only 28% had been categorised as 'Data Deficient' and 'Not Evaluated' (Chapman 2009; Regnier et al 2015). Insufficient data on marine gastropods diversity, distribution, and poor documentation on the ecology may result in a biodiversity crisis when estimating threats on habitat loss, impacts of introduced species, exploitation, collecting, and vulnerability to climate change (Cowie et al 2017). This opens the possibility that the unnoticed molluscs may be extinct before being recorded, following a lower quality and quantity gained compared to vertebrate species (Regnier et al 2009).

Conclusions. This study provides baseline information of malacology communities and highlights insufficient information for a proper assessment of conservation status. It is recommended that the sampling period extends, so that further survey and monitoring of other benthic taxa, including algae, crustaceans, molluscs, and polychaetes, can provide a comprehensive study useful for scientists and members for follow-up and evaluation programmes.

Acknowledgements. This study was funded and supported by the School of Marine and Environmental Sciences, the Central Laboratory of UMT for equipment, and the Discovery vessel. The authors would like to thank the undergraduate students (Bachelor of Marine Biology and Marine Science) from the semester I-2016/2017 cohort enrolled in the subject of Field Ecology (MMB3000) and the technical assistants who helped sample marine gastropods. Sincere thanks are extended to Dr. Izwandy Idris for providing his high resolution DSLR Nikon camera for photography and to Mr. Yuzwan Mohamad for Pulau Bidong map.

References

Abbott R. T., 1991 Seashells of South East Asia. Graham Brash, Singapore, 145 pp.

Abbott R. T., Dance, S. P., 1982 Compendium of seashells: a color guide to more than 4,200 of world's marine shells. EP Dutton Inc., New York, 424 pp.

Abol-Munafi A. B., Norazmi-Lokman N. H., Asma N. A., Sarmiza S., Abduh M. Y., 2011 Histological study of the gonad of the protandrous anemonefish (*Amphiprion ocellaris*). Journal of Animal and Veterinary Advances 10(22):3031-3036.

Adanan N. A., Basari N., Rosmidi F. H., Pesiu E., Abdullah M. T., 2016 Preliminary studies on bees at Pulau Bidong and Pulau Perhentian, Terengganu. Journal of Sustainability Science and Management 1:36-40.

Alqudah A., Saad S. B., Hadry N. F., Susanti D., 2015 Identification and phylogenetic inference in different mollusc nudibranch species via mitochondrial 16S rDNA. Brazilian Journal of Biological Sciences 2(4):295-302.

Arai T., Amalina R., Bachok Z., 2015 Growth effect on liver fatty acid composition of damselfishes genus *Abudefduf* collected in coral reef habitats of the Malaysian South China Sea. Springer Plus 4(71):1-6.

Arularasan S., Kesavan K., Lyla P. S., 2011 Scanning electron microscope (SEM) studies of radula of the dog conch *Strombus canarium* (Gastropoda: Prosobranchia: Strombidae). European Journal of Experimental Biology 1(1):122-127.

Arumugam P., 1981 Algal distribution in a Malaysia coral reef at Pulau Bidong. Pertanika 4:99-102.

Baharuddin N., Marshall D. J. 2014 Common aquatic gastropods of Brunei. Education and Technology Centre, Universiti Brunei Darussalam, Brunei, 19 pp.

Belding D. L., 1930 The soft-shelled clam fishery of Massachusetts: including the natural history of the soft-shelled clam and a discussion of sewage pollution and shellfish. Marine Fisheries Series No. 1, Commonwealth of Massachusetts, Department of Conservation, Division of Fisheries and Game, Marine Fisheries Section, Boston, USA, 65 pp.

Boo W. H., Reimer J. D., Safuan M., Saidin J., Hong T. C., Bachok Z., 2017 Zoantharian abundance in coral reef benthic communities at Terengganu Islands, Malaysia. Regional Studies in Marine Science 12:58-63.

Brusca R. C., 1980 Common intertidal invertebrates of the Gulf of California. The University of Arizona Press, USA, 513 pp.

Carpenter K. E., Niem V. H., 1998 The living marine resources of the western Central Pacific. Volume 1. Seaweeds, corals, bivalves and gastropods. FAO, Rome, 686 pp.

Carter R. M., 1968 On the biology and palaeontology of some predators of bivalved mollusca. Palaeogeography, Palaeoclimatology, Palaeoecology 4:29-65.

Chaloner D. T., Hershey A. E., Lamberti G. A., 2009 Benthic invertebrate fauna. In: Encyclopedia of inland waters. Likens G. (ed), Elsevier Press, New York, pp. 157-172.

Chapman A. D., 2009 Number of living species in Australia and the world. Second edition, Department of the Environment, Water, Heritage, and the Arts, Australian Government, Canberra, 78 pp.

Cob Z. C., Arshad A., Sidik B. J., Nurul-Husna W. H. W., Mazlan A. G., 2014 Feeding behaviour and stomach content analysis of *Laevistrombus canarium* (Linnaeus, 1758) from Merambong shoal, Johor. Malayan Nature Journal 66(1-2):184-197.

Cowie R. H., Regnier C., Fontaine B., Bouchet P., 2017 Measuring the sixth extinction: what do mollusks tell us? The Nautilus 131(1):3-41.

Dance S. P., 1992 Smithsonian handbooks-shells. Dorling Kindersley Ltd., London, 256 pp.

Dayrat B., Conrad M., Balayan S., White T. R., Albrectht C., Golding R., Gomez S. R., Harasewych M. G., Martins A. M. F., 2011 Phylogenetic relationships and evolution of pulmonate gastropods (Mollusca): new insights from increased taxon sampling. Molecular Phylogenetics and Evolution 59:425-437.

Demoran W. J., Gunter G., 1956 Ability of *Thais haemostoma* to regenerate its drilling mechanism. Science 123:1126.

Diniz-Filho J. A. F., de Marco Jr. P., Hawkins B. A., 2010 Defying the curse of ignorance: perspectives in insect macroecology and conservation biogeography. Insect Conservation and Diversity 3(3):172-179.

Escamilla-Montes R., Granados-Alcantar S., Diarte-Plata G., Pacheco-Heredia P. J., Gill-Leon J. A., Luna-Gonzalez A., Fierro-Coronado J. A., Alvarez-Ruiz P., Esparza-Leal H. M., Valenzuela-Quinonez W., 2018 Biodiversity of gastropod in the Southeastern Gulf of California, Mexico. In: Biological resources of water, Sajal Ray, pp. 119-139.

Flores-Garza R., Garcia-Ibanez S., Flores-Rodriguez P., Torreblanca-Ramirez C., Galeana-Rebolledo L., Valdes-Gonzalez A., Suastegui-Zarate A., Violante-Gonzalez J., 2012 Commercially important marine mollusks for human consumption in Acapulco, Mexico. Natural Resources 3:11-17.

Frid C. L. J., 2011 Temporal variability in the benthos: does the sea floor function differently over time? Journal of Experimental Marine Biology and Ecology 400:99-107.

Google Earth, 2018 Pulau Bidong. Accessed: May, 2018.

Grismer L. L., Wood Jr. P. L., Ahmad A. B., Sumarli A. S. I., Vazquez J. J., Ismail L. H. B., Nance R., Mohd-Amin M. A. B., Othman M. N. A. B., Rizaijessika S. A., Kuss M., Murdoch M., Cobos A., 2014 A new species of insular rock gecko (Genus *Cnemaspis* Strauch, 1887) from the Bidong Archipelago, Terengganu, Peninsular Malaysia. Zootaxa 3755(5):447-456.

Hammer O., Harper D. A. T., Ryan P. D., 2001 PAST: paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1):1-9.

Hayasaka I., 1933 Fossil occurrence of pelecypod shells bored by certain gastropods. Memoirs of the Faculty of Science and Agriculture, Taihoku Imperial University 6(4):65-70.

Hickman Jr. C., Roberts L., Keen S., Larson A., Eisenhour D., 2015 Animal diversity. Seventh edition, McGraw Hill Education, New York, 492 pp.
Hook P., 1999 The world of seashells: a fully illustrated guide to these fascinating gifts from the ocean. PRC Publishing Limited, London, 128 pp.
IUCN species survival commission, 1994 IUCN red lists categories. IUCN Council, Switzerland, 18 pp.
Lewis F. G., Stoner A. W., 1981 An examination of methods for sampling macrobenthos in seagrass meadows. Bulletin of Marine Science 31(1):116-124.
Lie U., 1968 A quantitative study of benthic infauna in Puget Sound, Washington, USA, in 1963-1964. Universitetsforlagets Trykningssentral, Oslo, Norway, pp. 237-556.
Liew H. J., Ambak M. A., Abol-Munafi A. B., 2006 Embryonic development of clownfish *Amphiprion ocellaris* under laboratory conditions. Journal of Sustainability Science and Management 1(1):64-73.
Long S. M., Ramli R., 2010 [Keys of snails and shellfishes on the east coasts of Malaysia]. Universiti Malaysia Terengganu, Malaysia, 167 pp. [in Malay]
Lorenzo B., Kochzius M., Cardenosa D., Borsa P., Ambak M. A., Joseph J., 2016 Connectivity and population structure of blacktip reef sharks, *Carcharhinus melanopterus*, in two islands in Terengganu, Malaysia. In: VLIZ Marine Scientist Day, VLIZ Special Publication 75. Mees J., Seys J. (eds), Vlaams Instituut voor de Zee – Flanders Marine Institute (VLIZ), Belgium, pp. 19.
Magurran A. E., 2004 Measuring biological diversity. First edition, Blackwell Publishing Company, United Kingdom, 256 pp.
Matsunuma M., Motomura H., Matsuura K., Shazili N. A. M, Ambak M. A., Meguro M., 2011 Fishes of Terengganu: east coast of Malay Peninsula, Malaysia. National Museum of Nature and Science, Universiti Malaysia Terengganu and Kagoshima University Museum, 251 pp.
Miller B. A., 1970 Studies on the biology of Indo-Pacific Terebridae. Doctoral dissertation, Department of Zoology, University of New Hampshire, 213 pp.
Mohammad H., Jamil W. A. N. W. A., Abas F., Mohamad K. S., Ali A. M., 2009 Octacosanoic acid, long chains saturated fatty acid from the marine sponges *Xestospongia* sp. Pertanika Journal of Tropical and Agriculture Science 32(1):51-55.
Mohd Z. M. S., Okamoto N., Subarjo M., 1999 Growth form and distribution pattern of corals around Bidong Islands. In: Proceedings of the 10th JSPS Joint Seminar on Marine and Fishery Sciences, Malacca, Malaysia, pp. 15-20.
Morton B., Blackmore G., 2001 South China Sea. Marine Pollution Bulletin 42:1236-1263.
Mutlu E., 2004 Sexual dimorphisms in radula of *Conomurex persicus* (Gastropoda: Strombidae) in the Mediterranean Sea. Marine Biology 145:693-698.
Nakajima R., Yoshida T., Fujita K., Nakayama A., Fuchinoue Y., Othman B. H. R., Toda T., 2010 Release of particulate and dissolved organic carbon by the scleractinian coral *Acropora formosa*. Bulletin of Marine Science 86(4):861-870.
Nakajima R., Yoshida T., Azman B. A. R., Yamazaki H., Toda T., Othman B. H. R., Zaleha K., Effendy A. W. M., 2013 A preliminary study of small scavenging crustaceans collected by baited traps in a coral reef of Bidong Island, Malaysia. Malaysian Journal of Science 32(2):59-66.
Odum E. P., Barret G. W., 2004 Fundamentals of ecology. Thomson Brooks Cole Publishing, Belmont, USA, 624 pp.
Oliver A. P. H., 1983 The country life guide to shells of the world. Fourth edition, Country Life Books, London, 320 pp.
Olivera B. M., Showers Corneli P., Watkins M., Fedosov A., 2014 Biodiversity of cone snails and other venomous marine gastropods: evolutionary success through neuropharmacology. Annual Review of Animal Biosciences 2:487-513.
Pechenik J. A., 2016 Biology of invertebrates. Seventh edition, McGraw Hill Education, New York, USA, 606 pp.
Phang S. M., Wee Y. C., 1991 Benthic marine algae. In: The state of nature conservation in Malaysia. Kiew R. (ed), Malayan Nature Society, Kuala Lumpur, Malaysia, pp. 51-61).
Phang S. M., Lim P. E., Yeong H. Y., Ng W. S., Song S. L., 2010 Marine algae collected during the scientific expedition to Bachok, Kelantan and the islands of Terengganu with one new record, *Pterocladiella* for Malaysia. Malaysian Journal of Science 29:31-45.

Ponder W. F., Lindberg D. R., 2008 Phylogeny and evolution of the Mollusca. University of California Press, California, 469 pp.
Regnier C., Fontaine B., Bouchet P., 2009 Not knowing, not recording, not listing: numerous unnoticed mollusk extinctions. Conservation Biology 23:1214-1221.
Regnier C., Achaz G., Lambert A., Cowie R. H., Bouchet P., Fontaine B., 2015 Mass extinction in poorly known taxa. Proceedings of the National Academy of Sciences of the USA 112(25):7761-7766.
Reid T., 2000 The other 99%. The conservation and biodiversity of invertebrates. Pacific Conservation Biology 6:178.
Reimer J. D., Wee H. B., Put Jr. A., Hoeksema B. W., 2015 Zoantharia (Cnidaria: Anthozoa: Hexacorallia) of the South China Sea and Gulf of Thailand: a species list based on past reports and new photographic records. Raffles Bulletin of Zoology 63:334-356.
Rumeaida M. P., Daud S. M. M., Badri F. M. I., 2014 Fish diversity and abundance in Bidong Island, South China Sea, Malaysia. AACL Bioflux 7(3):176-183.
Saxena A., 2005 Text book of Mollusca. Discovery Publishing House, New Delhi, 528 pp.
Shamsuddin A. A., Lukman Hakim A. A., Kumari G. M., Noraznawati I., 2010 Anti-bacterial activity of three species of sea urchin extracts from Pulau Bidong, Terengganu. Journal of Sustainability Science and Management 5(1):116-124.
Sidik B. J., Harah Z. M., Kawaguchi S., 2012 Historical review of seaweed research in Malaysia before 2001. Coastal Marine Science 35(1):169-177.
Siti Shazlina M. R., Yusuf Y., Norainy M. H., Amirrudin A., 2009 Species diversity and distribution of sea urchin at Bidong Island. In: Proceedings of the International Conference on the Marine Ecosystems, Langkawi, Malaysia, pp. 502-506.
Smith W., McIntyre A. D., 1954 A spring-loaded bottom sampler. Journal of the Marine Biological Association of the United Kingdom 33:257-264.
Sonak S. M., 2017 Marine shells of Goa. Springer Nature, India, 249 pp.
Strong E. E., Gargominy O., Ponder W. F., Bouchet P., 2008 Global diversity of gastropods (Gastropoda; Mollusca) in freshwater. Hydrobiologia 595(1):149-166.
Tan K. S., Chou L. M., 2000 A guide to common seashells of Singapore. Singapore Science Centre, Singapore, 168 pp.
Thompson L. C., 2010 Refugee workers in the Indochina exodus, 1975-1982. McFarland & Company, Inc, Publishers, Jefferson, North Carolina, 269 pp.
Vermeij G. J., 1977 The Mesozoic marine revolution: evidence from snails, predators and grazers. Paleobiology 3:245-258.
Wan Hussin W. M. R., 2014 Marine fish farming in Bidong Island, Malaysia and its implications on benthic community structure and functional diversity. AACL Bioflux 7(6):431-440.
Webb T. J., 2012 Marine and terrestrial ecology: unifying concepts, revealing differences. Trends in Ecology and Evolution 27(10):535-541.
Wilhm J. L., Dorris T. C., 1966 Species diversity of benthic communities in a stream receiving domestic and oil refinery effluent. The American Midland Naturalist 76(2):427-449.

Received: 04 June 2018. Accepted: 01 July 2018. Published online: 16 July 2018.
Authors:
Nursalwa Baharuddin, School of Marine and Environmental Sciences, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia, e-mail: nursalwa@gmail.com
Nur Afiqah Zakaria, School of Marine and Environmental Sciences, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia, e-mail: shineeafiqah@gmail.com

How to cite this article:
Baharuddin N., Zakaria N. A., 2018 The biodiversity and conservation status of the marine gastropod (Mollusca; Gastropoda) in Pulau Bidong, Terengganu, Malaysia. AACL Bioflux 11(4):988-1000.