THE DESCRIPTION OF SEA CUCUMBER ON THE NEARSHORE SOFT-BOTTOM OF SELECTED SITES IN THE STRAITS OF MALACCA, MALAYSIA

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by

VINCENT TEOH YONG JIAN

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

H'	Value for Shannon Weiner's Species Diversity Index
p_i	Proportion of individuals of a species
ln	Natural logarithm
S	Species richness
D	Value for Simpson's Species Dominance Index

PEMERIHALAN TIMUN LAUT DI KAWASAN DASAR LEMBUT PERSISIR PANTAI TERPILIH DI SELAT MELAKA, MALAYSIA

ABSTRAK

Timun laut adalah satu jenis hidupan laut yang dikumpul untuk kegunaan makan di Malaysia. Oleh itu, mereka mempunyai nilai komersial dan perlu dipantau. Tetapi, kajian mengenai kepelbagaian dan pemerihalan timun laut di persisir pantai di Selat Melaka, Malaysia terhad kepada tiga kajian dalam tempoh sepuluh tahun yang lalu. Kita memerlu lebih banyak kajian untuk menghasilkan rancangan pengurusan stok timun laut di liar. Kajian ini disediakan untuk melaporkan penerangan taksonomi timun laut di kawasan dasar lembut pesisiran pantai terpilih dalam Selat Melaka, Malaysia. Tinjaun lapangan dibuat di Middle Bank, Tanjung Kupang, Blue Lagoon, dan Merambong Shoal dari April 2021 sehingga Jun 2022. Spesimen dikumpulkan semasa air surut. Spesimen tambahan dari koleksi Pusat Kajian Samudera dan Pantai (CEMACS) dan USM juga diperiksa. Osikel timun laut diekstrak, diperiksa, dan dirakam menggunakan mikroskop dengan kamera yang dipasang. Gambar ossikel dilakar menggunakan ADOBE Photoshop. Semua spesimen diawet di CEMACS, USM. Sebanyak 13 jenis timun laut telah dikenal pasti. Middle Bank mempunyai kepelbagaian timun laut tertinggi dengan lapan jenis timun laut, 1.688 untuk Indeks Kepelbagaian, dan 4.405 untuk 'Dominance Index'. Merambong Shoals mempunyai kepelbagaian timun laut kedua tertinggi dengan lima jenis timun laut, 1.423 untuk Indeks Kepelbagaian, dan 3.745 untuk 'Dominance Index'. Dua jenis species timun laut baru, *Euthyonidiella Zulfigaris* sp. nov. dan *Acaudina spinifera* sp. nov. telah ditemui dan diterangkan.

THE DESCRIPTION OF SEA CUCUMBER ON THE NEARSHORE SOFT-BOTTOM OF SELECTED SITES IN THE STRAITS OF MALACCA, MALAYSIA

ABSTRACT

Sea cucumbers are one of the targeted animals collected for food. As such, they possess commercial value and should be monitored. However studies on the description and diversity of sea cucumbers in the nearshore zones of the Straits of Malacca in Malaysia for the past ten years were limited to three studies. More studies are needed to manage sea cucumber stocks. This study was conducted to provide a description of the sea cucumbers on the nearshore soft-bottom zones of selected sites in the Straits of Malacca. Field samplings were conducted at Middle Bank, Tanjung Kupang, Blue Lagoon, and Merambong Shoal in the Straits of Malacca from April 2021 to June 2022 during low tide. Additional specimens from the collection of Centre for Marine and Coastal Studies (CEMACS) and USM were examined. Ossicles were extracted, examined, and photographed using a microscope with a camera attached. Images of ossicles were traced with ADOBE Photoshop. All specimens were preserved in CEMACS, USM. A total of 79 individuals were examined and 13 species of sea cucumbers were identified. Middle Bank had the highest diversity of sea cucumbers at eight species with a Diversity Index of 1.688 and Dominance Index of 4.405. Merambong Shoals had the second-highest diversity of sea cucumbers at five species with a Diversity Index of 1.423 and Dominance Index of 3.745. Two new species of sea cucumbers, *Euthyonidiella zulfigaris* sp. nov. and *Acaudina spinifera* sp. nov. were discovered and described.

CHAPTER 1

INTRODUCTION

1.1 General Introduction

The definition of nearshore varies depending on the field of study and the different processes being studied (Moulton et al., 2023). Holman & Haller (2013) defined the nearshore zone as the narrow strip of ocean that borders continents and stretches up to a distance in which the offshore depth reaches 10m. Elko et al. (2015) defined nearshore as the transition region in between land and continental shelf which includes a variety of habitats such as coastal plains, wetlands, estuaries, coastal cliffs, dunes, beaches, surf zones, and inner shelf. Micallef et al. (2021) defined nearshore zones as "the region where the waves steepen, break, then re-form in their passage to the beach, where they break for the last time before surging up to the foreshore." Moulton et al. (2023) defined the nearshore region as the region extending from the shoreline to a few kilometers offshore which includes several sub-regions such as the surfzone and inner shelf. In this study, we defined the nearshore zone as the region extending from the supralittoral zone, intertidal zone, and to the shallow subtidal zone.

The supralittoral zone is defined as the region above the high tide mark and may occasionally only be inundated during storms (Lalli & Parsons, 1997). The intertidal zone is defined as the region immersed during high tide and exposed during low tide while the subtidal zone is defined as the region extending from low tide mark to the outer edge of the continental shelf (Lalli & Parsons, 1997).

Despite the harsh living conditions that organisms had to endure, rough ocean currents, changes in salinity, and desiccation (Halim et al., 2019), intertidal zones remained as one of the most productive coastal ecosystems that support a diverse marine fauna population (Khaironizam & Norma-Rashid, 2005; Hwang et al., 2019). Certain soft-bottom intertidal ecosystems, such as seagrass beds, provided breeding and nursing grounds for organisms with economical value (Nakaoka, 2005; Ilias et al., 2021). As such, intertidal zones had long been utilized by coastal communities, including those in Malaysia, to collect food and generate income through small-scale fisheries (Teh & Sumaila, 2013; Ilias et al., 2021; Stiepani et al., 2023).

One of the most common methods to exploit intertidal zones in Malaysia was gleaning where the coastal community collected edible marine invertebrates within the intertidal zone (Unsworth & Cullen, 2010; Rahman & Yaakub, 2020). Gleaning is defined as the act of "walking through intertidal zones during the low tide, with little to-no-gear, in search of species that can be consumed, sold or used as bait" (Pike et al., 2024). Nordlund et al. (2018) remarked that invertebrate gleaning in intertidal zones provided a consistent and low-cost means of obtaining food and income, highlighting the importance of this activity. The target organisms of gleaners were often molluscs, crustaceans, and echinoderms (Nieves et al., 2010; Furkon & Ambo-Rappe, 2019; Rahman & Yaakub, 2020).

Echinoderms, meaning 'spiny skin' in Latin, are a group of animals that have the following defining characteristics: pentaradial symmetry, true coelom, calcareous endoskeleton composed of separate pieces, and water-vascular system (Hyman, 1955; Nichols, 1967; Clark, 1977). The body wall of echinoderms is separated into the epidermis, dermis, and peritoneum (Hyman, 1955). The dermis layer of echinoderms is capable of producing calcium carbonate-based plates or microscopic deposits that form the endoskeleton, the former known as a 'test' while the latter known as 'ossicles' (Hyman, 1955; Nichols, 1967).

The water-vascular system, which is found only in echinoderms, is a system of tubes within the coelom that are filled with water (Hyman, 1955). Water is taken from the outside world into the water-vascular system by a modified plate known as the madreporite (Hyman, 1955). Between the ring canal and madreporite is the stone canal, serving as a bridge between the two (Hyman, 1955). The ring canal, located around the oesophagus, branches into radial canals found within the inner surface of the ambulacra before finally feeding into a series of tube feet (Hyman, 1955; Nichols, 1967; Clark, 1977). The tube feet serve as the locomotory appendages for echinoderms. An ampulla can be found in each tube foot. Upon contraction, it forces water down and extends the tube foot. It is through the extension and contraction of the tube feet that echinoderms achieve locomotion (Clark, 1977). Fig. 1 illustrates the process of the extension and contraction of tube feet.

Currently, extant echinoderms are classified into five different classes: Crinoidea, Asteroidea, Ophiuroidea, Echinoidea, and Holothuroidea (Nichols, 1967).

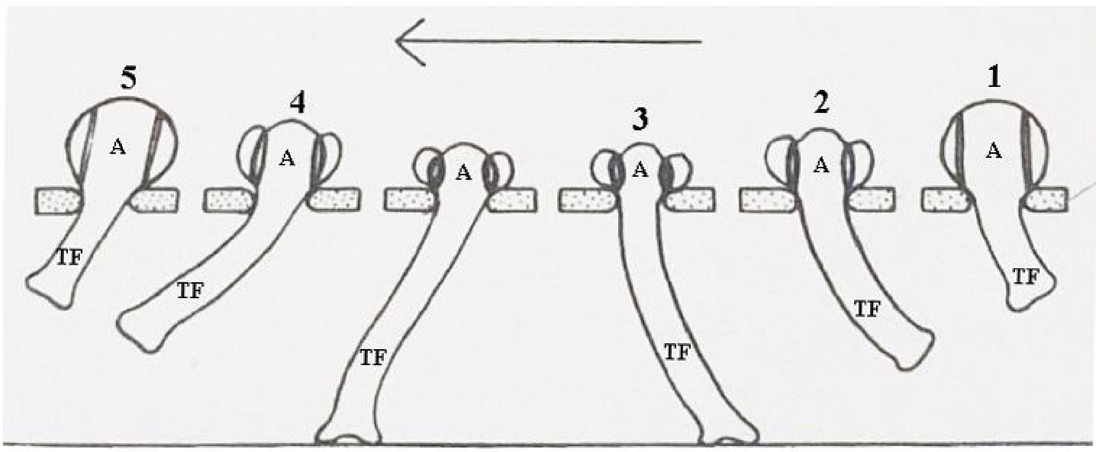

Figure 1 Movement of tube feet; arrow depicting the direction of movement; 1. ampulla relaxed, tube foot contracted; 2. ampulla contracting, tube foot extending; 3. ampulla fully contracted, tube foot fully extended; 4. ampulla relaxing, tube foot contracting; ampulla relaxed, tube foot contracted; A=ampulla; TF=tube foot (modified from Clark, 1977).

Holothurians, or sea cucumbers, belong to the class Holothuroidea. There are currently 1,820 extant species described (WoRMS, 2023). Currently, holothurians are separated into seven orders: Apodida, Dendrochirotida, Elasipodida, Holothuriida, Molpadida, Persiculida, and Synallactida (Pawson et al., 2010; Slater & Chen, 2015; Miller et al., 2017). Holothurians can be found in almost all marine ecosystems, ranging from the shallow nearshore zones to the deep oceanic trenches (Woo et al., 2013). In Malaysia, holothurians were highly valued as food (Woo et al., 2013) or as medicine (Choo, 2004).

Unlike the other four classes in the phylum Echinodermata, holothurians have a soft and elongated body, with the mouth on one end and the anus on the other (Hyman, 1955). Holothurians have two ambulacra on their dorsal plane and three ambulacra on their ventral plane, each separated by an interambulacra (Hyman, 1955; Clark & Rowe, 1971). Because of their body orientation, they exhibit a weak bilateral symmetry with a distinct anterior and posterior end (Hyman, 1955). Nevertheless, they still retain their pentaradial symmetry when viewed from the anterior-posterior axis. Fig. 2 depicts the morphology of a holothurian.

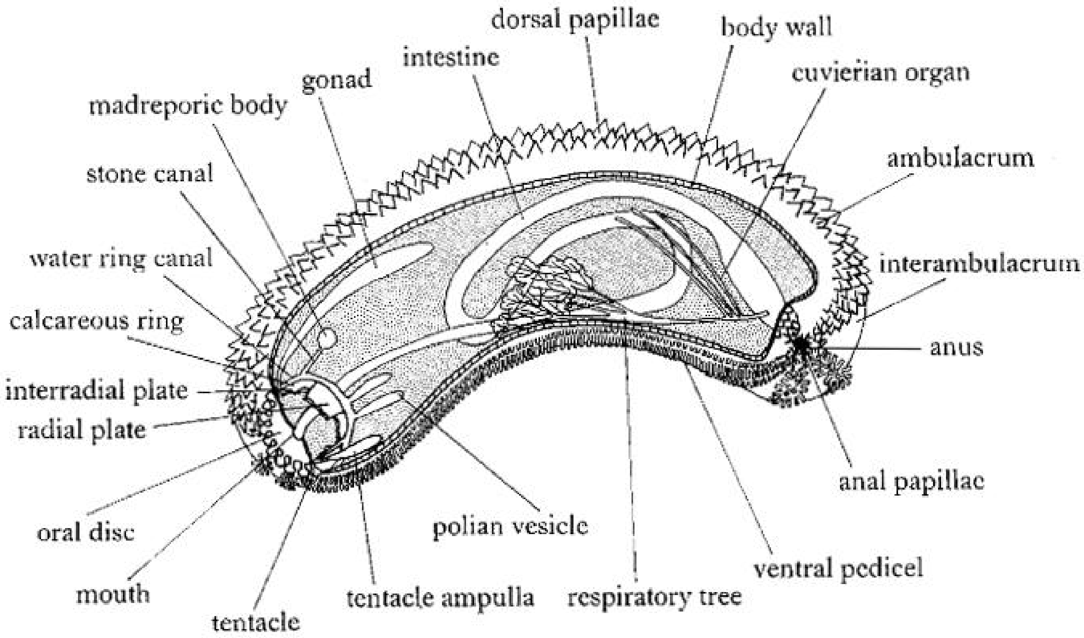

Figure 2 Morphology of a holothurian (adapted from Clark & Rowe, 1971).

The Straits of Malacca had long been an important area for the coastal and fishing community. The calm waters are unaffected by the monsoon season and the dense population on the west coast of Malaysia has led to an increased supply and demand for fish products (Cleary & Goh, 2000). The Straits of Malacca is also an important shipping route and the second busiest sea lane in the world, causing the waters to be extremely susceptible to anthropogenic activities and pollution (Cleary & Goh, 2000). Unfortunately, the nearshore zones where the holothurians inhabited were heavily impacted by anthropogenic activities (Khatri & Tyagi, 2015; Madricardo et al., 2019; Veiga et al., 2019; Polgar & Lim, 2011; Rasha et al., 2022), especially in the Straits of Malacca because most of the industrial and agricultural activities were concentrated here (Shazili et al., 2006). This would inevitably cause the decline of wild holothurian stocks. Considering that 70% of the fishermen of Peninsular Malaysia were also concentrated in the Straits of Malacca (Gran, 1999), the reduction in the numbers of commercially important holothurians would affect the livelihood of the fishing communities that relied on invertebrate gleaning to obtain food and income. Actions had previously been taken by the Department of Fisheries Malaysia to mitigate this by launching programs to determine the potential of sea cucumber aquaculture through obtaining broodstocks and inducing them to spawn artificially (Syed & Khairudin, 2022).

The increasing impact of anthropogenic activities on nearshore zones in the Straits of Malacca has sparked numerous research in that area. These include studies on pollution (Ikram et al., 2010; Yap & Pang, 2011; Haris & Aris, 2015; Looi, 2021) and biodiversity (Takita et al., 1999; Rezai et al., 2004; Zainuddin et al., 2008; Mohammad et al., 2016; Asmida et al., 2017; Samad et al., 2018; Ghazaly et al., 2019; Pfingstl et al., 2019; Jiang & Sun, 2020; Lavoué et al., 2022).

One of the most important data to collect in order to produce a management plan is a checklist of species inhabiting in a specific region. Proposed by Blankenship & Leber (1995), a responsible marine stock enhancement plan includes prioritizing and selecting a target species. As such, studies involving the taxonomy and identification of holothurian species in the Straits of Malacca were essential if we were to produce a plan to manage their stock in the wild.

Without sufficient data on the species of holothurians in a particular area, it would be difficult to prepare plans to manage and monitor the stock in the wild. While such studies has been conducted in Malaysia (Baine and Forbes, 1998; Zulfigar et al., 2007; Kamarudin, 2009; Kamarudin et al., 2009; Kamarudin et al., 2010; Mohamad Saupi et al., 2010; Kamarudin, 2011a; Kamarudin, 2011b; Woo et al., 2013; Woo et al., 2014; Kamarudin and Rehan, 2015; Kamarudin et al., 2015; Kamarudin et al., 2017; Harith et al., 2018; Wolfe and Davey, 2020; Akasha et al., 2021; Ilias et al., 2021; Ilias et al., 2022; Rahman et al., 2022; Abdul et al., 2023), only a select few had focused on the nearshore zone of the Straits of Malacca (Woo et al., 2014; Teoh & Woo, 2021; Teoh & Woo, 2022). Considering the limited studies conducted on holothurian species in the soft-bottom nearshore zones within the Straits of Malacca, the importance of holothurians as one of the target organisms for invertebrate gleaning activities, and the increasingly affected coastal areas, there was a need to conduct a study on the holothurians in the Straits of Malacca. This study is conducted to provide a checklist and description of holothurian species at the nearshore soft-bottom of selected sites in the Straits of Malacca in hopes that it would fill in the current gap in our understanding.

1.2 Objectives of the Study

This study aims to:

i) To produce a taxonomic account of holothurians found in the nearshore soft-bottom of selected sites in the Straits of Malacca, Malaysia.

ii) To produce a checklist of holothurians found in the nearshore soft-bottom of selected sites in the Straits of Malacca, Malaysia.

CHAPTER 2

LITERATURE REVIEW

2.1 Intertidal Zone

The intertidal zone is defined as the region immersed during high tide and exposed during low tide (Lalli & Parsons, 1997). Intertidal zones can be separated into soft-bottom or hard-bottom based on their substrate, with the former having unconsolidated substrates such as mud, silt, and sand (Dugan et al., 2013). Soft-bottom intertidal zones can be further differentiated into several ecosystems such as mangroves, estuaries, mudflat, seagrass, and sandy shores (Khaironizam & Norma-Rashid, 2005; Omar et al., 2011; Abu et al., 2023).

The intertidal zone is one of the most productive coastal environments bordering between land and sea (Hwang et al., 2019). Intertidal zones can be differentiated into various productive ecosystems such as beaches, estuaries, mangroves, mudflats, tide pools, and seagrass beds (Khaironizam & Norma-Rashid, 2005; Londoño-Cruz et al., 2014; Ilias et al., 2021). Due to their proximity to human activities, intertidal zones are important for food and recreation (Fincham, 1984). As such, intertidal zones have been subjected to increased anthropogenic stress originating from industrial, agricultural, deforestation, fishing, logging, and mining sources (Khatri & Tyagi, 2015; Madricardo et al., 2019; Veiga et al., 2019).

The intertidal zone in Malaysia is also an important place for gleaning in which the coastal communities could supplement their income or food source (Ridzwan & Kaswandi, 1995; Unsworth & Cullen, 2010; Nordlund et al., 2018; Rahman & Yaakub, 2020). For example, it was reported that the coastal community in Mukim Tanjung Kupang, close to where the Merambong Shoals was, often collected *Holothuria scabra* because of their high value which fetches MYR 10 per fresh individual (Rahman & Yaakub, 2020). The collected sea cucumbers would then be dried and sold for up to approximately MYR500 per kg (Rahman & Yaakub, 2020).

2.2 Identification of Holothurians

Identification of holothurians largely relies on external morphology. The body shape of holothurians is diverse, ranging from cylindrical to spherical (Hyman, 1955). The external body of holothurians, except those from the order Apodida and Molpadida, is covered in podia (Hyman, 1955; Clark & Rowe, 1971). The podia are usually distributed on the ambulacra but may sometimes be present on the interambulacra or even scattered throughout the body (Clark & Rowe, 1971). The podia with locomotory function, known as tube feet, are hollow tubular projections containing a branch of the water-vascular system (Hyman, 1955). Holothurians from the orders Holothuriida, Persiculida, and Synallactida have their tube feet restricted to their ventral surface, forming a flattened 'sole' (Hyman, 1955; Miller et al., 2017). Podia without locomotory function, known as papillae, may be found instead on the dorsal surface of holothurians in the order Elasipodida, Holothuriida, Persiculida, and Synallactida (Hyman, 1955; Clark & Rowe, 1971; Pawson et al., 2010). Hyman (1955) remarked that they functioned as sensory appendages.

Modified tube feet, called tentacles, encircle the mouth (Hyman, 1955). The shape and number of tentacles vary between orders, making them an important diagnostic feature for holothurians (Hyman, 1955; Clark & Rowe, 1971; Pawson et al., 2010; Kamarudin et al., 2010, Smirnov, 2015). The four tentacle shapes are: dendritic, peltate, pinnate, and digitate (Conand, 1998; Pawson et al., 2010). Dendritic tentacles branch like a tree; pinnate tentacles have a central axis with a series of side branches on each side; peltate tentacles have a central stalk with numerous horizontal branches encircling it, and digitate tentacles have short projections with or without terminal digits (Hyman, 1955). Table 1 lists the seven orders of holothurians and their respective tentacle shape. Fig. 3 illustrates the different tentacle shapes of holothurians.

Table 1. The seven orders of holothurian and their respective tentacle shape (Hyman, 1955; Clark & Rowe, 1971; Pawson et al., 2010; Kamarudin et al., 2010; Smirnov, 2015; Miller et al., 2017).

Order	**Tentacle Shape**
Dendrochirotida	Dendritic
Apodida	Pinnate or digitate
Molpadida	Digitate
Elasipodida	Peltate
Holothuriida	Peltate
Persiculida	Peltate
Synallactida	Peltate

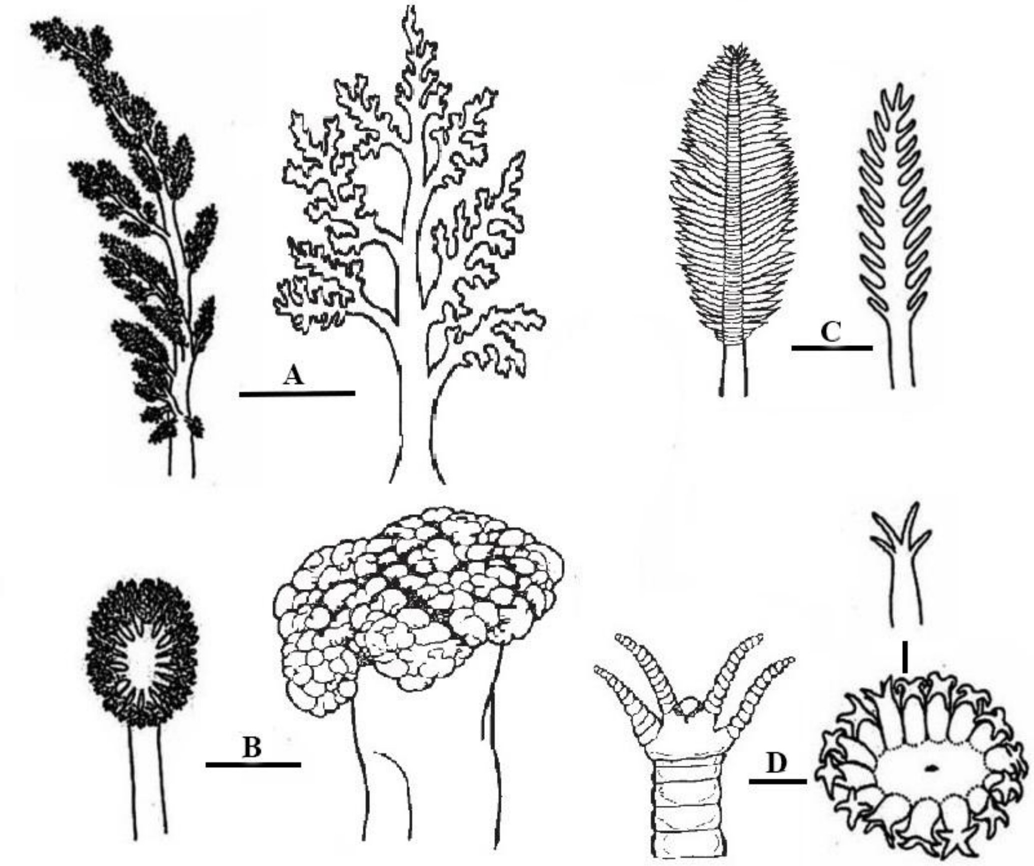

Figure 3 Representative tentacle shapes: A. dendritic; B. peltate; C. pinnate; D. digitate (modified from Conand, 1998; Pawson et al., 2010).

The esophagus of holothurians is surrounded by the calcareous ring (Pawson et al., 2010). The calcareous ring is usually formed by ten calcareous plates separated into radial and interradial plates, the former to which the longitudinal muscles are attached (Hyman, 1955; Pawson et al., 2010). The calcareous ring plays an important role as it provides support to the pharynx, nerve ring, water ring canal, and insertion point for the longitudinal muscle bands (Hyman, 1955). Since the size and shape of the calcareous plates vary between species, they could also be used to differentiate species (Hyman, 1955). Fig. 4 illustrates some examples of calcareous rings.

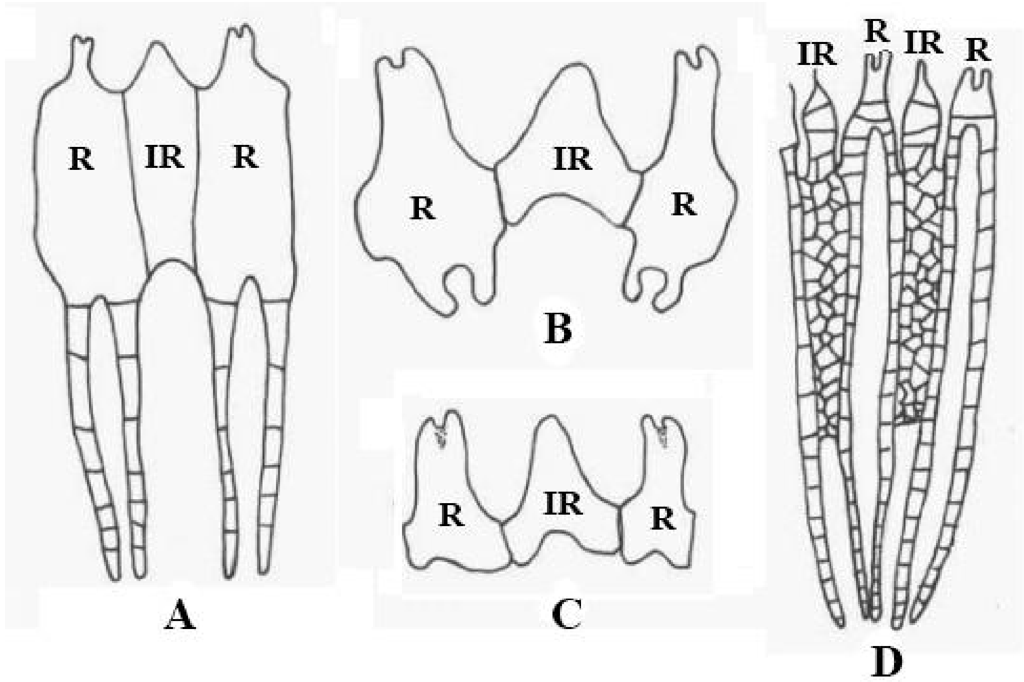

Figure 4 Representative shapes of calcareous rings: A. ring with medium posterior projections; B. ring with short posterior projections; C. ring with no posterior projections; D. tubular ring with long, complex, posterior projections; R—radial piece, IR—interradial piece (modified from Pawson et al., 2010).

Ossicles are minute calcium carbonate structures found within the dermis layer of holothurians that provide structural support to the body wall (Hyman, 1955; Pawson et al., 2010; Smirnov, 2014). They are exclusively found in holothurians, forming a three-dimensional mesh-like skeleton (Smirnov, 2014). Ossicles occur in numerous shapes, many of which have been assigned unique names based on their shape (Pawson et al., 2010). The assemblage of ossicles is distinct and different between species, making them the most important morphological feature in the identification of holothurians (Pawson et al., 2010; Purcell et al., 2012; Zhao, 2015).

Anchor-shaped ossicles (Fig. 5A) have two arms, known as flukes, attached to the central shaft (Clark & Rowe, 1971). The arms may be smooth or denticulated while the vertex, the area where both arms connect to the shaft, may be denticulated or smooth (Clark & Rowe, 1971). Anchors are connected to anchor plates (Fig. 5B) by connective tissue (Hyman, 1955). The anchor plates have a transverse bar located at the posterior end to which the anchor ossicles are connected (Hyman, 1955; Clark & Rowe, 1971). Anchor plates come in different shapes such as oval, rectangular, rounded, or pear-shaped (Clark & Rowe, 1971). Basket ossicles (Fig. 5C) are concaved perforated plates with either a smooth or denticulated edge (Hyman, 1955; Clark & Rowe, 1971).

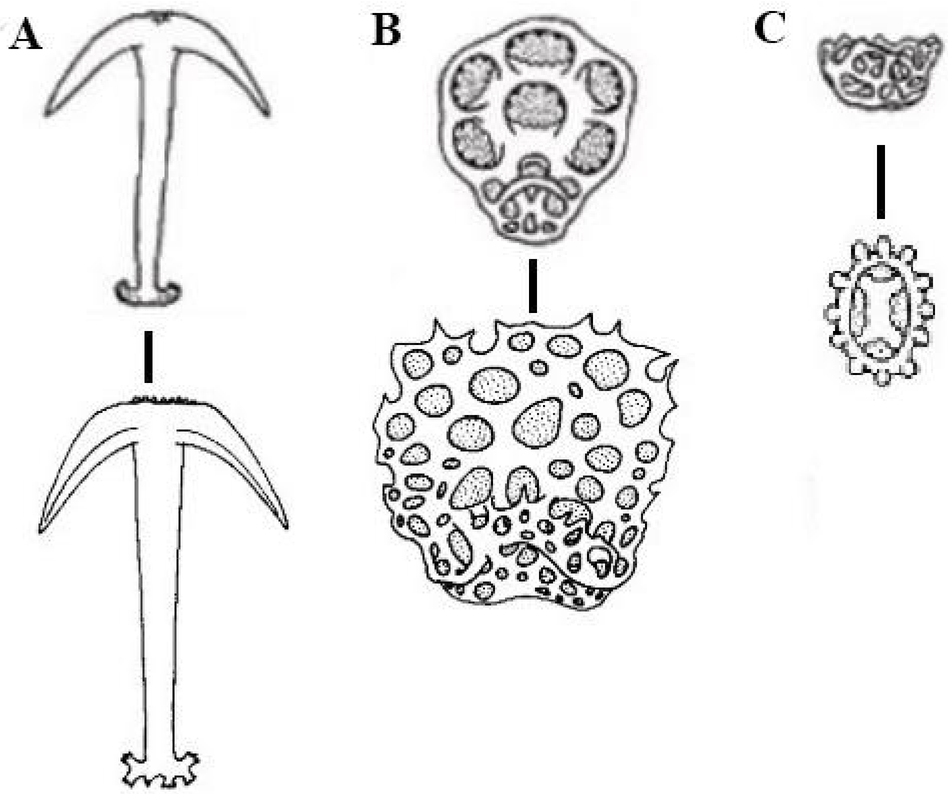

Figure 5 Representative shape of ossicles: A. anchors; B. anchor plates; C. baskets (modified from Clark & Rowe, 1971).

Button ossicles (Fig. 6A–H) are elongated or circular plates with four or perforations arranged in two rows (Hyman, 1955; Clark & Rowe, 1971). The size and shape vary between species, ranging from smooth to highly knobbed (Hyman, 1955; Clark & Rowe, 1971). Endplates (Fig. 7) are large, circular perforated plates found at the terminal of the tube feet (Clark & Rowe, 1971). Fenestrated ellipsoids (Fig. 8A) are ossicles formed by modified buttons with interconnecting knobs while fenestrated spheres (Fig. 8B) are formed by modified table ossicles with the spines from the margin of the disc interconnecting with the spire (Clark & Rowe, 1971).

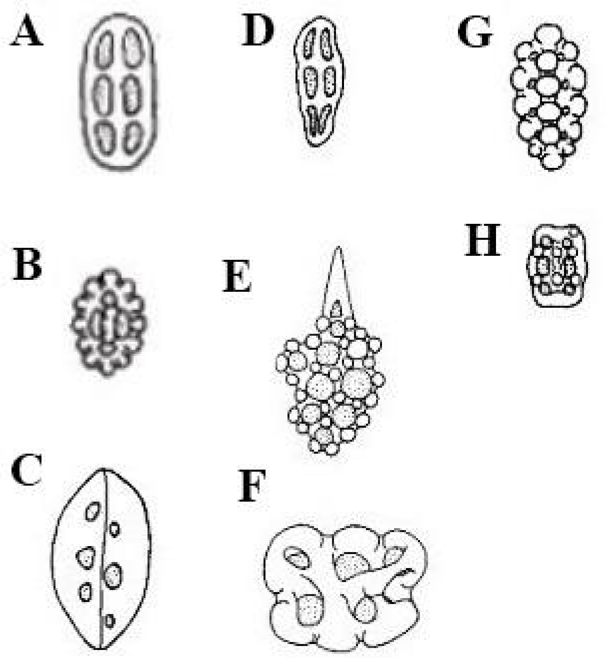

Figure 6 Representative shape of ossicles: A. button; B. knobbed button; C. flattened oval button with median optical discontinuity; D. irregular button; E. fircone-shaped knobbed button; F. swollen smooth nodular button; G. button with large regular knobs; H. button with moderate irregularly placed knobs (modified from Clark & Rowe, 1971; Thandar, 2007).

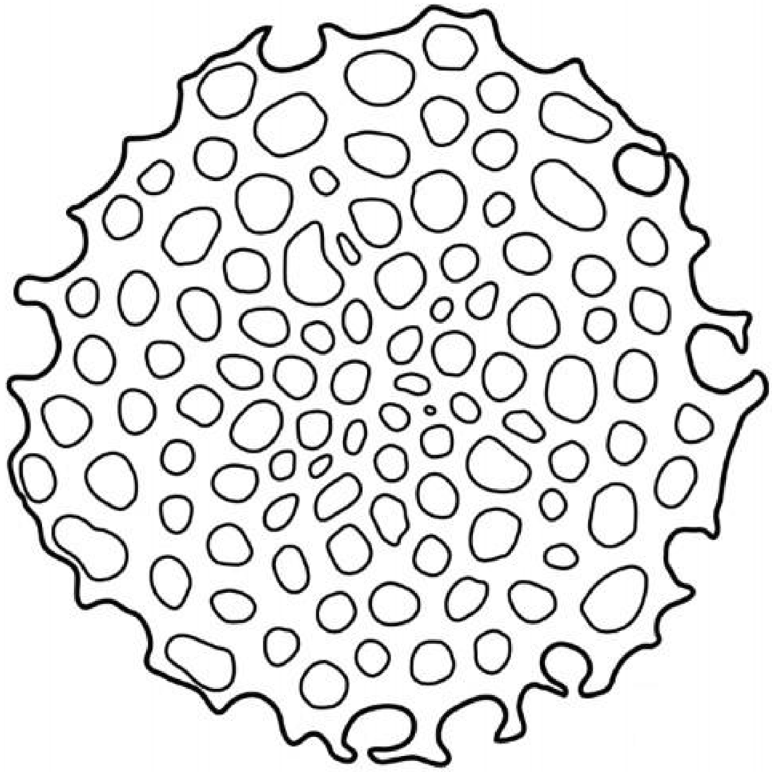

Figure 7 Endplate ossicle (Modified from Ong et al., 2016).

Lenticulate plates (Fig. 8C) are double-convexed in shape in which the perforations are often obstructed by the thick plate (Clark & Rowe, 1971). Miliary granules (Fig. 8D) are small solid ossicles that may also present themselves in a rosette-like or rod shape (Hyman, 1955; Clark & Rowe, 1971). Perforated plates (Fig. 8E–F) are plates of different sizes, shapes, and textures with numerous perforations (Clark & Rowe, 1971).

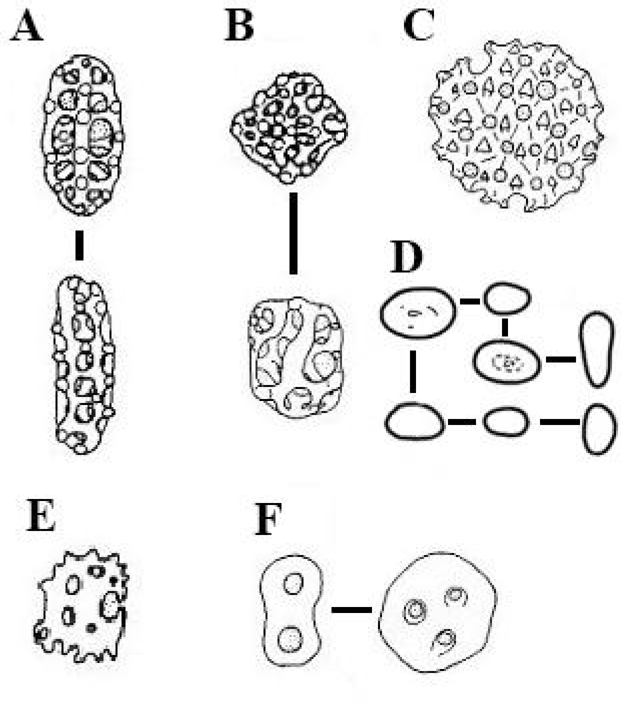

Figure 8 Representative shape of ossicles: A. fenestrated ellipsoids; B. fenestrated spheres; C. lenticulate plate; D. miliary granules; E. perforated plate; F. smooth swollen perforated plates (modified from Clark & Rowe, 1971; Ong et al., 2016).

Phosphatic bodies (Fig. 9) are present only within the order Molpadida (Clark & Rowe, 1971). Derived from anchors or rosettes, they are covered in iron phosphate as the specimen matures (Clark & Rowe, 1971). Pseudo-buttons (Fig. 10A) are incomplete button ossicles, often twisted and reduced with only a single row of perforations (Clark & Rowe, 1971). Rods (Fig. 10B–E) are bar-like with a diverse spectrum of shapes such as S-shaped, C-shaped or branched (Clark & Rowe, 1971). The surface of rod ossicles is also diverse, ranging from smooth to spinose (Clark & Rowe, 1971). Rosettes (Fig. 10F) derived from highly dichotomously branched rods with various perforations and terminal ends (Hyman, 1955; Clark & Rowe, 1971). Sigmoid bodies (Fig. 10G) are derived from curved rods with one blunted end and one sharpen end, which are curled at right angles to each other (Clark & Rowe, 1971).

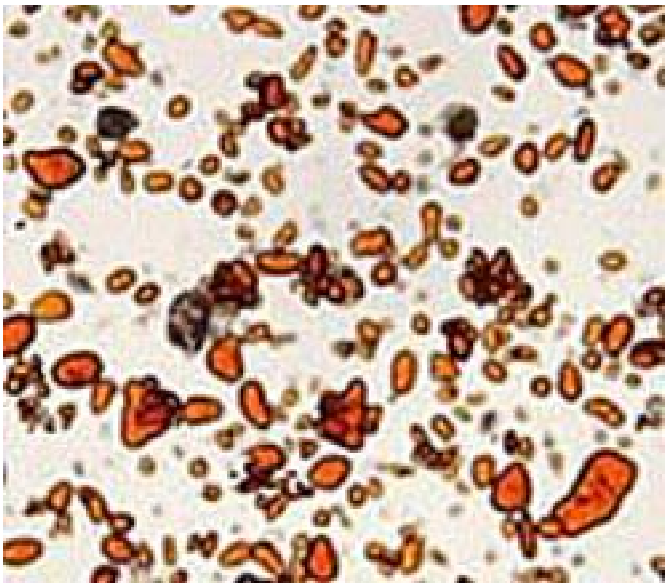

Figure 9 Phosphatic bodies (adapted from Pawson & Vance, 2007).

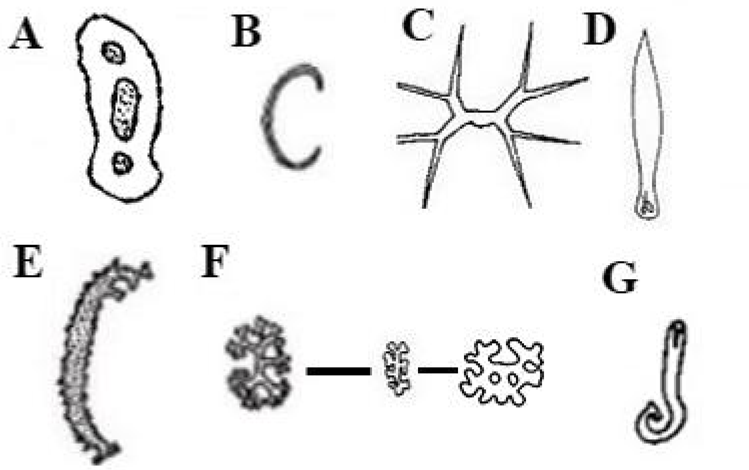

Figure 10 Representative shape of ossicles: A. pseudo-button; B. C-shaped rod; C. dichotomously branched rod; D. rod derived from table; E. spinose rod; F. rosette; G. sigmoid bodies (modified from Hyman, 1955; Clark & Rowe, 1971).

Tables (Fig. 11A–I) have a spire erected on the base of a circular perforated plate (Hyman, 1955). The surface and rim of the disc could be smooth or denticulated, with some species exhibiting larger spines (Clark & Rowe, 1971). The spire is formed from two to four pillars connected by transverse bars, called bridges, while the tip of the spire ends in either a tip, a crown, or a cluster of spines (Clark & Rowe, 1971). Table ossicles may be referred as 'tourelles' in French literature and stühlchen in German literature, translated as 'tower' and 'chair' respectively (Sluiter, 1901; Hyman, 1955; Cherbonnier, 1960). Finally, wheels (Fig. 12) are ossicles with a circular rim and six or more spokes connecting in the middle (Clark & Rowe, 1971).

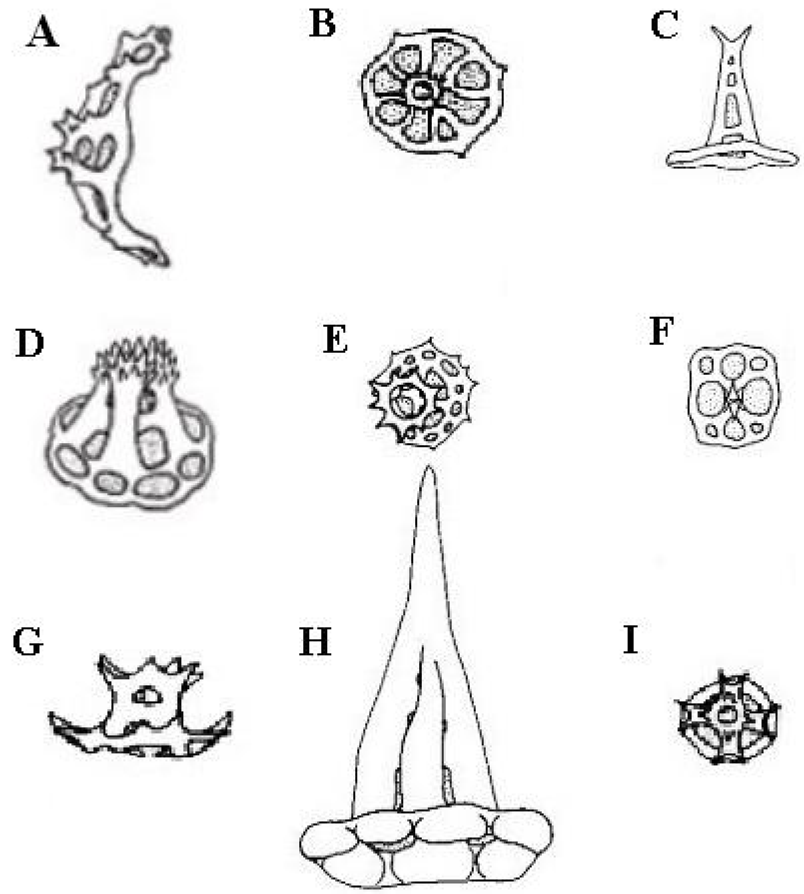

Figure 11 Table ossicles: A. table with arched disc; B. table seen from above showing cruciform central hole; C. table with two-pillared spire; D. table with four-pillared spire; E. table from above showing ring of apical spines on spire; F. table with two-pillared spire from above; G. table seen from side; H. tack-like table with large, almost solid spire; I. table seen from above showing maltese cross formation of terminal spines of spire (modified from Clark & Rowe).

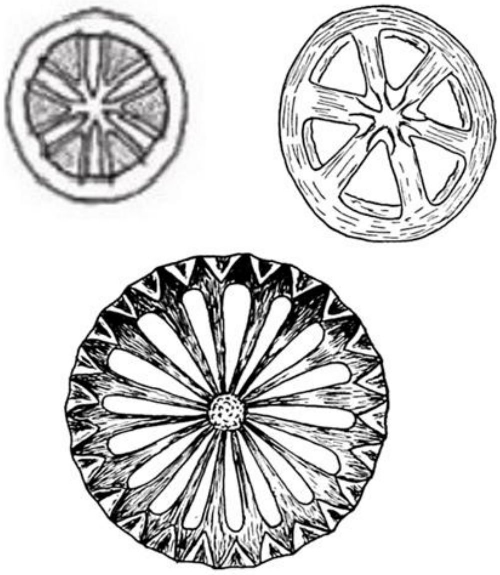

Figure 12 Wheel-shaped ossicles (modified from Hyman, 1955; Clark & Rowe, 1971).

2.3 Past Studies of Nearshore Holothurians in the Straits of Malacca

Studies on holothurians, especially on the diversity, had previously been conducted in Malaysia (Baine and Forbes, 1998; Zulfigar et al., 2007; Kamarudin, 2009; Kamarudin et al., 2009; Kamarudin et al., 2010; Mohamad Saupi et al., 2010; Kamarudin, 2011a; Kamarudin, 2011b; Woo et al., 2013; Woo et al., 2014; Kamarudin and Rehan, 2015; Kamarudin et al., 2015; Kamarudin et al., 2017; Harith et al., 2018; Wolfe and Davey, 2020; Akasha et al., 2021; Ilias et al., 2021; Ilias et al., 2022; Rahman et al., 2022; Abdul et al., 2023). However, only some of the studies focused on the nearshore zone within the Straits of Malacca (Woo et al., 2014; Teoh & Woo, 2021; Teoh & Woo, 2022).

Singapore has also conducted studies on the diversity of holothurians previously near the Straits of Malacca (Teo et al., 2010; Ong & Wong, 2015; Ong et al., 2016; Zhou & Goh, 2024). From the studies they've further described one new species of caudinid sea cucumber (O'Loughlin & Ong, 2015), one new species of synaptid sea cucumber species (O'Loughlin & Ong, 2015), and two new species of psolid sea cucumbers (Ong et al., 2019).

Towards the north of the Straits of Malacca, Thailand has also launched numerous studies on sea cucumber species diversity and checklist near the Andaman Sea (Munprasit, 2009; Kritsanapuntu et al., 2014; Ninwichian and Klinbunga, 2020; Panithanarak, 2022; Theeratatthanakorn et al., 2023).

Finally, towards the western side of the Straits of Malacca, Indonesia had also completed several studies on sea cucumber species diversity and checklist near the Straits of Malacca (Wiadnyana, 2009; Setyastuti et al., 2024).

CHAPTER 3

MATERIALS AND METHODS

3.1 Sampling Site

A total of four sites were identified and five field samplings were conducted during the low tide. The satellite images of the sampling locations are shown in Fig. 13–17, while the sampling dates and sampling area covered are recorded in Table 2.

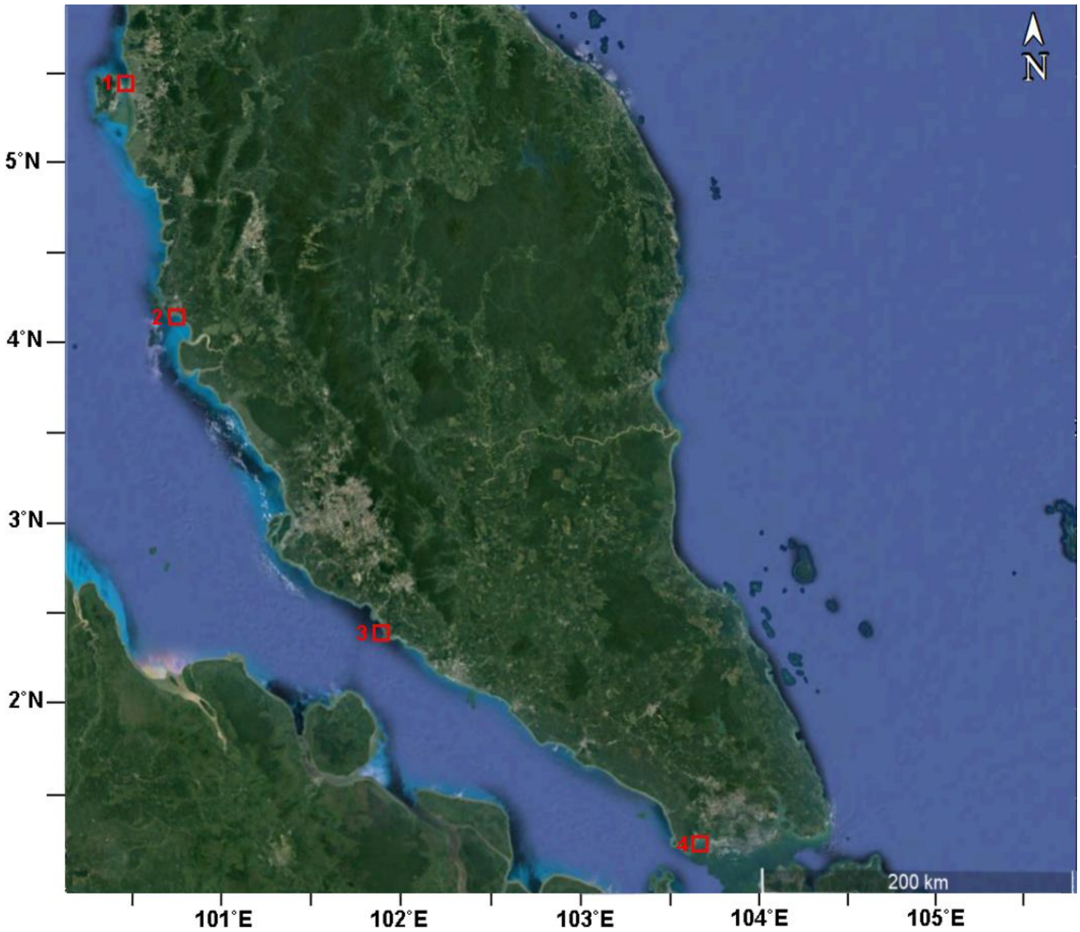

Figure 13 Sampling sites: 1. Middle Bank; 2. Tanjung Kepah; 3. Blue Lagoon; 4. Merambong Shoal.

Figure 14 Middle Bank. Red dotted lines denote sampling area.

Figure 15 Tanjung Kepah. Red dotted lines denote sampling area.

Figure 16 Blue Lagoon. Red dotted lines denote sampling area.

Figure 17 Merambong Shoal. Red dotted lines denote sampling area.

Table 2. Sampling sites and the date of sampling.

Sampling sites	Sampling dates	Total Area Covered (km^2)
Blue Lagoon, Port Dickson, Negeri Sembilan	25th–28th April 2021 20th–22nd September 2021	0.06
Middle Bank, Penang	6th–7th December 2021	0.88
Merambong Shoal, Johor	16th–19th March 2022	1.16
Pusat Riadah Laut Tanjung Kepah, Sitiawan, Perak	14th–15th June 2022	0.05