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Research Article

Biomonitoring of Benthic Organisms for Coastal Protection: A Checklist Study from Pantai Remis and Blue Lagoon on the West Coast of Peninsular Malaysia

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Abstract: The objective of the study was to provide an updated checklist of benthic marine organisms in Pantai Remis (Selangor) and Blue Lagoon (Negeri Sembilan) in November 2022. The research areas comprised a total of 26 species of marine benthic organisms, which were divided into 12 orders, 18 families, and 22 genera. Benthic macrophytes formed the largest group (11 species), followed by other benthic macrofauna (molluscs, with eight species). In addition, three coral species, two gastropods, and two crabs were also recorded. The findings revealed that both sites are fertile and suitable habitats for marine benthic organisms. The established checklist of benthic organisms can serve as an ongoing basis for future reference as part of our efforts to develop coastal marine ecosystem management and conservation on the west coast of Peninsular Malaysia. In summary, the checklist of benthic organisms provides the basic information that is much needed for the protection of coastal ecosystems.

***Keywords*:** benthic organisms, Peninsular Malaysia, intertidal molluscs

1. Introduction

In many studies, biomonitoring of intertidal molluscs as seafood for the protection of coastal resources has always been reported in the literature [1-6]. There are also many reported studies on the relationships between the diversity of benthic edible intertidal seafood molluscs and coastal pollution levels [5-10]. It is postulated that the low biodiversity of benthic organisms can be a result of human activities that contributed to the elevation of chemical contaminants in the coastal ecosystem [4]. However, information on the biodiversity (or checklist) of benthic organisms in a coastal area needs to be provided regularly (possibly every five years if not yearly).

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Checklists are living documents that contain all species listed in a given area and serve as living documents of diversity and species composition. The list is a baseline document that contains information for a specific area [11]. Local conservation practices are built on extensive assessments and inventory levels. Regional marine benthic organisms in a checklist provide basic information and important data for comparative biodiversity studies and an important role in estimating resource availability [12]. Marine benthic organisms are an important component of aquatic ecosystems. It occupies the entire stratum of sediment and keeps the marine ecosystem healthy. It consists of both flora and fauna that are interconnected through their food web [13, 14]. There are numerous food web relationships in which one species interacts positively or negatively with others, or where the addition or elimination of one species changes the dynamic of the food web [15, 16]. Many marine food webs rely on benthic primary producer habitats, supporting productive and economically important fisheries. They also help to protect our shorelines and coastal infrastructure by attenuating wave and current energy [17].

The west coast of Peninsular Malaysia is rocky, with sandy bays alternating with mud flats and mangrove areas, and some areas are surrounded by coral reefs [18]. Coastal areas are often highly productive but can also be severely stressed by anthropogenic impacts and human activities [19]. The west coast of Peninsular Malaysia has been an area where ecotoxicological studies have been conducted since the 1990s [20-22], especially on intertidal molluscs [23]. Therefore, the benthic organisms in the coastal areas of Pantai Remis (Selangor) and Blue Lagoon (Negeri Sembilan) are among the hotspots that require intensive biomonitoring studies. Pantai Remis and Blue Lagoon are located on a busy waterway along the Strait of Malacca, which has caused both direct and indirect damage to the benthic communities in these areas, and the data obtained will be useful for future reference and comparative studies.

According to a review of the literature, there are limited reports on the checklist of marine benthic organisms, except for a few in Malaysia [18, 24-26]. Therefore, the objective of this study was to provide an updated checklist of marine benthic organisms in Pantai Remis (Selangor) and Blue Lagoon (Negeri Sembilan).

2. Materials and methods

2.1 *Study location*

Pantai Remis, Selangor (3° 12’ 10.35” N, 101° 18’ 18.65” E) and Blue Lagoon, Negeri Sembilan (2° 24’ 54.95” N, 101° 51’ 11.23” E) are two locations on the west coast of Peninsular Malaysia that were selected for the present study.

2.2 *Field sampling*

Observational studies and sampling for marine benthic organisms were conducted in Pantai Remis (Selangor) and Blue Lagoon (Negeri Sembilan) during the lowest tides in November 2022. The benthic organisms of the fauna were discovered by digging over the substratum in the intertidal zone and the shallow water zone with a spatula and hand. Scraping collected benthic organisms clinging to rocks on the shore and rocks and pebbles. After washing with seawater to remove debris, all collected specimens were placed in clean polyethylene bags.

2.3 *Identification of benthic organisms*

In the laboratory, the morphological characteristics of each specimen, such as shell morphology, hinge band, radial ribs, cardinal teeth, and growth lines, were recorded. Benthic macrophytes (algae) were identified by morphological and anatomical studies. Species identification was based on dichotomous keys published in [25, 27-29]. Identification of species of benthic macrofauna (bivalves, gastropods, corals, and crustaceans) was mainly done by studying their molluscan characteristics such as shell morphology, color, lustre, and teeth (cardinal and lateral). Literature was consulted for the identification of bivalves, gastropods, and coral species [30-33]. All organisms collected were photographed and identified. The taxonomy of the individual organisms was taken from the websites of the World Register of Marine Species (WoRMS) (https://www.marinespecies.org), the AlgaeBase (https://www.algaebase.org), and the Molluscabase (https://www.molluscabase.org).

3. Results

Table 1 shows the species collected from the coasts of Pantai Remis, Selangor, and Blue Lagoon, Negeri Sembilan. During the nearly two-hour duration of each sampling, a total of 26 species of benthic organisms from 22 genera, 18 families, 12 orders, and seven classes were recorded (see Figures 1 and 2). A total of 11 species of benthic macrophytes from seven genera, six families, four orders, and three classes were collected. Of these, five species each belong to Chlorophyta and Ochrophyta, and one species belongs to Rhodophyta. Of the collected species, 45.45% belong to Chlorophyta and Ochrophtyta, and 9.09% belong to Rhodophyta. Eight species of bivalves from eight genera, six families, and four orders were identified. In terms of the proportion of bivalves (by order), the order Venerida had the most species (37.5%). The orders Cardiida, Myida, and Arcidae each accounted for 12.5% of the species. Two gastropod species from two genera, two families, and two orders were noted during the observation. Three coral species from three genera, two families, and one order were identified. The site hosted two species of crabs in the genus Anthropoda, representing two genera, two families, and one order. The International Union for Conservation of Nature (IUCN) status is verified on the official IUCN Red List of Threatened Species website (iucnredlist.org) [34]. Three IUCN-listed species from the order Scleractinia are *Favites abdita* (near threatened [NT]), *Platygyra sp*. (least concern [LC]), and *Galaxea fascicularis* (NT).

4. Discussion

The checklist of benthic organisms in two different bays is recorded. This checklist shows that the two study areas have a diversity of benthic organisms adapted to their respective coastal conditions. These sites were selected because of their strategic location along the west coast of Peninsular Malaysia, which has a well-known port industry and various anthropogenic activities. Pantai Remis is located 20 km south of Kuala Selangor and is one of the eco-tourism destinations that are gaining popularity among the public. It is a popular destination for tourists to enjoy the beauty of nature, especially to watch the sunset and eat delicious seafood. The muddy and sandy coast is inhabited by a variety of shellfish species, which provide income for the locals. The Blue Lagoon is located about 15 km from Port Dickson. It is one of the most popular recreational areas, so rapid development is inevitable. This may affect the species composition of benthic macrophytes in the area. In the Blue Lagoon, a rocky area that is part of the bay, there are a variety of macrophytes (seaweed) that cling to and dominate the rocks.

According to a previous study by Asmida et al. [26], the algae in the Blue Lagoon are classified into three groups: green, brown, and red algae. Brown and green algae dominate the areas, with 19 (44%) and 16 (36%) species detected in each division, respectively. Red algae make up 20% of the total species detected in the Blue Lagoon, with nine species. During the current survey, eight species of bivalves, two species of snails, and three species of corals were detected. The bivalve, which lives below the substrate surface in burrows, plays an important role in the marine ecosystem, including the mineralization and cycling of organic matter. Previous studies on the distribution and composition of macrofauna in the different Malaysian states do not provide information on the entire country but are rather focused on highlighting the different regional and ecosystem conditions of macrofauna [35]. Similarly, this study was limited to two sites in Pantai Remis and Blue Lagoon. Only two species of gastropods and three species of corals were found. Due to global warming and several other reasons, such as coastal pollution, coral reefs are declining worldwide.

A comparison of the research results with those of neighboring countries with similar environmental conditions, such as Singapore, can be carried out as a result of the studies. A total of 994 intertidal marine species (macroflora, macrofauna, and macroalgae) were collected at 27 intertidal sites in the northern and southern regions of Singapore. Species richness and communities were analyzed to determine spatial patterns of species richness and composition along the coastline. Species richness at sites along the Johor Strait in the north and the Singapore Strait in the south does not differ significantly. The south is more species-rich than the north, most likely due to the broader range of habitat types around the Singapore Strait. The species richness of intertidal sites in Singapore was higher in molluscs and macroalgae at the southern sites than at the northern sites [36]. Despite the large discrepancy between the number of species in this study, which covers only two intertidal zones, and the results from the Singapore coastal area, which covers a large area with 27 intertidal zones, it can be seen that the diversity of benthic life in the adjacent area is large, especially in macroalgae and bivalve species.

All species were classified as 'not evaluated' by IUCN, which means that none of the conserved species are assessed by IUCN, except for the corals from the tribe of cnidarians, which were classified as LC and NT. A least-concern species has been classified by the IUCN as not being of conservation concern because the species in question is still abundant in the wild. A species is considered NT if it has been assessed against the criteria but has not been categorized as critically endangered or vulnerable, but is on the verge of becoming so or will be shortly [34]. The IUCN introduced this rating system in 1994. It contains explicit criteria and categories for ranking the conservation status of individual species based on their probability of extinction.

The present study on benthic macrophytes and macrofauna recorded from Pantai Remis, Selangor and Blue Lagoon has provided important updated information on the protection of the coastal environment in Negeri Sembilan [12, 13]. First, the present list of benthic organisms can serve as baseline information for future references with similar or related future biomonitoring studies [13]. Second, the list can be used for the selection of potential biomonitors in ecotoxicological studies [4, 12]. This usually involves chemical pollutants (or newly emerging pollutants) and microplastic quantification studies in these intertidal molluscs. Third, these molluscs are also seafood resources for many local inhabitants. Therefore, the list is useful for public concerns since most of them are seafood delicacies [1-10].

The present list can contribute to the maintenance of the seafood-water-energy nexus [37, 38]. This is because this basic information is also related to the United Nations' Sustainable Development Goals, namely, Goal 3 (good health and well-being) and Goal 15 (life on land), which are considered integrated into the conceptual relationship of the seafood-water-energy nexus [4].

Table 1. Checklist of benthic macrophytes and macrofauna recorded from Pantai Remis, Selangor, Blue Lagoon, Negeri Sembilan

Class	Order	Family	Scientific name
Benthic macrophytes: Division Chlorophyta			
Ulvophyceae	Bryopsidales	Caulerpaceae	*Caulerpa lentillifera* J. Agardh, 1837
			Caulerpa racemosa (Forsskål) J. Agardh, 1873
			Caulerpa taxifolia (M. Vahl) C. Agardh, 1817
		Codiaceae	*Codium* sp. Stackhouse, 1797
		Halimedaceae	*Halimeda opuntia (Linnaeus)* J. V. Lamouroux, 1816
Benthic macrophytes: Division Ochrophyta			
Phaeophyceae	Fucales	Sargassaceae	*Sargassum aquifolium* (Turner) C. Agardh, 1820
			Sargassum baccularia (Mertens) C. Agardh, 1824
			Turbinaria conoides (J. Agardh) Kützing, 1860
	Dictyotales	Dictyotaceae	*Padina minor* Yamada, 1925
			Padina gymnospora (Kützing) Sonder, 1871
Benthic macrophytes: Division Rhodophyta			
Florideophyceae	Gracilariales	Gracilariaceae	*Gracilaria salicornia* (C. Agardh) E. Y. Dawson, 1954
Benthic macrofauna: Phylum Mollusca			
Bivalvia	Cardiida	Donacidae	*Donax faba* Gmelin, 1791
	Myida	Pholadidae	*Pholas orientalis* Gmelin, 1791
		Myidae	*Cryptomia elliptica* A. Adams, 1851
	Venerida	Veneridae	*Paratapes undulatus* Born, 1778
			Gafrarium tumidum Röding, 1798
			Dosinia lupinus, 1758
		Glauconomidae	*Glauconome virens* Linnaeus, 1767
	Arcidae	Arcidae	*Tegillarca granosa* Linnaeus, 1758

Table 1. *Continued*

Class	Order	Family	Scientific name
Gastropoda	Neogastropoda	Melongenidae	*Volegalea cochlidium* Linnaeus, 1758
	Caenogastropoda	Potamididae	*Cerithidea* sp. Swainson, 1840
		Benthic macrofauna: Phylum Cnidaria	
Anthozoa	Scleractinia	Merulinidae	*Favites abdita* Ellis & Solander, 1786
			Platygyra sp. Ehrenberg, 1834
		Euphylliidae	*Galaxea fascicularis* Linnaeus, 1767
		Benthic macrofauna: Phylum Anthropoda	
Malacostraca	Decapoda	Dotillidae	*Dotilla myctiroides* H. Milne Edwards, 1852
		Portunidae	*Portunus pelagicus* Linnaeus, 1758

Figure 1. Benthic macrophytes and macrofauna recorded in Pantai Remis, Selangor, and Blue Lagoon, Negeri Sembilan: (a) *Caulerpa lentillifera*, (b) *Caulerpa racemosa*, (c) *Caulerpa taxifolia*, (d) *Sargassum baccularia*, (e) *Halimeda opuntia*, (f) *Sargassum aquifolium*, (g) *Codium* sp., (h) *Turbinaria conoides*, (i) *Padina minor*, (j) *Padina gymnospora*, (k) *Gracilaria salicornia*, and (l) *Donax faba*

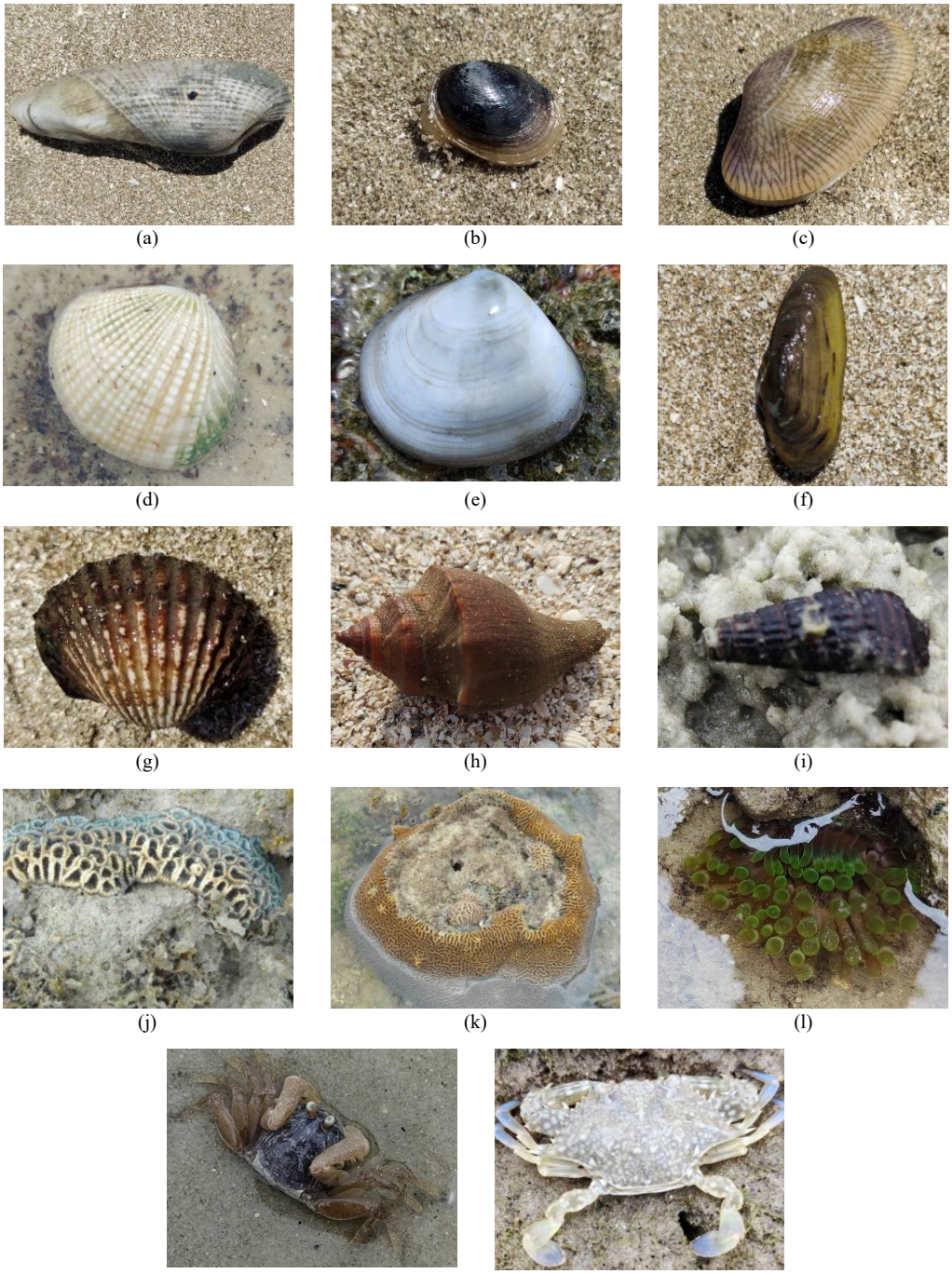

Figure 2. Benthic macrophytes and macrofauna recorded in Pantai Remis, Selangor, and Blue Lagoon, Negeri Sembilan: (a) *Pholas orientalis*, (b) *Cryptomia elliptica*, (c) *Paratapes undulatus*, (d) *Gafrarium tumidum*, (e) *Dosinia lupinus*, (f) *Glauconome virens*, (g) *Tegillarca granosa*, (h) *Volegalea cochlidium*, (i) *Cerithidea* sp., (j) *Favites abdita*, (k) *Platygyra* sp., (l) *Galaxea fascilcularis*, (m) *Dotilla myctiroides*, and (n) *Portunus pelagicus*

5. Conclusion

The present checklist of 26 species belonging to 12 orders, 18 families, and 22 genera of marine benthic organisms is critical to providing a continuing basis for future reference. The species previously reported in Pantai Remis (Selangor) and Blue Lagoon (Negeri Sembilan) can still be found and will continue to be listed. No new species have been added

to the checklist as new entries for benthic organisms. Commercially important species of shellfish and macrophytes were identified in the area. Detailed ecological and phenological studies of important species should be conducted to determine the status of benthic organisms in Malaysia and identify threatened species and habitats. This study was conducted as a first step to obtain the most recent information on the benthic organism community on the west coast of Peninsular Malaysia. Long-term biomonitoring studies are recommended to assess the impact of human activities on local marine communities. This checklist will be part of our efforts to develop a management strategy for the conservation of coastal marine ecosystems in Malaysia. From an ecotoxicological point of view, the present checklist of benthic organisms in the coastal areas of Selangor and Negeri Sembilan is invaluable and provides basic information that is much needed for the future protection of coastal ecosystems.

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Conflict of interest

The authors declare no conflict of interest.

References

[1] Haseeb-ur-Rehman M, Munshi AB, Atique U, Kalsoom S. Metal pollution and potential human health risk assessment in major seafood items (fish, crustaceans, and cephalopods). *Marine Pollution Bulletin*. 2023; 188: 114581. https://doi.org/10.1016/j.marpolbul.2023.114581

[2] Tanhan P, Lansubsakul N, Phaochoosak N, Sirinupong P, Yeesin P, Imsilp K. Human health risk assessment of heavy metal concentration in seafood collected from Pattani Bay, Thailand. *Toxics*. 2022; 11(1): 18. https://doi.org/10.3390/toxics11010018

[3] de Almeida Rodrigues P, Ferrari RG, do Rosário DK, de Almeida CC, Saint'Pierre TD, Hauser-Davis RA, et al. Toxic metal and metalloid contamination in seafood from an eutrophic Brazilian estuary and associated public health risks. *Marine Pollution Bulletin*. 2022; 185: 114367. https://doi.org/10.1016/j.marpolbul.2022.114367

[4] Yap CK, Al-Mutairi KA. Biomonitoring–health risk nexus of potentially toxic metals on *Cerithidea obtusa*: A biomonitoring study from Peninsular Malaysia. *Foods*. 2023; 12(8): 1575. https://doi.org/10.3390/foods12081575

[5] Liu Q, Liao Y, Shou L. Concentration and potential health risk of heavy metals in seafoods collected from Sanmen Bay and its adjacent areas, China. *Marine Pollution Bulletin*. 2018; 131: 356-364. https://doi.org/10.1016/j.marpolbul.2018.04.041

[6] Zhao R, Yan S, Liu M, Wang B, Hu D, Guo D, et al. Seafood consumption among Chinese coastal residents and health risk assessment of heavy metals in seafood. *Environmental Science and Pollution Research*. 2016; 23: 16834-16844. https://doi.org/10.1007/s11356-016-6817-8

[7] Soegianto A, Putranto TW, Payus CM, Zarqasi FR, Syafitrirulla PP, Muchlisin MI, et al. Metals in the tissues of the East Java Coast Indonesian green mussel (*Perna viridis* Linnaeus, 1758) and associated health risks. *Regional Studies in Marine Science*. 2021; 48: 102045. https://doi.org/10.1016/j.rsma.2021.102045

[8] Da Le N, Ha Hoang TT, Phung VP, Nguyen TL, Duong TT, Dinh LM, et al. Trace metal element analysis in some seafood in the coastal zone of the Red River (Ba Lat Estuary, Vietnam) by green sample preparation and inductively coupled plasma-mass spectrometry (ICP-MS). *Journal of Analytical Methods in Chemistry*. 2021; 2021: 6649362. https://doi.org/10.1155/2021/6649362

[9] Orajiaka-Uchegbu C, Patrick-Iwuanyanwu KC, Ogbo AB, Egbuna C. Bioaccumulation of heavy metals and potential health risk through consumption of seafoods from selected creeks in rivers state, Nigeria. *Egyptian Journal of Aquatic Biology and Fisheries*. 2020; 24(7-Special issue): 1033-1053. https://dx.doi.org/10.21608/ejabf.2020.133858

[10] Saher NU, Kanwal N. Assessment of some heavy metal accumulation and nutritional quality of shellfish with reference to human health and cancer risk assessment: a seafood safety approach. *Environmental Science and Pollution Research*. 2019; 26: 5189-5201. https://doi.org/10.1007/s11356-018-3764-6
[11] Kontula T, Haldin J. (eds.) *Checklist of Baltic sea macro-species*. Baltic Sea Environment Proceedings No. 130. Helsinki, Finland: Helsinki Commission; 2012. http://www.helcom.fi/Lists/Publications/BSEP130.pdf
[12] Lozano-Cortés D, Barona M, Londoño-Cruz E, Arias F, Izquierdo V, Zambrano V. Checklist of benthonic marine invertebrates from Malaga Bay (Isla Palma and Los Negritos), Colombian Pacific. *Check List*. 2012; 8(4): 703-708. http://dx.doi.org/10.15560/8.4.703
[13] McCave IN. (ed.) *The benthic boundary laye*r. New York, USA: Springer; 1976. https://doi.org/10.1007/978-1-4615-8747-7
[14] Bhandarkar SV, Paliwal GT. Short notes on types of benthic invertebrates. In: Darade MS, Bahndarkar SV, Vivek C, Nirbhavane GS, Vhanalakar SA. (eds.) *Limnology*. India: Bhumi Publishing; 2020. p.25-32. https://www.researchgate.net/publication/342500708_SHORT_NOTES_ON_TYPES_OF_BENTHIC_INVERTEBRATES
[15] Covich AP, Palmer MA, Crowl TA. The role of benthic invertebrate species in freshwater ecosystems. *BioScience*. 1999; 49(2): 119-127. https://doi.org/10.2307/1313537
[16] Tagliapietra D, Sigovini M. Benthic fauna: Collection and identification of macrobenthic invertebrates. *Terre et Environnement* [*Earth and Environment*]. 2010; 88: 253-261.
[17] Environmental Protection Authority. *Environmental Factor Guideline: Benthic Communities and Habitats*. Western Australia: EPA; 2016. https://www.epa.wa.gov.au/policies-guidance/environmental-factor-guideline-benthic-communities-and-habitats
[18] Phang SM. Yeong HY, Lim PE. The seaweed resources of Malaysia. *Botanica Marina*. 2016; 62(3): 265-273. https://doi.org/10.1515/bot-2018-0067
[19] Kjerfve B. Chapter 1 Coastal lagoons. *Elsevier Oceanography Series*. 1994; 60: 1-8. https://doi.org/10.1016/S0422-9894(08)70006-0
[20] Yap CK, Ismail A, Tan SG, Omar H. Concentrations of Cu and Pb in the offshore and intertidal sediments of the west coast of Peninsular Malaysia. *Environment International*. 2002; 28(6): 467-479. https://doi.org/10.1016/S0160-4120(02)00073-9
[21] Yap CK, Ismail A, Tan SG. Cd and Zn concentrations in the straits of Malacca and intertidal sediments of the west coast of Peninsular Malaysia. *Marine Pollution Bulletin*. 2003; 46(10): 1349-1353. https://doi.org/10.1016/S0025-326X(03)00193-0
[22] Yap CK, Al-Mutairi KA. Comparative study of potentially toxic nickel and their potential human health risks in seafood (fish and mollusks) from Peninsular Malaysia. *Biology*. 2022; 11: 376. https://doi.org/10.3390/biology11030376
[23] Yap CK. *Mussel watch in Malaysia. Past, present and future*. Serdang, Malaysia: UPM Press; 2012.
[24] Asmida I, Ahmad I, Faezah P, Norrizah JS, Nornanysya FK. Seaweeds composition in littoral zone of Blue Lagoon, Port Dickson. In: *2013 IEEE Business Engineering and Industrial Applications Colloquium (BEIAC)*. Langkawi, Malaysia: IEEE; 2013. p.842-845. https://doi.org/10.1109/BEIAC.2013.6560254
[25] Norashikin A, Harah ZM, Sidik BJ. Intertidal seaweeds and their multi-life forms. *Journal of Fisheries and Aquatic Science*. 2013; 8(3): 452-461. https://doi.org/10.3923/jfas.2013.452.461
[26] Asmida I, Noor Akmal AB, Ahmad I, Sarah Diyana M. Biodiversity of macroalgae in Blue Lagoon, the Straits of Malacca, Malaysia and some aspects of changes in species composition. *Sains Malaysiana*. 2017; 46(1): 1-7. http://dx.doi.org/10.17576/jsm-2017-4601-01
[27] Geraldino PJL, Liao LM, Sung MB. Morphological study of the marine algal genus *Padina* (Dictyotales, Phaeophyceae) from southern Philippines: 3 species new to Philippines. *Algae*. 2005; 20(2): 99-112. https://doi.org/10.4490/algae.2005.20.2.099
[28] Phang SM, Lim PE, Ooi JLS, Yeong HY, Ng WS, Kupper FC. Marine algae of Perak Island, Jarak Island and the Sembilan Group of Islands in the Straits of Malacca. *Malaysia Journal of Science.* 2008; 27(3): 47-60. https://mjs.um.edu.my/index.php/MJS/article/view/7708
[29] Gan MH, Siti Aisyah A, Nur Wahidah A, Amyra Suryatie K, Noraien MP. The diversity of seaweed in the veracity of Johor: With emphasis on the East Coast Peninsular Malaysia expedition II 2006. In: *Proceedings of Universiti Malaysia Terengganu International Annual Symposium, 11-13 July 2011*. Terengganu, Malaysia: Universiti Malaysia Terengganu; 2011. p.429-433.
[30] Htwe HZ, Oo NN. Marine gastropods and bivalves in the mangrove swamps of Myeik Areas, Taninthayi region, Myanmar. *Journal of Aquaculture & Marine Biology*. 2019; 8(3): 82-93. https://doi.org/10.15406/jamb.2019.08.00246

[31] Chan SY. The Melongenidae (Mollusca: Gastropoda) of Singapore. *Nature in Singapore.* 2009; 2: 63-67. https://lkcnhm.nus.edu.sg/wp-content/uploads/sites/10/app/uploads/2017/06/2009nis63-67.pdf
[32] Mohamad Saupi I, Nur Hazurina O, Dzulfikkar BM. Growth and survival of four selected corals of Port Dickson in an ex situ nursery. *Malaysian Fisheries Journal*. 2014; 13: 16-24. http://fri.dof.gov.my/fri/resources/MFJ/2013/2.PDF
[33] Azman H, Kamarudin KR, Che Cob Z, Baharin UNA, Mohd Fadzil SN, Mohd Faid NH, et al. Preliminary studies on species diversity of coastal bivalves and the traditional knowledge on bivalve fishery in Sedili Kechil, Johor. *Journal of Sustainable Natural Resources.* 2021; 2(2): 39-45. https://penerbit.uthm.edu.my/ojs/index.php/jsunr/article/view/9984
[34] IUCN. *The IUCN Red List of Threatened Species*. Version 2022-2. https://www.iucnredlist.org [Accessed 25th December 2022].
[35] Al-Asif A, Hamli H, Kamal AHM, Idris MH, Gerusu GJ, Ismail JB, et al. Benthic macrofaunal assemblage in seagrass-mangrove complex and adjacent ecosystems of Punang-Sari Estuary, Lawas, Sarawak, Malaysia. *Biodiversitas Journal of Biological Diversity*. 2020; 21(10): 4606-4615. https://doi.org/10.13057/biodiv/d211019
[36] Lim LJW, Loh JBY, Lim AJS, Tan BYX, Ip YCA, Neo ML, et al. Diversity and distribution of intertidal marine species in Singapore. *Raffles Bulletin of Zoology.* 2020; 68: 396-403. http://dx.doi.org/10.26107/RBZ-2020-0056
[37] Orimoloye IR. Water, energy and food nexus: Policy relevance and challenges. *Frontiers in Sustainable Food Systems.* 2022; 5: 824322. https://doi.org/10.3389/fsufs.2021.824322
[38] Gephart JA, Troell M, Henriksson PJG, Beveridge MCM, Verdegem M, Metian M, et al. The 'seafood gap' in the food-water nexus literature—issues surrounding freshwater use in seafood production chains. *Advances in Water Resources.* 2017; 110: 505-514. https://doi.org/10.1016/j.advwatres.2017.03.025